Chemistry

Reader

An Orientation to Developing Chemistry Instruction In Waldorf Schools

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Chemistry Reader

Contents

Dirk Rohde, Marburg Waldorf School, Christmas 2013

Introduction to the Waldorf Chemistry Reader

I General Notes

Chemistry is a very exciting and interesting science that is highly relevant to each one of us. In health and illness, in medicine and nutrition, in all sorts of technological aspects, in global climate issues, in space travel – almost everywhere we look, we encounter not only the many possible positive applications of various directions in chemistry but also the risks they entail, which must not be overlooked. Chemistry, therefore, is included in all school curriculums today as a matter of course. By exposing young people to multiple points of contact with this important science and introducing them to its very fluid reasoning, Waldorf schools aim to empower their students to deal with the subject of chemistry as self-reliant, discriminating personalities.

To this end, Waldorf education has developed its own specific approach that has proved at least somewhat fruitful. For example, the 2006 PISA study ascertained that students in German and Austrian Waldorf schools demonstrated not only as much factual knowledge as students in public schools but also significantly greater interested in scientific subjects. Furthermore, there were obvious gender-specific differences (to the disadvantage of girls) in the public schools but not in the Waldorf schools involved in the study. Not surprisingly, a study by Heiner Barz and Dirk Randoll revealed that scientific professions were the second most popular career choice among Waldorf school graduates. (1, 2; see the end of this introductory chapter for these and subsequent footnotes).

These findings are anything but self-explanatory. Many of our contemporaries seem to have difficulty developing a connection to the natural sciences in general and to chemistry in particular. There are only relatively few chemists, and they tend to have a reputation for specializing in a questionable minor discipline rather representing a generally acknowledged and valued field. Intensive interdisciplinary exchange is all the more important for them, and especially for the few Waldorf chemistry teachers, due to the challenges of their specific instructional model.

At a continuing education conference on chemistry for Waldorf teachers in Moscow in the spring of 2010, we heard a request to make basic written information available to the international Waldorf school movement for purposes of preparation and review. This request is all the more understandable when we consider how difficult it is – especially because of the geographical distances involved – for many of our colleagues to share ideas with other Waldorf chemistry teachers outside of these occasional continuing education events.

Another problem is that the German professional literature on teaching chemistry in the Waldorf schools has become so extensive over the decades that it would be almost impossible to translate all of it into all the languages in international use. Even if the staff and the funding were available, it would take much too long. In addition, beginners would probably be overwhelmed by this large body of work and daunted at the prospect of having to make meaningful selections to meet their needs in a hurry.
That is why I proposed to take up this issue myself. I have been teaching chemistry in the

Marburg (Germany) Waldorf School since 1988 and have also been involved in teacher training and continuing education for many years. My offer to compile an electronic Chemistry Reader for beginners was received positively, and so work began on it in the autumn of 2010.

It must be emphasized that this reader is intended specifically for *beginners* – as a handbook to help them develop chemistry instruction in Waldorf schools or assume responsibility for chemistry classes in situations when little outside help is available. It is also meant to provide suggestions on preparing for continuing education events and the mutual sharing there, which will then aid in the further development of their courses.

For this reason, this reader will *not* include many of the interesting points raised for further exploration at conferences by teachers with many years of experience, including (for example) the anthroposophically developed imaging techniques that are so important to me personally. Beginners, however, need secure foundations before venturing further. I have also not dealt with anything directly related to governmental requirements regarding curriculums, graduation standards, etc., which vary too much from one country to the next. Solutions to dealing with these will often need to be found locally.

Another exclusion criterion was the text lengths of the individual articles available. Translating a page into another language requires considerable effort on multiple levels. For that reason (as well as regard to the intended usage), it was clear from the beginning that the Chemistry Reader's total length should be limited to approximately 100 double-sided pages. Because Waldorf chemistry instruction involves all the grades from seven through twelve (in Germany) and must therefore touch on a whole series of different subjects, longer articles were eliminated from the very beginning.

Additional considerations included my desire to provide a platform for many different authors spanning the entire development of the Waldorf school movement – that is, from 1919 to the present – and to present the very individual impacts of their chemistry classes on our schools. I hope that in spite of any difficulties in translation, these riches will be preserved at least to an extent that allows "newcomers" to hear many different voices in their own words, the voices of teachers with very different approaches and temperaments and thus with many different inspirations to offer. My sense is that these voices form a harmonious "choir" in which the individual authors complement each other well, since they are not competing with each other but share a common starting point for their interpretations, namely, the curriculum specified by Rudolf Steiner. At the same time, however, we can also see that these interpretations have conquered ever new realms of thought and extended the scope of their subject over the decades.

In this time period, however, chemistry has also made tremendous progress outside of the anthroposophical movement. As a result, all of the articles required careful reading and, in some instances, corrections and omissions. Much information had become scientifically outdated, and (at least in Germany) certain topics can no longer be presented in the classroom due to safety issues. In addition, some of the articles included contents that the Reader does not cover and so the passages in question had to be deleted. I hope that all users of this material will feel bound to investigate further on their own: The science of chemistry continues to evolve, so all of these contents will require repeated checking to see if they are in need of updating.

II The Waldorf School Curriculum

In 1919, the first Independent Waldorf School was started in Stuttgart (Germany) and included grades one through eight. Its curriculum was developed in a series of conferences Rudolf Steiner held with the faculty from 1919 to 1924. Steiner's curricular suggestions on the occasion of the school's establishment included the topics in chemistry to be covered in those first seventh and eighth grade classes. The conferences continued until 1924, emphasizing indications for each newly added grade – that is, for grade nine in 1920 and so on. Chemistry, like many of the other subjects, reveals one of the most important instructional principles in Waldorf education, namely, the historical approach. Each successive grade studies examples of individual discoveries and insights in the order in which they appeared in the history of chemistry itself.

It is also important to note that each grade was intended to have only one chemistry block, as is often still the case today. During those blocks, chemistry was – and often still is – taught in daily lessons of approximately two hours each for three to four weeks, for a total of 30 to 50 hours in the course of a whole school year.

After Rudolf Steiner's death in 1925, his concrete indications (in chemistry as in all other subjects), which had been aimed at specific grades in one specific school at one specific time, were taken as suggestions and starting points for all other grades and schools that have since been added to the international Waldorf school movement. This Reader is also intended in that sense: It is not suitable for use as a "recipe," nor is it designed to be implemented word-for-word. Rather, it is a compendium of suggestions intended to support faculty members in their efforts to ensure the optimal development of each single student. Individual teachers, therefore, immediately assume responsibility for weighing these suggestions against the requirements of their specific instructional situations and for applying them to the development of their own instructional model.

In 1920, Eugen Kolisko, then 27 years old, joined the faculty of the first Waldorf School. His father was a distinguished physician in Vienna. Kolisko himself had also studied medicine, but beyond that he was very intelligent, highly gifted, and had enjoyed a well-rounded education. He was also an intimate pupil of Rudolf Steiner's and a very active anthroposophist. Kolisko became the first school physician in the Waldorf school movement and left a deep initial imprint on that new profession. In addition, he was a subject teacher for science blocks and devoted himself especially to developing a specifically Waldorf approach to teaching chemistry. These efforts were so successful that from then on, Rudolf Steiner called the specific procedures of the anthroposophical approach to chemistry "Kolisko's chemistry." (4) Kolisko's 1929 essay offers a very pertinent description of the unique aims and concerns of science instruction in the Waldorf School. Here it precedes and introduces the more specific essays on topics in chemistry. (3)

II.1 Grade 7

Rudolf Steiner's indication for grade seven reads: "Take a process such as combustion as your starting point. From this everyday process, you should then attempt to find the transition to simple chemical principles." (4) Kolisko developed this suggestion into a procedural method for the introductory chemistry block that is still used today by many, if not all, Waldorf schools as one of the central guidelines for teaching chemistry. For this reason, I have included Kolisko's significant 1932 essay "First Lessons in Chemistry" as the basis for grade seven in this Reader. (3)

II.2: Grade 8

Steiner says about this grade: “Continue presenting simple concepts in chemistry, but now in such a way that the children also learn the relationship between chemistry and industrial processes. In connection with chemical concepts and terms, you attempt to develop what needs to be said about the substances that make up organic bodies: starches, sugars, proteins, fats.” (4)

It is worth noting that Steiner’s indications include all three groups of essential organic substances that nourish us: proteins, fats, and carbohydrates. In a 1923 lecture to workers at the Goetheanum, the center of the anthroposophical movement, Steiner described how these three groups of substances relate to the makeup of the human being (in which anthroposophy distinguishes the so-called constitutional members of the physical, etheric, and astral bodies and the I). The relevant portion of this lecture was therefore selected for inclusion here. (5)

It is followed by an essay by Frits H. Julius. (6) From the 1930s to the 1960s, Julius was a science teacher at the Waldorf School in The Hague (Netherlands) and also a researcher and one of the most important Goetheanists the anthroposophical movement has produced. He was distinguished by an exceptional talent for observation as well as by the great spiritual depth and inwardness that are also apparent in his essays. He wrote extensively about his rich experiences and trains of thought. His articles on teaching chemistry in grades eight and ten seemed especially suited for inclusion in the Reader because in addition to offering concise summaries of many of the essentials for these grades, they are also deeply imbued with Waldorf pedagogy.

II.3: Grade 9

“The topics we assigned to grade eight – namely, introductory aspects of organic chemistry (with the word ‘organic’ being used only for the sake of brevity) – should now be continued in grade 9 with discussions of what an alcohol or an ether is, for example” (4). That is all Steiner has to say about teaching chemistry in this grade. As teachers, therefore, we are handed the difficult assignment of developing a conceptual plan for an entire three to four-week block and adapting it to our immediate needs on the scant basis of this single sentence. Manfred von Mackensen is a master well suited to this task. Until recently, he taught science at the Kassel (Germany) Waldorf School, but his field of activity was much broader. Among other initiatives, he founded a center for educational research and in that context researched and described many materials and sample lesson plans for teaching science in the Waldorf schools. Much of this material has been published, so this extensive documentation – distinguished by comprehensive, up-to-the-minute knowledge, profound thinking, and outstanding practical relevance – is now available to the international Waldorf school movement. Mackensen’s significance in this connection cannot be overestimated.

For reasons mentioned above, this Reader can include only a few passages from Mackensen’s extensive work, passages that can also be seen as stimulating representative glimpses into his other writings. A short text on the ninth grade chemistry block is reproduced here as an example of how one of Steiner’s suggestions can serve as a starting point for designing a lesson plan steeped in profound understanding (7).

As I interpret Steiner's indication for grade nine, the carbon cycle is a very appropriate central theme for this block. Over the years, I have thoroughly researched and tested this interpretation and written it up in a dissertation. The brief excerpt in the Reader is intended to give a quick first impression of this work. (8)

II.4: Grade 10

Here Steiner's indications are somewhat more extensive. The block is meant to give the class "a clear picture of the overall significance of salts, acids, and bases," first through "systematic observation of alkaline, acidic, and saline substances," then by "talking about how alkalis and acids react" and finally "drawing connections to physiological processes." (4) In just a few pages, another essay by Julius presents this topic both in depth and – by introducing several important sub-topics – in its full scope and variety. Because it also covers certain aspects of electrochemistry, it also offers a preview of the transition to grade eleven. For these reasons, I again chose one of Julius' articles as the main text for this block (9).

II.5: Grade 11

In spite of their brevity, Steiner's statements about this grade touch on many very important issues that remain highly relevant today, so his remarks are reproduced here in their entirety: "In chemistry, the key concepts of acid, salt, and base must be developed as completely as possible as a basis for understanding what an alcohol is and what an aldehyde is. We will pay less attention to traditional issues such as the division between organic and inorganic chemistry. – This seems to me to be where an overview of the substances can be inserted. It would not seem right to me to begin by deriving chemistry from a study of substances. It is better to gain an understanding of the *processes* first and only then to insert substances and metals. Your instruction should leave the students with the sense that the substances we are dealing with are simply processes held fast. When we look at a chunk of sulfur, we confront an arrested process. If rain is pouring down where I am standing, that is a *process* in which I am involved, but if I look at the cloud from a distance, it appears to me as an *object*. Observing certain processes is like standing in the rain. When I observe that chunk of sulfur, it is like observing the cloud from afar. Substances are processes that appear to be congealed or arrested." (4)

As we notice immediately, topics from grades nine and ten reappear here, the distinction between inorganic and organic is dealt with anew, the concept of matter is approached in a very specific way, and the "overview of substances" could also be taken to mean the periodic table of the elements. Although sulfur was named only as an example, it is a very important substance and also a chemical element. Accordingly, it plays a major role in chemistry instruction in the Waldorf schools. Because these topics touch on many different aspects of chemistry, the essays related to them are given more space in the Reader.

In terms of the history of science, the transition from grade ten to grade eleven topics can also be seen as the transition to modern chemistry that took place around 1800. It began with attempts to define chemical elements anew, which also led to the discovery of a number of new elements. As the nineteenth century continued, another new discovery – electricity – was increasingly put to use, especially in electrolysis. In grade eleven in the

Waldorf schools, therefore, electrochemistry is the focus of the chemistry block.

Rudolf Steiner goes into the subject of electrolysis in detail and in depth, although briefly, in a lecture to physicians, relating electrolysis to bases, acids, and salts on the one hand and on the other to the metals lead, tin, and iron with their radiating effects and connections to the I, astral body, and ether body. In my opinion, familiarity with Steiner's indications on this subject is indispensable to preparing to teach chemistry in grade eleven, and so in the Reader they come first in the list of materials for this grade. (10)

Günther Heuschkel is a chemist from Hamburg, an outstanding experimental researcher, and a very active anthroposophist. He spent his professional career in the chemical industry, but in retirement he took up Steiner's explanations of metals (both those cited here and others), researching them very thoroughly from a variety of perspectives before publishing many of his findings. With regard to teaching chemistry, it occurred to both Heuschkel and myself that Steiner's statements on electrolysis could be incorporated into this block not only by focusing the discussion on electrolysis but also by conducting experiments with the typical radial patterns of lead, tin, and iron that appear at the cathode as the result of reduction. An excerpt from Heuschkel's comprehensive book "Metal Processes" is included in the Reader and describes the requisite techniques. (11)

The next article is by Gerhard Ott, one of Kolisko's most dedicated students, who also became an enthusiastic Waldorf teacher after completing his education. He taught first at the Hannover Waldorf School, moved to the Waldorf School in Dresden during World War II, and later returned to the school in Hannover. Among other writings, he authored a two-volume work on a phenomenological approach to chemistry. To my way of thinking, the section on how electricity intervenes in the sphere of chemistry is exceptionally clear; beginning teachers will find much of value in these passages with regard to experiments to conduct in grade eleven. (12)

In chemistry, any involvement with the elements leads consistently to the issue of the relationships among these elements and thus to the periodic table. The thinking that went into it and the debates about different ways of depicting it are much more diverse than most of our contemporaries realize. A very good introduction to this subject, followed by coverage of a number of grade twelve topics, is provided by Wolfgang Schad, professor emeritus at the University of Witten and one of the most prominent anthroposophical scientists. Schad's field of activity is broad and his publication list impressively comprehensive. Because he also taught at the Pforzheim Waldorf School and trained teachers at the Waldorf Teachers' Seminar in Stuttgart, he is intimately familiar with all questions related to Waldorf education. The essay included in the Reader, an excerpt from his book "Chemistry in the Waldorf Schools," is directed specifically at Waldorf Chemistry teachers. (13) Schad himself revised this text specifically for the Reader.

The discussion of the periodic table of the elements is rounded out by a graphic representation of the table as proposed by Friedrich A. Kipp and reproduced in the above-mentioned book by Ott (12). Kipp was an excellent anthroposophical scientist with significant accomplishments, especially in biology. – A recently published, groundbreaking article by Peter Brodersen, a colleague from Flensburg, can only be mentioned here. Taking mathematical reasoning as his starting point, Brodersen establishes a well-founded connection between the chemical elements and the planets, which he then expresses in a new representation of the periodic system. (14)

The writing of chemical formulas, as a further aspect of dealing with the chemical elements, must be discussed and introduced in this grade (at the latest). Mackensen's essay in the Reader describes a well-founded and time-tested way of dealing with this challenge from the perspective of Waldorf education. (15)

In the third lecture of his course on agriculture (CW 327), Rudolf Steiner describes certain individual elements from the perspective of spiritual science, an approach that is also essential to instruction in the Waldorf Schools. The relevant excerpt, which includes these outstanding examples and also serves as the transition to protein chemistry in grade 12, has been included in the Reader at this point. (16)

II.6: Grade 12

An overarching theme encompasses all of the subjects in each grade in the Waldorf School. In grade nine this theme could be called "revolution and upheaval," in grade ten "polarity and potentization," in grade eleven "the individual and his/her connection to the whole, to the world," and in grade twelve, "overview and conclusion." (The Waldorf School ends with grade twelve, although in some cases a thirteenth grade is added to meet national graduation requirements.)

These themes are also evident in Steiner's indications with regard to teaching chemistry in Grades nine, ten, and eleven. In grade twelve, finding an overarching theme becomes significantly more difficult. By the end of grade eleven, the students have still learned relatively little about organic chemistry (in the conventional sense) and have barely encountered structural formulas and the chemistry of modern technological processes. In addition to reviewing and summarizing the contents of earlier grades, therefore, a number of new topics must also be tackled.

Steiner's indications with regard to grade twelve are relatively extensive, which also has to do with the fact that in his time (as is also the case still today) the need to prepare for graduation exams had to be taken into account. Even today, the following excerpts are frequently taken as the starting point for twelfth grade chemistry instruction: "For the present, you must attempt to bring chemistry to some kind of conclusion …. An overview of geological formations (types of stone, fossils) up to the Ice Age … the nature of organic toxins, alkaloids, and some concept of cyanogen compounds in contrast to hydrocarbons. Here we need the qualitative connections. It can all be understood entirely on the basis of qualitative connections." "If we were to use three-dimensional formulas, then at least it would make sense. Usually, formulas are written in two dimensions and are meaningless." "Let us consider chemistry in intimate connection with the human being…That would mean going all the way up to processes that are found not only in animals but also in human beings. We would need to talk about ptyalin, pepsin, the formation of pancreatin, and so forth. – We must approach the metal processes in the human body as further developments of the basic metallic principles, but we must show that all substances and processes are completely transformed inside the human body. For example, we must identify a "lead process" in the human body so that [the young people] understand it. With regard to pepsin production, we must begin again with the production of acid as the lifeless manifestation and then consider pepsin formation as something that can happen only within the ether body – and in fact, even the astral body must play into it. In other words, the process must be completely laid bare and then built up again. We must start over again with lifeless hydrochloric acid, whether obtained from table salt or through synthesis, and discuss its properties. Then we attempt to evoke a sense of how it differs from what can happen only in the living, organic body. These considerations must then culminate in the differences among plant, animal, and human proteins – in other words, in a concept of ascending types of protein grounded in the differing structures of the ether body. Human protein is something different from animal protein. … Chemistry would actually need to include inorganic chemistry, organic chemistry, animal chemistry, and human chemistry. … [And as a further example:] “The formic acid/oxalic acid metamorphosis." “We would need to begin with the rhythm of worlds, to explain the periodic system on the basis of cosmic rhythm. … For example, the relationship of hydrogen to oxygen is something like an octave, but that would lead us too far afield.” And a separate Technology block in grade twelve is to cover the chemical processes of in greater depth and in connection with the most important factors in the global economy. [All from (4)]

The grade twelve topics, therefore, are very demanding and multi-faceted, and they repeatedly pose great challenges even to Waldorf teachers with years of experience. As yet, no one has come up with a time-tested written proposal for the entire grade twelve chemistry block such as we have available for grades seven through ten. Nor do the materials included in the Reader produce a coherent picture of both a multi-faceted approach and a unified thrust, as was the case for grade eleven. For grade twelve, there are essays available on some of the above-mentioned topics and, just recently published, a very broad approach by Ulrich Wunderlin (17). In my experience, experiments involving the formic acid/oxalic acid metamorphoses are especially important and informative with regard to Steiner’s call to make a distinction between plant and animal chemistry, which is why Mackensen’s concise and practical description has been included in the Reader. I must emphasize that the work from which these few pages were excerpted also include additional essential material on this topic as well as on the lead process mentioned by Steiner. (18)

In conclusion, I will attempt a brief summary of my own approach to the twelfth grade block. Because I also teach biology and chemical technology and because the state guidelines for secondary school graduation in Germany require considerable knowledge of both biochemistry and genetics, I combine my subjects in an attempt to take advantage of synergies resulting from the increased number of class hours. For example, I can then take Steiner’s indications on protein as guidelines for a combined approach to both chemistry and biology. I use protein digestion experiments to deal with the topics of hydrochloric acid, ptyalin, pepsin, and pancreatin (trypsin). At the end of this digestive sequence, we arrive at the amino acids. Similarly, I have the class conduct experiments using restriction enzymes and gel electrophosphoresis to break down DNA. Amino acids and DNA form the starting point for a discussion of protein biosynthesis. We then move from peptide bonds to different protein structures (primary, secondary, tertiary, and quaternary structures). The spatial consequences for protein structures offer a starting point for the step from written structural formulas to the more realistic spatial conceptions Steiner calls for (see above). The specificity of individual proteins (in the context of the immune system, for example) offers opportunities to identify distinctions between human and animal proteins. In contrast, I deal with the topic of plant protein in conjunction with the Papilionaceae (legumes), which in many respects represent one of the few – and one of the most important – means by which inorganic nitrogen from the air gains access to the biosphere. This example, which I like to introduce using Goethean exercises in plant metamorphosis, not only illustrates the specific biochemical potentials of plants but also delineates them from animal potentials, especially with regard to different proteins but also in relationship to other substances. At this point it is helpful to heavily emphasize the difference between active, process-related proteins (enzymes) and structural proteins (including storage proteins). – For more details on this sketchy outline, you are welcome to contact me at the e-mail address listed below.

II.7 Conclusion

In my view, a short lecture by Rudolf Steiner, given at Eugen Kolisko's request in a faculty meeting of the Waldorf teachers of that time, makes it very clear what Steiner expected of Waldorf teachers in terms of their knowledge of chemistry in relationship to their job as educators. Because this lecture touches briefly on all the topics covered in teaching chemistry in the Waldorf schools and provides an immediate practical context relevant to all of us as Waldorf teachers, it seemed very suited to rounding out and concluding the material presented in this Reader. (19)

III Thanks

This Reader could not have come about without the financial support of the Software AG Foundation (for the German, Russian and English version) and the Mahle Foundation (for the Spanish version), to whom the international Waldorf School movement is greatly indebted; let me herewith offer sincere thanks on behalf of us all. I am also extremely grateful to the Freunde der Erziehungskunst ["Friends of the Art of Education"] for offering crucial assistance in carrying out the project. My very personal thanks go to Professor Dr. Dirk Randoll, to Alexander Lerch and to Eleonore Jungheim, my project advisers at the Software AG Foundation, the Mahle Foundation and Friends of the Art of Education, respectively, without whose competent support I would not have been able to compile this Reader.

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IV Acknowledgements

<u>The Russian translations were undertaken by:</u>

Maria Babkina, Moscow, Russia: Kolisko, "Developing and Shaping Science Instruction in the Waldorf School" (3); Steiner lecture of September 22, 1923 (5); Heuschkel on electrolysis (11); Mackensen on chemical formulas (15).

Oleh Faliy, Dnepropetrovsk, Ukraine: this introduction to the Reader; Kolisko, "First Lessons in Chemistry" (3); Julius on grade eight (6); Mackensen on grade nine (7); Rohde on grade nine (8); Julius on grade ten (9); Ott on electrolysis (12); Schad (13); the periodic system as cited by Kipp (from 12); Mackensen on formic and oxalic acid (18).

All of these translations except 10, 16 and 19 were cross-read by Ksenia Kudrenko, Dnepropetrovsk, Ukraine.

Russian translations of three out of four Rudolf Steiner's lectures (texts 10, 16 and 19) were already available:

- The lecture of April 18, 1921 was translated by Olga Vartazaryan. It is reproduced here with the kind permission of the publisher of volume 313 of Steiner's complete works in Russian; the agreement was facilitated by Sergey Ivashkin, Samara, Russia.
- The course on agriculture (CW 327), translated into Russian by Maria Zhemtschuzhnikova and Alexandr Demidov, was published in 1997 by Nikolay Banzeliouk, Kaluga, who kindly permitted the inclusion of the third lecture into this reader.
- The lecture of February 6, 1923 was translated by Michael Sluch. It is reproduced here with the kind permission of the publisher of volume 300b of Steiner's complete works in Russian; the agreement was facilitated by Sergey Ivashkin, Samara, Russia.

The English translations were undertaken by:

Catherine Creeger, Ithaca, New York, USA: the introduction to this reader; both Kolisko essays (3); Rohde on grade 9 (8); Heuschkel on electrolysis (11); Ott on electrolysis (12); the Schad-article (13); the periodic system as cited by Kipp (from 12). Peter Glasby †, Wights Mountain / Brisbane, Queensland, Australia, assisted Catherine Creeger's translations.

Diederic Ruarus, Littelton, New Zealand, and Martyn Rawson, Elmshorn, Germany: Mackensen on chemical formulas (15); Martyn Rawson, alone: Mackensen on formic and oxalic acid (18).

English translations of the remaining seven articles were already available:

- The three Steiner lectures of September 22, 1923 (5), April 18, 1921 (10), and June 11, 1924 (16) have been published on the internet (wn.rsarchive.org/GA/GA0350, wn.rsarchive.org/GA/GA0313, and wn.rsarchive.org/GA/GA0327). They are being used for this Reader with the kind permission of Jim Stewart, e.Librarian.
- An English translation of the essay by Julius on grade 8 (6) was published years ago by the Steiner Schools Fellowship in Great Britain in the volume "The World of Matter and the Education of Man" (undated). The issue of copyright has not been definitively resolved. Thanks to Verlag Freies Geistesleben, Stuttgart, for the loan of the volume.
- Mackensen's contribution on grade 9 (7) was translated into English by Peter Glasby † and published in "Phenomenological Organic Chemistry" in 2009 by the Pedagogical Section of the Anthroposophical Society in Australia. Peter Glasby has generously made the translation available for inclusion in the Reader.
- The English translation of the essay by Julius on grade 10 (9) was published by the Association of Waldorf Schools of North America in the book "Fundamentals for a

Phenomenological Study of Chemistry" in 2000. It is reproduced in the reader with the kind permission of David Mitchell † of AWSNA Publications on the proviso that it be identified as copyrighted material made available by the publisher.

- The English translation of the Steiner lecture of February 6,1923 (19) was published by Anthroposophic Press, USA in 1998 in "Faculty Meetings with Rudolf Steiner, vol. 2." It is reproduced in the Reader with the kind permission of Gene Gollogly, Anthroposophic Press.

The Spanish translations were undertaken by:

Lia Tummer, Buenos Aires, Argentina: both of the Julius essays (6, 9), Rohde on grade 9 (8), Heuschkel on electrolysis (11).

Miguel Lopez-Manresa, Valparaiso, Chile: this introduction to the Reader, both Kolisko essays (3), all four Steiner texts (5, 10, 16, 19), all three Mackensen texts (7, 15, 18), Ott on electrolysis (12), Kipp's periodic table (from 12), and the Schad article (13).

References:

(For practical purposes, these references are listed in the order of their appearance in the introduction to this Reader, rather than in alphabetical order.)

1: Cited in: Press release of 2009.03.24 by the Landesarbeitsgemeinschaft der Freien Waldorfschulen [State Consortium of Independent Waldorf Schools] in Hesse; business offices: Hügelstraße 67, D 60433 Frankfurt, Germany

2: Cited in: Press release of 2009.03.06 by the Bund der Freien Waldorfschulen [Association of Independent Waldorf Schools]; business offices: Wagenburgstraße 6, D 70184 Stuttgart, Germany

3: The Kolisko essays "The Development and Design of Science Instruction in the Waldorf School" and "First Lessons in Chemistry" have been taken from: "Auf der Suche nach neuen Wahrheiten", Philosophisch-Anthroposophischer Verlag am Goetheanum, Dornach 1989. They are reproduced here with the kind permission of the publisher. A new German edition of the book is in preparation and other works (in German) by Eugen Kolisko are also available from the same publisher.

4: All lesson plan indications are as cited in: E. A. Karl Stockmeyer, "Angaben Rudolf Steiners für den Waldorfschulunterricht" [Rudolf Steiner's Indications for Instruction in the Waldorf School], published by the pedagogical research center of the German Waldorf School Association, Stuttgart 1988

5: Rudolf Steiner, "On Nutrition," from "Cosmic Workings in Earth and Man" (CW 350), lecture of September 22, 1993. This translation is available online at www.rsarchive.org and is being used for this Reader with the kind permission of Jim Stewart, e.Librarian.

6: Frits H. Julius, “Grundlagen einer phänomenologischen Chemie. Teil 1: Zum Chemieunterricht der Mittelstufe” [Foundations of a Phenomenological Chemistry. Part 1: Teaching Chemistry in the Middle School] © 1960 Verlag Freies Geistesleben GmbH, Stuttgart. It is reproduced here with the publisher’s kind permission and preferred format for indication of source.

7: Manfred von Mackensen, "Curriculum & Pedagogy" was published in German in 2004 by the Kassel division of the Waldorf pedagogical research center, Verlag Bildungswerk Beruf und Umwelt, Brabanterstraße 45, D 34131 Kassel, Germany. This English translation by Peter Glasby was published in 2009 by the Pedagogical Section of the Anthroposophical Society in Australia and is used here with the kind permission of the translator.

8: Dirk Rohde, “The Carbon Cycle,” is taken from “Was heißt 'lebendiger' Unterricht?" [What Does ‘Living’ Instruction Mean?], Tectum Verlag, Marburg 2003

9: Frits H. Julius, “Grundlagen einer phänomenologischen Chemie. Teil 2: Zum Chemieunterricht der Oberstufe“ [Foundations of a Phenomenological Chemistry. Part 2: Teaching Chemistry in the High School] © 1965 Verlag Freies Geistesleben GmbH, Stuttgart. All other information: see 6 above.

10: Rudolf Steiner, Lecture 8 in “Anthroposophical Spiritual Science and Medical Therapy,” CW 313, This translation is available online at www.rsarchive.org and is being used for this Reader with the kind permission of Jim Stewart, e.Librarian.

11: Günther Heuschkel, “Metallprozesse“ [Metal Processes], self-published, Hamburg 2002. Used here with the kind permission of the author.

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14: Peter Brodersen, “Vor 200 Jahren postulierte Döbereiner das ‘chemische System’“ [200 years ago, Döbreiner postulated the ‘chemical system’], in: “Chemie in Labor und Biotechnik“ (“CLB“) [Chemistry in the Lab and in Biotechnology], 01-02/2011, pages 48-58; Agentur & Verlag Rubikon, Gaiberg bei Heidelberg

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19: Rudolf Steiner, “Faculty Meetings with Rudolf Steiner, Volume 2”, Anthroposophic Press 1998, CW 300b, faculty meeting of February 6, 1923. Used here with the kind permission of the publisher.

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Marburg, Christmas 2013

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Eugen Kolisko

Excerpt from
“Auf der Suche nach neuen Wahrheiten” [In Search of New Truths], 1989

The Development and Design of Science Instruction In the Waldorf School

Giving a satisfactory description of science instruction in the Waldorf School is no easy task. Although the area we touch on there is among the most essential features of anthroposophical pedagogy, it also diverges greatly from many modern ideas about how science should be taught. The fact that we are living in the age of the development of modern science makes it imperative to incorporate the results of the modern scientific world view into modern education and culture. The long struggle to do so is still clearly visible, running like a red thread through the development of our educational system in the past hundred years. The nineteenth century began with a humanistic educational ideal that essentially emerged from German Idealism: the ideal of educating the whole human being. That holistic idea, however, was derived primarily from the world-view of antiquity – specifically, from Greco-Roman culture. What came striding toward it as a result of the further development of modern science, especially in the second half of the nineteenth century, was not incorporated harmoniously into this humanistic, holistic educational system but rather appended to it like a foreign body of some sort.

We can observe this phenomenon in the development of new types of schools such as the German *Realschule* and the Austrian *Realgymnasium* with their emphasis on science and mathematics. Ultimately, it can be traced right down into science instruction in all the grades, even in early elementary school. Rather than being simply a question of whether Greek and Latin are taught, which was how the struggle for and against the so-called “humanistic” *Gymnasium* was framed, the whole educational system is involved. The *Realschule*, for example, resulted not from any unitary idea of education but rather from the somewhat forced integration of new elements – the contributions of modern natural science – into the old system. The scientific aspect of culture, with its earliest precursors dating only to the fifteenth century, is humanity’s most recent acquisition. It was attempting to shape its world-view through observation and experimentation, and the big issue was how to integrate it into the old, essentially spiritually based element of Greco-Roman culture. Although the old ideal of education was to educate the *whole* human being, that “whole” was the human being of a bygone cultural era in seemingly new clothes. The new educational ideal did not see this “whole,” harmonious human being but aimed only to impart knowledge specific to the newly dawning scientific era. We now have a science that bypasses the human being, especially as a being of soul and spirit, and attempts to see the human body as a product of natural evolution. This monumental struggle has not yet ended; it continues uninterrupted. At all levels of education, from the universities down to the elementary schools, science instruction is a testimony to this evolutionary process. We must indeed incorporate this new element into education, but how can we do so in a way allows the ideal of the “image of the human being” to emerge, an ideal that is justified in standing up to the demands of this scientific worldview?

This is the perspective I have chosen for considering the development of science instruction in the Waldorf School, since it enables me to touch on the essential points that anthroposophy can contribute to education in this field. In its essence, anthroposophy is characterized by its attempt to apply thinking, as trained by modern science, to understanding the whole human being of spirit, soul, and body in interaction with the world.

When Rudolf Steiner accepted the leadership of the Waldorf School in 1919, he spoke to the teachers about the ideal of the "image of the human being" and presented them with a new goal for education. Their task appeared before them with great clarity: When children and adolescents study the natural world, every natural phenomenon must illuminate the connection to the entire *cosmos* and its great laws on the one hand and to the human being on the other. This cannot remain mere theory but must be implemented on the practical level in every detail. It must become possible to understand the human being on the basis of the entire cosmos and the entire cosmos on the basis of the human being. From how Rudolf Steiner spoke to us teachers about this ideal, we learned: Yes, it is possible to understand nature in a way that allows human beings to find their place within it again. And we set to work, inspired by enthusiasm for this ideal.

First of all, we were faced with the *science curriculum* Rudolf Steiner provided for the first eight grades. What does it actually contain? When all of nature is presented to the children's souls during their first three years of school, the sun, moon, stars, animals, plants, and stones appear as living, soul-endowed figures that talk to each other. The entire cosmos, near and far, is presented to the children's souls as if from a fairy-tale world so they can breathe and move within it.

Actual instruction in science starts in fourth grade and begins with the human being. While the cosmos still remains imbued with spirit and soul, human beings are the first to emancipate themselves from it and to manifest as independent entities. We point out aspects of the human/world and world/human relationship: how the shape of our heads reflects the cosmic *heavens*; how our limbs and lower body are connected to the earth; how the air that surrounds us shapes the midsection of the human body. Only then do we move on to the animal kingdom, deriving its various forms from the human form. We demonstrate how animal forms emerge through one-sided development of aspects of human nature. In birds, the head is developed above all else; in carnivores, the chest; and in horses and cattle, the limbs and the lower torso, and so forth. We then move on to cover the plant kingdom, followed by the mineral kingdom.

When the children are about twelve years old, we introduce the study of physics and chemistry. These subjects no longer deal with the individual beings of the natural world but rather with the laws of inorganic and organic nature, laws that pervade the entire cosmos and all living things. The first topic of study in physics is *sound*, which we approach through its connection to the familiar artistic element of music. We then move on to study light, heat, and the gaseous and liquid states before finally considering the solid element and *mechanics*, which is the last aspect to be considered in physics in this age. In other words, the laws governing lifeless matter are considered *last*. They are then contrasted with the study of the human being, which is taken up again in eighth grade, showing how the design of the human body, although based on all these kingdoms of nature, nonetheless represents something new and different from them. In the Waldorf School, the children are guided down from the fairy-tale world to the human being and then on down to earth, where they discover the human being again, but now in the total context of how we human beings are connected to the earth and the cosmos.

As the first Waldorf School grew, a new upper grade was added each year, and each year Rudolf Steiner designed a curriculum for it. Looking back over all the grades once the school was complete, we saw that the path of the upper school curriculum was the inverse of grades one through eight. First, the subject matter of grade eight is reconfigured and reviewed in grade nine. Then, in grade ten, the mineral kingdom is considered in connection with the whole earth as an organism. The plant and animal kingdoms are covered again in the next two grades, and finally, in grade twelve, just before the young people leave school, the focus is again on the human being, but this time as a synopsis of all of the natural kingdoms that presents itself to the young people's souls. Waldorf science instruction begins with the human being and then traverses the entire cosmos to conclude with an enhanced understanding of the human being.

This curriculum with its grand perspectives was certainly capable of inspiring us to tackle great tasks. The timing of each subject is not arbitrary; child development reveals why it must be presented at one particular time and not at another. At first we were only dimly aware of the curriculum's fundamental importance. The full scope of its consequences became apparent only later, as we tried it out and thought about it. In the moment, however, it was up to us to develop the details of our lessons on the basis of these fundamental ideas, and to do that we needed more.

It may seem paradoxical that Rudolf Steiner gave courses on scientific subjects very soon after the school opened. They were aimed at Waldorf teachers, but others interested in science and affiliated with the anthroposophical movement also participated. These courses, which covered the subjects of light, heat, and astronomy, contain countless suggestions for research and many approaches to solving specific problems. Above all, however, the purpose of the courses was to *open teachers' eyes* to how science must be taught once we have truly seen all of nature with new eyes and learned to think about it in new ways.

I still have not forgotten how Rudolf Steiner talked about these subject areas. Whole worlds of insights were revealed to us. First, for example, we heard about contrasting elements such as light and electricity. Light belongs to the extraterrestrial cosmos. It is the opposite of matter (the heavy or earthly element) and is closely related to human consciousness, to the clear, alert conceptual activity that is the "light-filled" element in the human being. The same is true of sound. Although actually also related to the super-earthly element, electricity is bound up with the very structure of matter and struggles to rise from those depths. In human beings, it is related to the unconscious will that works in our limbs. Light and electricity are similar only inasmuch as both can manifest as "light," but in reality they are polar opposites in origin, one coming from cosmic expanses, the other from the depths of matter. Rudolf Steiner distinguished with great clarity between the clear, geometrical, thought-related manifestations of light and the mysterious, dark, almost ghostly manifestations of electricity, focusing on their connection to the human being in particular. We understood that light and sound relate to conscious human conceptual activity whereas electricity relates to the will pole. But heat, for example, lies in between: All of its manifestations mediate in some way between matter and ether, consciousness and unconsciousness, conceptualization and will; as such, they are related to feeling, to the middle aspect of human nature.

At this point, insight dawned on us – insight into the role each force of nature plays, both within the cosmic whole and in the human being. For example, we realized that a lesson on light would have be developed very differently from one on electricity, not only in terms of their content (which is self-evident) but also with regard to the teacher's overall tone and attitude. If we view light as only a different manifestation of electrical vibrations, this view will be expressed in everything we present and it will not allow the children to experience that we are dealing with two forces of nature originating in opposite poles of the human organism. But if as teachers we take such thoughts about the essential character of natural forces into account, we are then able to identify the right materials, the right sequence, and the right examples to use in our lessons.

Countless phenomena became comprehensible as a result of such flashes of insight. We also learned to think very differently about the states of matter and their essential nature than we had done before. In the gaseous element, for example, we recognized the activity of forces that are directed out into cosmic space; in the solid element, we recognized the contracting, Earth-oriented forces. The fluid element stands between them. These ideas cannot be found in any book on physics, but every detail of our lessons can be linked to them. They are seeds for pedagogical activity.

It was similar with *astronomy*. For example, we learned how the starry heavens relate to the configuration of the human organism. In the head, in the shape of the skull, the system of *fixed stars* is revealed, while the midsection of the body with its loop-shaped ribs reflects the *planets'* lemniscatic courses. In the radial orientation of limb development, we recognize the forces of the *Earth*, which are directed toward its center. These perspectives are applicable both to astronomy and to the study of the human being. What is most important is not the specific insight but rather the inner schooling that results from this way of looking at things. If we think from this perspective, we can make ever new discoveries about the connections between heavenly processes and the structure of the human body, and we teach differently when we know about these things.

In effect, therefore, Steiner's science courses were an esoteric school of science for the participating teachers. Rudolf Steiner always aimed to present new views of the essence of the human being and its connection with the cosmos. This shapes and educates teachers, and in a certain sense they become different people. If we take up these perspectives in our preparation, each lesson we present will be different.

The teachers were then charged with implementing science instruction in their classes, whether in the main lesson as class teachers or as specialized teachers in science blocks. At this point, I would like to give a more narrative account of my own experience. In my previous work in chemical laboratories, I had wrestled with the problem of understanding chemical phenomena on the basis of what they reveal directly, one illuminating the other, as they express their essential character. I called this type of observation "phenomenological chemistry." It was an imperfect attempt to grasp nature in the sense of Goethe's statement, "We must not look behind the phenomena; they themselves are the teachings." The methodology of this approach now helped me flesh out the consequences of Rudolf Steiner's very surprising ideas. "The initial foundations of chemistry are best provided by beginning with combustion phenomena," said Steiner tersely in his explanations of the curriculum. It took me years to exhaust the full content of this statement. I began by attempting to demonstrate what a flame is: On the one hand, it radiates light (and heat) out into the world – imponderables returning to the heavens. On the other hand, ash precipitates – dead, material, solidified ash that has become totally earthly. Between these two poles, the air that feeds the flame is active, along with smoke, in which air and water wrestle. The whole phenomenon is what we call a flame. It is where the great cosmic opposites separate: light and heat separate from solid matter, from the salt-like, earthy element. Everything that is alive is combustible. The coloring and fading of leaves in the fall is actually like an extensive development of flames that ascend to heaven, leaving ashes behind. We must view the combustion process as spirit extricating itself from matter. A stanza by Goethe beautifully summarizes what needs to be said about this: "Whate'er a living flame may surround, / No longer is shapeless, or earthly bound. / 'Tis now invisible, flies from earth, / And hastens on high to its place of birth."

This is how we can talk to the children about individual manifestations of combustion. We allow fire, the combustion process, to emerge from nature itself. We show how it develops out of blooming and fading, how dead fire emerges from life. In each instance of combustion we find these same great cosmic contrasts, and the children learn to feel the same toward *every* manifestation of fire. Only later will we talk about oxidation. Oxygen supports ash formation. It is earth-oriented and wants to solidify and condense everything. It takes the opposite direction from light. Through it, everything becomes earthly.

There are fire processes within the human body, too, but where are they? They are in the movement of our limbs, in actions in which the will is at work. Your will, your moving limbs, are filled with living, soul-imbued flame! This is where the outer process of burning can be found within, although totally transformed. And where is the ash? It is found in the human skeleton, in the structure of bones, and most especially in the human head. So we see that the human body is an inverted flame that burns in the metabolic/limb system, with the ash "precipitating" into the head. This flame, too, lives on air – the air of human breathing, which houses our human soul life.

It is different in plants. In their life process, they burn from below upward toward the heavens. Colorful flowers ascend from green leaves like flames; ash accumulates in the roots and in the bark of trees. Leaves, which breathe and hold water, are located between these poles. When ignited, each plant reveals a flame that is an image of its outer form. The flame from a burning blade of grass is different from that of a broad leaf or a flower. Animals are like hot, air-driven flames that crackle passionately, greedy for air. Human beings overcome this aspect to a certain extent, and the human "flame" is inverted because we walk upright. These ways of thinking are already familiar to the children from a different perspective: From studying the human body, they know that uprightness orients humans in cosmic space like inverted plants, with the horizontally oriented animals occupying the middle ground.

The basic phenomena of all of chemistry lie concealed in explanations of this sort. For example, in class we can experiment with heating plant matter of some sort in a hermetically sealed container, as in "dry distillation" of wood, to produce coal gas. The gas "blooms" upward; while down below in the retort, the charcoal (which will contain the ash as combustion continues) "takes root." Between these two poles, all sorts of fluid components develop and can be condensed, especially if leaves are burned instead of wood. Burning flowers produces more flame; heating bark, more charcoal. Even dead plant substance, therefore, produces a plant-like formation under the influence of fire. Coal gas, composed largely of methane and hydrogen, develops in the top of the retort. The children learn how hydrogen "grows" out of the combustion process when air is excluded and then ignites or "blooms" as it rises. They understand that hydrogen is part of the materialized manifestation of the plant's striving toward the heavens. When they then learn the chemical properties of hydrogen, they are not surprised to discover that it is so light, expandable, volatile, flammable, warming, and unstable or that its distinctive activity is always the opposite of oxygen's. Hydrogen is directed out into the cosmos, oxygen toward the earth.

Once we have laid the foundation so carefully, it is then tremendously meaningful to the children to discover that water can be transformed into hydrogen and oxygen. They are already familiar with water as the mediator than connects opposites wherever it is found. It is the bridge between heaven and earth, between acid and base, between gases and solids, in human blood circulation, between peoples and nations, and so forth. Now they understand why this is so: Within itself, water binds together the fiery, volatile element of hydrogen and the solidifying, earthly element of oxygen, which would turn everything to ash. As an experience, this is totally different from confronting the children very early on with the fact that water consists of two atoms of hydrogen and one atom of oxygen and that its chemical formula is H_2O. Instead, we want them to understand on the level of feeling and thinking *why* the laws of the entire cosmos require water to have the specific inner makeup that corresponds to this formula.

Of course an essay such as this can provide only partial indications, but all the facts children learn in other schools can be approached in this same way at any level of instruction, always building on what came before. It is important to emphasize this point because it would be easy to give the impression that Waldorf children do not learn the facts they need to know, which is not the case at all. It is only a question of *how* they learn about the same facts they would have to learn otherwise. For example, when I talk about salts, the whole tone of my lesson must be different than when I talk about the combustion process. Salts are the solid element that crystallizes out of fluids, acquiring form, condensing, and becoming earthly. *Salt processes* are the opposite of *fire processes*. That is why ashes contain such high concentrations of salts. Water, however, actively mediates between and unites these two poles.

In a faculty meeting devoted to determining the chemistry curriculum for grade eleven, Rudolf Steiner said something like this: “Talk about each substance in a way that allows the class to recognize that its effects are distributed throughout the natural world, that it also works within the human body, and that the substance itself is only the solid-looking part of a living process.” That’s all he said. We had to take it from there. For example, when I had to talk about sulfur, I attempted to make it clear to the class that it is only one part of the earth’s Vulcan or fire process and that it also works in the same way in plants, animals, and humans. It promotes growth, digestion, and all metabolic processes; it is at work in the caustic plant oils, in human metabolism, and in all forms of rot; as a medication, it initially re-inflames old disease processes, and so forth. In short, sulfur is only a small part of a comprehensive *sulfur process* that pervades and fuels all living things. As such, all substances are the corpses of *living processes*. When we grasp these processes, we stand in the focal point of nature’s creative activity and from there gain access to the entire cosmos as well as to the human being.

Similar lessens can be developed around any substance. For example, young people must know that *calcium* is inseparably linked to processes in *animals*. All calcium is actually the product of animal life in various stages of transformation. The element of *potassium* stands in a similar relationship to *plants* and *sodium* to *minerals*. Our understanding of calcium is inadequate if we fail to realize where its process takes root in the living, natural world. This is the only way to understand all outer processes (including technological processes) that involve the use of substances.

In one lesson on combustion, I showed the children various examples and also demonstrated how sulfur, for example, forms an acid when it burns whereas other substances form bases. Rudolf Steiner was sitting in on the class, and after listening for a while, he said to the children, “Now that you’ve seen all this, think about what goes on inside your own body. Something acidic always forms when you move your arms and legs, but when you sit very still and only your head is working hard, something like a base develops in your brain.” So the children sensed the connection between the process taking place in the beaker and processes in their own bodies. Rudolf Steiner often offered support of this sort for teachers, suggesting directions for further work.

He offered similar suggestions in other areas, too. Once when I was preparing to teach *zoology* in grade twelve, it became evident in a faculty meeting that there would be only twelve to fourteen days available for that block. I asked Rudolf Steiner how I could possibly hope to cover the subject in such a short time. Always in favor of economy in teaching, he didn’t hesitate a bit but said as if it were the most natural thing in the world: “Twelve to fourteen days! That’s just right! There are twelve groups of animals, so you can talk about one each day and still have a little time left to sum it all up.” I was astonished. “Twelve groups of animals?” “Yes, I’ll write up the list for you by tomorrow,” Steiner said, and he did. The next day, I had the names of the twelve animal groups and my real work began, namely, researching the characteristic features of each group. By the time I finished teaching that block, I knew how to teach zoology because I realized that those twelve groups, taken together, accounted for the entire human being. And moreover, combining those twelve groups into three larger groups of four each revealed that the first four are repeated on a higher level in the second four and on an even higher level in the third four. For example, in all its attributes, *polyps* or jellyfish manifest as lower forms of worms and worms as lower forms of snakes or other *reptiles*. Or insects (seventh group) reveal themselves as an imperfect level of birds (eleventh group), and so forth. In short, the entire animal kingdom appeared wonderfully structured and in the closest possible relationship to the human being. I realized this not through speculation but as a matter of direct perception when I had finished teaching about the twelve groups.

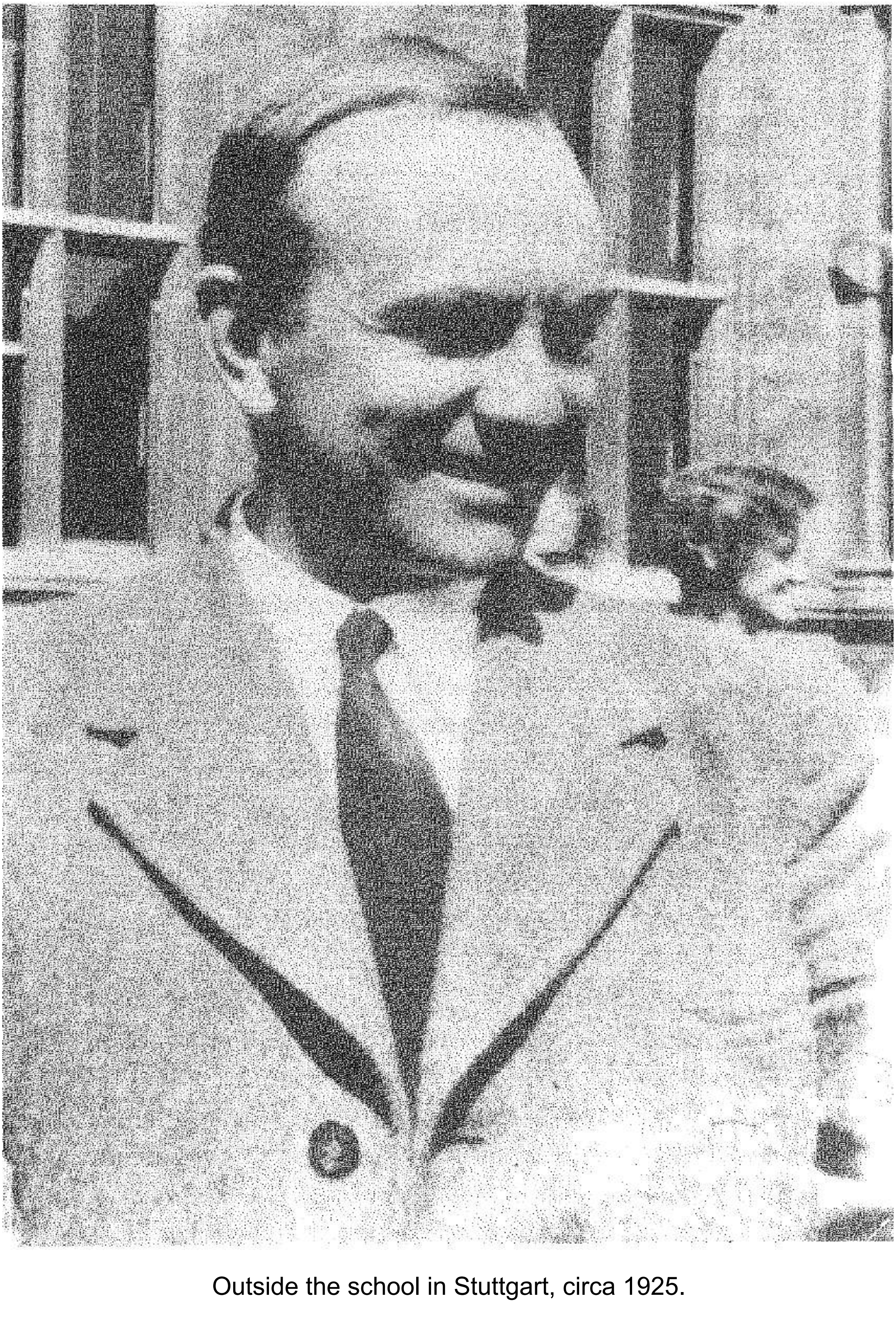
Of course the actual *study of the human being* is a natural focus and is taught repeatedly on all levels, so it developed in unique ways. The guiding light for teachers is Rudolf Steiner's principle of the *threefold human being*, which was one of the first contents of Steiner's original teacher training course. Having spent some time teaching in the way described here, it is difficult to imaging studying the human being without this view of human threefoldness. The study of the human being overlaps with all other subject areas, and in this sense teaching science becomes the common property of the whole school. How can we talk about the human being without beginning with the distinction between the head (the waking, conscious part of the body that serves cognition) and the unconscious limbs and metabolism? When we cover the nervous system, we find the same division: the *brain*, which is completely at the service of our waking, conscious psychological activity; the *spinal chord*, which is totally devoted to reflexes and semi-dreaming actions; and the *sympathetic nervous system*, which is totally unconscious and involved with digestion and the internal organs. The same subdivision is also apparent in the limbs: down below are the legs, totally subject to gravity; above, the jaws (the head's "limbs"), completely incorporated into the roundness of the head; and between these poles the arms, freely mobile and accessible to rhythm and to the gestures of speech. The upper human body is shaped by cosmic forces, whereas the lower port, which serves nutrition and locomotion, is shaped by the earth; the midsection with its rhythmic system mediates between these extremes. These truths, however, are not taught to the children exclusively in blocks on the human body but also appear (more or less consciously) in all other subjects. Isn't this threefoldness present as a self-evident active principle in eurythmy, gymnastics, or art – or for that matter, in every other subject? The children sense this unity running throughout the entire school. The study of the human body is the foundation of the entire art of education.

Teaching science in this way is an ongoing living, growing process that must constantly be shaped by the community of teachers. In the first Waldorf School, for example, when a teacher succeeded in developing a specific subject block for one of the upper grades, those efforts were not wasted but was shared with other teachers who would cover it later, on either the same level or a very different one. Still, of course, every teacher had to prepare for the block anew, since no two classes and no two teachers are alike. Waldorf teachers engage in a unique form of pedagogical work when they develop the methodology they need for a specific class by applying the sum total of Rudolf Steiner's indications, the practical experiences of colleagues, and publications that have appeared in the meantime, ultimately arriving at a way of teaching chemistry or a topic in physics that is unique to that class. Conventional textbooks are of little help in this approach. They usually present only a very small fraction of the subject matter, and much of what they do include is unusable, so we teachers must laboriously compile much of our material from a wide variety of books. Where would we ever find a single book that gives a complete description of the effects of silica and lime? We might find one aspect in a book on human physiology, others in botany or zoology texts or in older works by Goethe's contemporaries, for example, who developed similarly comprehensive concepts of nature as a whole.

Today we also owe a great deal to scientific works by anthroposophical friends, who have covered a wide variety of subjects in the past ten years, offering teachers a wealth of stimulating ideas to draw from. For example, when *Guenther Wachsmuth*'s book on etheric formative forces in the cosmos, the earth, and the human being appeared, it also gave a great boost to activity in the schools because it provided teachers with countless possibilities for teaching at any age level. Anyone who has read this book and then has to teach a class about geography, weather, the course of the sun, or the earth as a whole will bring the subject to the children very differently from before. And when *Hermann*

Poppelbaum's book "Man and Animal" was published, it struck me that it made available a tremendous amount of material that would help teachers prepare to present the Earth's evolution in ways appropriate to the children's souls. What good does it do to talk about spirit if what we convey to the children is an image of the earth in which the human race appears as nothing more than the highest among animal species? Formerly, it was possible to avoid this dilemma only by laboriously compiling the geological and paleontological facts discovered by the natural sciences and then comparing them to Rudolf Steiner's "Esoteric Science," struggling to combine the two. A few indications were available, but what we had was, on the one hand, scientific presentations with endless lists of facts but no spiritual content; on the other, humankind's evolution in spirit and soul. We knew that each list of scientific facts had to be understood anew in conjunction with the contents of "Esoteric Science." And after that, we still had to adapt everything to the needs of the children. The availability of so many stimulating ideas in the writings of anthroposophical researchers certainly does not mean we should not use other literature, recent scientific publications, and so on in our preparation. But we need more than just those, and that "more" could only be developed as described above. Even today, there are still no children's science textbooks; we have had to compile them ourselves.

In short, a totally new way of teaching science had to be developed, and perhaps it is justified to say that this new way of teaching is beginning to live up to the ideal presented at the beginning of this discussion. It really does integrate nature into human cognition in ways that allow us to acknowledge that the human being subsumes all the forces of nature and transforms them into something higher. In turn, however, the human being is what makes the natural world understandable for us. In the context of education, therefore, science uses modern insights into nature to vindicate the "image of the human being," the ideal that must present itself to humanity's view today.



Outside the school in Stuttgart, circa 1925.

Eugen Kolisko

Excerpt from
“Auf der Suche nach neuen Wahrheiten” [In Search of New Truths], 1989

FIRST LESSONS IN CHEMISTRY

Preface

The descriptions that follow are the result of my experiences in teaching at the Independent Waldorf School in Stuttgart. The block presented here is taught in grade seven, when the children are thirteen years old, and is preceded in grades four through six by age-appropriate introductions to animals, plants, minerals, and the human body. In the first three grades, imaginative descriptions of nature guide the children down out of a fairy-tale ambiance to the human being, which then becomes the starting point for learning about the animal, plant, and mineral kingdoms, in that order. After the children have been led down naturally to the inorganic world, physics is introduced in grade six, followed by the first chemistry block in grade seven. In this way, the children are led slowly and systematically from the world of spirit-imbued, soul-endowed, living beings to the processes inherent in matter. At this point, we introduce basic, essential basic concepts of chemical activity. These concepts must be ones that can “grow with the children,” as Rudolf Steiner put it. Through all of their studies, right up to the chemistry blocks in the upper school, the children must be able to carry these concepts along, constantly building upon them and confirming them through new experiences. Concepts of this sort can be found in Goethe’s teachings on nature. In his youth, Goethe often became aware of fundamental phenomena. Throughout his long life, everything he subsequently observed in nature from day to day linked up with these early experiences and concepts and was illumined by them. Concepts like these are the ones teachers must present, because the teacher’s job is not simply to convey knowledge but to plant seeds in the children’s souls that will then continue to grow for a lifetime.

When we take this approach, conventional chemistry textbooks are of little help. Most of what they present is like excerpts from college curriculums. Instead, we must seek out what is truly appropriate to the children’s makeup, to what they are really looking for at this particular age. Although of course we must take the discoveries of the science of chemistry into account, we must present the world of chemical processes to the children’s souls in very living and vital forms. Only in this way do children’s souls become mature enough to understand the basics of chemistry. The scientific element, however, is alive even in these simple beginnings and can then develop further on the basis of the foundation that has been laid.

Special importance is attached to two considerations:

1. Everything the teacher presents must draw connections to the human being, because nature studies come alive for children only in connection with insight into the human being.
2. The connection to practical activity must always be taken into account. Insight into chemical processes must be applied to understanding the mechanical, technical, and economic aspects of everyday life.

Every lesson in natural science must meet these two requirements. By understanding the connection between human beings and nature, we bring spirit into the study of science. By drawing attention to technological applications, we establish the connection to the necessary demands of practical life in the modern world.

This approach integrates the first block in chemistry into the larger structure of the curriculum as a whole. With regard to details, however, each teacher will certainly plan the block very differently. The following examples are intended to stimulate ideas; each one must be considered as only *one* possibility among many.

1. About Combustion

What is the easiest way to approach the subject of chemistry with children? Chemistry is something entirely new to the children's souls. Initially, they are much more at home with the concepts of physics. What light and sound do in the natural world is more self-evident, whereas chemistry takes us inside the world of matter and its processes. To unbiased observation, it is clear that even to adults, the world of chemistry often remains more foreign than we usually imagine – and often for their entire lifetime. The easiest way to introduce children to essential, basic ideas about chemical processes is through the process of *combustion*. This is the best point of departure, a point that permits many meaningful connections.

We begin with activities that demonstrate a series of different examples of combustion. Let's assume it's an autumn day. We go for a walk in the woods, and the children collect all kinds of flammable materials to bring back to the classroom: dry leaves, twigs, bark, dried moss, dead grass, pine cones, and more. To this collection, we add different kinds of wood, green plant parts, straw, paper, wax, oil, and petroleum. Now we simply go through the whole series and demonstrate how these plant parts and other items burn. We ignite them and observe, together with the children, the extreme variation in the flames that result. Each twig, each plant, each item has a different flame. We can often recognize the type of plant by the flames it produces. Grasses burn with pointed flames, pine needles flicker and spark, pinecones crackle and burn with dense flames, and each type of leaf burns differently. We end up with an entire "botany of flames." The children are quick to notice that the entire inner character of each living plant is revealed again in its flame. The flames of other burning substances and objects also vary greatly. We experience the living, mobile aspect of fire and also the fact that it consumes. Very little needs to be said about the whole process; the phenomena speak for themselves. The children watch with great excitement, experiencing the distinctive character of the element of fire in its very different manifestations.

One thing in particular should be pointed out: On the one hand, *light* and *heat* always develop, manifesting as flame. On the other hand, *ash* remains behind. Ash is lifeless, dead, totally mineral. We encourage the class to experience the great contrast between light and heat on the one hand and ash on the other. The children's pleasure in the flames and their slight sadness when only ash remains is enough to ensure that they have experienced this contrast. On the first day, it is a good idea to simply allow the children to experience the phenomena. All commentary is superfluous. Choleric children are especially impressed with the flames, but we notice that the process of ash formation makes a greater impression on the melancholics in the class. Everyone notices the infinite variety of flames and the primordial living character of fire.

As teachers, we have to reckon not only with what happens in the children by day but also with their experiences during the night. What the children take in through observation returns the next day, at the beginning of the class, as an unconscious question about the essence of the subject. Now is the time to sum up the many phenomena we have observed in a simple way that makes the children aware of the essential character of combustion.

For example, we might say: Remember all those leaves and other plant parts we brought back from the woods. When we set them on fire, light and heat rose up and away.

On the other hand, ash developed down below and fell to the ground. It is totally dead. Light moves heavenward, ash moves earthward. We saw fire break out from plants that were once alive, and the fire went up to heaven while the dead, earthly, ash-like part remained behind.

With the right questions or even none at all, it will not be difficult to elicit spontaneous expressions of these and similar ideas from the children themselves. We ask, where does the light come from? It is none other than the sunlight that the plants once took in. The sun shines on the earth; plants sprout and grow up toward the sun. *Everything that is alive is combustible. When we light a fire, light returns to the sun.*

The children sense what combustion is all about. Light that is completely condensed in wood or coal becomes invisible and disappears. That light is then released. Here the children grasp the very important dichotomy of *light* and *weight*. Their earlier education has already accustomed them to sensing such contrasts.

Next we can talk about plants. Just look at their flowers: red, yellow, or multi-colored, they often look like flames – poppies, for example. When we burn flowers, do they leave a lot of ash behind? No! When we burn roots, they leave a lot of ash but don’t glow as brightly. Why not? Flowers glow even before we set them on fire. Blooming is already like burning. Flowers are related to the heavens, as their beauty shows. Roots, however, belong to the earth. That’s why so much dead, mineral ash remains behind. So what are plants, really? Living flames! From their green centers, flowers escape upward like flames, but the ash sinks down into the roots.

After the children have learned these basics, we can put the whole thing into an image, drawing it on the board with colored chalks. A picture like this remains meaningful for a lifetime. Having brought the combustion process into connection with the whole world, we will never succumb to the temptation to view it as a purely material, chemical process. We set the dead plant on fire, but actually the burning is already present in the living plant. What plants do when they grow, flower, and make roots is simply continued in a more forceful and destructive way when they are burned. What unfolds at a more moderate pace in the rhythms of life, manifesting in flowers and roots, is torn apart into shining flame and ash when the dead plant burns.

At this point, we can also make the connection to the human being. Is there combustion within the human body, too? It is easy for the children to guess that heat is at work in blood, digestion, and limb activity. They feel how heat works inside their bodies, and they know that the internal and lower organs are warmer. But where is there the most ash in the human body? From their human studies blocks, the children know this, too: the head is the most mineral or ash-like. In the human body, therefore, the heat is down below and the ash is up above. This means that a flame of sorts also burns in the human body, but it is upside down in comparison to the flame in plants. The children enjoy this realization because they have already heard that our human orientation in space is the opposite of plants’ and that plant roots actually correspond to the human head. At this point, we also have the children paint the contrast between combustion processes in human beings and plants.

Observations of this sort can also be taken further. We remind the class about the significance that cremation has held for humanity since ancient times. The soul extricates itself from the living body just as light extricates itself from matter during combustion, and the corpse remains behind. Ash corresponds to the corpse, and the soul dwells in the living body just as light dwells in combustible matter. This parallel provides opportunities to link to historical and religious ideas and allows us to draw an intimate connection between science and art on the one hand and spirituality and religion on the other. In this context, we can also remind the children about the significance of sacrifice by fire and the connection between earth and heaven that human beings seek in the sacrificial flame. We can all find other connections for ourselves. The most important point is to be deeply moved by a spiritual view of fire and combustion.

These observations can be summed up in simple sentences and dictated for the children to write down.[1] They have taken great interest not only in painting the different flames produced in the combustion experiments but also in creating pictures of the activity of fire in humans and plants. Now a short text is added, ending with a verse as a self-explanatory summary of the two lessons. The pedagogical significance of such a conclusion is great. The text can read somewhat as follows:

"All living matter is combustible, so if we set the dry parts of plants on fire, flames come spurting out. Light and heat escape upward, out into the big, wide world, but the ash remains behind. Light is bright and weightless; ash is heavy and has to fall to the ground. This means that combustion always separates light from heavy, earthly matter. When a plant burns, the light that was held spellbound within it escapes. That light is the sun's energy that the plant once took in. It is no different when we burn part of an animal body, because hidden light enters the bodies of animals and humans through the plants they eat. The plant is a living flame that burns upward, toward the blossom. There are living flames in animals and humans, two, but they burn in different directions. In the human body, the flame burns downward and the ash settles in the head. When we look at fire, we sense how it consumes everything and carries it up to heaven, back to where everything comes from when it comes down to earth."

Whate'er a living flame may surround,
No longer is shapeless, or earthly bound.
'Tis now invisible, flies from earth,
And hastens on high to its place of birth. (Goethe)

The next day, we can continue by talking about the *interaction of flames and air.* We do another series of experiments, this time to demonstrate that flames need air. Flames burn stronger in a draft and weaker when air flow is poor. Both the speed of combustion and the amount of heat it generates depend on the supply of air. A candle flame soon goes out if we put a jar over it. Then we do the famous experiment with a candle that is secured to a cork plate and floated on water. After lighting the candle, we invert a bell jar over it. The candle goes out after a while and the water level rises in the jar, raising the candle by a height equal to about one-fifth of the original volume of air in the jar. The children can see that the flame has consumed part of the air.[2,3] It is not yet necessary to identify that fraction as oxygen. It is enough to acknowledge the fact that air stimulates the flame and is partially consumed in the process. Next we present a series of flames with different means of increasing the airflow: First we blow on a candle with a blowpipe, then we demonstrate various gas burners with or without forced air, such as a Bunsen burner or a propane torch. Finally, we demonstrate the use of a foot-operated bellows. The flames increase in strength with each increase in air flow, so the class can readily see the effect. They also see that increasing the air supply requires increased effort, especially in the final example, where you have to step on the big bellows to make it move. Finally, the children learn about a number of features that will be used repeatedly throughout their lives. We

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[1] I would find it important for the children to compose their own text, or at least work together on it as a class. (P. Glasby)

[2] This description is incomplete: The volume is actually reduced by less than one-tenth, and the chemical process is complex. (D. Rohde)

[3] This "classic" experiment has been exposed as a misinterpretation of the phenomena, which are now understood in a much more complex way that involves expansion, cooling, and contraction. In any case, I think it should be treated with caution as it tends to jump ahead to understanding chemistry in terms of individual substances rather than remaining with the understanding of qualities. (P. Glasby)

point out that without extra air, flames burn a beautiful yellow but are not very hot. With increased air flow, they become blue and hotter. This is another opportunity to mention the contrast in colors that is evident in any candle flame. Why is the lower part of the flame blue? It appears blue against a dark background, just as the sky appears blue because we are looking into the darkness of space through light-filled air.[4] The class will be interested to note that if the intense pale blue flame produced with the help of the bellows is totally invisible when seen against a light background (for example, if the sun is shining on it). The children are already long familiar with the contrast between blue and yellow – that is, between light and darkness. We expose the children to a flame's full variability: how it changes, becoming brighter and darker, growing and shrinking – in short, how it has a life of its own.

The contrast between heaven and earth, up and down, applies to the *development* of a flame, to the formation of light and ash. *Changes* in flames are brought about by air. Air changes the color of flames and makes them grow or shrink.

In this way, the children learn about fire as an independent element. They sense how a flame encompasses aspects that strive to separate – namely, upward-directed light and heat and downward-directed ash. When combustion is incomplete (for example, when we try to burn green plant parts), neither a bright flame nor ash can escape fully, and smoke, steam, and soot develop in the middle. That is why only dry, dead plant materials burn well. The watery element in living matter creates smoke and the flame cannot prevail, so no real separation between up and down takes place.

Before we move on to more abstract chemical explanations, the children must first have these experiences of the element of fire. Once we have related the essential nature of the flame to the entire cosmos and to the human being, we can then talk about the practical uses of flames and describe their importance for heat and illumination.

We begin with the phenomenon of a bright flame that deposits soot on a cold surface. In other words, the flame generates carbon. Carbon can glow, but only when not too much air is added. With sufficient air, it burns and releases heat. We show the class an acetylene flame, which burns brightly and readily deposits soot, followed by a hot, blue, non-blazing gas flame. The former can be used for *illumination*, the latter for *heat*, as in a gas oven. Flame is always an interplay between light and air, and heat is what unites these two contrasting aspects.

But since hot flames are not bright, is there any way we can use them for illumination? Can they be used to make something else glow brightly? The children soon realize that carbon is not appropriate for this purpose because it burns up too quickly. We need something that is non-combustible but still emits light when heated – in other words, something ash-like or mineral-like. The children can now understand the principle behind the incandescent gas mantles formerly used in street lighting: A mineral substance shines brightly when heated by a non-luminous flame. A contrasting principle is at work in the original carbon filament light bulbs: The carbon filament glows when heated by electricity but cannot burn up because the air has been pumped out of the bulb.[5] In this instance, the light-emitting material is combustible but is not allowed to burn, whereas in incandescent gas lights, the heat of a non-luminous gas flame makes a non-combustible substance glow.

Using examples like these, it is easy to expose the children to the wide variety of practical and technical applications of flame. All of this material can again be summed up in drawings, paintings, and a dictation.

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[4] This description is incomplete; the phenomenon is related above all to the different substances involved in combustion (e.g., carbon, hydrogen, carbon monoxide). (D. Rohde)

[5] This is a cross-reference to the main lesson block on galvanic electricity, which also falls in grade seven and includes the wonderful story of Edison's work in developing the light bulb. (P.Glasby)

In the next lesson, we can go one step further, introducing other combustible materials, some of which are not directly derived from the domain of life. We investigate *sulfur* and *phosphorus* and compare them – of course – to natural *coal*.[6]

First we talk to the children about *sulfur*. It is yellow, indicating the fire within. When we set it on fire, it burns with a unique dark or light blue flame that looks like a particularly intense and one-sided version of the blue portion of a candle flame. Sulfur comes from the depths of the earth, emerging mainly through volcanoes. It is solidified fire from the earth's interior. This is what we tell the children, letting them sense how the chunk of sulfur on the desk is only a very small portion of the fire process at work deep within the earth. Sulfur also works similarly in plants and in humans. For example, we remind the children of the color of a field of flowering mustard plants in flower and tell them about the sulfur-containing oils in these plants, which give mustard and radishes their sharp taste. In the human body, the effect of sulfur is to speed up metabolic processes. Sulfur baths have healing effects on rheumatism and other conditions involving stiffening or hardening. The initial effect of sulfur baths is often to reactivate old illnesses that have long lain dormant: Rashes may erupt on the skin, for example, or old wounds break open again. In the human body, therefore, sulfur's effects on bodily processes are enlivening and volcanic.

Phosphorus is very different. Its flame is very bright and light-colored, almost like the sun. Phosphorus radiates light even in the dark. The children are very impressed to I glow. They say, "That's not matter at all, that's light!" No heat accompanies this light. The contrast between sulfur's dark blue flame and the white flame of phosphorus is worth noting. It is as if the other, glowing portion of the candle flame now exists on its own. Next we tell the class that phosphorus is present in the human brain. Phosphorus, with all its luminous energy, is at work there! But why specifically in the brain? The children soon discover that phosphorus is related to thinking in the human head. Thinking "lights up" in the brain, and we need phosphorus for that. Phosphorus has a unique and characteristic smell, the same as the smell in the air after a thunderstorm.[7] It is like something from the cosmos radiating into the earth. The opposite is true when a volcano erupts: Then something hot radiates upward from below the surface, and the disgusting smell of sulfur is characteristic. But when lightning strikes, the smell is the same as when phosphorus burns.[8] What do we say when we suddenly understand something? We say, "A light went on inside!" or "I just had a bright idea." This experience is related to the phosphorus present in the brain. In fact, phosphorus is a heavenly fire on earth, but sulfur is a sub-earthly fire. Sulfur exists in nature as a product of volcanic activity, but pure phosphorus must be produced by artificial means.

Carbon, or *coal*, occupies the middle ground between these two flammable elements. The children already know that coal comes from dead plants, so its ultimate origin is still the living world. That's why it is combustible. Its light, however, is spellbound and hidden deep within. Coal itself is dark and black, having been formed inside the earth. When coal burns, the flame is the ordinary type with a shining upper portion and a blue base. Coal unites the two types of flames that show up separately in sulfur and phosphorus. All organic combustibles contain carbon, so we see the same type of flame when they are burned.

At this point, having illustrated how these elements work in the cosmos, we can again establish a connection to the human being. In the human body, the effects of sulfur emanate from the lower organs, working their way upward and outward from the digestive

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[6] I would discourage class teachers from including phosphorus in the main lesson at this point. Unlike in the 1920s, when phosphorus matches were probably quite common, it is not part of most children's lives today. It is also highly toxic and difficult to obtain, so I feel it is best to wait for the grade 11 block to introduce this substance in all its glory. (P. Glasby)

[7] In fact, the smell is not the same but only similar. Used here for purposes of comparison only. (D. Rohde)

[8] See note 7.

system into the blood. Sulfur is a fire burning inside the human body. But the cold light of phosphorus emanates from the brain. It is what we use for thinking. But what about carbon? We burn carbon in our bodies and exhale it through our lungs. We will tell the children more about this later, when they have learned about carbon dioxide. Plants contain carbon that they have breathed in under the influence of sunlight, and that light is given off again when plant carbon burns. Explanations of this sort awaken a living awareness of the three most important flammable elements – sulfur, phosphorus, and carbon – that are not directly derived from the living world. They relate to very different processes in the human body: *sulfur* to *digestion*, *carbon* to *breathing*, and *phosphorus* to the *light of thinking* that develops in the brain. These connections can again be summed up in a short dictation such as this:

"There are three especially important flammable elements: *sulfur*, *phosphorus*, and *carbon*.

Dark, consuming fire erupts from fire-spewing volcanoes. It roars and thunders out of the depths of the earth. Sulfur comes from volcanic vapors. In its beautiful yellow crystals, fire shines out of the depths once again. Sulfur burns with a dark, blue flame. This fire is also inside us. It works in our blood, warming it, setting all fluids in motions. It makes the body lively and fiery.

Phosphorus is very different. With a flame that shines like the sun, it is all light. When lightning strikes, the smell of phosphorus also appears.[9] This light is also inside us, because phosphorus is present in our brain. It lights up there when we understand something well. It lights up our head from above.

In the middle, *carbon* works in the breathing of our lungs."

2. About Calcium and Salt Formation

Understanding opposites is very important in chemistry. We began by discussing combustion, and *the opposite of combustion is salt formation.* Calcium provides the best example for presenting salt-forming phenomena. First we show the many different ways in which calcium appears in nature: in shells of mollusks and snails, coral, calcareous sponges, ammonites, chalk, and bones of all sorts – all belonging to the animal kingdom. Then there are rocks with obvious organic origins, such as chalks formed from freshwater calcareous mud and fossil ammonites or trochites, and so forth. Finally, we show the class calcite, stalactites and stalagmites, marble, and granular limestone. The more examples we can present, the better. Next we ask, how did all these formations come about? Ultimately, they were all deposited by water. It takes a long time, for example, for stalactites to develop through the evaporation of lime-rich water. We also explain how the delicate shells of dead animals are constantly raining down out of seawater to form calcareous mud on the ocean floor. That is how chalk develops – out of the countless shells of tiny living things. In some cases entire mountains, such as the chalk cliffs along the North See and the Baltic, formed out of chalk deposits. Shell limestone develops through a similar process. All of this takes a very long time. Limestone mountains develop very slowly. Calcium drops to the sea floor and is compacted and solidified. This process is very different from combustion. In combustion, we must first set the various plant parts on fire, and then they disperse as they are transformed into fire and smoke.

Now we bring an assortment of shells and stones into class – as many different ones as possible. They have all either been deposited under water or excreted by living things. When the solid element separates from the fluid element, everything proceeds very slowly and quietly, as when salt precipitates out of seawater. In fire, the activity of heat,

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[9] See note 7.

light, and air predominates, and little solid substance remains. The processes of crystallization and precipitation of lime and other salts are totally different. It is true that lime develops from living things, but the process is not at all like fire, which consumes everything living and returns it to heaven. Instead, everything precipitates to earth out of the watery element of life. Here gravity and heaviness predominate. When children observe these phenomena over a longer period of time, they often discover these great contrasts for themselves.

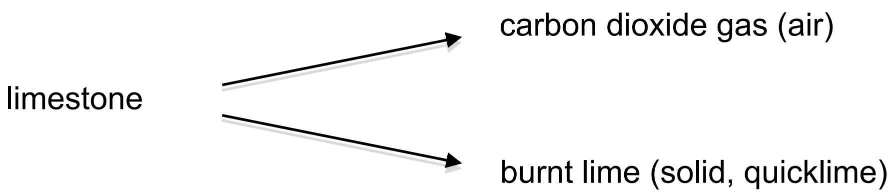
Water not only allows lime to be deposited but also dissolves it again, and it can then be deposited again later – for example, as stalactites and stalagmites in caves, as calcareous tufa, or as the crusts of lime that develop relatively quickly around objects placed in calcareous springs such as the hot spring at Karlsbad. Streams and rivers dissolve large amounts of lime and carry them away. Logically, there would have to be even more lime in the ocean because all rivers empty into it, but strangely enough – as we tell the children – there is very little lime in seawater. Where does it all go? It is used up by marine animals and is found in coral and in the shells of snails, mussels, and so forth. When these creatures die, their shells are deposited on the ocean floor and ultimately become the rock of mountains. In this sense, lime circulates, and animals are a part of the cycle. Actually, all lime comes from animals, because calcite, drip formations, marble, and so forth all come about when the original, organic mountain limestone dissolves in water and then re-crystallizes. The dissolved minerals, however, can then be used by marine animals to form their shells or bones. Lime cannot be considered without reference to the animal kingdom. The lime cycle was known in ancient times and is the origin of the Latin saying, *omnis calx e vermibus*, all lime comes from worms (“worms” being the name formerly given to all lower animals). Lime is redeposited, either out of organic fluids into shells and bones or out of water into new rock formations. Water carries lime over the earth, dissolves it, and allows it to precipitate out again. This is how the solid earth is built up out of the fluid element. We have chosen the term “salt formation” for this and all similar processes of deposition out of water.

The behavior of the class is quite different during these descriptions of salt formation than during previous discussions of fire. Fire is stimulating. The young cholerics are especially stimulated, but most children become livelier and somewhat choleric when observing combustion processes because the effect is transmitted to the will, the metabolic system, and the blood. When we consider lime, the mood is different and more thoughtful. We are encouraged to ponder how this infinite variety of rocks developed over long periods of times. Crystallization takes time, and the process must not be disturbed if perfect crystals are to form. When snow falls, huge quantities of crystals are produced. This, too, is a salt process of sorts. Of course the product is not a salt in the chemical sense, but the process is similar.

We can then ask, if fire works in human blood and in the movement of our limbs, where do we find salt processes in the human body? They are concentrated in the head, where there is also the most bone. If lime were not deposited up there in our heads, clear thinking and calm understanding would never be possible for us. There would also be no bony scaffolding to support us, and the whole body would collapse. This is how we relate lime formation processes to the human being. We have seen that combustion processes are related to the lower part of the human body and its limbs; salt processes to the upper part, to the head. On the other hand, we have also laid the foundation for a perception of the fact that death constantly emerges from life, and in fact that is how most of the globe was formed. Anyone who has internalized this fact will never attempt to explain life on the basis of dead matter. Our observations about lime, therefore, are connected to the human being on the one hand and to the world on the other.

In the next lesson, we can take our observations of lime in a different direction. We “calcine” a piece of limestone by heating it, preferably under forced air inflow such as with bellows.[10] We allow the burnt lime to cool and then pour water on it. It fizzes and heats up. We repeat the experiment with a larger quantity of burnt lime. It swallows the water greedily. Relatively large amounts of water disappear into the burnt lime without a trace. After a while, it begins to smoke and generates a lot of heat. Burnt lime appears to be deficient in water. Through the activity of fire, it has been completely separated from the water from which it originated, which is why it then absorbs water so greedily. The thoroughly “animal” nature of lime is evident even long after its last cycle through animal bodies. Adding even more water produces a milky liquid known as milk of lime or whitewash. If the mixture is left undisturbed, the slaked lime settles, but some of it remains in solution in the clear liquid (limewater). This limewater turns litmus paper blue, whereas the original, unburnt lime did not. A liquid that turns litmus paper blue is called a base. All bases also share a very characteristic taste, just as acids do. Heating limestone and slaking it with water produces a base. When limestone is exposed first to fire and then to water, it is transformed into a different substance. Did something escape when the limestone was heated? Carbon dioxide gas is what escapes in the limekiln when lime is calcined. We can collect it, or at least tell the children how that can be done, and then show them the carbon dioxide gas that is produced. This is the same gas that bubbles up out of naturally carbonated water. The limestone “exhaled” something when it was heated. The burnt lime that remains is more solid and becomes a base when mixed with water. That is also why burnt lime is called a “base,” because it forms the solid base or basis of the salt we call “lime.” The gas that escapes can also be mixed with water. Carbon dioxide gas gives water a sour taste, and litmus paper turns red in it. This is how carbonic acid develops from limestone.

We have now introduced the children to the concepts of *acid* and *base*. Limestone is actually a salt, the product of a salt-forming process. Limestone changes when exposed to fire, releasing carbon dioxide gas. Burnt lime remains behind, and when water is added to it, a base is formed. So:



Adding water to the substances separated by fire results in an acid and a base. Their opposite character becomes evident when each is combined with water.

These differences can be presented even more graphically. We show the class two bottles, one containing naturally carbonated water from a mineral spring, the other limewater. The first liquid contains bubbles of carbon dioxide gas, the same gas that escaped from the limestone. This liquid tastes slightly sour; the bubbles make it feel tingly and lively. It turns litmus paper red. The limewater in the second bottle tastes flat and dull, and it turns litmus paper blue. The children enjoy being able to experience these major differences directly. It is no surprise to them that the prickly, sour liquid turns red while the dull, boring one turns blue. This makes perfect sense to them from their own experiences of color and from painting. Carbon dioxide bubbles up out of the carbonated water. The cork will pop out of the bottle if there is no fastener to secure it. The bottle of limewater

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[10] This experiment has been refined considerably by Manfred von Mackensen’s account (which I have elaborated). It involves creating a 1000 degree kiln in the classroom that allows both the carbonic acid given off by calcination and the “ash” (“thirsty lime”) to be collected. (P. Glasby)

develops a white layer of sediment on the bottom. Its cork stays in place or may even stick because solid matter is deposited on it. In the bottle of carbonated water, the movement is upward: air tries to escape. In the limewater bottle, the motion is downward: solids settle out. Litmus testing reveals the same contrast. These opposites, therefore, were originally combined in lime. They were then freed by fire, and water reveals the nature of each one individually. In the next experiment, we take some of the carbonated water (carbonic acid) and pour it into the limewater, which turns cloudy. A white salt settles out. This salt is also lime. It looks just like a slurry of ground chalk. So the opposites have been reunited.

Next we take a glass of limewater and blow into it through a tube. The same white precipitate develops. This means that the air we exhale contains the same gas that escapes when lime is heated – carbon dioxide gas. When fire transforms limestone, carbon dioxide gas escapes out the top and solid burnt lime remains on the bottom. Water mediates between solids and gases and also between calcined lime and carbon dioxide gas. Adding it to each of these separately produces a base and an acid, which if combined then produce lime again – or, as we can now state more precisely, calcium carbonate. Fire separates and reveals the two different aspects of lime; water exposes their individual natures but also recombines them. *Water reconnects what fire once separated.*

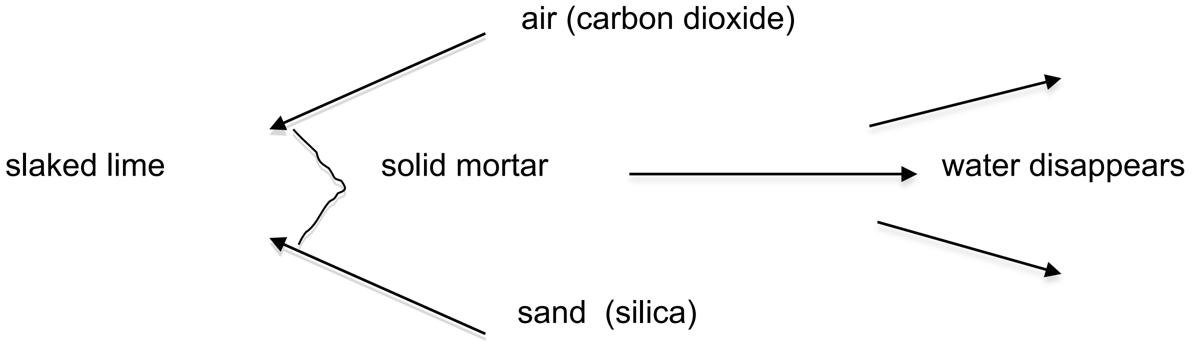
It is very important to avoid the usual approach of beginning with the acid and the base and deriving the salt from them. Instead, we must take the opposite approach, which is the natural way, because lime already exists everywhere in nature whereas the acid and the base are only produced later and by artificial means. The opposites inherent in lime become apparent only when we intervene to chemically alter the salt. Similarly, when we teach addition to little children, we don't begin by adding the addends to get the sum. Instead, we begin with a unity and allow the children to understand that this original unity has been divided and the parts added together again. We begin with the sum, not with the addends. In chemistry, too, we begin with the totality and allow the parts to emerge from it. This is an important point. Even at this level of instruction, teachers must sense that a "chemical compound" cannot be seen as simply the sum of its parts or the chemical sum of its elements. It is something new. In many cases, it is actually the natural, original material.

In this case, we look first at lime as the natural substance involved in the organic processes of bone and shell formation and only later at its differentiated derivatives. Lime is the product of organic processes. Through the intervention of fire, which results in an acid and a base, we can demonstrate that lime is calcium carbonate.

The *technical and practical applications* are then covered in a subsequent lesson. Lime occurs naturally in the earth. It is dug up out of quarries and then hauled to the lime kiln. We describe this facility to the class. The lime has to be heated so that carbon dioxide escapes and burnt lime remains behind. We draw the layout of a lime kiln and visit one if the opportunity presents. We then explain how the burnt lime is bagged in the processing plant and then shipped by rail to wherever it is needed. We can also take this opportunity to describe the economic connections surrounding a lime kiln (also part of the curriculum for this age group). Some of the lime goes to masons, who must first slake it. Once again, we demonstrate the intensity of the reaction when large quantities of lime are slaked. And now we ask, where does the heat come from when lime is slaked? Slaking lime releases heat because so much heat went into the lime when it was calcined. This heat is now contained in the burned lime and also in the carbon dioxide that escaped. The dried-out lime contains a dormant fire of sorts and has a tremendous thirst for water. When water is added to it, this thirst is quenched and the heat is released. We can also point out the dangers involved in slaking lime by demonstrating the caustic effects of limewater. In this connection, we can also touch on some of the social impacts of such industries and on the science of health.

Masons mix the slaked lime with sand, and the result is mortar. Here we discover a different contrast that we would also do well to emphasize to the class, namely, the contrast between lime and silica. Sand is silica – silicon dioxide or silicic acid – but mortar is alkaline. At this point, there is no need to address the acidic nature of silica, which will come up later in connection with glass-blowing. Even so, there is an obvious contrast between the greedy lime, which forms a smooth, slippery base, and the inert sand, which is hard, formed, and brittle.

We go on to demonstrate how bricks are put together with mortar, which then hardens rapidly. Interaction of the two opposites results in something new. We also tell the class about the practice of building a fire inside a newly constructed masonry house. Of course the heat drives the water out of the slaked lime, but that's not why the walls dry out. The fire gives off carbon dioxide, which combines with the slaked lime to form calcium carbonate. Mortar solidifies due to the addition of both solid sand (silica) and air, with its carbon dioxide content. The water disappears.



The drying of masonry walls can also be accomplished by allowing people – who exhale carbon dioxide – to live in the newly constructed house, although at the expense of their health.[11] In German, there is even a name for these temporary tenants – *Trockenwohner* ["drying tenants"], who were usually allowed to live in the building rent-free. This example of a practical application of what we have already seen in laboratory experiments shows how respiration resembles the combustion process in the natural world, but on a living level.

Next (preferably on the very next day) we bring the lessons back to their starting point with a review that might run something like this: So we came full circle to calcium carbonate again, but now, combined with silica, it is holding the stones or bricks of houses together. But calcium carbonate was already present when the limestone was still in the quarries. Why did we go through this whole process just to end up with what we had in the first place? Calcium carbonate was there in the limestone rock to begin with, and in the end it is also present in the walls of our buildings. But it had to be split apart and recombined to make those walls strong and solid. Human beings intervened, first by exposing natural calcium carbonate to fire to separate it into its hidden opposites and then by combining the lime and carbonic acid again. This process does more than simply recreate limestone, however. The energy released when its components recombine also holds our houses together. We human beings have separated the natural components of limestone as it is found in quarries and have used them to hold bricks or stones together in the masonry buildings we have constructed all over the world.

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[11] In Central Europe, this practice was abandoned long ago. (D. Rohde)

It as if the quarried limestone that has been fragmented and dispersed throughout the world has come together again to provide stability for the houses of humans. The students are impressed when they sense how human beings have used technology to isolate certain forces of nature and then rapidly recombined them to accomplish all sorts of technical projects. A dammed-up lake can supply water power when the flow is restored. Something similar applies here in the field of chemistry.

On the other hand, what we said about lime also included its effects in the living world. The students learned that they have lime to thank for their internal skeleton and that lime is related to animal life and has its origins in the animal kingdom. Thus lime is revealed as a process that is present in all of nature and related to the human being.***

After this review, we can expand on the concept of salt formation by talking about *sea salt*. This salt is inextricably associated with the oceans. We tell the class about how it is extracted from seawater, through either evaporation or freezing. The class experiences how slowly salt crystallizes out of liquid takes place and learns about methods of salt extraction. Then we talk about how salt is also found in the mountains, where it is mined and then processed in salt refineries. We emphasize the difference between this salt, which becomes our table salt, and lime. Table salt is much less closely related to any life process. Purely mineral salt is the only mineral nutrient human beings need. The foods we eat contain the other mineral nutrients, and only salt as such needs to be added to food. Human beings die if they get no salt at all. Salt maintains and preserves and prevents decay. This is the basis of food preservation methods such as salting and lacto-fermentation. Ocean air has a similar effect, making people more alert. On the other hand, no living things can survive in bodies of water (such as the Dead Sea) with very high salt concentrations.

Can this salt also be treated similarly to lime? In the heat of the burner, it melts and even vaporizes. At extremely high temperatures, a gas is driven off – hydrochloric acid gas. This gas can also be produced by treating rock salt or table salt with concentrated sulfuric acid instead of heat. The result is a white, very pungent steam that forms hydrochloric acid when it is dissolved in water. Separating mineral salt into its component acid and base is much more difficult than calcining lime and requires much more heat. It is easier to do through electrolysis, but the children will learn about that later.

Now we show the class caustic soda and hydrochloric acid. The acid-base polarity is much more obvious here. We present the contrast again:

acid:	*base:*
sharp taste	dull taste
colors litmus red	colors litmus blue
stimulating	dulls sensation on the tongue
gaseous	solid

Once again, we relate all of this to the human being. We tell the class: Each time you move your arms, acidity develops in your muscles, and even more acid forms when you walk or run. During any kind of physical work, acid is produced in the human body. But what happens if you sit quietly in your room, thinking hard about something? What develops then is not acid; instead, more alkaline or basic substances develop in your brain. So when you move, your muscles become acidic, and when your thoughts are active even though you are sitting quietly, something alkaline-like develops in your head; in other words, a base forms. This is what the opposites, acid and base, do in your body. (I have Rudolf Steiner to thank for this example, which he described very vividly while sitting in on a chemistry lesson in the Waldorf School.)

Next we describe the same opposites in the *plant kingdom*. Bases or alkalis predominate in plant roots, but plant acids are more prevalent in the green shoots and leaves as well as in the fruits. For example, the leaves of clover taste sour, but its roots, where bases are concentrated, taste more salty or alkaline.[12] This makes sense, because acids actually belong to the air and bases to the solid earth. At this level, we do not need to mention exceptions to this rule, although they will become very important at a later stage.

This block can again be summarized in a dictation:

"Opposites can also be produced from salt. The smell of hydrochloric acid gas is pungent and its taste is sharp, sour, and stimulating. It colors litmus paper red. It is an active substance. In contrast, caustic soda tastes dull and dulls sensation. It colors litmus paper blue. Alkalis or bases such as caustic soda are usually solid and heavy. Plant roots contain more alkaline substances, but more acids are found in the leaves, which often also taste sour, as in wood sorrel, for example.

Acids relate to the air, while bases tend to sink into the earth. Again, this process is reversed in us. When our legs are very active, acids develop, but the head is where alkaline or base-like substances develop when we think quietly, and there is also a lot of lime in our heads. We see that acids and basis are polar opposites that work throughout the natural world."

In a subsequent lesson, we can use this polarity as a subject for painting. The class is already familiar with contrasting colors. We remind the class about an experiment conducted in one of the earlier lessons, when we poured concentrated caustic soda and hydrochloric acid together. The reaction is intense: the liquid seethes, hisses, and spatters, perhaps even more so than when burnt lime is slaked. Having seen this, the students are now ready to depict this "battle" between acid and base in color. Remarkable images often emerge from the interaction of red and blue, and all of the children betray their individual temperaments. This exercise makes it possible to experience one of the fundamental pairs of opposites in chemistry from an artistic perspective. We have laid the foundations for a joint scientific and artistic sensibility in the children. (From the educational perspective represented here, it would be absurd to introduce the concepts of acids, bases, and salts by talking about hydrogen and hydroxyl groups, which is unfortunately the approach taken even by standard textbooks today.) In contrast, we take a vivid, graphic approach to cosmic and human processes related to acids and bases.

We began with combustion and then moved on to salt formation, so we have now introduced the class to a totally different subject in chemistry. We then review these two opposites thoroughly before continuing.

3. About Water and Metals

The early years of Waldorf schooling include considerable discussion of water and its properties, which can now be summarized and discussed from a new point of view. We begin with a more pictorial account of water's activities and effects on earth.

Turned to vapor by the sun's heat, water evaporates out of the oceans. In winter, conversely, it freezes solid and is then more earthbound. It never remains in either of these two states, however. It always returns from heaven and earth, reverting to the liquid state of rain or spring water. On the other hand, the ocean never freezes solid because ice floats on water. In the depths, the water is warmer – 4 degrees Centigrade. Water at this temperature is also the heaviest, so it sinks. That is why ocean water never freezes completely. A glacier slides down toward the valley because water accumulates at its base. Water also does not want to stay in the air forever but falls to earth again as rain. "Coming from heaven, Rising to heaven, And hither and thither, To Earth must then Ever

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[12] Presumably Kolisko is referring to "lemon clover," Oxalis sp. (D. Rohde)

descend," says Goethe. We may ask, why does the ocean never freeze solid? Because what water wants, above all else, is to remain fluid, so the surface freezes but the depths do not. Although ice is a solid, it is lighter than water and floats on it, while other substances sink when they freeze. Even in the form of ice, water still flows, as we know from glaciers. It never becomes truly solid but behaves like a liquid stone. We know that ice melts under pressure: When we skate on ice, we are actually skating on water, which develops on the surface of the ice under the pressure of the blades. We can sum up this discussion in a dictation as follows:

"Water always strives to remain fluid. That is why its home is in the oceans, which are the blood of the Earth. It is always trying to return to this home and to the fluid state. Water also connects the solid ground with the air. Water always contains dissolved air. If it did not, fish would be unable to live in it. On the other hand, seawater contains a lot of salt (dissolved solids). When water from any source evaporates, something salty and solid is left behind. Water always contains something that comes from the earth (the salty part) and something that comes from the air. That is how water connects earth and air and mediates between them."

Does water have other mediating characteristics? The children will be able to supply many answers based on what they have already learned: Water provides connections between continents and between peoples. People are connected by waterways that allow commerce to develop. The East and the West are connected by water. And doesn't the human body also contain water that connects everything? Yes, that's the blood. It flows throughout the entire body, creating connections everywhere. The earth's rivers connect cities along their waterways, and the arteries do the same, carrying blood to all locations in the human body. Water connects everything.

By now, the children have an approximate idea of the nature of water, and we can begin to explore its chemical aspects in greater detail. We recall that carbon dioxide gas does not color litmus paper red when it is dry, just as dry calcined lime does not color it blue. The red or blue coloring appears only when a drop of water falls on it. This means that acids and bases develop only when water is added. Acids and bases would also have no taste if our mouths were completely dry. Moisture makes taste possible, as another example demonstrates. We show the class crystallized citric acid (explaining that it can be derived from lemon juice) and ordinary baking soda. Without going into greater detail at this point, we can show that soda moistened with water colors litmus paper blue, so it is a base. Citric acid dissolved in water turns litmus paper red, so it is an acid. Now we mix the two dry powders together. Nothing happens. But if we pour water on the mixture, it foams and fizzes. The reaction is almost as intense as when we combine a base with hydrochloric acid. The citric acid/soda combination, with added flavoring, is sometimes sold in little packets as a sweet effervescent powder or as solid fizzy candies. We see from this example that acids and bases react with each other in the presence of water. Water is needed to establish the connection between them.

The next day, we can review all of these examples of the mediating roles water plays – for example, in slaking lime, combining acids and bases, dissolving air and salts, connecting peoples and nations, and so forth. We can then point out that colors appear only in water. The children have already heard a lot about rainbows and have often seen them. Rainbows develop where light and darkness, the sun and the dark wall of rain, come together. But raindrops, water drops, must be present between the darkness and the light. Here again, water is the mediator. The Greeks and Romans spoke of the divine messenger, Hermes or Mercury, who brings everything down from heaven to earth and carries it back up again. Water is a "Mercury" in this sense. The rainbow phenomenon is also visible in dewdrops that sparkle in all the colors. Dewdrops are real messengers that come down from heaven to earth.

When we sum all this up in a dictation, Goethe's poem "Song of Spirits over Water" might make a nice conclusion. Our lessons can lead up to the poem so that it needs no further commentary. It simply restates everything, rounding it off and summarizing it. All by itself, it transforms the children's initial understanding into something they can carry in their hearts, and we will be able to draw on it in later blocks. At this stage, we need not tell the children about hydrogen and oxygen; better they should learn about water as a unity first. Later, it will be all the easier for them to understand that even within water itself, opposites are united and work together. Water's ability to connect everything will appear in a higher light when we understand that it unites the greatest possible contrasts in itself.

Metals

Having presented the children with certain aspects of water in simple form, we can now give a brief overview of the metals. We show the children a series of metals. The children should see many examples and become familiar with their properties. It's best to choose only important metals that are relatively readily available. At this point, for example, we will not talk about sodium and potassium, which are actually just pseudo-metals. It's best to stick with these seven: gold, silver, lead, tin, iron, copper, and mercury. It will soon become obvious why these seven are the most suitable. We will try to present as many samples of metals as possible, especially objects made from metals – the more we present, the more familiar the children will become with their similarities and differences. But why do we call all of these substances "metals" when they are so different? They are all shiny, with a light that radiates from within, yet they are not transparent. Metals shine with their own inner light, which radiates out of their dark interiors. Even though metals are found in the Earth's interior, they look very different from rocks.

Now we talk about miners. We describe what they experience when they have been working in the rocks for a long time and then suddenly come upon a vein of metal – gold or silver or an ore. In that moment, it is as if a star suddenly began shining down upon the dark Earth. In fact, metals are like the stars of heaven shining deep within the earth. Next, we attempt to evoke the idea that a vein of silver discovered by a miner is just a very small part of the silver distributed throughout the earth. Within the earth, silver forms a distinct body of silver. Just imagine being able to see the earth's whole silver body, we say to the children. You would see delicate, shining threads running throughout the earth, and you would see similar bodies of gold and the other metals. Stars like this are shining everywhere in the Earth's interior. There is an entire starry heaven there, and these stars are what miners look for. It is a great thing when people dig gleaming metals out of the dark earth. That is why we consider these metals valuable.

Next we show the class some gold. The children will readily notice that gold shines like the sun. At this point, we explain how metals came about: They came to earth from heaven, because in earlier times the earth was not as solid as it is now, and the metals were dissolved in the vapor of the atmosphere. They precipitated out into the earth. Before becoming solid, they were fluid, and before that they were even less substantial. The earth existed in a gaseous state and the metals, still in gaseous form, were dissolved in it. Then everything solidified, and the metals were buried in the dark womb of the earth. The rocks solidified first, trapping the veins of metals. This is how all the metals, the children of heaven, came down from heaven and were embedded in the earth, which surrounded them like a mother's womb. That is why rock that contains metals and ores is sometimes called "mother rock" and a big vein of metal is called a "mother lode." Metals actually do not originate in the earth but have radiated in from the cosmos, so it's no wonder they have a light of their own, like the stars. It is easy to discover that gold shines like the sun and silver like the moon. We tell the class that the other metals also correspond to heavenly bodies, but the connections are harder to see.[13]

Now we can go into the individual metals – gold, for example. It is found in the mountains in veins that are like subterranean rivers and also in actual river beds. Gold moves almost directly from one river to the other, flowing out of the night of the earth into the light of day. The value we place on gold is related to the fact that people have always sensed its connection to the sun. At this point, we can mention a few historical connections. Gold was used by the Indians of Peru and Mexico in their sun cults. When the Spaniards took this gold away from them, much evil resulted from its use. The children know about this from their history blocks, and they sense that gold can be used in different ways. It can have good effects when put to use selflessly but bad effects when it is used for egotistical purposes. The children become very aware of the moral aspect of this natural phenomenon. We talk about how the value of all objects was measured in gold for many, many years. In the natural world, too, the light of the sun reveals the value of everything. Gold's relationship to the Sun is the deeper meaning behind its value.

Having talked about gold on this level for a while, we can then go into its more material properties. Gold is a precious metal. It does not burn, as we show the children. It is resistant to fire, which otherwise consumes everything. When exposed to fire, it is as unchangeable as stone or burnt lime.[14] Its color, however, is similar to that of sulfur, a combustible material. So although gold is not ash-like, like stone, it is nonetheless resistant to fire. It looks like sulfur but is indestructible. As such, therefore, it occupies a middle position between combustible sulfur and non-combustible salt. And it is the most precious of all metals. We let the children sense the significance of the fact that this material is protected against combustion, not because it is cold and dead like rocks and ash but because of its inherent resistance. Gold contains fire, but it is a controlled fire that is not allowed to escape. It makes a big impression when we realize that gold occupies central position in the midst of all chemical processes, so to speak. It stands between the passionate world of fire and the silent world of solids. When we look through a piece of gold leaf, it looks green – the opposite of the usual red gold. We can see something similar in flowers that usually appear to be red but look green when backlit. We go on to tell the class about how gold can be used as a remedy for heart disease because it is related to the heart. This discussion engenders a living sense of the importance of gold. The class has already become familiar with some of this from history blocks and religious instruction, and now it also helps us understand the economic importance of gold.

Next we look at two other metals that are opposite in character, such as *lead* and *silver*. We show the class objects made out of these metals. Lead is unattractive, gray and dull. It is remarkably heavy, indicating a strong connection to the earth. It is found deep underground and always accompanies limestone in mines. In air and water, it develops a grayish-white coating. It is not a precious metal. When exposed to air, it burns easily and turns into ash.[15] Our language has many expressions that capture the essential character of lead, such as "lead-footed," "heavy as lead," and so forth. Lead is used to make the characters in moveable type, and many, many books were printed with its help. Lead is toxic and produces strange effects in the human body. It makes bones brittle and causes hardening of the arteries; a person with lead poisoning looks very old. Of all the metals, lead is the one that is closest to the grave. In its descent from the cosmos, it penetrates the farthest into the dark grave of the earth. Its appearance is also sad and dull. It is very heavy but has little value because it is not a precious metal.

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[13] Kolisko is referring here to many different statements by Rudolf Steiner. (D. Rohde)

[14] Exaggerated, Gold melts at 1064 °C. (D. Rohde)

[15] This statement is exaggerated; however, lead does melt and evaporate easily. (D. Rohde)

Next we talk about silver. Silver shines brightly and is extremely reflective. The mirrors we produce today are made of silver, and in fact this metal makes the most beautiful mirrors, better than the earlier ones made with mercury. Lead is a dark, blackish gray, but silver is whitish and bright like a mirror, especially when it is newly smelted. When silver ore is melted, the silver collects in a shiny layer on the bottom of the crucible. We can even demonstrate this in the classroom. We sense that silver is involved with the forces of light. From the depths of the earth, it rises to the surface. It is very much a precious metal. The light of silver reminds us of moonlight. The moon is a mirror, too – a mirror that reflects sunlight. The effects of silver in the human body are the opposite of those of lead. It is related to fever symptoms and is very active in inflammations and feverish conditions. Its effects are not hardening or aging. Silver is still very young, and it shines as if it had just been born out of the cosmos. There are big differences between silver and lead.

Next we talk about another pair of contrasting metals, such as *mercury* and *tin*, for example. Tin is brittle. Bending a bar of tin produces the characteristic “tin cry,” a creaking or grating sound. Tin is neither as unattractive nor as heavy as lead. It is relatively inert, and objects made of tin are very durable, although they may crumble and break apart in extreme cold.

Mercury is very different, especially because it is a liquid. It looks somewhat similar to water and yet it is very different. Tin has an internal structure full of edges and corners; it grates and creaks. Mercury, however, forms round drops that merge and disperse readily. Everything about mercury is round and mobile. Tin is jagged and angular; mercury is like a rounded, moving wave.

The children are surprised to learn that mercury is a liquid. It’s a wonderful material; you can look at it forever. Now we tell the class long ago, when the whole earth was still fluid, all metals were once liquid, just as mercury is now. But mercury – so they say – has remained fluid ever since. That’s why it is so surprising to discover a metal that can flow like water. But is mercury really similar to water in all respects? We show the class that water often behaves just the opposite of mercury. When we pour both liquids into test tubes, the surface of the water is concave, but mercury’s surface is convex. Water gets everything wet, but mercury gathers its droplets into ever bigger drops and leaves everything dry. Water is light; mercury is noticeably heavy. The children are impressed when we have them pick up equal volumes of mercury and water. Even more surprising is how mercury gives way when you stick something into it. Mercury and water are almost the only naturally occurring liquids on earth.

Mercury is a liquid left over from long ago, and as such it is different from our modern water. Mercury, the water of very ancient times, is still preserved in the earth’s interior in fine drops. It can be extracted from ores. The very fine droplets are called “virgin mercury.” We then tell the class that mercury can dissolve gold and silver and most other metals, but not iron. Furthermore, when the solution (called an amalgam), is heated, the mercury turns into a gas and evaporates, leaving gold and silver behind. The mercury then condenses again in the surrounding area. In this sense, mercury is similar to water. Most salts dissolve in water and most metals dissolve in mercury, returning to their ancient liquid state. Mercury is as mobile as water and like water, it unites great opposites. Mercury was called *servus fugitivus*, the “fugitive servant,” by medieval chemists (alchemists). After dissolving gold or silver in mercury, we can get the gold or silver back by making the mercury evaporate. Similarly, anything dissolved in water can be regained through evaporation. In this sense, both mercury and water are servants that can be summoned and sent away again. In earlier times such properties, which are also related to these substances’ ability to form drops, were called *mercurial* properties.

Copper and *iron* are a similar contrasting pair. We show the class copper’s red color and how soft and flexible it is. Copper wire can be drawn out until it is very thin. Copper is combined with tin to make bronze, which is harder and can be shaped into a great variety of objects. Bronze bells have a beautiful tone. Before human beings learned to make iron do their bidding, they made weapons out of copper or bronze. Copper is capable of assuming a wide variety of colors. It turns black when exposed to fire, acquires a green patina after long exposure to air, and turns blue in acids. Copper, therefore, is soft, gentle, and colorful in character. Its beauty, softness, and flexibility are noteworthy.

Iron is very different. It is gray, often blackish, but with a metallic sheen. It rusts in air, especially in the presence of water. Iron-containing ores and salts tend to be reddish in color.[16] Iron is also present in our blood, and without it we would be unable to breathe at all. Iron has been used to make weapons, railroads, and all the machines we use. Iron is produced through the powerful fire process of a blast furnace. We use iron to make steel. Iron is hard and strong, almost warlike in character. It is present throughout the earth and is the most abundant of all metals. In many respects, copper is its opposite. Iron is blackish but turns red in air, and iron ores tend to be red whereas copper ores tend to be blue-green. We can see that there are major differences between iron and copper.

At this level, we first allow a very simple picture of the metals to emerge. We will later continue to build on these foundations.

Comparing water to mercury has already clarified the relationship between metals and water. Water is the Earth's upper, fluid sphere. It is always in contact with the atmosphere and thus also with the entire cosmos. All life has its origins in water, and water is active in all living things. In contrast, mercury is a metal that remained in the Earth's former fluid state. As such, it is a representative of an earlier metallic-watery element that has been cut off from the cosmos. The children can now sense the presence of two spheres of fluid, an upper and a lower one. The metals we extract from veins in the earth belong to the lower sphere. It is impressive to watch the distillation of mercury. When we perform this experiment for the class, the children see the metal disappear and then fall like rain as it cools. The metal requires a great deal of heat in order to evaporate before re-condensing. Water passes over into the atmosphere much more easily and then returns as rain. In the case of mercury, the same process requires the full force of fire.

Our discussion of water and metals has illustrated processes that occupy the middle ground between combustion and salt formation. Water and metals share the essential properties of drop formation, fluidity, and the ability to evaporate and recondense. We have now covered an initial selection of three topics in chemistry and can review them with the class. Once again, we present examples of three processes: 1. combustion (e.g., of sulfur); 2. salt crystallization out of a solution; 3. distillation of water or mercury (opposites/mediators). The tremendous contrast between combustion, which takes hold of our will, and cold, quiet crystallization, which we can observe calmly, is obvious. Finally, we look again at water, always mobile and always coming to rest again, and at the unique substance of mercury. These two alternate between gaseous and fluid states. With these three processes, we have provided the children with the foundations of the essential chemical concepts related to events both in outer nature and in the human organism. These first lessons in chemistry can lay the groundwork for instruction in years to come. There are certainly many ways of approaching this task, and the suggestions presented here are intended only as examples that individual teachers can then shape according to their specific needs.

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[16] Fe (II) compounds, however, tend to be greenish. (D. Rohde)

Cosmic Workings In Earth and Man

GA 350 September 22nd, 1923

III

ON NUTRITION

Protein, Fats, Carbohydrates, Salts

(Dr. Steiner asks if anyone has a question.
A question is asked about nutrition and about the potato as a foodstuff in Europe and elsewhere.)

DR. STEINER: We will think about the general question of nutrition and its relation to the spiritual world. As you know, it was not until the modern age that the potato was introduced as a foodstuff: I have told you that in earlier times people in Europe did not eat potatoes but food of quite a different kind. The subject cannot, of course, really be understood without studying the relation of the spiritual world to the whole process of nutrition.

You will remember that I once spoke to you of four substances upon which man's life essentially depends. Firstly, there is protein. Protein is a constituent of all food; it is found in its most characteristic form in the hen's egg, but it is present in all foodstuffs. Protein, then, is the first of these four essential substances.

Then there are the fats. Fats are consumed not only when the flesh of animals is eaten; all foodstuffs contain fat. Other substances, too, as you know, are transformed into fat-containing foodstuffs, for example, milk into cheese.

Carbohydrates are the third essential constituent of food. Carbohydrates come from the plant kingdom; they are of course present in other foodstuffs, too, but essentially in substances like wheat, rye, lentils, beans, potatoes — especially in potatoes.

Finally there are the salts. Salts are usually considered to be mere accessories but they play a particularly important part in man's life. The most common form, of course, is cooking salt, but all foodstuffs contain salts. It may therefore be said: In order that man may be able to live at all, his food must contain protein, fats, carbohydrates and salts.

I will now speak of how these different substances nourish the human being as constituents of the various kinds of foodstuffs. First of all we will think about the salts.

Even when salts are consumed in tiny quantities they not only add flavour but are an extremely important means of nourishment. We take salt with our food not only to make it tasty but really in order that we may be able to *think*. The salts that are contained in food must reach the brain if we are to be capable of thinking. If a person is so ill that all the salt in his food is deposited in the stomach or intestines and not carried by the blood into the brain, he becomes stupid, dull-witted. That is the point to which attention must be called.

We must of course be quite clear that the spirit is a reality, but if spirit is to be an active power on the earth, it must work in the earth's substances. In Spiritual Science, therefore, we must be able to perceive how the spirit works in the various substances. Otherwise it would be like saying: Oh, but we are spiritual people and machines are entirely material; we do not want anything material, therefore we shall not buy iron or steel but make machines entirely out of spirit. That, of course, is sheer nonsense! Substance is absolutely essential. The spirit working as the creative power in nature needs substance. And if spirit is prevented from making use of substance — for example, if salts are deposited in the stomach and intestines instead of reaching the brain by way of the blood — then a man becomes stupid and dull.

Needless to say, things are not as simple as all that. Man cannot derive nourishment from salt in the form in which it is present in external nature. If you were to make a tiny perforation in the brain and let salt trickle in, it would be quite useless. The salt must pass into the stomach and intestines and be brought into a finer and finer state of solution — even on the tongue it begins to dissolve. The result of what the human organism does with the salt is that it is already in a spiritualised condition when it reaches the brain. The process is by no means one of simply introducing salt into the brain — it is by no means as simple as that. But if a man's condition is such that the effects of salt cannot work in his brain, he becomes dull and stupid.

Now let us think of the carbohydrates. When we eat peas, beans, wheat, rye or potatoes — above all potatoes — we consume carbohydrates. The carbohydrates have a great deal to do with shaping the human form. If our food contained no carbohydrates, all kinds of distortions would appear: malformations of the nose or the ears, for example. It is due to the carbohydrates that we bear the outward stamp of *man*. If a person's constitution is such that the carbohydrates are not carried into the brain but deposited in the intestines and stomach, we shall see him becoming shrivelled and feeble, as though incapable of holding himself erect. The carbohydrates, therefore, help to give the human form its proper shape.

You see, therefore, that it is important for us to get hold of the right kind of foodstuffs. The salts work mainly upon the front part of the brain, the carbohydrates farther back. A man who cannot thoroughly digest the carbohydrates, whose organism is incapable of carrying them into the proper area of the brain, will very soon become permanently hoarse and be unable to speak with a really clear voice. Therefore if you have in front of you someone who used to speak quite normally but has suddenly developed hoarseness, you may surmise that he has digestive trouble of some kind. He cannot thoroughly digest the carbohydrates; they do not reach the right area of the brain and the consequence is that something goes wrong with his breathing and his speech. And so we may say: the salts work mainly upon thinking. The carbohydrates work, for example, upon *speaking* and the organic processes allied with it, and are an essential constituent of food. The carbohydrates help to give our human form its proper shape, but if left to themselves their tendency would be to make us into a mere form and leave it at that. They do not fill out the form — that is done by the fats. The carbohydrates have, so to speak, merely outlined the form and the fats provide the filling material. That is their function — to provide us with material substance. In fat itself, of course, this material has a definite character.

I have told you that the human being consists of an "I," an astral body, an etheric body and a physical body. Fat, needless to say, accumulates and is deposited in the physical body. But the all-important function of enabling the fat to be deposited and at the same time to remain *living* fat, is performed by the etheric body. Feeling and perception, however, depend upon the *astral body*.

When a man is awake, the astral body is within him; when he is asleep the astral body is outside. When he is awake and the astral body is working in the etheric body, fat is assimilated and absorbed all the time. Fat acts as a lubricant for the whole body. When a man is asleep and the astral body is outside him, fat is not assimilated but deposited. During waking life, fat acts as a constant lubricant; during sleep, fat is deposited. And both are necessary: deposited fat and lubricating fat.

If someone passes his days in a kind of continuous sleep ... such cases are less frequent now than they used to be, but think of some leisured gentleman who does no work at all. Fat is actually deposited during what is called his waking life — although it really amounts to sleep! Such a man grows very corpulent and fat accumulates all over his body. Healthy depositing of fat, therefore, depends upon proper assimilation and absorption, for fat is being produced inwardly all the time. A man who consumes just the quantity he can assimilate, keeps healthy; but if anyone goes on eating, eating, eating, and assimilates nothing, he will become corpulent, pot-bellied.

Country folk know these things by instinct. They know that when pigs are being fattened the life of these animals must be so arranged that their bodies are no longer lubricated and that everything they eat is deposited.

It may, of course, be impossible for fats to be properly deposited in the organism; if this is the case, a man is ill. In this respect a man of leisure is healthy. But another trouble may be that the carbohydrates are not deposited and then the voice gets hoarse. It may also be that the fats are not deposited in the right way but simply pass away in the faeces; when this happens there is too little fat in the organism and therefore inadequate lubrication. This is what happens, too, when our food is insufficient and we suffer from actual hunger. Fat is the material we supply to the body. What happens to a man who has to go hungry or whose digestion is such that instead of the fats being deposited, they pass out of the body in the faeces? A person who has not enough physical material in his body becomes more and more spiritual. But this is not the right way to become spiritual, for under these conditions spirit consumes him, burns him up. Not only does he wither and become more and more emaciated, but gasses form in his organism and this condition leads, eventually, to actual delusions. There is always some disturbance in the spiritual life when a man is ill. Inadequate absorption of fat leads to wasting — or consumption as it may also be called.

Now let us speak about *protein*. The presence of protein is essential from the very outset. It is present in the egg before a human being or an animal comes into existence. We can therefore say that protein is the substance which really builds up the human body and is the basis upon which it develops; it is the primary and fundamental substance out of which everything else in the body must unfold. Protein is present in the mother's womb as a tiny egg; the fertilisation of the egg enables the protein to become the basis of the human body. But man needs protein all the time; it must be a constituent of his regular food. If his organism contains too little protein, or he cannot thoroughly digest it, he will gradually waste away; but if at any moment of his life he were without protein he would immediately die. Protein is essential both for the beginning of existence and for man's very life. Absence of protein means death.

Now let us think again about the different kinds of foodstuffs. The salts have a special connection with the front part of the head; that is where they are chiefly deposited. The carbohydrates are deposited a little farther back. Upon the carbohydrates depends the proper shaping of the human form. The fats are deposited still farther back and from there they begin to fill out the body. The fats do not enter directly into the body but pass from the blood into the head and are distributed to the body from there. All the substances, including protein, pass through the head.

Now there is a great difference among the carbohydrates. In foodstuffs such as lentils, beans, peas, rye, wheat, it is the *fruit* that is the source of the carbohydrates. The wheat we get from the earth is the fruit of the plant; the lentil is fruit. A property peculiar to fruits is that they are already digested in the stomach and intestines and it is only their *forces* that reach the head. Typical conditions which follow the eating of lentils and beans are evidence to us all that the whole process of digestion is taking place in the intestines. The characteristic of fruits is that they are already fully digested in the intestines.

But we cannot eat the *fruit* of the potato plant, because it is poisonous. There is a difference between the potato as a foodstuff and lentils, beans, peas, rye, wheat, etc. What part of the potato plant do we eat? We eat the tuber, the bulb. Now the bulb is just that part of a plant or root which is *not* digested in the intestines. Fruits are digested in the intestines. But the fruit of the potato plant cannot be eaten, and the bulb is not a root in the real sense. Very well, then, when a potato is eaten it passes into the stomach and intestines where it cannot be digested; the blood carries it upwards in an undigested state. Instead of reaching its own area of the brain in a fine, etherealised condition and being at once sent down into the body — as happens with foodstuffs like rye or wheat — the digestion, properly speaking, has to take place in the brain. When we eat bread made of pure rye or wheat, it is fully digested in the stomach and intestines; the onus of digestion does not devolve upon the head but the head is left free for its task of providing for the distribution over the body. On the other hand, when we eat potatoes or potato-bread, the head has to cope with the actual digestion. But when the head has to be employed primarily for the digestion of the potatoes, it becomes incapable of *thinking* in the real sense, because in order to think its forces must be kept free; the abdomen should relieve it of the task of digestion. So if potatoes are eaten in excessive quantities ... this is a habit which has been steadily on the increase since the potato was introduced as an important foodstuff in Europe ... the head is gradually thrown out of gear for the purpose of really active thinking and little by little man loses the capacity to think with the middle part of his brain; he thinks, then, only with the front part of the brain — which is dependent on the salts. This tends more and more to make him a purely intellectual, materialistic thinker. The front part of the brain is incapable of genuinely spiritual thinking. It is through the front part of the brain that man becomes intellectualistic.

What has happened is that really deep and inward thinking began to wane in Europe from the moment the potato became an important constituent of food. We must realise, of course, that the human being is not a product of the forces of the earth alone. I have told you many times that man is created by the forces of the whole surrounding universe, by the forces of sun, moon and stars. When a man feeds on potatoes, the middle part of his head is used solely for the purpose of digesting them. The result is that having shut himself off from the universe around, he no longer acknowledges its existence and declares: All this talk about spirituality streaming down from the universe is so much twaddle! ... And so it may be said that too much potato food has helped to drive the modern age into materialism.

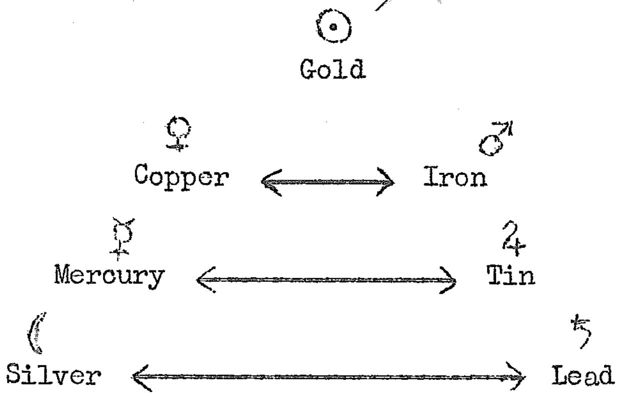
Needless to say, it is chiefly the poor who are obliged to fall back on potatoes simply because they are cheap; the well-to-do can afford to buy food containing substances like spices and salts which work upon the front part of the head. Spices have the same effect as salts in the front part of the head. And so these people become thorough-going intellectualists; and the others, being incapable of really active thinking, can easily be imposed upon. The potato as a foodstuff is related in a very special way to man's spiritual activity; it has actually furthered materialism.

Thinking now of the different members of man's being, we shall say: the physical body originates in the first place from protein. Protein is connected with the birth and death of the physical human being. The etheric body is at work in the fats, the astral body in the carbohydrates; the "I," or Ego, in the salts.

~~It can, however, be said that these are closely related, broadly speaking, to the motifs indicated.~~

~~In Wilhelm Pelikan's "Sieben Metallen", an excellent and detailed survey of these connections is given. Many other things are to be found there as well, e.g. a consideration of the role metals play in the earth's crust.~~

~~In the following diagram the connection of the metals to the planets is given. The mighty contrasts existing always between two planets and their metals are also indicated.~~



F. H. Julius "The World of Matter and the Education of Man"

WORK IN THE 8TH CLASS.

Occasionally almost the same themes are given in the syllabus for Class 8 and Class 9. At first glance this can be confusing but when one is faced with the task of actually taking the lessons one soon notices that the teaching matter can be subdivided and organised, and that the chief aspects of the work are so different that not the slightest muddle need arise.

In the syllabus for the 8th class attention is particularly directed to the carbohydrates, fats and albumen as foodstuffs. Elementary organic chemistry is spoken about in the 9th Class. This is a very broad subject to which the carbohydrates, fats and albumen also belong.

During the work one notices that all manner of things can be done and handled for which no time remains in the 9th Class. If the starting point is well chosen, the work in Class 9 can even be supported and well grounded through that preceding it. Above all care must be taken not to deal too early with isolated separate parts of the teaching matter and definitions. Usually this kind of "being very learned" is the result of a certain awkwardness for want of guidance, or through not being master of the subject. In a way, it is the greatest art, to make something out of simple things. And exactly through this, one succeeds in fostering and protecting the children's fiery enthusiasm and faculty of deeply immersing themselves in the phenomenon right on into the higher classes.

This epoch is best begun with sugar. One observes, e.g. how sugar reacts to water. First its great solubility is presented, through bringing water to the boil in a beaker, and then slowly adding sugar, taking care that only a little ever lies at the bottom. Meantime the rising of the liquid's surface is noticed. Finally the solution will occupy more space than the original pure water. The liquid is then allowed to cool. It becomes first like syrup and then viscous. After a little while crystallization begins, so that the whole mass hardens. One now does something which is more important than ever for children of this age; one lets them consider how these phenomena are utilised. Children of this age are extremely interested in the prosaic sphere of everyday life. We can satisfy them particularly well in this subject. The girls chiefly know the substance in question from cooking. Now they learn to understand, through thinking, what most of them for a long time already knew from experience. In some cases we can even give them a few practical tips.

The dissolving of sugar and then allowing it to set again is used, among other things, in making icing, confectionery, syrup, jelly, jam, etc.

Now sugar is brought into contact with fire. First a little is heated in a test tube. The sugar melts and if done very carefully the liquid remains colourless. Otherwise it quickly turns yellow and changes into a beautiful brown, pleasantly smelling state. This is called caramel, which is used among other things in preparing caramel pudding and certain sweets.

Stronger heating makes it boil furiously, while the colour of the liquid becomes darker, almost black. Simultaneously great quantities of smoke and inflammable vapours begin to escape. This experiment can be heightened through placing a lid on a greater quantity of sugar in an iron beaker. When the beaker is heated a mighty puffing, blowing and flaring up results. The swelling mass pushes up the lid, and drips over the edge. In the end only shiny-black, crunchy and porous carbon remains. Sugar can also be blown into the gas flame. Each grain then produces a small flame. The heating of sugar on an iron spoon is also quite effective.

Then one can deal with the forming of sugar in the plant leaf.

The presentation now of the role played by carbon dioxide and the formation of oxygen would not be out of the question. In any case this must come in the 9th Class. One will, however, definitely notice that the work on a substance can be much more intensive when its academic aspect is not immediately pushed into the foreground, but when, from its reactions to external influences, from its relationship to the four elements, that is from the "Deeds and Suffering" of the substance, its character or even kind of biography is developed. If this is done, abstractions become superfluous, and one develops instead a full and living view of the processes in nature. In this instance the accent is placed on the connections between air, water and light. The opportunity must never be lost, of referring to the Above and Below in nature, which appears so clearly again here. In sugar, that which comes from above as warmth, air and light and from below as the watery element, are woven together into a wonderful unity.

We can now give a sort of explanation for the way sugar behaved in the experiments. Its great solubility is connected with having been born out of the watery sphere. Its relationship to water is also demonstrated by the fact that it is always found in nature in a dissolved state. The crystallising, that is the emerging out of the liquid, is even comparatively difficult to bring about. Every plant is more or less permeated by sugar in a very dilute solution. In animals and men sugar circulates with the blood.

Another of sugar's traits is to give off gases when heated. Its relationship to the air is thereby evident.

When sugar burns so much that it bursts into flame, thereby producing warmth and light, it owes this to the sun-fire captured by it, and now set free.

In sugar a great contrast becomes a unity: sugar is related to water as well as fire. It is therefore understandable that sugar can be absorbed into our blood without any change. The same can be said of the blood as of sugar; fire and water unify in it also. However, we differ from the plants in what is done with the sugar in our bodies: it evolves into warmth, whereas in plants the greater part of it condenses and hardens into solid substances like Cellulose. The plant builds up its immobile form with the help of sugar, while the sugar builds for us the foundation of our mobility and production of warmth.

The various kinds of sugars could be differentiated when dealing with this substance, although I'm of the opinion that a general treatment of it could be stressed in Class 8, and then the different sorts defined in Class 9.

Probably it will mostly be necessary to differentiate Cane-sugar from Glucose, in certain circumstances also Fructose. This is the case above all, when the Fehling's solution test is already being introduced.

After sugar we can take starch. We take some potato flour, and other kinds of flour and let the children rub it between their fingers. Certain differences are experienced. Flour looks a little like sugar at first, but feels much drier.

Now we sprinkle some potato flour on to a glass of water. At first it floats, and then sinks without dissolving.

Then we heat dry flour. It doesn't melt, but carbonises. It flares up less than sugar; but burns much longer.

At this point we can insert a few remarks about the burning of food during cooking. One demonstrates, how e.g. such a half-carbonised mass is easily removed, after boiling with a soda solution.

Then we take the appearance of starch in the plant. Sugar is actually always in circulating, flowing movement. In contrast to this, the superfluous sugar on arising through assimilation, is already pushed out of the sap stream, in the form of insoluble grains of starch, and so to say put on one side. Small grains can be proved microscopically in the leaf. In poor light, or at night these starch granules are changed into sugar again, and dissolved. The plant, however, puts starch in places where life in the plant has temporarily come to a standstill, and where in connection with this, coarsening and hardening processes appear. Especially tubers and seeds often contain much starch. The trees also store up great quantities of starch in their trunks during the summer, which are kept through the winter, but when life begins to unfold in spring, all these grains are unlocked again, and taken up as sugar into the sap-stream.

While it is characteristic of sugar to flow through the plant in diluted form, the characteristic of starch is that it appears resting, separated into countless grains. When one of these grains is observed under the microscope, it shows a self-contained unity, centred around one point, and built up in layers. From every aspect starch brings to expression expulsion from the unity-building forces of life, and the continual stream of fluid. The plant as a whole depends mainly on the surroundings in the widest sense. In contrast, each grain of starch seeks its own central point.

We now add some starch to boiling water. We must first carefully mix some flour with a little cold water. This is poured into the simmering water. One sees then, how the grains quickly disappear to be replaced by a smooth, translucent, half stiff state. It is quite gripping, to observe the movement of the steam bubbles growing slower in the porridgy mass. After cooling, the mass becomes even stiffer. Starch paste is prepared in this manner. When the children are then told that actually in porridge and certain puddings, paste is cooked, it often causes a sensation. One can point out that bread-baking is based on a similar process.

In the making of paste it is evident that starch only allows itself to be partly dissolved, even in hot water. The boundary is disposed of between the original starch and the water. Each grain takes in water, and begins to swell, so that its structure is lost. Very soon all the free water has disappeared, and has been replaced by a jelly-like mass.

We can also deal with the way the transformation of starch into sugar is used. In nature this happens for example in the germination of seeds. We can let grains of corn germinate by bringing them into contact with moisture under certain conditions, and then get a mass of grains, after heating and drying these, which has both a starch and sugar content. We call this malt.

This change of starch into sugar is disturbingly noticeable in the potato, the life process of which ceases on freezing. A slight but constant production of sugar takes place in the potato, which continues even when frozen. Under normal circumstances this sugar is consumed through the scarcely noticeable life process which is retained even by the stored potato. In the frozen potato this sugar mounts up. This accounts for its unpleasant, sweet taste.

The children might even try to change bread or flour with the help of the saliva into sugar, by chewing it. Together with this it can be told that all the starchy food that we eat is completely transformed into sugar and absorbed into the blood in this form. It seems better to me to deal with the details in Class 9.

Now comes something which in my opinion can be taken in the 8th Class as well as in the 9th:- Proving that a substance contains starch or sugar through certain tests. In either case the children find this very stimulating. I believe it is good, when doing the Fehling's solution test, not to use it directly in its completely finished form. It is better to let it arise step by step. I now mention these steps:

(a) It is shown, how a solution of copper-sulphate and sodium hydroxide forms a blue precipitate.

(b) The same experiment is done in the presence of a sufficient quantity of dissolved sugar. The blue colour is now much deeper, but there is no precipitate.

(c) This deep blue solution is carefully heated. If cane or beet-sugar has been used, there will be no change. However, with Glucose a change of colour appears. The blue wanders through to green, to yellow and then orange. Finally there is a strong yellowish-red opaque precipitate. This experiment is strikingly effective when a flask is used. Not many chemicals are required either.

(d) For the usual laboratory experiments this deep blue liquid is prepared beforehand with the help of a substance, which is not a sugar, and which shows no change in colour when heated. Tartaric acid is chosen for this, or one of its alkaline salts, e.g. Rochelle salt. The solution to be tested is heated with a little of this blue liquid. This method is also used in testing urine. The so-called Fehling's solution is therefore prepared by mixing copper sulphate solution with a solution of tartaric acid or one of its alkaline salts, and later adding sodium hydroxide.

Flour or starch is most simply proved with iodine. A few iodine crystals are dissolved in some concentrated alcohol, or what is cheaper, in a potassium iodide solution. The resulting brown solution, called tincture of iodine is added drop by drop to a starch solution. A deep blue colour results, which completely disappears on heating, but returns when again cool.

All kinds of things can be demonstrated by these iodine and Fehling's solution tests in connection with food constituents. e.g. When a few pieces of carrot are cooked in water for a few minutes in a test tube, the resulting liquid cooled, mixed with Fehling's solution and heated, the wellknown colour change is achieved, proving that carrots contain sugar. In contrast to this, if a few drops of tincture of iodine are put on a cut carrot, at the most a few tiny blue spots appear. Carrots therefore contain very little starch. However, a cut potato, or a piece of bread, is turned a strong blue colour by iodine.

The following could also be demonstrated: One first shows that ordinary cane or beet sugar don't react with Fehling's solution. Then the sugar solution is heated with some acid. It will definitely react with Fehling's solution now if the acid is previously neutralised by the addition of a little alkali. In this way the fact can be made clear to a certain degree that other sugars, glucose or fructose, can arise from cane sugar. This fact is again particularly important in cooking. Sugar should be added to sour dishes only after they have cooled, as it otherwise decomposes and the sweetness is greatly diminished.

It is very important to present the children every now and then with clear broad summaries. In the sugar household of the Plant, certain great structures can actually be proved. We have seen how the sugar, in as far as this is the foundation of life, really only travels through the plant as a thin solution. It adopts thereby a kind of middle position. On the one side it is constantly being rejected from the stream and condensed into solid starch. This is, in a way, packed up and stored away. On the other side it flows in the form of Nectar right out of the plant altogether. It becomes scent and is sprayed out into space by the insects.

The baking of bread is especially important. I once saw how a farmer did it in the following manner: He first took his bowl of flour; then a basin with a little water into which he put a little yeast, as well as salt and honey. Having stirred this well together, he mixed it with the flour and kneaded the dough. In the meantime the fire in the stove blazed away merrily and now the dough was put into tins on top of the stove to rise. After this the burning wood was scratched out and the tins pushed in. This old recipe is as universal as it appears to be simple. Bread is one of the chief foods of man. His body is to be looked upon as the central point, as a combination of the whole of nature. In such an old farmer's recipe, a combination of the whole of Nature is found and thereby it expresses the attempt, already in the preparation, to pave the way towards building up the human body. One can consider how the flour is at first earth, and then takes up the water; how the air enters through the fermentation and lastly how fire concludes the process. When one reads the story of Prometheus who created men, one again encounters the same path through the four elements. Then we have the trinity: salt, water and honey. These are the representatives of the whole plant, of the root, the stem and the flower. We must know for ourselves that the three principles - salt, mercury and sulphur - are clearly expressed here. And then the grain itself. Grasses are those plants which are the tallest with the least matter. They are wonders in the art of construction. In grass each scrap of weight, so to say, serves the task of overcoming weight and holding that which is really heavy, the corn, as high as possible up to the sky. The grasses continually celebrate a great victory over the downward-pulling earth forces.

The grandeur of grasses and corn is most recognisable through a comparison with the potato. The potato tuber is actually a stem and therefore meant to be upright, but it bends back to push into the earth. It not only follows the direction of weight, but also grows into a plump mass.

The upright position, which is only possible after overcoming gravity is typical of man. We owe the possibility of kindling the light of consciousness to this position. Corn assists us in achieving this. It is an example to us of uprightness. It points so clearly to the overcoming of the earth, that it has always been regarded as a symbol of Christ's risen body. The potato seeks out weight and darkness; we therefore take into us through eating potatoes something that is the absolute opposite of that which the corn brings.

As a variation the children's enthusiasm for the potato can be aroused again by demonstrating the simplest way of preparing potato flour. A potato is grated on a large grater. Some water is run through the resulting mass and allowed to stand. A snow-white layer is discovered on the bottom after a while. This is potato flour.

Although it is not a food, it seems appropriate to me, briefly to draw attention to cellulose. Like starch, it is formed from sugar. It is absolutely insoluble, but burns well. It is interesting to see how the plant treats it quite differently from starch. Cellulose is also expelled from the living sugar stream, but never becomes grains. It is always built into the whole of the plant; and therefore never has its own form but is constructed so as to serve the plant.

We are here dealing with the actual building material of the plant. As this substance is quite indigestible to us, it presents us with great limitations with respect to plants as nourishment. Herbivorous animals however are able to break down and digest the cellulose.

For us, cellulose is a substance which is eaten in great quantities without its being nourishment.

We now come to albumen. We can introduce it by taking a hen's egg, breaking it, and separating the yoke from the transparent white. The children are given as strong an impression as possible of the sticky sliminess of egg white.

Then we put some of the white in cold water, and show how it spreads out, more or less dissolving. Afterwards we put a little of this in hot water, and the coagulation is visible. In a dilute acid solution coagulation also takes place. Then we can cook the set egg white with an alkali and see how it dissolves again.

To be quite thorough one can also heat the white directly with a flame. It is not inflammable, but is carbonised black and is crusted. During this the same smell is noticeable as with burnt hair, wool or horny nails. All these substances are hardened and transformed albumen.

The egg white particularly lacks form and is in a very subtly balanced state, as is evident from the experiments. Owing to these characteristics it is the actual life-bearer. When it hardens, as in the formation of horn, it achieves in contrast an especially dead, set form.

Further experiments can be done; e.g. letting the albumen in milk coagulate through the addition of acid. This is the cause of the forming of the curds in buttermilk and sour milk.

Also coagulation by means of alcohol can be demonstrated, followed by the explanation of how dead animals may be preserved in alcohol.

Lastly we shall discuss fats and oils. We let a piece of fat float on water and show how the water runs off it when it is pushed under so that it rises again. When oil is squirted on to water out of a pipette one sees a wonderful display of golden yellow drops, rising up as small balls. The pipette can also be blown out under water, whereby a ray is to be seen, which soon dissolves into rising drops. Should water happen to fall on oil, small clear balls are visible which sink down. When water with a thin layer of oil on the surface is shaken up, a cloudy, milky mass results of water and fine drops of oil, which slowly rise to the surface to join together, recreating the original state. This experiment can also be varied using distilled water, oil and a piece of soap. When this mixture is shaken, a much finer distribution of oil drops results and it takes the oil much longer to separate from the water again.

If one begins with a fairly concentrated soap solution in distilled water or has put a synthetic wash powder into the water, something very surprising happens when oil is added. No large oil drops are formed, but the mixture disperses, shooting apart in tiny particles. From such experiments it will be understandable that it is difficult to wash fatty articles with water. The role played by soap and other washing powders, becomes clear in this way.

We now allow fat to melt and reset.

Then we pour oil into an iron crucible and try to set it alight. Only when the oil has been heated does a bright yellow, very smoky flame appear. If the burning oil is heated to boiling point one can produce wonderful effects. When poured out e.g. the falling stream remains alight, so that one has a splashing mass of fire below. Mighty fire phenomena are achieved when drops of water are splashed on to hot burning oil, or even more so when water is just poured on. In this manner flames can be conjured up a few metres high! Immediately the warning is added that exactly the same thing can happen when water is carelessly poured into fat when meat is being fried.

It is somewhat calmer when oil is heated with some water. This is the well-known braising. It can be demonstrated with some very nice things, e.g. sliced potato baked with oil in a beaker or test tube. One hears again the crackling, and also sees how the slices slowly become brown. From the sizzling during heating one hears that butter and margarine contain a considerable amount of water.

From all these phenomena it is apparent that oil is penetrated through and through by the fiery element and has very little relationship to water. The result is that fatty foods are very heavy and difficult to digest. With butter the case is different, because fat and water appear there very finely interwoven.

The fat that we absorb is burnt for the most part by our bodies to produce warmth and energy. We therefore require fat especially in the cold and when doing strenuous work. Furthermore it serves as a lubricant, among other things.

Animals need fat to ward off water. Water birds, e.g. have a fat gland in the rump with the help of which they smear their feathers. The whale and seal even protect themselves from the cold, with a thick layer of fat.

In plants we find oil above all in the seeds which have been subjected to the greatest influences of warmth.

Through taking milk last of all, one can conclude this period in a very practical way. As milk is the only nourishment for some time for the small child and young animals, it must naturally contain all the necessary nourishing substances.

Sugar is easily proved again with Fehling's solution. It serves for nourishing, but also plays an important part in turning the milk sour. Depending on the extent to which the acid appears the sugar and accompanying sweet taste vanishes. We not only know this from sour milk, but also buttermilk, yogurt, etc. When milk is allowed to stand, a layer of fat, the cream, separates off. This process is hastened, by turning the milk centrifugally in the separator.

Through shaking or churning the milk itself or the cream, lumps of butter separate out. Although cream contains much fat, still other constituents of the milk are in it also. Butter contains chiefly fat and water. This water appears at first glance to be a sort of thinning or even an adulteration of the butter, but it is actually an indispensable ingredient. It gives the butter the consistency through which it is so easily digestible, and which the margarine factories likewise try to give to their products.

With milk the fat floats in the liquid in the form of small drops. In butter a fine mixture of water and fat is still always present.

The albumen of milk is noticeable in various ways. On heating only a certain part of the albumen coagulates - which forms the 'skin'. The whole amount of albumen can be coagulated by adding acid. When milk turns sour by itself, as with the usual sour milk or buttermilk, this coagulation also naturally takes place. Gradually a thick white mass separates from a light liquid, the curds and whey. When this coagulation is not yet noticeable with the cold milk, because it hasn't formed enough acid, but then appears on heating, we speak of the 'turning' of milk.

This coagulation of the albumen is used in the production of various things. Through draining buttermilk through a linen cloth it thickens into cream cheese. For thick cottage cheese this mass must be wrung out.

In the making of cheese the milk first has to curdle (that is, the albumen coagulate) through having rennet added - the juice from a calf's stomach. When the liquid has mostly been drawn off, processes can take effect in the coagulated solid mass, by which it becomes cheese.

Nearly all these processes depend on fermentation. It might even be referred to as the beginning of decay, or a particular type of it.

It may be possible that, after all these things, a list of constituents of a number of plant and animal foods can be made. Furthermore directions for the treatment of these substances and a sensible preparation of the food could also be given.

In the syllabus Rudolf Steiner pointed out the importance of dealing with industrial processes on a chemical basis, and there are many possibilities for this in the production of foodstuffs. Something about making soap might also be suitable. Perhaps there are even other possibilities in quite different directions.

Phenomenological Organic Chemistry

An Introduction Based on the Inner Nature of Substance in the Plant World

Class 9 Chemistry

Main Lesson Demonstration /Classroom Material
and
Laboratory Projects

Included are experimental descriptions, Discussion of Deeper Themes and Methodology for Carrying Out a Student Laboratory Project in Home-Medicine making

Dr. Manfred von Mackensen

Freely Translated by Peter Glasby
Mt Barker,
South Australia, 2009
and unrevised by the Author.

The translation was made from the original:
Vom Kohlenstoff zum Aether
Materialen fuer den Chemieunterricht der 9. Klasse, mit Versuchsbeshreibungen und Vertiefungen von Einzelthemen, zugleich eine Einfuhrung aus phaenmenologischem Ansatz unter dem Begriff innere Naturen.
Manfred von Mackensen

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I. CURRICULUM & PEDAGOGY

1.1 THE CURRICULUM INDICATIONS AND ITS EPISTEMOLOGICAL DIRECTION

The outline for the chemistry block curriculum in class 8, based on Rudolf Steiner's indications, is as follows:

> *"... extend the simple chemical concepts so that the child learns to understand how industrial processes are connected with chemistry. Using chemical concepts you try to develop a link with substances which build up the organic bodies: starch, sugars, proteins and fats."*[1]

And, for the 9th class, he has suggested:

> *"Chemistry: That which we have established for class 8 -- the first elements of an organic chemistry, what an alcohol is, what an ether is -- these should now be carried further in the 9th class."*[2]

The First Elements - Organic Chemistry. The conventional textbook approach to chemistry introduces so-called "organic[3] chemistry" by considering the completely non-living hydrocarbons of petroleum; however, Steiner clearly placed great value on the block having a truly organic, living architecture, specifically connecting to the substances indicated for study in 8th class (starches, sugars, proteins and lipids). However, the class 8 students didn't just learn about these substances as mere names for isolated substances, but rather as members of a series, by experiencing the intimate connections between natural forces and human nutrition.[4]

So also in class 9, it is not our task to learn to understand the "chemistry of the organic" as separate from life, or systematized according to formulae, nor to treat the substances as a series based on "homologous structures" or "functional groups;" rather, the goal is to pursue the traces of life. For, the imprints of life we see on the earth's surface always flow out of higher organizational principles, by which they must be understood, not only (in an additive sense) out of lower, non-living precursors (substances, molecules) which [are thought to be the cause of] the living substances and so explain them.

Certainly, it is also clear that by "first elements" of organic chemistry, Steiner did not mean chemical elements (constituent substances); in that case, we would have to study elemental analysis and inorganic chemistry in general. This, however, is deferred until grade 11. It is not material elements which are meant, but the elements of understanding.

The block should not be fashioned out of a mere sequential treatment of the properties of substances, nor from an examination of manufacturing-industrial processes, nor technical applications. Rather, we should examine just a very few phenomena, and therefore really study them thoroughly. The students should practice a thoughtful consideration of the qualities chemically interwoven in each substance. Thereby, the more factual knowledge developed in class 8 can be understood in retrospect in the light of new questions and new activities of soul in the students at this age.

Plainly, these 'new elements of understanding' (going beyond the four food substances indicated for class 8, perhaps) are given preference by studying the transformations of the substances indicated by Steiner for the 9th class: alcohols, ethers (esters), and the like [aldehydes, carboxylic acids]. So, if we take up sugar and starches from the class 8 syllabus, then

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[1] *Discussions with Teachers, Lect. II, on 9-6-1919, pg. 167 (in German edition); GA No. 295.*

[2] *Conferences with Teachers, 9-22-1920; Vol I, pp. 223, GA No. 300; 4th Ed. 1975.*

[3] *Today, meaning carbon-based, rather than products of living organism, as was its meaning in antiquity.*

[4] *Compare the section introducing the Class 8 chemistry block in my book: Chemistry blocks in Classes 7 and 8, 1976, p. 107*

we deal with a clear series from most solid to most volatile. [emphasizing transformations of qualities]

We must note that when Steiner speaks of "an ether," right up to the beginning of the 20th century, esters were still termed "ethers." Thus, a chemist of that time writes "It is quite deplorable, that although it is on the best grounds that we now think of these as esters, nevertheless many of them are still called ethers."[5] Even today, the aromatic branch deals with various 'fruity ethers', which are systematically arranged as esters of lower fatty acids and simple alcohols. So it is not entirely wrong if we introduce the preparation of strong-smelling esters out of acid and alcohol, in order to focus our gaze from that starting point on the variety of fragrant/aromatic etheric oils, which we typically obtain from the plant world.

2. ON THE "INNER NATURE" OF SUBSTANCE

The "inner nature" of a substance has three aspects in the way it moves our thoughts: metamorphosis, uniqueness, and overall imprint of the four elemental qualities from the whole world of Nature.

2.1. METAMORPHOSIS

The first aspect is metamorphosis or transformations of qualities; e.g., an increase in the characteristic we could call "the watery-nature" can be seen in the sequence from wood to sugar (clarity, solubility, ease of melting). This is also shown in the large quantity of water vapor given off with thermal decomposition of sugars. With sugars, the carbon nature (solidity, structure, form) decreases a little, although a carbon residue and soot still persist. The chemist can now play with these inner qualities: imagine an increase in the flammability (the fiery-volatile quality) of sugar -- we come into the domain of "fire water", the alcohols. Now, remove its watery nature in our imagination, and we come to something like an ether -- a fire liquid. (A more precise treatment follows, below). In this way we work in our thinking with qualitative principles which can metamorphose one with the other; not as a mere additive juxtaposition in the manner of summary-formulae of organic chemistry, nor assembled in a material-spatial arrangement like structural formulae.

Such a type of thinking-in-metamorphosis is indicated by R. Steiner by the word "is" ("... what an alcohol is ..."). Therefore, we should not simply go through a mere sequence of the occurrence, preparation, characteristics and commercial uses of a family of substances, say, methyl alcohol, then ethyl alcohol, etc., in order to extract those characteristics which occur repeatedly, and in general explain 'alcohol' [i.e., the term 'alcohol' as meaning a combination of all the characteristics common to this group].[6] Rather, in the above metamorphic sense, it is a question of conceiving of each alcohol as one particular example or a step in a series of transformations from solidity (wood, starches) towards volatility (ether, aromatic substances) - alcohol as movement. The idea of a 'substance' should arise out of such a transformation, inwardly grasped, not just outwardly defined. In what follows, it is important to show how this step-by-step path in thought, from rigidity to volatility, reveals itself to the students in worked-through experimental observations, initially unconnected; but later, demanding connection. For it is essential that the students can look back later on their mastery of clear steps in learning and pithily formulated connections cannot be left out of schooling.

2.2 THE "INNER NATURE"

The "inner nature" of a substance is a phenomenological measure, a way of characterizing. Initially this 'nature' is something physical which doesn't disappear but remains in physical space. The "inner nature" is however, more than a material component, and should not be thought of in a mechanistic sense. It is not matter, but rather a type

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[5] *Lassar-Cohn, Methods for Organic Chemistry Laboratories, Leopold-Voss Publisher., Hamburg, 1907.*

[6] *See Bortoft on "Authentic and Counterfeit wholes."*

of activity which can be transposed from one space to another.

Such a notion is foreign to our way of speaking nowadays. But, still, we could change the words we use to describe things; but as a teacher, we will simply speak about the subject as we have experienced it in our own perception. Some words which might be used to stand for the impressions of the "nature" of substances are: "aspect, quality, inclination, characteristic tendency, affinity, relationship, impression or 'imprinted by', action or activity."

So that the mobility in thinking which has been achieved, isn't allowed to run away into uncertainties, when we put up descriptions on the black-board, with a more schematic presentation of the transformations of a substance, or in comparing various substances, we can make sure that each particular 'nature' is always written with the same color; for example, the "solid-burable" (as in carbon-nature) written in black-gray or brown, the "balanced, extinguishing" watery-nature (of sugar) written in green, the "fiery-volatile" nature, in red.

2.3 Uniqueness

A second aspect of the transformation of the "inner natures" of plant substances is their uniqueness according to their origin. The simple diethyl ether with its recognizable smell and physiologic effects, and still more the aromatic substances found in all sorts of plant organs, are each unique; they could never be derived definitively from a mere intermingling of the "solid" and fluid" natures discussed above. Here a connection with the (unique) wholeness of the individual plant must be brought into consideration: its location, environment, cultivation, season it ripens, etc. Then, chemistry leads to individual plant species and to new botanical questions.

2.4 Imprint of the Whole of Nature

The substances studied here, are arranged from wood to etheric oils, relating to the growth and development of plants and how qualities like the various Greek elements interweave, from moist earth up into the warm air. From this arises the third aspect: the four elemental qualities, an idea which gives a real picture of the overall process of Nature over the surface of the earth. Warmth and light indicate the region of Nature in which a sugar or an ether (ester) is 'at home.' Individual substances are representatives of the cosmic working of nature-processes. The precise, thoughtful penetration of chemical activities in the laboratory (which is important for young people at this age), is therefore combined with a comprehensive, experiential understanding of Nature.

So, we have the three main points:

- The *transformation of qualities*, like solid, volatile, fiery, etc. in the laboratory; the overall 'inner nature;'
- *The originality* of individual substances and individual plants, the uniqueness of the aroma of a substance, the therapeutic action etc.
- The *'impulse'* or imprint given by outer nature through the whole cycle of seasons in forming substances.

3. Possible Approaches to the Block

3.1. Transformations in Living Nature

The introductory topics could build on a discussion of the environment, or raw material issues; e.g., about burning fossil fuels, or the waste heat from atomic reactors. From this whole cluster of issues about how the human being rightfully stands within nature (and how he is imperiled), we take up the idea of breathing. Various gaseous components of the atmosphere are demonstrated and named (carbon-dioxide tester experiment). The carbonic acid which arises from carbon compounds (charred) leads us back to class 7 where we considered burning, albeit in a much more imaginative manner, and which we now interpret at a new level. Oxygen is mentioned, but comes in with the experiments (see below) simply as a component of the air, initially. For only then can we enter into the chief theme of the block: the transformations of plant substances arising from building-up, constructive life-processes; and, we won't get lost in the chemistry of oxygen, which by itself leads to tearing-down and decomposition processes, to oxidation agents (and explosives) [themes for class 10 and 11]. The theories of burning, from phlogiston to the stoichiometric (weight analysis) ideas of Lavoisier have, in short, followed a path towards the inorganic-mechanistic. We should not pursue these in this block, but rather work on the qualitative transformation of substances in the fertile, pure realm of plant life. We could learn a preliminary classification of the substances of interest into: 'enkindling' (able to ignite things, promote burning), 'burnable', and 'balanced'. All substances in the world are, finally, various interweaving and aspects of these three principles (three natures).

The class 9 main lesson block primarily takes up "burnable" substances, class 10 focuses on the "balanced" (salts), and the 11th or 12th class main lesson blocks investigate the "enkindling" ones, experimenting with pure oxygen, nitrates, explosives, or halogens.

3.2 ORIGIN OF COMBUSTIBLE SUBSTANCES

Now, we have to ask: how do burnable substances arise in Nature? The rigid crust of the earth is sealed up, stony, chemically stable and in equilibrium with the conditions at the surface of the earth. Only where the enlivened loose earth turns toward the mantle of air, can a mantle of plants begin to grow, and it is their remains that provides us with combustible materials. All aspects of the growth of plants are an image of the cycly of the year i.e. an occurrence outside on the earth's surface. And together with humankind, they stand in a reciprocal relationship to the air. True, they do not have a sentious consciousness, no reaction from an inner life (e.g. with lack of air), and no ability for self-movement provided by appendages. Rather they move gently in the wind with all other plants, and give themselves over to the free air outside and to the rhythms of the environment. Just this makes them able to supply combustible material (class 7) and nutrition (class 8).

Thus, it is even less thinkable that we would enclose the plant mantle that covers the earth in a glass jar, than we would enclose our own breathing. To plants belong the above-mentioned openness to the environment. Indeed, we may decide to intervene in this way and demonstrate rising oxygen concentration. We shouldn't go too quickly into the usual study of carbon-dioxide assimilation which, in the final analysis, views the plants as a chemical machine. The reality of assimilation is the illumined plant leaf, is seasonally given multitude of forms, which grow and become larger. Systole and diastole, in growing aloft, developing/maturing in the course of the year – this we experience in an eternal rhythm of densification and out-streaming. Certainly, assimilation is a sort of densification process, but of such a kind as leads back again in rhythmic transformations to an out-streaming in the blossom's fragrance. The whole path of plant development from leaf right up to blossom and fruit is the reality of assimilation, not concepts of gas-exchange or bio-mass accumulation. All the substances we work with (wood, resin, sweet sap, aromatic oils) simply portray this path in nature in an image of true assimilation, as we enhance one or another aspect of it by manipulating one or another of these substances in our laboratory. The capacity to transform, not to accumulate mass, characterizes the "activity" of carbon substances (the 'carbon principle'). ***Here lies the field of study for this main lesson block; experimental realities, which through concrete, qualitative thinking, can be led over by the feelings into a deeper participation with processes of nature***. For, there could be no plant world without these perpetual transformations of phenomena and organs from stiff and dense below, to fluid/volatile above. Within this field of transformations is presented to thinking a field of activity, which can open up a spiritual, yet content-rich, reality based chemistry. Schematics and diagrams of environmental cycles of a mere material assimilation theory cannot accomplish this. They hold the thinking rigidly in mere concepts and abstractions, and thereby, finally in non-understanding. Only in the end would it permit us to clearly reflect on how, out of the growth of plants, the air can possess a gentle increase in its stimulating/enlivening quality, its refreshing character, and how these qualities are connected with the up-building course of the yearly cycle of plant growth.

A very accessible arrangement of topics for the main lesson block is provided -- as indicated above -- by starting from carbon and carbon dioxide and the question of the special appearance of burnable substances including wood, and then on to sugar, alcohol, ethers & esters.

3.3. Earth Coal vs Sugar

If we took our starting point from hard-black coal, or soft-brown peat from the earth, then we would have the consequences of a one-sided process on our hands. Although coal arose from plants which–albeit over immeasurably long time–had their fiery-volatile nature and watery-balanced nature reduced or removed, natural coal now shows only the slightest trace of these two natures. However, if we ourselves bring this process to completion with distillation (coking) of wood, to achieve the transformation in a shorter time, then we get **charcoal**, which is practically pure carbon. When heated anew, this wood-coal (in contrast to mined coal) no longer produces any water vapor as a secondary combustion product. On the other hand, we can isolate a related plant substance by pressing the fluid sap out of the solid plant fibers, and allow something with a more watery-balanced nature in this sap to come to expression: **sugar**. We encounter sugar as transparent, water-soluble solid crystals, which, however, combine within it the solid-burnable and the fiery-volatile. Through various technical means, we can increase or suppress each of these natures. One of these processes is fermentation, which leads us to alcohol. With alcohol (and its subsequent products ether and esters), the carbon-nature is so intensively transformed through either the watery or the fiery-volatile, that with heating a sooty residue is no longer formed. Remnant influences of carbon-nature are shown by the more or less yellow or sooty flame. The products of burning too reveal which 'natures' are to consider in the reactions. For example, if a great deal of water vapor arises, which is lighter than air (upward cloud formation), the fiery-volatile nature is correspondingly strong (hydrogen-nature). With this study of decomposition products, we attempt a truly chemical concept formation. We don't merely view together outer qualities, but rather take hold in a clear way of natural processes, leading them to accelerated and intensified new phenomena, such as distillation, coking, combustion, or fermentation.

Refinement. The plants themselves – next to the solidifying process leading to wood – provide an example of such a "refinement" (c.f. Goethe), as the watery-leafy middle part of the plant leads up to the flower. There we find, above all, the fiery-volatile fragrant substances, which barely have any mass. If we imagine the refinement process carried so far that every trace of both of the other two qualities is overcome, then we would arrive at hydrogen as the quintessential fiery-volatile. It is not the basis, but only a variation of 'hydrogen-nature' taken to the extreme. Again, the study of combustion products (pure water vapor) makes this inner nature manifest but, in this case, in its one-sidedness. [See class 11 syllabus; hydrogen as an element in the Human Being and in the World]

If, in contrast, we consider the formation of fruit, we can recognize a kind of about-face into the watery forming realm, or also transformations of the solidifying type in the formation of skins, acids and oils. In the fatty oils, the fiery-volatile has been seized by a new variation of the carbon-nature, so that volatility has disappeared and there remains only a muffled-fiery quality: the fats and waxes.

Petroleum & Life.

In contemporary petroleum chemistry, usually treated as "organic chemistry," we can also discover all these tendencies and specialization of characteristics. We also find here more or less volatile, gaseous, fluid, and even solid black or aromatic products. These facts, mirror the origin of petroleum oil from the living kingdom. Still, won't all these characteristics only act like ghosts of the archetypal, living qualities, which in petroleum will be awakened to a 'transplanted' virtual-life, only through an out-of-joint / dislocated technology? Students should certainly be offered a glimpse into this virtual-world; nevertheless, petroleum chemistry such as the homologous series of the alkanes cannot serve as the starting point for our main lesson block, for then we would find ourselves with the deadest substances without any images from nature, and would understand nothing of the living connections.

Four Elements.

If to the carbon-nature (solidity), to water-nature (non-flammability), and to the fiery-volatile nature (hydrogen), we add a fourth: an airy-nature, making a non-flammable but volatile gas (carbon dioxide), then these inner natures can be thought of as images of the four elements. The activity of the Elements over the whole earth is indicated in further detail by Steiner in Lecture 6 of the "Supplementary Course"[7] [*Here Steiner contrasts the modern, abstract image of the human being proffered by natural science, with the Greek conception of things, which still incorporated an inner conception of the Life of Nature, and the importance of a living image for the growing youth. Translator's Note*]

It is interesting that in the Conferences, immediately following the above indication about the chemistry syllabus, Steiner continues on unprompted to speak about the Study of Man: "Anthropology – continue the study of the human being in order that a true anthropology is taught to the students. This must grow in concentric circles from class to class and the usual natural sciences be arranged about it." So, chemistry too orients itself about the central study of the human being, and needs no systematic of its own – but is connected into an existing order. As teachers, we ask ourselves how we should grasp the way hydrogen-activity (as a non-material "force") takes effect in the whole of Nature and in the human being. Deeper explanations by Steiner in the Agriculture Course,[8] in the workman's lecture on Bees,[9] and in the medical lectures[10] will prove useful The same applies for carbon.[11] There, in addition to the simple material interconnections, much is said about the effects on and within living beings, and in the whole of nature. We could also say that the substances discussed there are those that approach the etheric, or still more the spiritual. In contrast, in the chemistry main lesson block, we initially keep our focus completely on the physical substances and their outer characteristics, and the reaction-principles which appear in the laboratory.

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[7] *Waldorf Education for Adolescence; Supplementary Course - the Upper School; Stuttgart, June 1921, GA 302*

[8] *Agriculture Course, Lecture 5?; 11/06/1924; GA 327.*

[9] *Nine Lectures on Bees, GA 351-a; Lecture on 10/20/1923.*

[10] *Spiritual Relations in the Human Being, Lect. 2, 10/22/22; Mercury Press, 1978; Science & Medicine, 1st Medical Course, Lect 12, 4/01/20, GA 218; Steiner Press, London, 1975.*

[11] *Agriculture Course, GA 327; Bees, GA 351; 1st and 2nd Medical Courses, GA 312 & GA 313*

However, it can still warm the teacher to consider the wider aspects, even if at first, it is expressed in a form which is not immediately suitable for the lessons. An absolutely beginning consideration might be the following: we meet the fiery-volatile in our upwelling warmth; we live in it. We live in the solidifying-permanence, in our solid body. The watery streams through us, from the mouth inward. We experience it with every wound and also, in the plasticity of our body. The point is not to arrive at a 'perfect analogy,' but rather to return to the human being by thinking about such qualities.

4. Overview of the Syllabus

Main Themes.

If we survey the preceding thoughts, we can arrive at the following themes for this block:

- *carbon dioxide* and combustion (total oxidation), as a balancing of 'enkindling' with burnable qualities;
- *Coking* (enclosed destructive distillation) as liberation of the volatile-burnable from the solid-burnable;
- *sugar,* treated in class 8, and here again by liquefaction (making-watery) and thereby *activation to alcohol*, so-called 'fire-water;'
- formation of *ethers* as a loss of the watery-nature;
- acetic acid (vinegar) *fermentation*, a partial oxidation, i.e., the onset of a balancing out and aeration;
- formation of *esters* as another variant of the overcoming the watery-nature;
- etheric oils and the resins of plants.

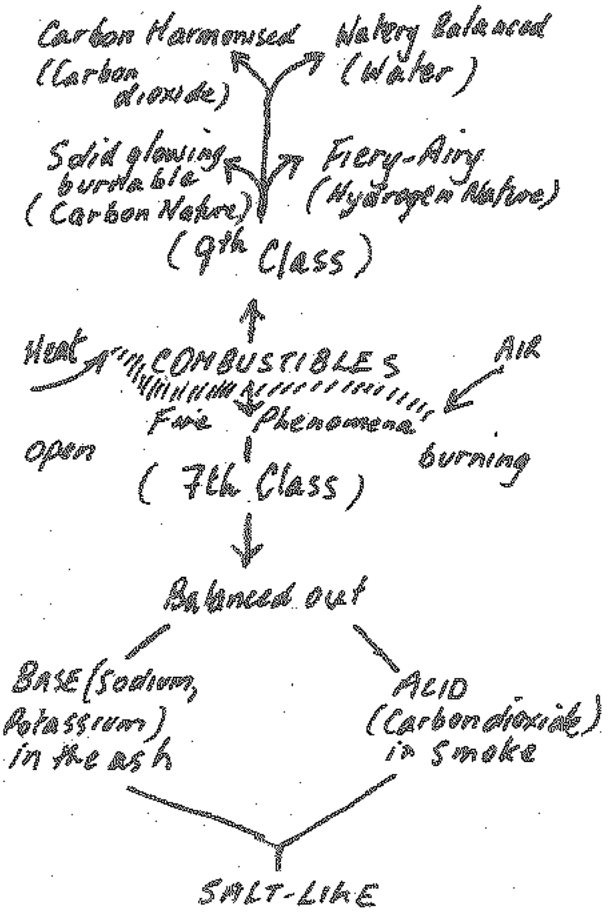
Background to Practical Work. The prelude could form a fundamentally inorganic theme (carbon-dioxide and combustion). Although that does not yet resonate with the actual theme of the block, namely the delicate metamorphosis of the inner nature, it has still proved useful to a certain degree as an entry point for the beginner. Probably this has more to do with teacher and students finding the right mood together about the more objective, merely material aspects (occurrence, characteristics, composition in the air, etc.) and how they work together. The feeling of meeting something concrete and learning something important (e.g., the components of the air) is beneficial for the beginning of the main lesson block. The specific steps in thinking the transformations of the inner qualities of the organic, where the will must penetrate the thinking more vigorously, are then recruited into an already begun learning process . With well-defined concepts we stimulate a spiritual mobility, which *then* is led over via the subsequent delicate phenomena into investigating and dealing with more open-ended concepts.

Each teacher will have to decide whether this sequence is necessary. Where it isn't, I have begun directly with burning and then coking (closed distillation, charring) of wood. The composition of the air is then tied in without any sort of special experiments, and carbon dioxide is briefly characterized as a waste gas of burning charcoal.

Consider carefully the sequence of introducing the three 'natures.' Perhaps it is advisable to shift the emphasis in stages from day to day. The smoldering-solid nature is developed initially along with the various combustion residues of carbon; the watery-nature is investigated after the coking-water [very watery initial distillation product from wood coking]; with the fiery-volatile nature, we show the 'wood-gas' [flammable gases produced in the middle part of a wood distillation run], and then back to the wood. For the transition cellulose to sugar and sugar to alcohol, all three qualities are available, as they are for the transformation to ether etc.

If exceptionally little time is available for the main lesson block or for preparation, it could start with fermentation and alcohol. The smoldering-solid and the watery nature investigated in sugar and also with wood are related in afterwards. We must then be careful that the concepts are formed rightly - the teacher has a more difficult task. This jump right into the center of the main lesson block can, however, be a great stimulus for the students!

The diagram below, again indicates the path:



We see how the themes of classes 7 and 9, both begin with combustibles but then develop differently. In the class 8 main lesson block, the theme of combustion is totally taken up within the theme of nutrition. The images presented by the phenomena of starch and protein, sugar and fats are researched there. In the 9th class, these same combustibles are now placed within a polarity of rigid and volatile, and from carbon, followed through the plant world, to hydrogen.

But, we should be cautious of too much inorganic chemistry. The causal-materially oriented path of development taken by modern science has made all chemistry inorganic, actually physical, at least in the way we actually understand it. In contrast, chemically poorly-defined substances are the most important for life. They originate in the living-organic and re-enter life processes again (food stuffs and medicines, etc.). A chemistry which aims to foster the growth and development of the whole *human being* should *not* develop its basic concepts from molecular mechanics or chemical technology. Technology, being based on finished, inorganic concepts, inserts itself into the world as something independent of the cosmos. It keeps the world and life outside. Mechanistic foundational concepts, especially when they are technically powerful, do not belong as the basis of a chemistry which strives for qualitative concepts of the living-organic world. A purely inorganic chemistry is never indicated for any class by Steiner. (And nevertheless, the chemistry teacher often tends to base everything on inorganic chemistry, since they were trained that way. From this we ought to extricate ourselves.....).

5. PEDAGOGY & METHODOLOGY

The task given for the young person in class 8 and 9 is to connect to society and the world, their awakening independence (through which they become free) and also strengthened – that is, to integrate them in a socially productive way with the community. At first, they may wish to emulate the outer, visible deeds of others, and understand how they master things. These young students want to penetrate such things with their own power of discernment, so that in this way they learn as a first step how to grasp the most external aspects of the world–the world of technology. As Rudolf Steiner says in the curriculum lectures of September 6, 1919, "An interest for everything worldly and for everything human" comes to life. Young souls feel a newly awakened power to exercise control and are also completely given up to the forces of personal desires (the urge towards power and eroticism—see Rudolf Steiner's lectures on June 21 and 22, 1922). Such young people exhibit a new physical strength, independence, and resistance to the established order of previous generations, as well as a desire to try new things. If the school and home do not harness these forces and attempt to integrate them into life, then, depending upon the student's natural tendencies, it is possible that depression or even suicidal tendencies arise in boys' young souls, while girls escape into an external, superficial world.

The help that teaching can offer consists at least partly in *providing a thorough understanding* of technology, transportation, and business. How have these things changed our life together, that is, the way one person interacts with another? We think of the telephone and the locomotive in physics. Here we encounter a world made by human beings. In this case, intellectuality and cleverness act in the service of comfort and make human beings independent of the limitations of nature. Technology arises from technically specialized but outwardly highly effective human thoughts, and today is maintained only by such thoughts. Although, in relation to the phenomena of nature, these thoughts may be very incomplete and restricted to the quantitative, nevertheless they *are* a very accessible sequence of thoughts; and have in fact become decisive in the events of the external world!

Whereas in physics, the discussion revolves more around finished technical devices, in chemistry our concern is more with technology in the laboratory, for instance working with gases or simple devices such as a fire extinguisher or a pressure relief valve. Our discussion in the ninth class is much less connected with the chemical industry–which we might present in twelfth grade chemical technology. The entire way we perform experiments undergoes a characteristic transformation in class nine in comparison to class seven. In the class 7, we present large, open experiments, ones in which air plays an unhindered role–like an unlimited sea of air in these experiments, e.g., in combustion, or in dissolving lime with acid, or in its re-solidification in mortar. Even in class 8, things are still cooked or decomposed while exposed to open air. We begin quite simply by growing grain and go on to grind it, sift it, and rinse out the starch, which we then make into paste. Open smoldering experiments such as caramelization, vapors from boiling fat, and boiling coagulated egg white, belong to this series of open experiments. However, in class 9 the vessels are closed up. The distillation flask forms a small hollow sphere, the setup of condensers and receiving flasks look more like labyrinths. Unknown vapors, neither the air nor a smoke from our world, fill these chambers and tubes. The students should live into them through their feeling. This occurs in numerous new variations from simple distillation and reflux heating to rectification and steam distillation.

The transformation to the volatile oils, the freeing of "spirit" from murky, watery brews, pictorially shows the students a purification and enrichment, a sublimation. Something like an inner soul process can thereby be seen externally. Such distillations also occur through smoldering/charring, during which, especially in class 9, we catch and contain the gases thus released. The situation is similar for fermentation, in which we collect carbon dioxide.

During puberty, young people have an impulse to learn about objective things without taking the circumstances surrounding them into account. Thus, they penetrate into their surroundings only through their own conceptual images (as technology generally does). At first, the student can comprehend only the separated part, that is, the technical aspect; through that they then come to their own judgements. Students are somewhat passive when presented with the broad pictures of nature; their will cannot yet draw together those pictures into a self-sufficient thought-framework. Thus, what they seek, runs away.

If you present only nature-pictures, then the result would be a chaotic discharge of the students' energies of will. On the other hand, much in the details of the apparatus of conventional school experiments, amounts to giving children of this age a bone to chew on—which we are supposed to get them to gnaw on, but it is still only a bone. The teacher needs to continually guide them towards the deeper and softer phenomenological connections. At first, they are kept in mind, but left unspoken; then later, mentioned in a short overview. And, finally presented in the way the teacher illuminates objective science on the basis of the phenomena, and never by means of [theoretical] model-concepts of particles and their "bonding," which only provides an inventory of the object and how and where specific elements exist within it.

6. LITERATURE

The following books may be useful for obtaining a deeper and firmer understanding as part of your preparation [many are specific to German-speaking countries].

Fritz H. Julius attempts to give a comprehensive phenomenological description of chemistry instruction in Waldorf schools in his booklet "*The World of Matter and Human Development*," Book I, Stuttgart, 1978, 2nd edition; English translation by Steiner Schools Fellowship. See also, his book II, "*A Phenomenological Study of Chemistry*," translated by AWSNA Publications, Sacramento CA.

Gerhard Ott gives a number of good experiments and interesting thoughts in his 2-volume work "*Outline of Chemistry by Phenomenological Methods*," Basel, 1960 [not translated].

You can find a discussion of carbon and hydrogen similar to that presented in this volume together with a complete overview of chemistry in Rudolf Hauschka's, "*The Nature of Substance*," Frankfurt, 1976, 6th edition.

For its clear, systematic presentation and the amount of reference information it contains about chemistry, we should mention Beyer's standard university textbook of organic chemistry: Textbook of organic chemistry). [see also, Seyhan Ege's *Organic Chemistry*, UofM text, Houghton-Mifflin, 2000]

You can find a broad description of the chemistry discussed in this book in: Winnacker-Küchler, Chemische Technologie (Chemical technology), vol. 3, Munich, 1972, 3rd edition. [Often a valuable resource is older editions of "industrial chemistry" texts which give details of processes, no longer mentioned in the more theoretically-oriented modern texts.]

Exact descriptions of experiments, particularly for presenting specific materials can be found in Arndt-Dörmer, Technik der Experimentalchemie (Techniques of experimental chemistry), Quelle & Meyer Verlag, Heidelberg, 1969, 8th edition.

The following two volumes contain interesting information about nutrition and intoxicants:
F. Hauschild, Pharmakologie und Grundlagen der Toxikologie (Pharmacology and the basic elements of toxicology), Georg Thieme Verlag, Leipsig, 1960, 2nd edition;

and also in J. Schormüller, Lehrbuch der Lebensmittelchemie (Textbook of nutritional chemistry), Springer Verlag, Berlin, 1974, 2nd edition.

You can also use the following books for learning about how to obtain essential oils, their characteristics and uses.

H. Janistyn, Handbuch der Kosmetika und Riechstoffe (Handbook of cosmetics and fragrances), vol. 2, Alfred Hüthig Verlag, Heidelberg, 1969;
and in K. Bournot, Rohstoffe des Pflanzenreichs: Ätherische Öle (Raw materials from the plant kingdom: Essential Oils), J. Kramer Verlag, [place not given] 1968.

Concerning the themes presented in class 8 and 9 chemistry, I have developed two projects.
The first one is for producing alcohol—distillation, rectification—with the resulting cologne or mellisengeist using raisins as a starting point.

The second project is soap-making, coloring, and perfuming of the soft soap.
Both of these projects are in my volume "Laboratory Projects in Chemistry" [See PART 2 in this volume for the first project. The second project has not been translated yet.]

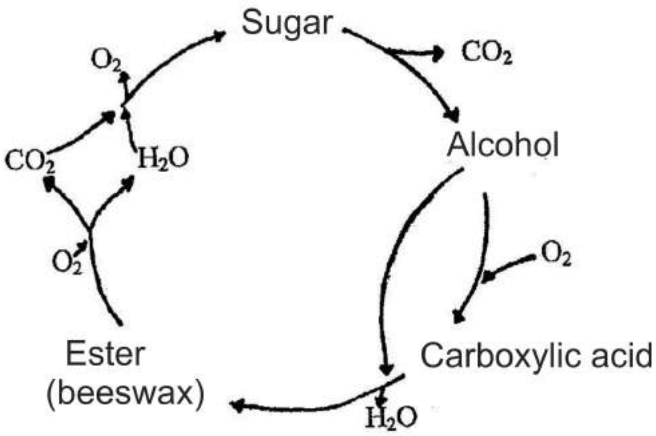
Dirk Rohde

Excerpt from
“Was heiβt ‘lebendiger’ Unterricht?” [What Is ‘Living’ Instruction?], 2003

The Carbon Cycle

The hard work of attempting to explain the *carbon cycle* has occupied many people for a long time – perhaps even since antiquity, depending on one’s point of view – and by now we have been able to glean an abundance of insights. Carbon is a very special chemical element. Together with water, it is the key to all life processes, and as such it is responsible for many of the defining characteristics of the Earth as a whole. Consequently, knowing about its material cycle also strikes me as extremely important. Substances cycle through the world and all things are interconnected – not only reciprocally and in networks but also in cycles of metamorphosing configurations. In my view, this is an insight that the natural sciences have truly achieved only in the last hundred years and that is now gradually beginning to leave an ever stronger imprint on our view of the world. For this reason, all elementary and secondary students should become familiar with at least one such cycle – whether of water, carbon, a commodity, or some other good example – in the course of their school years, and as a rule we should expect them to be familiar with multiple cycles of this sort by the time they graduate from high school.

The Waldorf School chemistry curriculum for grade nine can be interpreted to include an introduction to some of the main features of the carbon cycle. In terms of substances, it leads from sugar through alcohols and carboxylic acids to esters (and secondarily to ethers). In terms of processes, it leads from photosynthesis through alcoholic and acetic acid fermentation to esterification (and dehydration). In all these processes, carbon dioxide, water, and oxygen are the constant companions of carbon. All this can be summarized in a cycle that looks like this when combustion is included:



In fact, beeswax is not a typical ester, neither in comparison to esters that are easily produced in the classroom (such as acetic acid ethyl ester) nor in principle: In chemical terms, beeswax is a mixture that consists largely of esters but also contains other families of chemical substances.[1] The great advantage of beeswax, however, is that it offers a natural transition to combustion. Both experimentally and phenomenologically, combustion is a good conclusion to the carbon cycle, and it is also easier to understand than if we take the much more difficult route via human and animal metabolism, which also leads to the release of CO_2 and H_2O.

The cycle presented above provides a first impression of the carbon cycle and forms the basis of my grade nine chemistry block. It provides opportunities to revisit what was covered in chemistry in grades seven and eight, expanding upon it and raising it to more comprehensive level – ideally, a process that continues all the way to grade thirteen (when it will provide a good foundation for studying the Krebs cycle, for example).

In principle, the cycle can be approached through any one of its five transitional processes. For example, we might choose to begin either with the fermentation of fruit to produce alcohol (a good starting point in autumn), with acetic acid fermentation, by producing (or extracting) esters, by investigating the combustion of a carbon-hydrogen compound, or by conducting experiments in photosynthesis. I have tried a number of different variations, but in my experience, beginning with investigating an example of combustion works best in terms of getting the class involved in independent activity and in learning about experimental techniques and the development and investigation of scientific problems. These are the objectives I attempt to achieve in grade nine in order to begin the transition from the heavily teacher-oriented educational approach of grades seven and eight to ever more independent ways of learning that will ultimately culminate in college readiness. With this in mind, I wondered whether a lesson on the candle[2] would help optimize the first part of the grade nine chemistry block and make these objectives easier to achieve.

If we want time to do many experiments in class, to go into individual aspects in greater depth, and to include several subsidiary topics (in particular, how animals and humans relate to this cycle), covering this block will take three weeks – that is, 15 to 18 two-hour sessions. I allow plenty of time – approximately the first week, or 6 or 7 two-hour sessions – for the discussion of the candle, since I use this time to cover not only the topic itself in the narrower sense but also a certain amount of basic material that will reappear repeatedly in the next two weeks and will then only need to be revisited briefly. As a result, the other four chemical processes (see illustration above) can be quite adequately covered in the number of double sessions remaining. Whenever four weeks are available for the block, I also link to practical applications that are directly related, such as wine and beer production, cosmetics, aromatics in foods, and saponification.

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[1] Meroth in “Natur” no. 12/1987, p. 80

[2] Michael Faraday, The Chemical History of a Candle. Full text available online at www.gutenberg.org/ebooks/14474

Fundamentals for a Phenomenological Study of Chemistry
author: Frits H. Julius

available from :
AWSNA Publications
458 Harold Meyers Road
Earlton, NY 12058

publications@awsna.org
www.whywaldorfworks.org (Books Online)

III

Salts, Acids and Bases: Chemistry in Grade 10

Crystallization of Salts

In this class, we start with salts—that is with substances which being crystalline are totally earthy, but earth that is strongly, regularly-formed and transparent.

With that we have also exactly struck a theme which is so important for students of this age. They have gone through puberty, and the subtle connections they still had with the cosmos have been severed now, for the most part. They have now become earth-dwellers and must learn to orient themselves with clear thoughts in this realm, which is for them as yet, unknown. Their life, which for their consciousness takes place in first instance on earth, must be given structure through the power of thinking. Their thinking must be so strengthened that it can order the multitude of individual phenomena, but it should also remain so sensitive, so subtle, that it can really grasp the noble organization of the universe.

The whole main lesson block should have the following style: a pronounced clear conceptual structure, that orders the wealth of phenomena, through which it becomes possible to understand and even to use this structure. A nobly shaped, beautifully colored salt crystal can actually become an ideal for us, when thinking about this main lesson.

We start by showing a number of crystals. From the beginning, it is a good habit to use certain devices, so that the impressions become as expressive and characteristic as possible. Such a transparent substance with its shining surfaces doesn't show up very well on white paper. On black paper and with illumination from the side it shows an exiting beauty.

We could perhaps let some salts crystallize beforehand: table salt, copper sulfate, potassium nitrate and others. A wonderful fresh brilliance and beauty meets the eye, if we choose the proper lighting.

If now we reflect on the essence of salts, then we should stress their marvelous precise shape, their transparency and clarity. The real wonder of salts only becomes evident when we consider them in relation to the whole of nature. The salt is earthy, dense, rigid matter, and yet it opens itself to a large extent to the play of light. Actually, the earthy region beneath us is dark, dull, silent and pressing, while in the region above the earth light weaves in a very rarefied, clear world. The greatest contrast exists between the realm of light above and the realm of matter below us. The salt crystal, which actually belongs to the realm of heaviness, is nevertheless largely open to raying-in from the realm of light.

We may take the following thought for our own consideration: In primeval times, matter was separated from the realm of light and condensed. Light has become rarefied; matter has lost its ability to shine on its own and is subject to gravity. Such a crystal shows its isolation from light to a high degree. In its essence it exhibits the *memory* of light, but just because of that it can make such a dull, empty impression on us. If we illuminate it in such a way that it seems as if it is shining of its own accord (backlit or from beneath), then we can achieve a splendid effect. In a sense, we raise it up from its fall and bring it back to its origin. That can be done in various ways. For example, cut small holes in a piece of black paper; in front of every opening place a well-formed salt crystal. Then, darken the room and illuminate the holes one after the other. Then the crystals will radiate beautifully. We can also show crystallization in front of a dark screen strongly illuminated from the side. For example, take a saturated solution of table salt and add some concentrated hydrochloric acid. That gives rise to a magnificent brilliance of crystals, which very often may be so small that individual ones cannot clearly be distinguished. When the crystals are somewhat larger, they are seen forming themselves like delicate clouds, slowly sinking to the bottom, white and pure as freshly-fallen snow.

To experiment on a large scale, use a 3-litre conical flask filled with a hot, nearly saturated solution of potassium nitrate. When the carefully wrapped up flask is allowed to cool slowly, the crystals build enchanting forms—impressive highly transparent shapes with a subtle play of color (the slower, the better the crystals—editor's note).

Crystallization in general, but especially with table salt, evokes the image of the primordial coming-into-being of matter, the original densification of spirit to matter. A sort of "fall" takes place, an expulsion from a surrounding world, but in the magical purity of the forms, a memory of its origin remains.

It's a good thing to let the students totally experience how, in the liquid state everything is in flowing, swirling motion, and how crystallization is something like a protest against fluidity repeated again. Time and again some salt will shoot out of the liquid and becoming rigid and sharply formed, enclosed by planes; repeatedly the fluid movement is thwarted. This is especially apparent with cubic crystals such as table salt. Such a crystallization consists of many jumps from one stage to another that are specially dramatic. Every time, there is a transition that seems impossible but nevertheless happens.

Now is the time to investigate the salts in our body. We find them above all in the skeleton. Here this also happens through a continuous deposition and fixation of salty substance from the flowing blood. However, it is remarkable that here the salts don't take on their own form, but totally adapt to the necessities of the human body.

If the teacher feels justified in mentioning it, then they can draw attention to the fact that especially in relation to the crystallization of table salt, we have here something of a process that also occurs very subtly in our whole organism when we form a thought. Just as in a crystal the earth opens itself to the light, so in ourselves matter must, so to speak, take on crystalline form, if our bodily organs are to become transparent for a spiritual reality, to which our thoughts give expression.

Phenomena Occurring when Salts Dissolve

Once we have occupied ourselves with these considerations for a few days, we can move on to the process of dissolving of salts. We place an ~~orange-colored potassium dichromate~~ crystal, for example, in a beaker glass with water, and let the students observe what happens. The crystal slowly gets smaller and takes on a rounded form, while all around the crystal the water begins to share its color. ~~If someone has enough courage to taste the water, one can taste its saltiness (HAZARD with potassium dichromate—try it with dissolving spears of saltpeter)~~. The crystalline salt, first enclosed within its walls, lets go of itself and loses itself into the surroundings. This process is like a longing for infinity, for perpetual expansion and rarefaction.

Crystallization is a continuous falling-out of unity into multiplicity, a sort of splitting-up, but at the same time a drawing into specific, individualized forms. From solutions of various salts we see each salt taking on its own shape. During dissolving the opposite takes place—the multitude of salt crystals become one with the water. Many salts even dissolve without interfering with each other.

If we suspend potassium permanganate crystals just under the surface in a large glass cylinder filled with water, a particularly lovely process of dissolving can be observed. For example, we can attach the crystals with Vaseline to the underside of a floating cork or to a loop of copper wire. The strongly-colored violet solution sinks, and thereby creates a number of elegant streamers with eddies and vortices. The best results are achieved against a white background, which is strongly side-lit. Then it is possible to observe it all even from a distance.

To be able to do calculations later on, it is now time for a preliminary discussion of various concepts, which will be developed more precisely later on: solubility, concentration, saturated, unsaturated, supersaturated solution, water of crystallization, osmosis, diffusion, heat of solution and of crystallization, elevation of the boiling point, depression of the freezing point. We will treat these in another chapter.[1] Here it is necessary only to point to the fact, that all these concepts can be related to an inner experience of the specific dynamics of the phenomena, and only later be developed into mathematical relationships. If we don't proceed very carefully here, we only add to an aspect that is already being cultivated to a high degree: forming concepts which are very precise and make it possible to manipulate natural phenomena, but are not very helpful in creating a living picture of reality. During the last centuries man has ever more moved away from nature by using such concepts, and has become more and more a prisoner of his own thoughts. We are concerned, therefore, with preserving just that quality that is specific to children, namely their unity with the surrounding world. We must teach the students to develop thoughts which do not break their connection with the world, but elevate them out of the sphere of mere instinctive feeling, to a sphere where conscious precision rules.

It is, of course, good and necessary to bear in mind all the phenomena that occur in life, specially those that occur in human beings. A few indications may point the direction in which they may be found.

We have already discussed the relation between crystallization with thinking, and with the formation of the skeleton. We can also show how aging is accompanied by a continuous deposition of salt in the skeleton, and finally also in the walls of the arteries.

During sleep a large amount dissolves which had been deposited during waking. During the growth of the skeleton a continuous dissolving of certain parts takes place, while at other places new substance is precipitated.

We can speak about the blood as a salt solution, and about the kidneys as strict regulators of the salt levels. This constant salt level is most closely connected to the fact that the tissues, and in particular the red blood cells, depend on a specific osmotic pressure. That must be taken into consideration when giving a blood transfusion after a heavy loss of blood. We can discuss the problems of osmosis that a young salmon encounters when going from fresh to salt water, and vice versa for the adult going to spawn. We can describe how a frog doesn't drink, but a nearly dehydrated frog only needs to place its finger in water to fully recover.

So, there are many topics, some of which are important or must be dealt with at any rate, while others may be included as desired.

Splitting of Salt by Fire: Acid and Alkali

When we have dealt extensively in this manner with these phenomena relating to salts, especially those that occur in interaction with water, we can examine how fire acts on salts. For example, a piece of blue copper sulfate is held in a flame. We see that it gradually loses its transparency, and it becomes opaque white, then brown, and even black. It becomes an inert, earthly, insoluble mass. If we heat the crystal in a heat resistant test tube, then we notice how water of crystallization initially appears as vapor. That is the reason for the cloudy white substance. Subsequently, an acidic pungent gas evolves. This gas colors blue litmus paper red.

If we heat a salt like calcium nitrate, then brown, acidic fumes are generated, and we are left with a moderately soluble milky white substance, which is chemically reactive. This substance colors red litmus paper blue. So we have before us the process of splitting salt. Out of a single substance, which for our perception formed a complete unity, entirely different substances have come about. The original substance has disappeared to the same extent as new substance is formed. These are typical examples for the decomposition of salts. Now we must direct our attention to the transition, to the "interval" between the first state of the substance and the next, as we already did with crystallization. However, we will confine ourselves to the essentials, in that we will not focus on the water of crystallization. We observe, therefore, a well formed, transparent substance changed to a shapeless mass. The "memory of light" spoken of earlier, disappears, and in its place something arises that makes an earthly impression on us.

If we turn our attention specifically to the "phase" of vapor production, then we observe how a gaseous, fine dispersing substance is freed from a clearly defined, rigid, heavy substance. The immobile salt changes into a mobile, active, here even aggressive, gas.

First, there was a piece of earth that was transparent (open to light); now, on the one hand, we have a piece of earth that shuts itself off from light (is opaque), and on the other hand, a substance that seeks out the light filled space and identifies itself with it. The substance that remains behind has retained the solidity of the original salt. Therefore, it is called "the basis" or "base" of the salt. The substance which escaped has taken with it the transparency.

We already mentioned previously,that it can be economical to make a distinction between topics which are dealt with in more detail, and others where we don't do more than give a list of facts. We can use this principle now.

After discussing the creation of acidic and alkaline substances, due to the decomposition of salts, with great care we can list the names of the most important acids and bases:

Some important bases	*Some important acids*
sodium hydroxide ("caustic soda")	sulfuric acid sulphurous acids
potassium hydroxide ("caustic potash")	nitric acid nitrous acid
calcium hydroxide ("slaked lime")	hydrochloric acid
magnesium oxide ("magnesia")	silicic acid
ammonium hydroxide ("ammonia")	phosphoric acid phosphorus acid
iron oxide ("iron rust")	carbonic acid
copper oxide ("copper rust"[2])	

These substances can also be exhibited, at the same time and, if one has sufficient time, also be characterized with the aid of typical phenomena.

Now we consider the acidic and the alkaline state in greater detail. For example, place three beaker glasses filled with water colored with litmus solution. In the left beaker we pour some sodium hydroxide solution, so that the liquid colors blue; in the right beaker glass we pour hydrochloric acid, so that the liquid turns red. Then we add to the left beaker glass some hydrochloric acid, to the right one some sodium hydroxide solution, whereby the colors change.

It can be made clear to the students that red is a typical expression of the active, aggressive acid, blue that of the more passive base. Although there are other indicator substances that reveal the acidity by a color, and that these colors can be quite different, is not so important here; most are synthetic products which have very little relation with life in nature. Instead, litmus shows us the original and typical phenomena, which we have isolated from nature and are demonstrating on the laboratory bench.

Although litmus is obtained from lichens, it does have the character of a flower pigment. Now, draw attention to the variety of color changes in flowers, for example in forget-me-nots when they change from red to blue. Also, the extract of red cabbage could also be shown as a substitute for litmus.

We arrange three beakers: one with dilute sodium hydroxide, one with dilute hydrochloric acid, and one with tap water; some litmus solution can be added to all three beakers if desired. Then, we have the whole class come up and let them feel how the first solution makes the finger slippery, the second counteracts that, making them "squeaky" or "rough." The third glass is used to rinse the fingers. Remind the students of the similar slippery feeling they had when dipping their fingers into a solution of soap or washing-soda (sodium sulfate).

We now try to discover where we can find acid and base in our bodies. Our whole skin is slightly acidic because of perspiring. Our blood in contrast has to be slightly alkaline. Our saliva is somewhat alkaline, our stomach quite acidic, the intestines again alkaline. In general we can say, everything that is directed outwards (open to the outside world) is acidic, and everything that is directed inwardly is alkaline. The function of the stomach, besides being a storage place, is in the first place to defend against harmful influences that arise from assimilating food. Hardly any nutrients pass through the stomach wall into the blood. A muscle that contracts tends towards the acidic; on relaxation the alkaline comes to the fore.

In 1929 a little book ***Ten Years of the Free Waldorf School*** was published .[3] It contains a very inspiring article by Eugen Kolisko (1893 - 1939) entitled "On the development and forming of science curriculum in the Waldorf schools." He quotes therein a remark of Rudolf Steiner made in a class where they were just discussing the making of acids and bases: "All right, now you have seen all this demonstrated. Now also think, does any of that take place in my body? When you move your limbs, some acid is always formed; but when you are really quiet and are only active in your head, then something alkaline-like forms in your brain." Such a remark is at least as important for the teacher as for the students. From it we can gather in which direction to look.

In the ***Curriculum Indications***,[4] Rudolf Steiner particularly emphasizes the circumstances in the bees, the polarity between the acidic nectar and the alkaline bee blood.

In this context, the contrast between acidic and alkaline types of soil is also very interesting.

Salt Formation by Adding an Acid and a Base

Now we will turn to the action of acids and bases on each other. We take, for example, a beaker glass full with water and add copper oxide, whereby the clear water becomes dark and cloudy. (The copper oxide can be prepared beforehand from a hot solution of copper sulfate and a hot solution of sodium hydroxide. The freshly prepared copper oxide reacts more quickly). Now add a dilute solution of sulfuric acid. We can notice that the dark mass clears and changes into a crystal-clear blue liquid. Also, if water is heated beforehand, everything then proceeds much more quickly. Illuminating the moderately large beaker glass from underneath makes the process visible from a large distance, and many exciting details become observable.

This experiment shows us again a certain peculiarity of acids. They have the ability to consume excessive earthiness and to open the way for light. Precisely because of the illumination, this effect of the acid comes so clearly to the fore. If the blue solution were then evaporated, the well formed, deep blue, transparent copper sulfate crystals would be obtained. A process just as dramatic as the decomposition of a salt has taken place. Here, a shapeless and lusterless mass changes into clear crystals. Also, an active, mobile acid changes into an inactive, motionless salt.

We can now pour some concentrated hydrochloric acid into a test tube and bring a piece of sodium hydroxide in contact with the surface. A sharp sizzling can be heard, while a number of clear salt crystals fly away like dust and sink like snow to the bottom. The experiment can also be arranged in such a way that it takes on a slight sensational touch. Place the test tube with hydrochloric acid in a test tube stand, and drop a pellet of sodium hydroxide in the tube. The liquid begins to boil violently, and the tube begins to dance up and down.

When different ways of salt formation have been dealt with extensively in this way, then a lot of scientific knowledge can be introduced in a concise way.

We discuss the rule according to which we can, in principle, combine every acid with every base and always arrive at a salt. This can be done diagrammatically as follows:

Then we discuss how we find the names of the salts and make a list of the acids and their related salts. Then we make a list with their common everyday names and also their scientific names.

Transition to Chemical Equations

Now show how the general rules for the formation and decomposition of salts can be put into simple schema:

salt decomposition:

$$\begin{tikzcd} & \text{acid} \\ \text{salt} \arrow[ur] \arrow[dr] & \\ & \text{base} \end{tikzcd}$$

or, even more abstractly:

salt → base + acid

salt formation: acid + base → salt + water

With the help of these general schemes, specific reactions can be inferred by inserting the names as required. So for example:

caustic soda + sulfuric acid → sodium sulfate + water

slaked lime + carbonic acid → calcium carbonate + water

Or a salt decomposition:

calcium carbonate → unslaked lime + carbonic acid

In such a way the foundation is laid step by step for the subsequent use of reaction equations and formulas.

It isn't really possible to introduce formulas on the basis of the curriculum of grade 10. If the path going from the whole to the parts is consequently followed, if the whole is taken as the origin, and the parts that come from that as secondary, we just don't get that far. Besides, it isn't yet possible to treat the chemical elements so extensively and in such a lively way that could counterbalance such a far reaching abstraction. If we do it anyhow, a distinction is very easily created between the students. The more intellectually inclined will fall into the illusion that they now really have understood it, while in reality they have lost the connection with existence, and besides they don't grasp the difficulty of the formulas (they are abstractions). The formulas become an intellectual game. For the intellectually less-inclined, the formulas become a more or less unfathomable and unconquerable wall that discourages them from taking a real interest in the world of matter.

Yet, something important must be added. We have mentioned at the beginning of the discussion of grade 10 that we must be careful that the conceptual development is clear and lucid. The general reaction equations as mentioned for the salt formation and salt decomposition are in agreement with this; the area of the formulas, however, contains so many facts that the clarity quickly diminishes.

We will see that the full treatment of formulas, if postponed until grade 11, are better discussed from a different angle and then present an unexpected possibility for schooling.[5]

Besides, formulas have the disadvantage of unintentionally diverting our attention from the fact that every substance, be it an element or a compound, presents itself as a wholeness. Talking about sulfuric acid is in harmony with this fact. Writing down the formula H_2SO_4 however, specifically draws attention to the fact that this substance can be produced in a reaction from other substances.

However, it is possible to abbreviate our "general" equations somewhat and make them more lucid. We can do that in the following way:

base + acid ⟶ salt + water

B + A ⟶ BA + water

salt ⟶ acid + base

BA ⟶ A + B

Strictly speaking, the formula BA for a salt is already too analytical; in the end every abstraction, even the most circumspect, removes us from reality. But doubtless we have to put up with this.

On getting this far in the treatment of the curriculum, we have reached an important point. The students now possess the concepts not only to be able to gain insight into the processes to a certain extent, but also to know beforehand how a chemical process will proceed. They can even put reactions together for a specific purpose. For example, if we want to make copper nitrate, then we have to react copper hydroxide (copper base) with nitric acid. In this domain, students can predict and then check through experimentation if their thinking was correct.

Weight Relationships

If you wish to introduce the concepts of atomic and molecular weight later on, then I think it is appropriate to point out here that all these reactions proceed according to definite weight proportions. It is easier to treat this fact now as an expression of a strict harmony in nature than it is later on, as long as you don't yet have to do quick calculations. It is quite possible to proceed from the equivalent (combining) weights, e.g.:

caustic soda	40
sulfuric acid	49
sodium sulfate	71
water	9

caustic soda +	sulfuric acid ⟶	sodium sulfate +	water
40	49	71	2 x 9

It seems to me absolutely necessary to remain in the realm of abstract numbers, because only then will it be clear that we are dealing with ratios (of weights) and not with absolute weights. Nevertheless, it is possible to make simple calculations with these simple numbers. For example, we can find how many grams of sodium sulfate we get, when using 80 grams, or else using 2 grams of caustic soda (sodium hydroxide).

caustic soda + sulfuric acid ⟶ sodium sulfate + water
40 : 49 = 71 : 2x9
80 : 2x49 = 2x71 : 2x18

or (dividing all weights by 40):

2 : 49/20 = 71/20 : 18/20

If we give the students a list of the equivalent weights, then any number of calculations can be done.

Oxygen, Oxidation, Burning, and Rusting

We now demonstrate that acids come about when we burn certain non-metallic substances, and bases when we let metals rust. So, we must investigate in more detail the role oxygen plays when an acid or a base is formed.

It is quite possible to start historically and discuss how oxygen was discovered by Priestly. This presents us with the great advantage of being able to follow the historical development, which is mostly accompanied by an instructive struggle for the clarification of concepts. Moreover, this gives the opportunity to include biographies. This is particularly important for the girls, who more than the boys are inclined to assimilate everything with the soul and relate to people.

Priestley produced an unknown gas by heating mercury "rust" (oxide) and established that this gas stimulates the breathing process and also keeps the burning process going. It was, therefore, a gas with "enhanced air qualities."

Now, for example, burn some sulphur or phosphorus and demonstrate how the rising vapor and smoke will color a piece of moist blue litmus paper red. For completeness sake we can demonstrate that these substances will only burn if there is sufficient oxygen in the surroundings. If necessary, we can enhance the burning process by supplying pure oxygen (although this is not usually necessary, except with charcoal).

We then place a piece of iron in humid surroundings and let it rust. The tough, shiny metal slowly tarnishes, becoming rough and finally becoming a brittle, reddish-brown, crusty mass. The most interesting thing about this process is its slowness and lethargy—but this will not usually mean much to the students. Best of all, also, is to show the students a piece of severely rusted iron.

Going further, a bright piece of iron can be heated, and then copper. You can observe then how quickly the shiny surfaces tarnish. You can then discuss, and perhaps demonstrate, that the resulting copper oxide is the same substance as the base which we got from the decomposition (heating) of copper sulfate salt.

We now compare these processes of burning and rusting. In principle, both are caused by the action of oxygen. If both are expressed in chemical equations, then they both look quite similar.

$$\text{sulphur} + \text{oxygen} \longrightarrow \text{sulphur oxide}$$

$$\text{copper} + \text{oxygen} \longrightarrow \text{copper rust}$$

However, looking at the dynamics of the process and the qualitative image they give us, each processes shows a totally opposite character.

Burning proceeds quickly. It is a particularly striking and radiant process, because of the production of light and heat, and through the pungent smells that normally occur also. The substance that was before us initially as a solid object becomes totally consumed and changed into a mobile, space-filling gas. The whole process is primarily directed upwards.

Rusting is a slow process. The smooth, bright surface of the metal turns itself, as it were, away from the light to become tarnished and earth-like. Very little heat production can be noticed. While the burning substance goes with the oxygen into its sphere of gases, the rusting substance draws the oxygen down into the earthy realm.

Here is something mysterious, in that combustion only occurs when a certain (kindling) temperature is reached, while rusting also takes place even at low temperatures. However, this riddle can form the key to understanding the pattern that underlies all this. Combustion occurs through heat, rusting through moisture. During combustion mostly gasses and other volatile substances are formed. During rusting earthy substances are formed.

Combustion:	caused by heat	Firey
	result: gas/vapor	Airy
Rusting:	caused by moisture	Watery
	result: earthy substance	Earthy

We observe that the relatedness of both processes becomes clear, as soon as the four elemental qualities are taken into consideration. From that viewpoint it is particularly interesting to note that metals can be protected from rusting (watery) using an oily coating—stopped by combustible, "Firey" substances, while we fight fire with water.

Now we demonstrate how the products of combustion of substances like carbon, sulphur and phosphorus become acids in water, while metal oxides appear as bases. All this contributes to clarifying the typical properties of acids and bases. The acid, as it were, is the chemical herald of the two higher elements (Firey and Airy). This explains a lot of their aggressive mobility and their ability to open up the way for light. The alkaline is the chemical herald of both lower elements (Watery and Earthy). That explains their property of avidly absorbing acid vapors and binding them. Strong bases like caustic soda have more affinity to the Watery element; the insoluble bases, like the rusts of the heavy metals, have more affinity to the element of Earth.

Later on we will see how the properties of silicic acid are generally opposite to those mentioned, for silicic acid contributes a lot to the solidity of the earth, and it also has a special relationship with the cosmic aspect of nature. With bases, ammonia forms the exception; it is a volatile gas instead of a solid.

The Importance of the Approach Chosen

We could ask again, why does all this have to be treated in such a complicated way? Why don't we just start the block deriving acids from combustion and bases from rusting, and then the salts from reacting the acids and bases? From our description built up so far, we can make various answers. If we had started with burning and rusting, this would have followed an analytical method (emphasizing weights as Lavoisier did), even though we are seemingly proceeding on a synthetic path. But, this way gets into treating the substances that constitute a higher unity (such as acids, bases, and salts) as if they were made up out of these parts. Unconsciously, we lose sight of the wholeness. Taking the opposite approach, as we did, then we keep the wholeness in sight, even when going into the greatest detail.

From this it follows that this method is in harmony with the laws of evolution of a living being. This always begins as a unity with slight variations and goes on into ever finer differentiated detail. Using our method means we are working in accordance with the development of the child, which of course also follows the general laws of life.

Through the analytical methods widely used in science, there is always a danger of destroying the image of nature, resulting in unintelligible parts. Of course, this forms very well-defined concepts in relation to the phenomena, but then we wouldn't be very concerned whether they were an expression of the *context of reality,* within which the phenomena are embedded.[6]

Indeed, with our exact concepts, and infallible definitions we are continuously cutting parts out of the whole of nature. We are often so impressed by the clarity of the concepts, that we start to view the details as independent entities. The creators of mechanical theories, for example, suffer from this malady. They want to explain reality by using such parts from which they can develop the most lucid thoughts. If, however, you start from the whole, as we have been trying to do, then the concepts of the details developed will always remain in a harmonious relation with one another and with the wholeness of nature. They then acquire an aspect which reminds us of the organs of a living being. In this way, we create in the students quite a different orientation towards life. They develop the habit of keeping sight of the whole of nature and come to their own judgement and point of view from that whole.

In connection with the formation of acids and bases, it can be very fruitful to discuss the great French scientist Lavoisier. He is indeed the actual discover of the role of oxygen in this process. But to clarify the direction of his work, it is really necessary to talk about the alchemists. We can explain how the serious alchemists weren't after riches, but rather their striving was directed towards inner development with the help of chemical experiments. Related to that is also the strange names they gave, which is a way of expressing processes in imagistic form. Here we are dealing, on the one hand, with suggestions and hints about substances and their states, but also, on the other hand, with descriptions of inner changes occurring in human observers. During experiments they concentrated specially on the image-like aspects of the processes, on which we also have focused. They perceived the divine in nature in these images and the changes in themselves.

In Lavoisier's time the alchemical movement was long past its prime; it had become confused and decadent. Indeed, he has contributed a lot to the thorough extinction of the residue of alchemical views.

For him, the balance was the most important instrument, and this means that he tried to approach all phenomena from the aspect of weight. By that approach, the pictorial was totally eliminated. It is very remarkable that he was able to weigh oxygen before he even knew that it existed. In a closed vessel he let zinc oxidize and was able to show that something went from the air into the rusting metal. The total weight of the vessel and contents remained the same; however, the metal increased in weight. When he heard from Priestley about his studies of combustion in an oxygen atmosphere, he quickly developed his theory of combustion.

He also contributed a lot to the modern non-pictorial nomenclature. He proposed the name "oxygen" (from Greek, oxoos-gen = acid producer), and also the name "oxide" for an oxygen compound. He is also associated with the Law of Conservation of Matter. As a practical person he was primarily interested in an experimental method. He based his experiments on the conviction that the total weight of the substances taking part in a reaction remained unchanged. That really is only a working hypothesis. He most probably never would have drawn the conclusion, as materialists later did, that everlasting existence, and not even the human soul, had no divine being as its essence, but only matter. If matter can't be created or destroyed, then Creation isn't possible. Because of such considerations, in a sense God was robbed of his power, and matter was set upon God's throne.

Lavoisier is seen as the founder of modern chemistry, and in practice, chemistry views the material world primarily from the viewpoint of matter and energy. Maybe it is right to discuss such things with the students, mostly because we've learned since then that matter can actually be destroyed and created. Materialism, on this level, has been disproven. Besides, we can show the one-sidedness of such considerations precisely by studying rusting and combustion. If only the weight is considered, then the qualitative differences between these processes disappear. If, however, we pay attention to the image and the process, then the greatest differences can be discovered. Up to a certain extent it makes sense to consider rusting only from the aspect of weight. However, fire is in constant contradiction with gravity, and in the same manner, it is in harmony with the radiant light side of nature, just as rusting is related to gravity. With such thoughts the students are not only given a harmonious world view, but it should even be possible to help them find their own relation to nature. The young students have just recently deeply experienced in puberty the falling apart of human beings into male and female. At the same time, they became caught up in an interplay of soul forces that, although they may elate or fill them with idealism, can also pull them down. They feel fractured.

An image of this drama stands objectively before them in the decomposition of salt into acid and base, in the process of combustion and rusting, and what may be followed up from there. While they feel themselves more or less ejected from the care of a divine world-unity, this image may also contribute to the feeling that what they are going through now is also founded on profound laws of the universe. This drama becomes part of the world-drama. Their task is to acquire a new dignified bearing in the interplay of forces in which they find themselves. Once, they had to achieve an upright stance, between the world of light above and the world of gravity below them. At this age, they become mentally aware that there is something which wants to pull them into illusory worlds and also something that wants to pull them down and bind them to unconscious forces. They must learn to stand spiritually upright in this mental field, as previously they had to do this with their body. They must consciously find a new spiritual equilibrium. The curriculum, as reviewed above, may be a support for this.

Reduction

We have now reached a point where we can discuss the phenomena of reduction more closely. We place some brown, powdery iron oxide in a heat resistant glass tube. We then conduct natural gas (methane) or hydrogen gas through the reaction tube, and heat it where the iron oxide is. We observe the powder becoming gray-black, while a precipitate of water becomes visible on the walls. We can put this directly into a reaction equation. First we had iron oxide and hydrogen gas, now iron and water.

iron oxide + hydrogen gas ⟶ iron + water

This can also be expressed as follows:

iron oxide - oxygen ⟶ iron

hydrogen gas + oxygen gas ⟶ water ('hydrogen oxide')

After it has cooled down, the powder can be attracted by a magnet, a clear proof that metallic iron has been formed. It is also possible, while the tube is still hot, to pass air through. We see then that the powder immediately changes color back into reddish iron oxide.

A very impressive way of showing the alteration between oxidation and reduction is by quietly and strongly heating a piece of copper and letting the flame play over the surface. Inside the sphere of the flame, the metal becomes shiny; where the flame is removed, a rapid oxidation starts, that initially displays itself in a beautiful play of colours but ends in a gray-black zone. The longer the flame is moved about, the more splendid the colours shine out.

The students already have an idea of what occurs during a reduction, because photosynthesis has been discussed extensively in grade 9. We should recognize in it the archetypal phenomenon of a reduction process.

During the discussion of the discovery of oxygen, we also mentioned the decomposition of mercury oxide by heat.

Often, reduction is brought about by really combustible substances, like hydrogen gas, carbon, or carbon monoxide. From this, we may realize why all this occurs. The combustible substances are in a state of tension with regards to their surroundings. They are laden with energy, so to speak, which they radiate primarily as light and heat. In contrast, the oxides have reached a totally relaxed state. If we want to conjure up the initial substances from a combustion product (oxide or metal ore), we achieve this tension again by applying light and heat.

During photosynthesis carbon dioxide is changed to carbon by sunlight.* When decomposing mercuric oxide, the heat of the gas flame, or, in the case of Priestley, the warmth of sunlight, was used. During the reduction of iron oxide, hydrogen gas "snatches up" the oxygen, and gives some of its energy to the iron.

It's a good thing to draw attention to the fact that not only combustion, but also oxidation of metals, is accompanied by heat radiation. Mostly we don't notice this, because it goes so slowly. But, for example, if the process is accelerated by scattering iron into a flame as powder, the metal is seen forming glowing sparks—a kind of "meteoric burning."

In this way, we can discuss that with every chemical process an interchange takes between the ponderable and the imponderable. And each time, light or heat is either absorbed or emitted.

This point in the review of reduction can be discussed in such a way that we still keep completely within the sphere of the qualitative, connect up with life processes, and put things into thoughts that remain in the realm of images.

Solution of Metals in Strong Acids

Besides the normal way of salt formation by reacting acid with base, there is also the possibility of producing a salt by dissolving a metal in a strong acid. Many significant changes take place during this process.

For example, pour some dilute sulfuric acid in a test tube and add a small piece of zinc. The zinc is immediately consumed, accompanied by loud sizzling, a very combustible gas evolves, and finally, a clear mass of crystals accumulates at the bottom of the tube.

Once again, the qualitative reaction equation for the process taking place can easily be written out:

zinc + sulfuric acid ⟶ zinc sulfate + hydrogen gas

The metal is changed into salt crystals by the acid.

* (Not directly; the process is much more complicated.) (D. Rohde)

We are here faced with one of the strangest, most remarkable transformations. We have already previously characterized matter as that part of the universe which has been abandoned by light.[7] With the metals there has arisen a sort of contrast to light. If a piece of metal is held against the light, it appears as a dark opaque mass—indeed, it is completely opaque. Metals are the most reflective materials; they send the light back to the highest degree. However, at the same time this reflective ability points to the fact that they are also attuned to light. That becomes more pronounced the stronger they reflect, silver being most pronounced.

If a metal is dissolved in an acid, then the light repulsive properties are totally conquered. Again, acid opens the way for light.

If salt crystals are allowed to form immediately, as in the experiment described above, then the elasticity of the metal, its malleability, changes into the brittle, hardness of crystal structure.

In this context it is specially interesting that transparent solids are never good conductors for electricity, while the best conductors, the metals, reflect light the strongest. Here the polarity between electricity and light becomes very evident. Where one has access, the other is excluded.[8]

From all these phenomena we may conclude that there are polar states of matter; the metal state and the transparent crystal state form such a contrast.[9]

Electrolysis

Having come so far, it is quite possible to incorporate the first phenomena of electrolysis. Again, this will have to be done in a particular "Grade 10-way" and not anticipate the electricity curriculum of grade 11.

Start with a diluted salt solution (not table salt or other halogen salts) colored by litmus. For electrodes one can initially use carbon rods, and later on certain other metals. The results are as follows:

CATHODE (-) tendency towards	ANODE (+) tendency towards
base formation separation of hydrogen gas phenomena of reduction precipitation of metals	acid formation separation of oxygen gas phenomena of oxidation dissolving of metals

In this way we achieve a "phenomenology of the electrode." We can see how electricity, in its polarity, is related to the contrasts we have already discussed.

We should set aside all theory. In the light of practice and application, it is much more important at this point to give a characterization of the phenomena, rather than abstract explanations.

In this way we even are already laying a certain kind of foundation for the physics block (Electricity) in grade 11.

Finishing the Main Lesson Block

Acid or Base Substitutions—Double Substitutions (Displacements)

We now come to a part of the main lesson block wherein many new phenomena occur, which often include the most impressive ones we can observe. Generally, we will be able to use the concepts we have learned up to now. That makes possible constant repetition and practice. The students learn to play, as it were, with the concepts. They must be made to find explanations for many cases and to devise examples which can then be experimentally verified.

Furthermore, it is a question of finding all the possibilities that can occur when combining salts with acids and bases. Chiefly, there are three such combinations: base and acid, acid and salt, salt and base. We bring them together and observe the results.

For example, we begin by adding a base to a salt solution. If we take table salt and copper oxide, nothing will happen, just as with sodium hydroxide (a stronger base) and table salt. But, an impressive phenomena occurs if sodium hydroxide is gently poured into a bright blue solution of copper sulfate that is not too dilute. This results in a magnificent, veil-like translucent blue precipitate. If we follow the process carefully, small globules are observed. Within these globules there is sodium hydroxide; the walls consist of a delicate jelly-like substance, surrounded by copper sulfate solution. These globules, which also can occur with other salts, often look like protozoa. If one of them is destroyed, the contents will indeed flow out. However, a new skin is immediately formed; something like the of healing of a wound comes about. These bubbles are, therefore, rather stable, notwithstanding their delicacy.

Of course, the teacher should try the experiment in all possible variations, to ensure that they can demonstrate the phenomena in the most impressive way possible. Several glass vessels containing different concentrations can be used. If large glass containers and bottom illumination are used, the most enchanting phenomena can be achieved.

In a certain sense, the image becomes more clear if the copper sulfate solution is instead poured into a sodium hydroxide solution. The blue flakes then are quite visible in a colorless solution. Also, something very surprising happens when we hang a copper sulfate crystal in a sodium hydroxide solution—it is possible for pillars of precipitate to form.

Similar experiments can be done, if salts of other heavy metals are used with strong alkaline solutions.

We pose the question to the students: what may have occurred? We can write:

copper sulfate + caustic soda → ?
BA + B′ → ?

There certainly will be some who will be able to discover the answer. Hardly any other reaction is possible than that a new combination has come about, and in fact this is what has resulted:

sodium sulfate + copper base
B′A + B

The whole process looks like this:

BA + B′ → B′A + B
copper sulfate + caustic soda → sodium sulfate + copper base

The strong, readily-soluble base has displaced the weak, slightly soluble one. If that is right, then we must be able to dissolve the blue precipitate with a strong acid. Indeed that can be done. Of course, we shouldn't forget to show such an image of dissolving to its best advantage.

If our chain of reasoning was accurate, then the solution must contain sodium sulfate, and the blue precipitate must be some sort of copper base. To prove the first is difficult. However, the students will accept our statement that sodium sulfate really was formed. The second can easily be proven by heating the blue, jelly-like precipitate. Then a brown, black mass of copper oxide is produced. It then isn't very difficult to understand that the blue precipitate is copper hydroxide, a "watery" (hydrated) copper oxide. Such a hydroxide can be viewed as a base that has become stuck halfway to becoming a solid. If we add an acid to a salt, the phenomena can again be quite varied.

On addition of hydrochloric acid to a solution of sodium sulfate, no changes are seen. However, if hydrochloric acid is poured over soda (sodium carbonate), then it starts to sizzle and effervesce, volatile carbon dioxide escapes. Again, it isn't very difficult to understand what has happened here:

sodium carbonate + hydrochloric acid ⟶ ? + carbon dioxide
BA + A′ ? + A (gas)

From the equation it becomes clear that BA′, sodium chloride, must be produced.

sodium carbonate + hydrochloric acid ⟶ sodium chloride + carbon dioxide

Again, a general rule is achieved here: if we add a strong acid (HCl) to the salt of a weak acid (carbonate), the weak acid will be displaced and a salt of the strong acid will be formed. If necessary, we can draw attention to the fact that the volatility of the acid plays a role.

For practical purposes, acid displacement is of great importance. It could perhaps make sense to discuss the production of nitric acid, hydrochloric acid, carbon dioxide, and other acids from their salts.

It is important to show with such experiments how during a typical base displacement reaction, a substance falls prey to gravity, and how during an acid displacement reaction, a substance is taken up by levity.

As a last possibility of the interaction between acids, bases and salts we still have that of two salts. If we add a table salt solution to a potassium sulfate solution, no visible reaction occurs. However, using calcium chloride and sodium carbonate produces a white precipitate. It is strange to observe how two, clear fluids, on mixing, produce an opaque, solid mass as if by magic. This precipitate is not jelly-like, but is more likely to be powder-like. What has happened?

calcium chloride + sodium carbonate ⟶ calcium carbonate + sodium chloride

BA + B′A′ ⟶ BA′ + B′A

The precipitate could be either calcium carbonate or sodium chloride. Since sodium chloride is soluble, it has to be calcium carbonate. Because of the different combination of acids and bases, two new salts have been produced. The following rule can be deduced: If solutions of two salts are poured together, then a double displacement reaction will occur with the formation of a precipitate, if one of the possible products is an insoluble salt.

Now, which salts are soluble and which are not should be overviewed. In case the students haven't already got such an overview, a list of the most important insoluble salts can be handed out, and also for those acids and bases whose salts are always soluble. The students can then explain and even predict the phenomena.

How double displacement reactions are used as a method of identification of certain salts in solution can be pointed out. With sea water very nice experiments can be done.

The problem of hard water can also be discussed—why soap becomes flaky and why soda softens water.

Lastly, different salts can also be produced via the double displacement reaction, e.g. lead chromate (chrome-yellow), lead carbonate, mercuric chloride or potassium nitrate (as always, CAUTION with toxicity hazards).

Endnotes

[1] See Chapter 6 of this book: "Process of Solution - Phenomena, Concepts, Laws."

[2] In Dutch, "roest" and "roesten" (to rust) are used quite generally for corrosion changes in other metals, similar to when iron rusts.

[3] Special volume of ***Zur Paedagogik Rudolf Steiners,*** 1929, III, vol. 3/4.

[4] Steiner, R. ***Discussions with Teachers*** 1919 - 1924, Jan./Nov 1921,17/6, p41; GA 295, Chapter 3.

[5] See "Formula," Chapter IV.

[6] See Chap. VI, the "Concept of Concentration."

[7] See Chapter III, "Crystallization of salts."

[8] Steiner, R, ***First Scientific Lecture-course*** (Light-course); GA 320.

[9] See Chapter X.

10 This article is included in this Chemistry reader. (D. Rohde)

Anthroposophical Spiritual Science and Medical Therapy

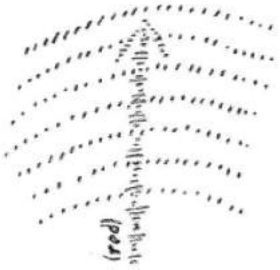
GA 313

Lecture VIII

Dornach, April 18, 1921

If we wish to understand the effects of the mineral element in the human being, however, we must look at the general effect of the mineral in the earth. It is necessary first to become acquainted with the significance of salts in the evolution of the earth. The significance of the salts in earthly evolution is that the earth actually produces them. In salt processes we find what the earth brings into being. In developing salts, the earth builds itself up. And when we turn from the salts to the acids — looking, for example, at the acid's element present in the watery earth regions, we have the earthly process corresponding to, though the polar opposite of, the inner digestive process in the human being, that is, the digestive process beyond the stomach.

We need to study all these processes taking place in earthly development, inasmuch as they represent a relation between acids and salts. When we consider the process that develops from bases through acids to salts, which can be observed outwardly today in chemistry, we see that, regarded in this way, the process leading from base to acid to salt coincides with the earth-forming process.



This process is essentially a negative electrical process. To put it more exactly: this process, expressed in its external, spatial aspect — i.e., as a process working its way out of the spiritual into the physical — can be represented schematically as follows. We have here an effect proceeding from the bases through the acids to the salts; it is indicated only in its direction here (**see drawing**, red arrows), but it is actually a process of deposition expressed schematically. Now, when we express this process in reverse, passing from the salts through acids to bases, we must always remove these lines of deposition. They would act in a compressing way, and the opposite radiations appear, which radiate out (**see drawing** on right, arrows). Then we have to do with a positive electrical process. If you look at this sketch, I believe you will hardly doubt that it has been drawn by nature herself. Just look once at the anodes and cathodes and you will find this picture sketched by nature herself.

Now, if we approach the metallic process, that is, if we approach the metals themselves, we find in the metals that element by which the earth "unbecomes" ("*ent-wird*") most, if I may use this expression, though it has long disappeared from the German language, despite the fact that it corresponds to reality: *werden* — *entwerden* — to become — to unbecome. With metals we find the tendency for the earth to disintegrate, to shatter in pieces, rather than the tendency to preserve or consolidate themselves in the earthly kingdom. They actually represent the "unbecoming" or passing away of the earth, and as a result they develop hidden radiating events, concealed even to external observation. You have this radiating effect everywhere. It is very important to observe this wherever we approach the metallic element with our interpretations of nature in an attempt to derive remedies.

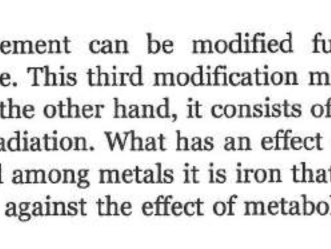
It is especially interesting to study individual metals from this viewpoint. Such a study leads us to the viewpoint represented outwardly by this table of the mineral remedies we consider valuable. To arrive at these things it is necessary to gather everything yielded by such a correct interpretation of observations. They will be reliable, because we have prepared only those remedies that have their basis in a comprehensive interpretation of observations. Here we can elaborate on this interpretation, for I am really not concerned with simply repeating this list to you. Any additions that have to be made can be given in a written exposition. At some point this will have to be done. I am less concerned with repeating this list than with guiding your thoughts in the direction that could lead to such a list in the first place.

Let us now study the metals — I would prefer to say: the metallic nature — from this viewpoint. There we find what I have just described as a radiation, and it is present in the most varied forms. It can exist in the emanating form of radiation, destroying the earthly and passing into cosmic space. This is especially the case with the lead-activity. Through this lead-activity the human being has implanted into his organism those forces that would like to disperse him into the world. This dispersing into the world is an aspect of lead-activity, so that we can best regard this effect as a radiating one. Such radiating effects appear in a different way in other metals, for example, magnesium. This can be seen clearly and is the basis for the role magnesium plays in the teeth. Through the human organism this must be brought to the point of a metallic activity. This actually happens, but the radiation must then be able to metamorphose itself again. And when this radiation has metamorphosed, it becomes what I would like to call simply “direction.” The radiation is now only “direction,” what happens, however, is an oscillation, a pendular movement to and from this direction.

We must study such effects in the healthy and sick person. In the healthy person, these radiating effects are present in the radiations of the sense organs, as remnants, you could say, of the life before birth, of prenatal existence. These are always present. What radiates from the sense organs consists basically of after-effects of lead, in which lead itself is no longer present. These radiations occur throughout the entire organism wherever there is sense activity. Nerve activity, that is, the functional activity going on in the nerves, has its basis essentially on a weakening of the sense activity in this direction. This activity is therefore based on a weaker radiation. You can see from this why I said in my book, ***Riddles of the Soul*** (*Von Seelenrätseln*), that it is difficult to describe the actual nerve-sense activity, because I would first have had to introduce everything I have now presented to you.

In this oscillatory process, this pendular movement, in which the radiation is only considered in regard to its direction, we have to do with what functionally underlies all breathing in the human organism, in fact all rhythmic activity. Rhythmic activity is based on setting up such pendular movements, on setting up a movement more consolidated in itself than the movement of radiations. Among the metals or metallic nature, tin, for example, has such a movement. The beneficial effect of tin in fairly high potencies on everything that bears upon the rhythmic system is based on this fact.

This radiating, pendular movement can be modified further, however, and this third modification is of great significance. This third modification maintains its direction and also its pendular motion only latently. On the other hand, it consists of spheres continually forming and dissolving in the direction of the radiation. What has an effect on the metabolism in the human being depends on these forces, and among metals it is iron that develops especially these forces. Hence the iron in the blood works against the effect of metabolism as a third metamorphosis of the radiating activity.

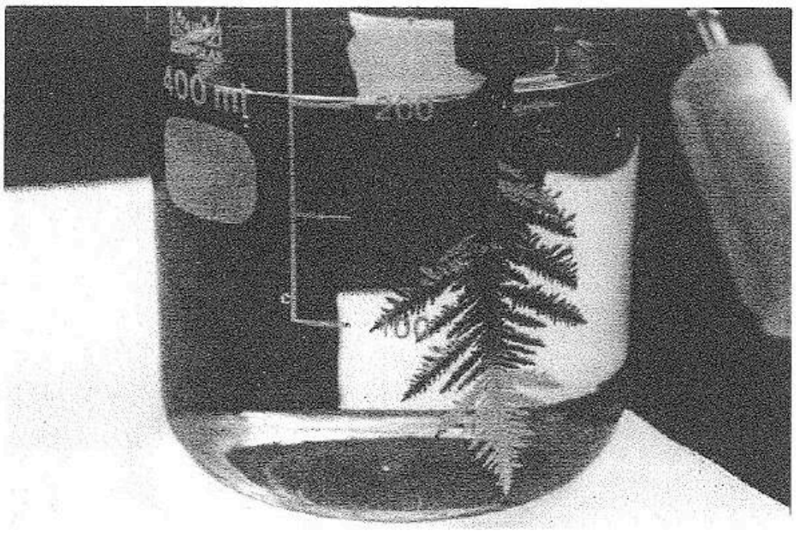


When we are dealing with the first metamorphosis, the effect is especially on everything that organically concerns the ego; when dealing with the second metamorphosis, the effect is organically on everything that concerns the astral body; and with regard to the third metamorphosis, the effect is organically on everything related to the etheric body **(see drawing)**.

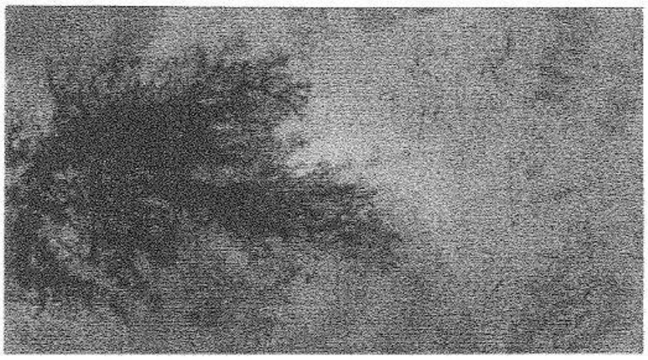
Günther Heuschkel
Excerpt from “Metallprozesse” [Metal Processes], 2002

Electrolysis of Metals

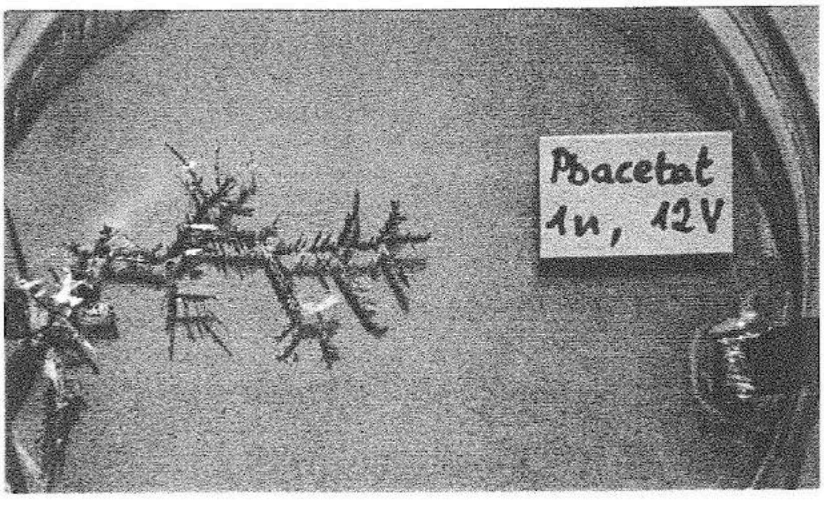
Lead



Lead “tree”



Lead “beard”



Electrolysis in the petri dish

Experiments in Electrolysis

Lead

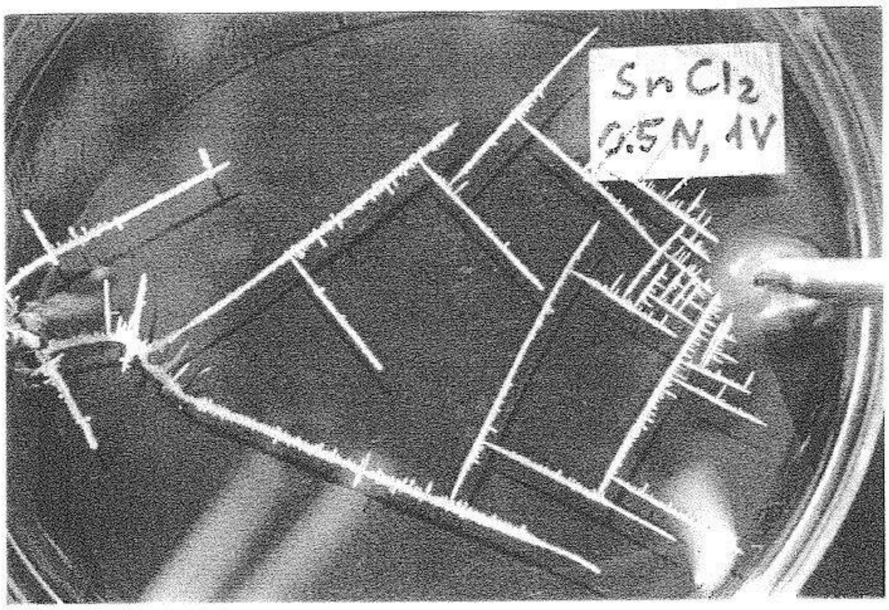
Lead "tree":

When a solution of lead acetate (1 N, for example) is electrolyzed, lead precipitates at the cathode in very characteristic "tree" shapes. At low voltages (e.g., 2 volts), lead "trees" appear: Enchanting little lead-gray metal platelets are arranged in multi-branched, fernlike formations that are shiny and glitter in the light. For this experiment, a 250 mA power supply is sufficient, and the reaction can take place in a small beaker.

At higher voltages such as 220 volts, metallic white "beards" rapidly develop in the direction of the current. These beards are reminiscent of the strands of moss that hang from trees in humid climates.

A dense lead beard develops slowly when a piece of filter paper is suspended from alligator clip in the lead acetate solution and a 12 volt current is passed through the solution. More rapid growth (still at 12 volts) can be obtained in a petri dish with its bottom covered with a 1 N solution of lead acetate. When the plane of crystallization is parallel to the bottom of the dish, the typical lead "tree" forms result. It may sometimes be necessary to help the process along by using a flat spatula to carefully press the crystals to the bottom.

Tin



Electrolytic deposition of tin

Electrolysis:

HCl is added slowly, drop by drop, to a freshly prepared 0.5 N solution of $SnCl_2$ until the solution is completely clear. (The acid must be added slowly because the solution becomes clear only gradually.) In the event that the solution does not become clear, it must be filtered.

10 ml of the solution is placed in a petri dish with a diameter of approximately 11 cm and then electrolyzed between zinc electrodes. Very shiny zinc crystals develop in straight lines with right-angled branching. They almost always lie all in a single plane and must grow parallel to the bottom of the dish if they are to develop properly. If the plane of crystallization is perpendicular to the bottom, the crystal does not branch but grows in tight zigzags between the glass surface and the surface of the liquid and may be either more or less straight or bent. Again, the crystals can be pressed to the bottom with a spatula to allow them to branch in a plane.

A 0.5 N solution at 1 volt yields rapid, variably branched, needle-like growth and forms very attractive shapes. Increasing the voltage to 2 volts can speed up growth. At higher concentrations, the crystals cover a larger surface area. Alkaline solutions yield only radial, two-dimensional formations, regardless of the voltage applied.

When 1 to 2 N solutions of zinc tetrachloride are used and higher voltages are applied, zinc precipitates are much slower to develop and are fine-textured and two-dimensional. At the same time, a white precipitate of stannic acid develops at the anode.

Iron

Electrolysis:

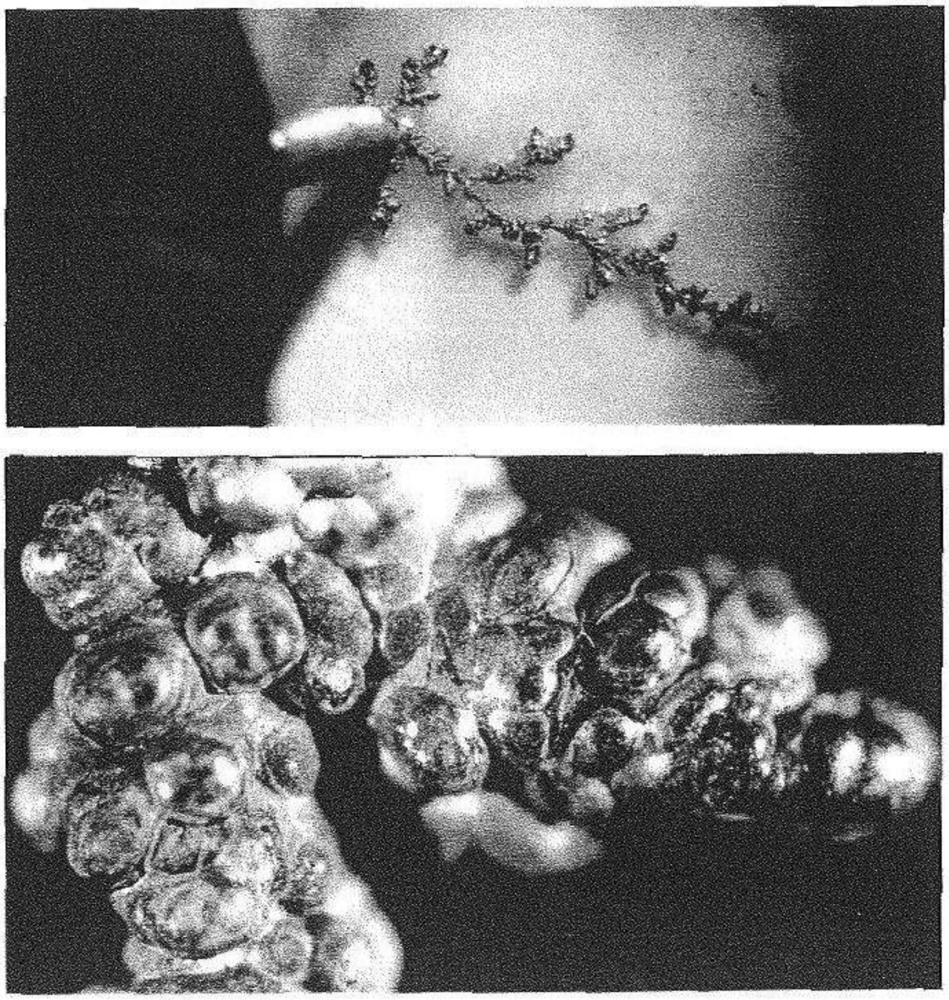
A 10 cm petri dish is first cleaned with commercial scouring powder and rinsed thoroughly. 10 ml of the electrolyte solution are poured into it, covering the bottom. The anode should be inserted flat and be fully submerged. It will need to be cleaned between uses because the anode sludge that develops on it may impede the flow of electricity. The cathode should be pointed, although the tip can be somewhat rounded; it should barely dip below the surface of the liquid.

A 6 N iron (II) solution is then produced (6g $FeCl_2 \cdot 4H_20$ in 10 ml of solution) and an applicator tip of powdered iron is added and stirred in. The solution is then filtered. The filtrate must be pure bottle-green and must be used immediately. During electrolysis, a corona of iron (III) chloride, initially yellow but then becoming brown, develops around the iron anode. A brownish ring also gradually develops around the cathode.

As a rule, electrolytically precipitated iron forms massive, tree-like aggregates rather than distinct crystals. Growth is accelerated at higher temperatures and at higher concentrations of divalent iron in the solution. In experiments conducted at room temperature and at 12 volts, deposition out of a 6 N solution of $FeCl^2$ begins slowly, accompanied by the development of hydrogen. Reducing the distance between electrodes to about 4 cm is recommended.

Under the microscope, we can see that the branches consist of little conjoined bowls or globules resembling kidney iron ore. The uppermost layer of bowls is often incompletely developed. Formations that are similar in structure but irregularly elongated or club-shaped may also occur, especially near the anode as growth accelerates. If the current is shut off and the iron remains damp, it quickly develops a brown oxide coating. If one of the globules can be broken open, the bowl-like structure of the massive iron can be seen under the microscope. Often the precipitate is light and interspersed with bubbles of gas.

Quick growth sometimes also results in metallic, iron-gray, plant-like crystals. These crystals tend to grow in a downward curve and eventually force themselves up out of the liquid, where they break off.



Electrolytic deposition of iron out of a 6 N solution of $FeCl_2$

Gerhard Ott

Chapter IV of
“Grundriss einer Chemie nach phänomenologischer Methode”
[Outline of a Phenomenological Approach to Chemistry], Vol. II, 1962

The Chemical Effects of Electricity

1. Preliminary notes on the subject and its instruction

We have already put electrical energy to use at two points in our chemical experiments, namely, in the oxidation of nitrogen and the reduction of phosphorus. In both of these instances, however, this energy did not work *directly,* in accordance with its essential nature, but only *indirectly,* through the production of extremely high heat in the form of an electric arc. It is certainly very interesting to note how simple it is, with electricity’s help, to produce extreme temperatures that allow substances to combine or separate in ways that are simply not possible at ordinary temperatures. In most cases, electrically induced combination or separation works contrary to the natural processes of the substances in question. For example, when nitrogen is oxidized, its extreme resistance to combining with oxygen is overcome and the combination is forced upon it, so to speak. Similarly, reduction of phosphorus wrests it out of its natural combination with calcium to expose it in its pure, elemental form.

We must also expect to see surprising transformations of substances (which would be very difficult or impossible to accomplish without electricity’s help) when electricity is actually applied to chemical processes in accordance with its true nature. In fact, the very first manifestations of electrical energy, discovered by Galvani and Volta, were intimately related to chemistry. The very fact that electrical energy was discovered in the context of chemical reactions spoke in favor of applying it to chemical substances. Moreover, the newly discovered force of electricity appeared as chemistry’s best possible helper just at the time when that field was reinventing itself, which seemed like a grand synergy in the realm of global discoveries and ideas. Galvani made his first discovery (the famous frog-legs experiment) in 1789. On the basis of this discovery by the physician from Bologna, Volta then constructed his first battery cell (1790) out of copper, zinc, and sulfuric acid. Shortly thereafter, from 1807 to 1820, the brilliant English chemist Davy used a strong battery of Volta’s cells when he made his significant discoveries of new chemical elements among the alkalis and alkaline earth metals, thus shedding light on a whole series of previously unexplained issues in chemistry. Davy’s work was facilitated by the French chemist *Proust’s* formulation of *the law of definite proportions* in chemical compounds (1799), which was soon followed (in 1802) by the discovery of the *law of multiple proportions* by the Englishman *Dalton*.

Thus when we consider the chemical phenomena related to these discoveries in greater detail in subsequent chapters, we will be retracing the development of chemistry itself. Completely new relationships will emerge, but we will also encounter familiar chemical changes that are now taking place under completely new and different circumstances.

In this chapter, however, our efforts must focus specifically on articulating the laws that emerge, fully honoring their purely phenomenological premises and refraining from imposing any preconceived notions on them. This is done here deliberately and in full knowledge of the usual conceptions such as ion theory and the like. My intent is to demonstrate the extent to which the phenomena themselves can be the teaching if it is simply presented in *a form of nature's own choosing*, so to speak. The task of self-cognizant thinking is not to come up with theories to explain phenomena but rather to *arrange phenomena in a way that allows the natural world to reveal its own laws clearly.* It is in this sense that we will proceed here.

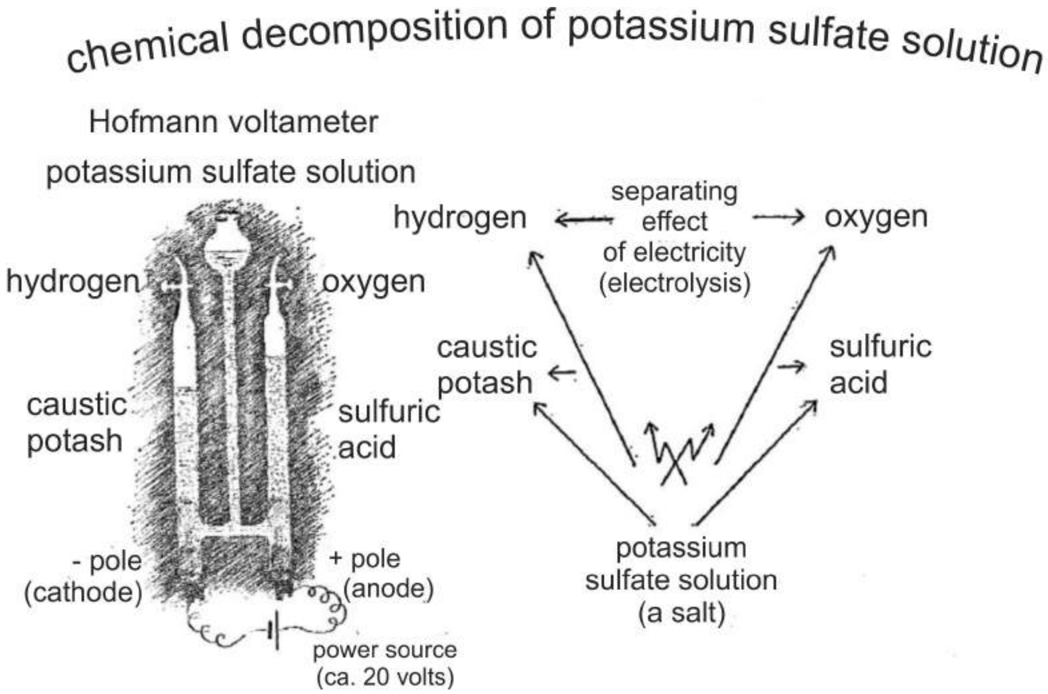
As to the pedagogical aspect of this chapter, suffice it to say that we are dealing with subject matter appropriate to grade 10 [and 11: D. Rohde]. This material offers excellent opportunities for new and interesting observations that will deepen and refine the students' understanding of fundamental concepts in chemistry: acids, bases, salts; sulfur and other chemical elements; oxidation and reduction. Upon completion of grade 10 [or 11: D. Rohde], the young people will have had experiences with chemical activity that can – and should! – serve them for the rest of their lives. They will also have learned about the history of the field of chemistry itself, which will help them to understand the purpose and significance of the time in which they live and to find their way in it – which is the basic purpose of any subject taught in school, of course. In particular, these "proposals for a living view of chemistry" are meant to serve this purpose.

Of course the suggestions presented in this chapter are merely suggestions, and it is not only absolutely possible but also desirable to add other phenomena. You may notice, however, that the basic laws have been articulated in ways that allow such additions from any direction.

2. Electrolysis of potassium sulfate: the basic processes in the electrolysis of a typical salt formed from a base (alkali) and an acid

Let us begin right away with an experiment that sets us down in the thick of the phenomena. Its sequence of events is so interesting that it will promptly catch the attention of this age group.

The apparatus, the so-called *Hofmann voltameter* (see illustration) consists of three joined glass tubes. The two side tubes are equipped with valves at the top and platinum electrodes at the bottom, while the open central tube is used for filling. We fill the tubes completely with a solution of potassium sulfate tinted with neutral litmus solution. Then we connect the electrodes to an ordinary 20-volt DC power source to create an electrical circuit in which the salt solution functions as a conductor.



We soon notice bubbles ascending from each electrode as gases develop. The bubbles developing at the positive electrode (anode) are significantly larger than those forming at the negative electrode (cathode). We can collect larger volumes of the ascending gases by closing the valves at the tops of the tubes. We soon also notice that the volume of gas that collects above the + pole (anode) is only half as great as the amount that collects above the - pole (cathode). Assuming that the valves close tightly, the ratio of volumes at the anode and cathode is always exactly 1:2.[1] We can confirm this at any time by checking the markings on the calibrated tubes. If we allow the process to continue for a longer period of time, the volume of gas in both tubes will increase steadily but always in the same 1:2 ratio. This experiment demonstrates how *nature itself* shows us that its processes are governed by strict numerical laws that we must then learn to understand.

It is of great educational importance to link discussions of numerical laws in the material world to sensory perceptions that elicit astonishment, as in this experiment. Only then will the students experience an *active desire* to learn to comprehend these laws. Teachers know that this active interest is an important prerequisite to learning about subjects that may otherwise seem dull.

At this point, however, there may be only enough time to notice and articulate this sense-perceptible fact, because this experiment will soon catch the students' attention with an even more striking

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[1] If the water is saturated with O_2, which can be accomplished by running the experiment with the valves open for a short time, if needed. (note by D. Rohde)

phenomenon: The uniform color of neutral litmus solution soon disappears from the two tubes.[2] Distinctly different tints gradually emerge: red in the liquid above the anode, blue above the cathode, while the salt solution in the central tube retains the original purple color of neutral litmus and can therefore serve as a comparison throughout the experiment.

If we repeat the experiment using fresh-pressed red cabbage juice to color the potassium sulfate solution, the color difference is even more striking: One tube turns a wonderful shade of *carmine red*, the other a brilliant *emerald green*, while the central tube retains the normal purplish color of fresh-pressed red cabbage juice. Because of the immediate impression of complementary colors, this experiment is especially visually striking for the students.

Both litmus and red cabbage juice, as we will demonstrate again later, always change color when combined with acids or bases of any kind. The pronounced reddening of the cabbage juice under the influence of acid is as informative with regard to the inherent laws of this organic material as is its shift to green (or, ultimately, yellowish).

This change in color, therefore, is an incontrovertible confirmation that the effect of electricity on the initially neutral salt solution is to “split” it or “break it down” into the polar opposites of an acid and a base, specifically, sulfuric acid and caustic potash.[3] That the entire process proceeds from the poles can be made even more obvious by inducing electrolysis in a U-shaped glass tube with electrodes inserted into the potassium sulfate solution *from above*, using the same potassium sulfate solution tinted with red cabbage juice. The changes in color (to red and green) then begin at the poles and work their way downward, while the original color is retained in the middle and lower portions of the U-shaped tube. This variation on the previous experiment is especially informative because the fact that the color change begins at the poles is a clear indication that the conversion to acid and base also proceeds from those locations. Of course the gases also develop in this version, and lateral glass tubes installed above the two electrodes allow them to escape.

So, what is happening here? Electrical energy is a natural force that is already inherently polar in its manifestation. When it works through the + and - poles, its effect is to reveal the *natural polarity inherent in any salt.* Through the action of electricity, the salt separates into actual acid and alkaline substances, which were already present as potentials. At the same time, the electricity undertakes a ´state of being´ switch by working in a fluid medium to transform the salt from the “sal”

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[2] This works better with litmus solution than with universal indicator, which can alter the 1:2 ratio. (note by D. Rohde)

[3] Only in concept; acid/base development is due entirely to the decomposition of *water*. Under these conditions, K^+ and SO_4^{2-} are not discharged (note by D. Rohde).

state into acid and alkaline substances, which we recognize as belonging to the middle, “mercurial” state.[4]

Formulated in this way, what we have accomplished here is nothing more than identifying the obvious facts of the case. These facts, however, prove to be of far-reaching significance. It is also not too soon to state this presumption: Whenever a natural force is capable of producing such strong chemical contrasts, it must also – as much as it originates in chemical processes – take chemical opposites as its starting point.

Our observation of the experiment would not be complete, however, if we neglected to confirm the nature of the two gases produced in the course of this same electrolytic process. When we open the valve located above the anode of the *Hofmann voltameter* and hold a glowing ember in the gas that escapes, the wood immediately begins to burn with a bright flame. This gas can only be oxygen. In contrast, if we open the valve located above the cathode and hold a burning match in the escaping gas, the gas ignites and burns off quietly. Here, the gas we are dealing with is hydrogen. (The flame gradually turns yellow, but that is due to the sodium content of the glass.) The development of hydrogen and oxygen – which are also polar substances – takes place at the same time as the separation into acid and base.

Now, however, the question arises, why do oxygen and hydrogen develop? Has the water in which the potassium salt was dissolved been “split” by the electric current?

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[4] Ott is assuming that the reader is familiar with the Tria Principia of Alchemy (note by P. Glasby).

Wolfgang Schad

Excerpt from:
“Chemie an Waldorf Schulen” [Chemistry in the Waldorf Schools]
Pädagogische Forschungsstelle 2004

Toward a Rational Chemistry

> “The man of intellect finds almost everything laughable,
> The man of reason, practically nothing.”
> Goethe, Maxims and Reflections

All too many of our contemporaries have come to view chemistry as the specter of crass materialism, environmental pollution, and a detached and antipathetic response to nature. Anyone buying a beverage in the supermarket wonders how many “chemicals” it contains: ascorbic acid, artificial colors, emulsifiers, “natural” flavors…. Not everyone is so skeptical, however. Youngsters in Waldorf middle school chemistry blocks taught by the class teacher are still enthusiastic about chemistry, but by the time they reach the upper school, where they encounter science and society in contemporary terms, chemistry usually becomes a curiosity at best. How many Waldorf graduates who absolutely loved their school years go on to study chemistry and become career chemists or enthusiastic chemistry teachers? Where are these people? Isn’t their nonexistence actually a *positive* reflection on Waldorf culture? The unspoken sentiment today is that chemistry, rather than being a life-enhancing profession, is downright ahrimanic! Or so we often think.

From the historical perspective, neither the extreme materialism of the natural sciences (including chemistry) nor their claim to the exclusive right to explain natural phenomena is inherent in the fields themselves. According to Rudolf Steiner’s analysis, this state of affairs dates back to 869 A.D., the year of the Council of Constantinople, which downplayed the human being’s spirit aspect and had consequences for all further cultural development in Europe. Ever since the sixteenth century, the representatives of “spirit” – namely, religious leaders – have turned their backs on all the grand and tempestuous discoveries of the emerging natural sciences. Both churches, stuck in the rigid vocabulary of their creeds, were unable to cope either with the increasingly explainable natural world or with the realization that the world is capable of transformation – and especially with the idea of evolution. Because God is omnipotent and good, he must have created a perfect world, so why should it have evolved from a state of presumed imperfection? That idea was simply unacceptable and could not be permitted to persist. Religious circles had no inkling of the living, active spirit that indwells all change and development. In today’s world, refusing to think in terms of metamorphosis and insisting on formally deriving evolution from either confessional or philosophical eternal types (God and the completed world of ideas, respectively) is an indication of distancing oneself from spirit. In 1870, the Vatican rescued itself by resorting to the dogma of papal infallibility – a tactic later reinforced by the beatification of the pope in question, Pius

IX, on September 3, 2000. In any case, the sciences were abandoned spiritually, and the effect, which rigid representatives failed to notice within their self-defined limitations, was to reinforce materialism. (*Steiner*, GA 93a:72; GA 293:150) As a result, scientists themselves often became inflexible and could more easily take the opposing position of denying spirit altogether. (*Steiner* 1917:217) The problem does not lie in the sciences themselves: "Science is full of benevolent spirit, although scientists are not always." (*Steiner*). We, however, should attempt to avoid falling into either of the camps with their reciprocally entrenched positions. On closer acquaintance, the know-it-all antagonists on both sides prove to share the same incapacity. All this in preface to our topic, the effort to bring *reason* into chemistry in addition to the intellectual understanding (or lack of understanding) with which we usually confront it.

All of the natural sciences share three basic perspectives. The *observational* approach fully embraces everything that can be discovered at present. In addition to identifying things as they are, however, we would all like to understand how they came to be, so we also take the *retrospective* approach, looking to the past for the original causes. Not content with that, either, we also want to be able to preemptively trace world trends into the future, so we take the *prospective* approach, asking how our discoveries might be applied in future. We demand predictability and replicability, although in doing so we run the risk of viewing the future only as an extension of the past. A case in point is our technological civilization, which applies the laws of causation as if they were finalities and then concludes that there is nothing more that can be done. All this makes it obvious that scientific understanding in this form has at least one advantage, namely, extending our temporal relationship to the world beyond preoccupation with the present moment, even if our view of time remains linear (that is, spatially conceived).

A fourth perspective, however, is a transcendent temporalization that takes a full view of the present and includes its antecedents and subsequent development in a comprehensive field of vision. This perspective achieves long-term sustainability, since there is nothing more practical than overcoming our temporal worm's eye view and replacing it with a temporally integrated bird's eye view, which will serve as a second starting point for the topic that we will now tackle in the narrower sense.

On the existential level, chemistry is deeply ingrained in our human existence. Its greatest accomplishments occur in the organ systems most removed from our consciousness: in protein synthesis, hormone synthesis and secretion, immunochemistry, muscle metabolism – and also in the highest form of bodily chemistry, the actual development of the embryonic body. Who among us knows anything about this chemistry of life as it unfolds, except from books?

Our experience of anything unconscious is holistic. In order to experience it consciously, we must extract it from the context of the whole and subject it to analysis. That is why the second approach to chemistry as a science has always focused on the "art of separation." Elemental analysis identified the chemical elements in both qualitative and quantitative terms. Soon the question became, what still remains to be done once enough separation has been accomplished? Once we confronted such an abundance of elements that we lost the overview, a counter-movement began. Which elements belonged together according to their chemical properties? Were they metals or non-metals, base-formers or acid-formers? Goethe was extremely interested in this question. In his color theory, he assigned the red and blue color poles to acids and bases, respectively. He also wrote to W. F. Wackenroder (1798-1854), hoping to elicit important information on the physiological chemistry of plant fluids in the sequence of leaf modifications in individual flowering plants (letter to Wackenroder, January 21, 1832).

In 1810, Goethe recruited Johann Wolfgang Döbereiner to the University of Jena where, at Goethe's request, he soon demonstrated the conversion of starch into sugar and the catalytic effect of platinum and explained the laws of stoichiometry. Goethe supported Döbereiner in whatever ways he could. "In years past I have met many an excellent young man in this way, but none who gave me more pleasure or, in my inmost conviction, offered me more hope" (letter to F. A. G. von Ende, April 28, 1812). When Goethe discovered celestine in Dornburg in 1817, he asked Döbereiner to analyze it. Döbereiner then proceeded to discover the first elemental triad (calcium, strontium, and barium), and his Law of Triads laid the foundation for the incremental development of the periodic table (*van Spronsen* 1969:1; *Krätz* 1992:207). Goethe would have been overjoyed if he had lived to experience the discovery of the *law of octaves* by J. A. R. Newland (1838 – 1889): in every eighth element the same chemical tonic note is repeated.

Both of Döbereiner's discoveries, the use of platinum as a catalyst and the elemental triads, would have unexpected consequences. The entire field of biochemistry is inconceivable without catalysts – substances that can cause chemical reactions without being affected themselves. The Law of Triads later culminated in the discovery of the periodic table of the elements: Order is indeed inherent in matter. According to Plato and Aristotle, philosophy begins with wonder, but Steiner recommends the reverse: "We must stimulate wonder whenever we get to the end of a lesson. We must make the students understand that even a Novalis would get down on bended knee in the face of such grandeur." (*Steiner,* GA 300/11: 42/43)

There are two sides to materialism. Its justified aspect draws our attention to the material world and researches it with all the means available to the sense-bound natural sciences. But with regard to its other aspect, its claim to universality (i.e., the claim that only matter exists), materialism is an ideology like any other that claims ownership of the absolute truth. Every anthroposophist is always ready – and justifiably so – to refute this second aspect, but we must always quote Rudolf Steiner himself on the first: "Can we say that the claims of the materialists are correct? Well, with regard to matter and its laws, they may be able to bring to light much that is extremely useful and valuable." (*Steiner,* GA 151, lecture of January 1, 1914; GA 237, lecture of August 4, 1924) For Steiner, materialism was one of *twelve* justified ways of viewing the world. It is always important to make a clear distinction between the ideological and methodological aspects of materialism. (*Schad* 2004)

The Main Groups of the Periodic Table

That last Steiner quote certainly applies to the periodic table, which is one of the most important and fruitful discoveries in the history of chemistry. Since the discovery of this organized arrangement, the field of chemistry would no longer be either meaningful or viable without it. Wherever predictability of the basic properties of elements is required, insight into the laws of the periodic table provides chemists with an abundance of initial answers. Which valences and transitions among the three main types of compounds are possible? Where does each element fall on the scale of alkalinity and acidity? What can we expect it to look like? Having achieved the first major view of periodicity in 1869, Mendeleev was soon able to predict many such properties. In many cases, the periodic table also allows us to estimate the time required for chemical reactions to take place. We are interested not only in acquiring knowledge for the sake of control, however, but also in a Goethean view of the qualitative aspects of this lawful arrangement.

For example, it is worthwhile to explore the periodic table with an eye to discovering which periods and groups include the elements most supportive of life. To the extent that life can be observed, it always consists in temporally active tensions between antagonists of different energy levels. Equilibrium is never finally achieved because it would result in death. The most obvious polarity or tension in chemistry is between alkalis and halogens, groups one and seven. Alkalis form strong bases, halogens highly reactive acids. Both are hostile to life at even moderate concentrations. Life requires moderate but never balanced conditions; strong bases and acids destroy it. Furthermore, the low molecular weight elements in the first few periods are quantitatively dominant in the chemistry of life. Life prefers lightweight elements over heavy ones. Beyond zinc (atomic number 30), very few elements are essential to life (see *Zeeck* 1997:16ff). In photosynthesis, life's central biochemical process, the preference for lighter elements goes so far that lighter $^{12}CO_2$ is selected over heavier $^{13}CO_2$ out of the natural mixture.

The fundamental characteristics of life processes explain make two phenomena: one, that the basic biochemical material of organic chemistry is supplied by *carbon*, the lightest representative of the middle (fourth) group, rather than by any element in the outer groups. Thus organic chemistry has been described as the chemistry of carbon compounds, even though water makes up a much higher proportion of every living cell, at least if the water in the hydration shells of hydrophilic carbon compounds is not counted as part of these organic compounds. Eugen Kolisko was the first to recognize carbon's position in the second period as an instance of the Goethean law of enhancement ["*Steigerung*"] between polarities, the two "drive wheels of nature."(Goethe, CW, Hamburg edition 13:48)

The next heavier element in the same group as carbon is silicon, an element often involved in physiological processes. It converts readily from soluble H_2Si0_3 to silica (opal, amorphous SiO_2) and thus easily moves from the soluble state in cell plasma to the solid state in silica structures. Just think of the silica "skeletons" of siliceous sponges, radiolaria, silicoflagellates, and (most especially) diatoms, or of the role silica plays in the support structures of all *Equisetum* species, the vascular bundles of bracken, the leaf edges and awns of grasses, the stinging hairs of nettles, etc.

Even more obvious is the scope of silicon's occurrence in the material processes of the Earth's crust, which consists largely of silicates, including all the intrusive igneous rocks (granite, gneiss, gabbro) and most extrusive igneous rocks, especially the products of subduction volcanism. *(Schmutz* 1986:12ff). In the Earth's crust (that is, to a depth of 16 km), silicon and oxygen, at 25.75 percent and 49.52 percent, respectively, are by far the most abundant elements, together comprising 75.27 percent. Comparatively speaking, silicon (always in oxidized form) is the "carbon" in the structure and metabolism of the accessible portion of our planet. Even ancient intrusive igneous rocks contain an average of three percent carbon in the form of graphite. (*Pflug* 1984:127) This means that there is more carbon in the Earth's crust than in the entire biosphere with all its organisms. In contrast, biogenic silicon dioxide is present in all organisms but in smaller quantities than carbon. As closely related as these two elements are, they are represented in inverse proportions in individual organisms and the body of the Earth itself.

With increasing atomic weight, alkalinity increases in group 1 elements while acidity decreases in group 7. As a result, the greatest contrast in this respect is between francium and chlorine (hydrofluoric acid remains too associated). All of the other main group elements form a cascade of transitional forms. The resulting arrangement makes it clear that shared similarities exist not only among elements of the same group or period but also among those located on diagonals running from upper left to lower right. Since these diagonal connections make a Goethean “archetypal phenomenon” visible, it is time to do away with any remaining barriers to understanding them.

One of the main criticisms of a Goethean approach to the chemical elements is that in most instances we are dealing with elements in their humanly or technologically altered states, not with given facts of nature. Under natural conditions, only a few elements occur in elemental form – carbon, nitrogen, oxygen, sulfur, copper, and mercury; all of the precious metals such as gold, platinum, silver, etc.; and the inert gases. This list is very short indeed in comparison to the majority of the 92 natural elements! At this point we will not consider how seriously Rudolf Steiner took the concept of individual elements in agriculture and medicine, in issues of fertility and medication, but will refer only to Goethean methodology:

“Let each of us take this opportunity to say that separating and combining are two inseparable acts of life, […] and the more actively these functions of spirit (such as inhaling and exhaling) interact, the better it is for the sciences and the friends of science.” (Goethe, CW, Hamburg Edition 13:233)

Goethe, the greatest biophilic synthesizer, has frequently but quite unjustifiably been seen as opposing the analytical approach. In practice and as a matter of conviction, however, Goethe never pitted synthesis against analysis but made use of both in alternation. In fact, most of his zoological studies were based on osteology, not on observing living animals. The skeleton, however, is a secondary or reductionist phenomenon and is often available only as a consequence of human intervention; it must first be extracted from the larger context before it can be reinstated. For Goethe, synthesis and analysis belonged together like inhaling and exhaling, “because throughout my life, whether in writing or in observation, I had engaged in synthesis and then in analysis. For me, this systole and diastole of the human spirit were like a second form of respiration, never separated and always pulsing.” (CW, Hamburg Edition, 13: 27) We should therefore refrain from further fruitless polarization and instead ensure that both synthesis and analysis always occur. Coming to agreement on this point should not be difficult; the fruitlessness of one-sided approaches should be sufficient warning. On its own, analysis leads only to data graveyards and synthesis to overviews with no sense of the facts. Our upper school students are vehemently allergic to both of these approaches and often offer the best possible reality check for teachers who apply Goethean methodology.

Now let’s look at the elements as they manifest under normal circumstances, first concentrating on group 1 and paying attention only to their relationship to light. A large number of metals are concentrated in the lower left of the periodic table. They appear in the form of free elements and are reflective and shiny, which means that most of the light falling on them is bounced back largely unchanged while they themselves remain dark within. Non-metals dominate the opposite pole at the upper right. Primarily gases, they are often transparent and colorless; light passes through them almost without resistance. If we look at the second period (lithium to fluoride), we note a progressive decrease in the elements' metallic sheen, beginning with beryllium and continuing through boron to the totally dull black of carbon. Carbon, however, is subject to modifications that reveal visible differences: it is blackest as amorphous soot, while the more mineralized graphite is blackish gray or even shiny. The recently discovered C_{60} fullerene appears reddish violet when dissolved in toluene, and pure diamonds are completely colorless and transparent. Carbon's neighbors nitrogen and oxygen are colorless gases, as are all of the inert gases. At room temperature, fluorine is an almost colorless, pale yellow-green gas.

In the second period, the metallic sheen persists from sodium through magnesium and aluminum to silicon, although the latter's chemical properties are largely non-metallic. Phosphorus (diagonally related to carbon) can be as black as carbon, but in its red and white forms it also establishes the transition to colorful elements such as yellow sulfur and chlorine.

In periods 3 through 7, the elements that are dull black in color are increasingly located farther to the right: Arsenic appears in red and yellow modifications, selenium in black, dark red, and red. In particular, the elements in the halogen series achieve increasing depth of color, until iodine ("violet" as a gas) becomes black and shining. Astatine is a radioactive element with such a short half-life that its color remains unknown, but it is expected to be dark and metallic. Between the solid metals and the lightest gaseous non-metals of the main groups – that is, between complete opacity and complete transparency – lies a shimmering "seam" of color. These transition elements absorb light superficially and disperse it transformed. In other words, their relationship to light is characterized by enhanced activity. As we have already seen, pure carbon can assume all three color attributes – black, colorful, and colorless/transparent – and in this context, too, it also represents the integrating middle. In the table below, the colorful elements of the main-group periods appear in ***bold italics*** for emphasis:

H	-	-	-	-	-	-	He
Li	Be	B	***C***	N	O	F	Ne
Na	Mg	Al	Si	***P***	***S***	***Cl***	Ar
K	Ca	Ga	Ge	***As***	***Se***	***Br***	Kr
Rb	Sr	In	Sn	Sb	Te	***I***	Xe
Cs	Ba	Ti	Pb	Bi	Po	At	Rn
Fr	Ra						

Light and darkness interact not only in shades of gray but also in colors that break out between them. The colorful seam in the periodic table, like countless natural phenomena, reveals this fact to a Goethean view.

Fluorescent Substances

The Spanish physician Niccolo Monardes was probably the first (in 1570) to describe a fluorescent fluid, presumably an organic solution. In 1602, Vincenzo Casciarolo, a cobbler from Bologna with an interested in alchemy, discovered that heavy spar ($BaSO_4$), after being heated with flour (a carbon source!) and exposed to light, continues to shine in the dark. (*Schulz* 1975) Since then, we have learned to distinguish between luminescence due to various energy inputs – such as photoluminescence, thermoluminescence, electroluminescence, crystalloluminescence (e.g., during crystallization of $AsCl_3$), and triboluminescence (generation of light through mechanical rubbing) – and the *bioluminescence* of lightning bugs, the mycelium of *Armillaria* fungi, luminescent bacteria, etc. (Cf. *Gehlig* 1995) Luminescence following exposure to light is traditionally called "phosphorescence." However, white phosphorus (discovered by Henning Brand in 1669) glows in the dark as a result of oxidation upon exposure to air and is therefore actually "chemoluminescent," not "phosphorescent," in spite of its name (phosphorus = "light-bearer").

The aurora borealis (luminescence of upper atmospheric layers) is one example of natural luminescence. Luminescence, therefore, can occur in gases, liquids, or solids. For example, green chlorophyll glows red when backlit, even in normal dispersed light. Ever since Stokes described the phenomenon in 1852, all such examples of photoluminescence have also been called "fluorescence." (The name comes from fluorite, CaF_2.) Many fluorites that appear violet when light falls on them shine greenish when backlit, and fluorites exposed to "black" (UV) light are even more impressive, often fluorescing in intense blue. (Very inexpensive little UV bulbs are readily available online.)

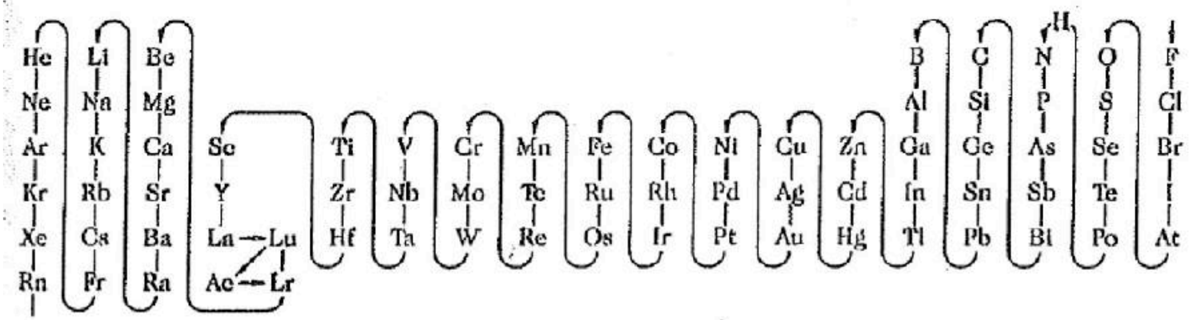
We will limit ourselves here to mineral fluorescence, which is extremely interesting in relationship to our topic. *Gleason* (1960) listed over 210 fluorescent minerals, 31 of which are also phosphorescent. The most important ones are fluorite, calcite, apatite, rock salt, sphalerite, willemite, scheelite, wollastonite, zircon, ruby, diamond, and autunite.

In most cases, the colors of mineral fluorescence are not at all characteristic of the primary mineral but only of finely dispersed mixtures. Zinc sulfide heated with trace amounts of copper fluoresces yellow-green, with the optimum ratio of Cu to ZnS being 1:10,000. (*Winkler* 1955) The color is entirely due to gaps in the crystalline structure and the addition of metal ions. An important difference emerges here between the elements of the main and sub-groups of the periodic table, which is why we are including this whole topic.

Most of the crystal-forming compounds of main group elements are colorless/transparent. Think of rock salt (NaCl), fluorite (CaF_2), calcite ($CaCO_3$), gypsum ($CaSO_4$), apatite ($Ca_3(PO_4)_2$), barite ($BaSO_4$), potash alum ($KAl(S0_4)_2$), quartz (SiO_2), corundum (Al_2O^3), or even pure diamond (C). Even cerussite ($PbCO_3$) can form clear, colorless crystals. These are consistently compounds of elements from the metal side of the periodic table with main-group non-metals. None of them are fluorescent in their purest forms, which allow light to pass through unhindered. Conversely, most sub-group compounds have strong colors of their own; the more idiochromatic they are, the less likely they are to fluoresce. Exceptions are the colorless compounds of zinc, cadmium, mercury, and zircon. Iron oxide and manganese oxides, even in trace amounts, extinguish fluorescence; iron is the most "earthy" of solid elements, and manganese is its closest relative in the periodic system. But when the other colorless main-group crystals are interspersed with homeopathic traces of sub-group metal ions, fluorescence generally appears under UV light in all colors of the rainbow, depending on the element and its valence. (*Lieber* 1957)

This is why ruby (corundum tinted red with traces of chromium) fluoresces even in visible light and the red color intensifies under UV light. In contrast, sapphire (corundum tinted blue with traces of iron) does not fluoresce at all due to the fluorescence-suppressing effects of iron. In fluorites, deep blue fluorescence under UV light is often due to trace amounts of rare earth elements, and in calcite, divalent manganese is often the “activator” of red fluorescence while europium – presumably along with other rare earth elements – is again responsible for blue fluorescence. (*Robbins* 1983) The most important activators are chromium, manganese, copper, silver, yttrium, many of the rare earth elements, and uranium. Uranium fluoresces under UV light even in the moderate concentrations found in ores, but only in the form of the 6-valent uranyl ion $(UO_2)^{2+}$. Calcium tungstate (scheelite, $CaWO_4$) and calcium molybdate (powellite, $CaMoO_4$) fluoresce even in their purest, uncontaminated forms. Here, main and sub-group elements come together in what appear to be especially quantitatively suitable combinations in which the sub-group elements tungsten and molybdenum, unlike typical metals, function not as cations but as quasi non-metals, forming acid radicals in combination with large amounts of oxygen.

Although there are exceptions, the general rule with regard to fluorescent minerals is that the basic mineral consists of main group elements while the trace amounts of activators are metals from the sub-groups of the periodic table, especially from the sub-groups within the sub-groups (rare earth elements). Here we encounter a concrete expression of an archetypal phenomenon: It is well-known that many sub-group compounds are highly colorful under normal light and fluoresce under UV light. This enhanced middle section of the periodic table is not merely a “colored seam,” as Goethe put it, but a wide colored band inserted between the contrasting poles of the metals and non-metals of the main-group periods, although it leans more toward the metal side, since all of these elements are metals. The following arrangement of the periodic table (from *Lexicon der Chemie*) makes it easy to visualize the situation:



Within the entire cosmos of elements, the polarity in the main groups is richly enhanced in the subgroups, where most of the fluorescent minerals are found and provide the most esthetically beautiful impression.

The Iron Group

The subgroups deviate substantially from the general rule that applies to the main groups (see above). They are inserted between the second and third main groups and only from the fourth period on down, so without exception they are all metals. Because the chemical similarities among the sub-group elements in each period are greater than those among main group elements, the “horizontal relationship” plays a greater role here than either vertical or diagonal connections. For all of their similarities, however, the subtle differences among these elements are impressive. The first subgroup merits special emphasis because it consists primarily of trace elements essential to life. We will disregard the first two (Sc, Ti) and the last (Zn) and look at the elements of the central group (vanadium, chromium, manganese, iron, cobalt, nickel, and copper) from the perspective of comparative morphology. In this context, it makes sense to consider not only these elements' metallic properties but also the colors they impart to their water-soluble salt compounds. Divalent iron, for example, yields a delicate, restrained green, whereas trivalent iron appears in shades of yellow, orange, red, and brown. Lower valency (ferrous) iron therefore tends toward passive colors, higher valency (ferric) iron toward the active colors of the spectrum. The former trait is intensified in the deep blue color that predominates in compounds of divalent cobalt, which turn a delicate pink only when chemically combined with water. The salt of divalent nickel is grass-green in combination with water but blue in combination with ammonia. Its neighbor, copper, is deep blue in many such complexes (such as azurite, its carbonate mineral) but depending on the water content, it may also be a saturated dark green (malachite). Its ammonia complex is a deep, dark blue. In addition to its common Fe (II) and Fe (III) compounds, iron can be chemically "forced" into a 6-valent oxidation state, yielding the red-violet ferrates. Such high valences are much more the natural, normal state of affairs in iron's lighter sisters. Manganese can easily be made to run the gamut of valences two through seven, manifesting in almost all the colors of the spectrum depending on the valences, complexes, and particle size (*Mohr* 1954: 202f.) Its most stable compounds tend toward the red end of the spectrum and include the naturally occurring manganese minerals rhodochrosite (manganese carbonate) and thulite (a manganese-bearing ziosite) and the well-known potassium permanganate, which is a deep red-violet. Although the colors of manganese compounds are very varied, they are all subdued, as is also the case with iron.

In contrast, chromium salts are strikingly colored, as the name of the element (from the Greek *chroma* = color) suggests. Again, this is especially true of higher-valency compounds, i.e., the 6-valent chromates and dichromates. Even trivalent chromium gives a violet color to chrome alum. When shaken in ether, trivalent chromium peroxide turns a brilliant blue. Most of the rainbow beauty of tourmaline is due to a range of chromium valences. Chromium is close to vanadium, which also tends to form higher-valence vanadates and is especially stable in the form of vanadium pentoxide, V_2O_5. The predominate colors of vanadium ores are yellows through reds, but salts created in the laboratory range through all the other colors as well. (*Mohr* 1954:193f.)

When all of its ions and complexes are spread out in front of an eleventh grade class, the color wheel of iron's seven relatives is an esthetic prize. It reveals the great wealth of nuanced color inherent in these otherwise completely colorless-looking pure metals (copper and gold are exceptions). In addition, in spite of the great diversity of color, each of the seven strikes an individual note of color saturation that is very characteristic yet difficult to describe in qualitative terms. How subdued the colors of most iron compounds are, and how gaudy most chromium compounds! Here the individualities of the metals are revealed.

We must not neglect the metallic properties of these elements. In appearance, they range from the dull steel-gray of pure vanadium to the warm, dark red of copper. The characteristic polarity in this sequence is evident in their alloys with iron. Steel that contains vanadium, chromium, or manganese is especially hard but tends to be brittle; it is good for making chisels and drill bits. In contrast, cobalt, nickel, and copper alloys of iron are distinctly elastic and make good ball bearings. At this point, it becomes possible to adequately incorporate the chemical properties of these metals into our summary of their sense-perceptible characteristics:

	V Cr	Mn Fe Co Ni	Cu	
gray	←	bright and shiny	→	reddish
hard	←	iron alloys	→	elastic
reds, yellows	←	colors of compounds: salts and complexes	→	greens, blues
high	←	valence	→	low
brittle	←	iron alloys	→	elastic

The role these metals play in biochemistry are also very informative. All of them function as biocatalysts. The essential vitamin B_{12} contains cobalt. Vanadium, iron, and copper play especially important roles in respiratory complex pigments. Iron (only divalent, in this case!) is of central importance in the heme of hemoglobin, the red pigment in blood, and even heme's precursor, iron-free protoporphyrin, is already red. Copper is the corresponding respiratory metal in hemocyanin, which carries oxygen in the blood of most mollusks (snails, mussels, squids). Copper (II) ions tint this blood blue when it is oxidized; it is colorless when reduced. Vanadium is concentrated in the blood of sea cucumbers, which are holothurian species related to sea urchins and starfish; like them (and also the tunicates), holothurians have parts arranged around a central axis in five equal sectors. At this point in the discussion, it is instructive to compare a holothurian, a vertebrate, and a snail.

As we have just seen, iron's central position is fully expressed only in comparison to its sister elements. Iron occupies the middle between extremes and occurs almost everywhere. This central position is reinforced when we look at the entire periodic table in terms of the invariability of the elements. In modern times, all the paradigms of invariability that have come down to us from antiquity are becoming dynamic: As early as 1440, Nicholas of Cusa realized that the Earth does not stand still but rotates and revolves around the Sun. Based on measurements made by Tycho de Brahe, Johannes Kepler concluded that planets, instead of moving at fixed speeds along circular orbits, revolve on ellipses and at variable speeds. As early as 1698, Leibnitz postulated the variability of species. The astronomers Edmond Halley (1718) and Johann Tobias Mayer (1760) then discovered even fixed stars can move and their relationships to each other are not fixed. Similarly, the discovery of radioactivity by Henri Bequerel in 1896 soon put an end to the notion of invariable elements. And as early as 1912, Alfred Wegener was talking about continental drift.

The heaviest elements (with molecular weights greater than that of lead) do not have fully stable isotopes.[1] Through nuclear disintegration, they are transformed either slowly or rapidly into lighter elements, one of which is often an inert gas. This

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[1] For many years, bismuth was considered the heaviest stable element, but according to the most recent investigations, it is metastable, with a half-life of 2 x 10^{19} years (Nature 422: 876-878, April 24, 2003).

is also true even of the lighter radioactive elements technetium and promethium. In contrast, the lightest elements can be transformed into more stable elements through nuclear fusion. Whether through fission or fusion, nuclear energy is released at both ends of the periodic table and the resulting persistent elements are more stable than their source elements. The energy potentials of elements decrease toward the center of the periodic table. In this sense, iron has proven to be the most stable element and is therefore the central element of the entire periodic table in terms of nuclear energy.

The Arrangement of the Periodic Table

It was once hoped that chemistry, as the “art of separation,” would be able to gain a better overview off the immeasurable abundance of substances by tracing all of them back to only a few chemical elements. To date, however, an unexpected wealth of elements (currently 109) have been identified, and the next step – describing them as comprised of three basic types of subatomic particles (protons, neutrons, and electrons) – has also been unable to avoid a plethora of new discoveries. For this reason, our students experience the inherent mathematical order of the periodic table as a major triumph of knowledge. We count the number of elements in each of the seven periods:

I	2
II	8
III	8
IV	18
V	18
VI	32
VII	19 + x

The second and third periods turn out to be the same size, as do the fourth and fifth. We can imagine the seventh period being completed, making another pair of equals together with the sixth. The resulting number sequence would then be 2/8/8/18/18/32/32. Even by itself, this sequence satisfies our need for order, symmetry, and periodicity, and the satisfaction is enhanced when we demonstrate the common formula shared by these numbers, namely, $2 \text{ x } n^2$ where n = 1, 2, 3, 4:

$$\left.\begin{array}{rcl} 2 &=& 2 \text{ x } 1^2 \\ 8 &=& 2 \text{ x } 2^2 \\ 18 &=& 2 \text{ x } 3^2 \\ 32 &=& 2 \text{ x } 4^2 \end{array}\right\} \quad 2 \text{ x } n^2 \quad (n = 1,2,3,4)$$

Matter, therefore, is not mere chaos. It possesses an inherent structure that can be formulated in mathematical terms – a fact that leaves students astonished and impressed with the esthetics of the idea.

It is worthwhile to allow this discovery to go through the night and then to approach it from a different perspective the next morning. Although the structure of the number series 2 x n^2 is unambiguous, the reality does not quite live up to it: The last period breaks off naturally at element 92 (uranium) and artificially (at least as of this writing) at 109 (meitnerium). Nine elements are missing, and the period would need to end with an inert gas (atomic number 118). These elements, however, remain unknown because all elements heavier than lead are radioactive and therefore constantly disintegrating into lighter elements

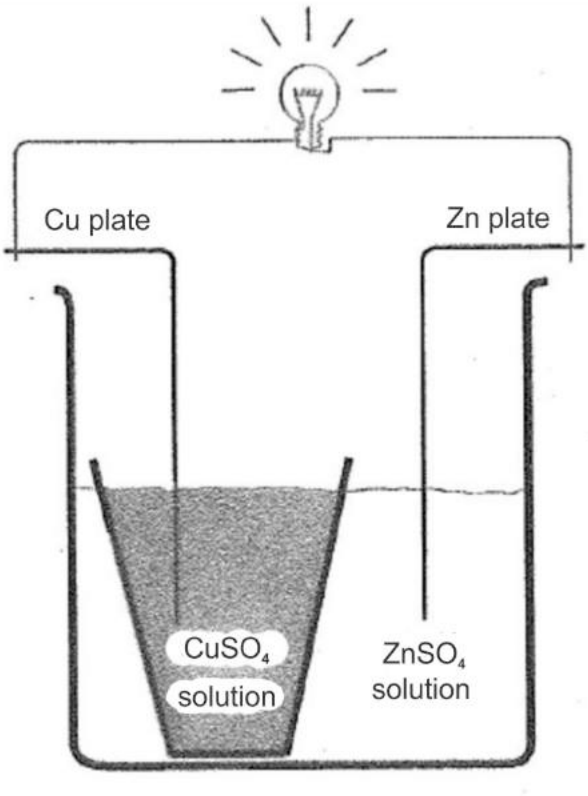
Moreover, the periodic table is also incomplete at the beginning, not just at the end. Just as there are two periods each for n = 2, 3, and 4, symmetry would actually require two periods for n = 1. In spite of its pervasive regularity, therefore, the periodic table is not complete. The material world simply is not complete, perfect, and self-contained. Whenever I have presented this problem to a grade 10 or 11 class, the students have always arrived spontaneously at a significant conclusion: Since the world of matter is not complete, it must be still evolving. A developing plant discards its cotyledons before its last shoots emerge, and something similar is true of the material universe. Realizing that even matter is not “finished” gives seventeen-year-olds verifiable knowledge that they can then use to free themselves from the dogma of material determinism.

The mere conceivability of a *dynamic* physical and chemical image of the world is valuable in itself. At the end of the block, when I ask the class what meant the most to them, they often respond – irrespective of their scientific talents as individuals – that the most important activity for them was the discussion of the open-endedness of the periodic table. It resonates with them because they are at the age when adolescent consciousness begins to experiment with developing a personal world-view.

As early as the 1950s, the anthroposophical physicist-mathematicians Arnold Blickle and Ernst Bindel (*Bindel & Blickle* 1952) tackled the truncated evolution of the periodic system. In their article, still eminently worth reading for its expertise, they relate the four stages in the numbers of elements per period (2/8/18/32) to the four elapsed stages of the Earth’s evolution (out of a total of seven). In 1913, Rudolf Steiner described these four stages as four embodiments of the planetary cosmos. Consequently, there are also four kingdoms of nature, four Greek elements, and four members of the human constitution. Blickle and Bindel, however, interpreted the temporal context of the periodic table in terms of Proust’s theory – in other words, they viewed hydrogen as the oldest element and thus as the basis of all others. This view is similar to that of modern cosmogony, which calculates that 99 percent of all matter in the universe exists in the form of hydrogen. However, if we view the modern astrophysical cosmos as the latest in a series of four embodiments, our interpretation becomes much more dynamic: For example, periods 7 and 8 are then the last disintegrating remnants of the earliest, most ancient epoch (“Old Saturn”), when these elements were still in a nascent state and therefore very light. Correspondingly, in our own epoch of Earth’s evolution, hydrogen and helium are the nascent Sun elements that provide the planetary cosmos with energy for life. In between these extremes lie substances at various stages of evolution that represent the intervening epochal stages. This view is a meaningful starting point for deepening the study of chemistry.

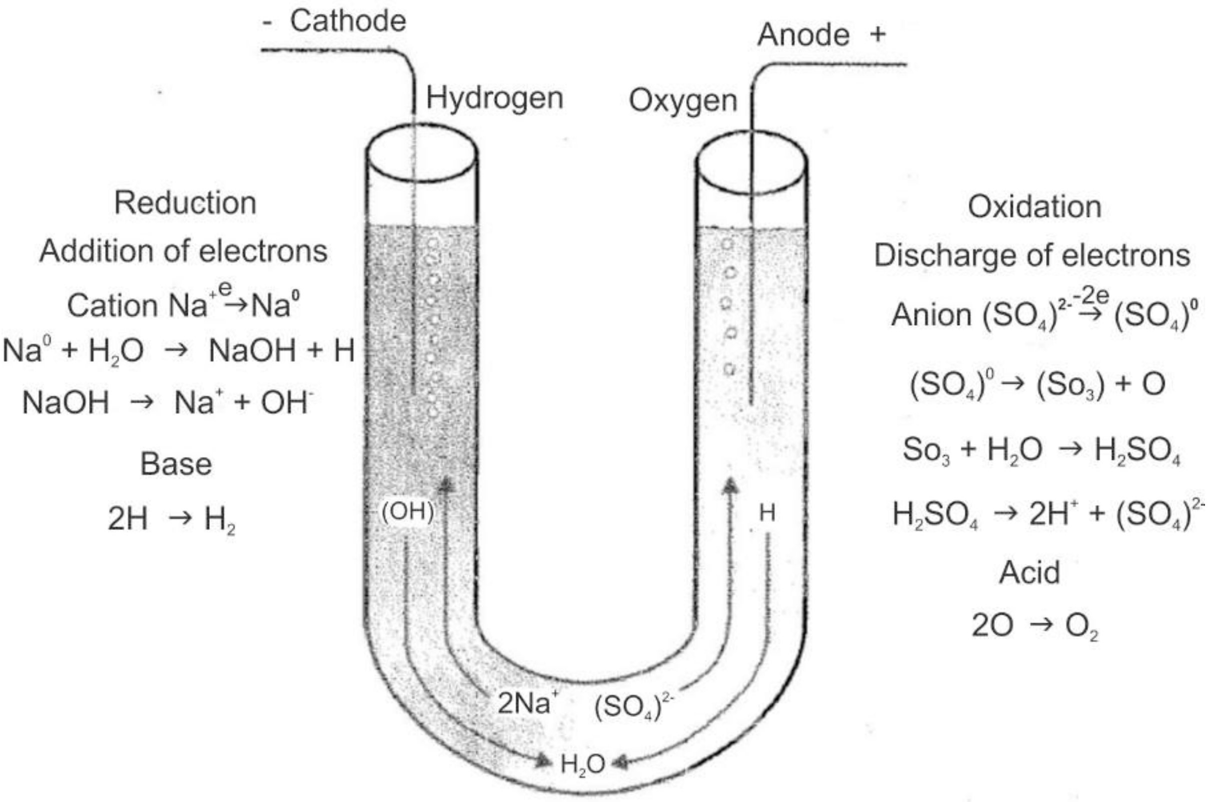
Electrochemistry and the Theory of Chemical Bonding

Apart from discussing its technological applications (electric batteries, electrolysis, galvanization), electrochemistry is important for the empirical development of the theory of chemical bonding. At this point, it is best to avoid a formal theoretical introduction, beginning instead by presenting experiments that demonstrate the archetypal phenomena. Here are two such experiments:



In the first experiment, we illustrate the possibility of deriving electricity directly from certain substances by constructing a *Daniell cell*. The light bulb lights up when an unglazed earthenware flower pot with a closed bottom is used as the inner container. We fill that container with a copper sulfate solution and the larger beaker with zinc sulfate solution and then insert a thin plate of the corresponding metal into each solution. With time, the copper plate becomes heavier and the zinc plate lighter, as we can confirm by weighing them. This means that zinc goes into solution as electricity is given off while metallic copper precipitates as electricity is taken up. The wandering charge carriers (dissolved zinc, copper, and sulfate) travel through the solutions in the form of *ions* (from the Greek *ión,* “going”). Sulfate ions must be passing through the semi-permeable membrane of the earthenware pot, since otherwise a surplus of sulfate would develop inside the pot and a shortage outside. We can see that this movement completes the circuit. As we view and think about this experiment, the basic concepts of ionic chemistry develop seamlessly.

The second, more phenomenologically comprehensive experiment is the inverse of the first: This time, electricity is actively added from outside. A solution of sodium sulfate plus a universal indicator is electrolyzed in a U-shaped tube with platinum electrodes (iron florist wire also works for a short time).



This experiment links to many basic concepts in chemistry, and the archetypal phenomenon of the color shift from blue to red through the full range of transitional hues makes an unforgettable esthetic impression. The universal indicator, of course, is an artificial mixture of various organic pigments selected to reveal as many pH levels as possible. Certain other pH indicators (Congo red, phenolphthalein, etc.) do not reveal the transition from base to acid by shifting from blue to red. Nonetheless, Goethe's vision in the chapter on chemical colors in his Theory of Colors is justifiable on the qualitative level: *"Yellow and orange are dedicated to the acids, blue and purple to the alkalis."* In particular, color shifts in the anthocyanins of many flowering plants conform to the qualitative experience of the contrast between blue and red. For example, many flowers in the Boraginaceae family (such as lungworts, forget-me-nots, and the gromwell *Lithospermum purpureo-coeruleum*) are pink in the bud stage, when the cell sap is acidic, but brilliant blue at full bloom, when it is alkaline.

In this second experiment, these polarities and their enhancements – i.e., ion formation at the poles, separated by neutral water – are made visible.[2] Electric current can be produced from chemicals, as in the first experiment, and this second experiment demonstrates that the opposite is also true: Electric current can cause chemical changes.

Goethe followed the early beginnings of electrochemistry with great interest. Reporting to Heinrich von Treba about Döbereiner on April 7, 1812, he writes: "Through the progress of galvanism, experience has become theory, and so everything is proceeding on a clear and secure course." And to Döbereiner himself,

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[2] These reactions take place in this way only in concept. Acid and base development is based entirely on the decomposition of water; Na^{+} and SO_4^{2-} are not discharged under these conditions. (D. Rohde)

on December 26, 1812: “As long as we never abandon the magnificent conceptual guidelines of electrochemistry, the rest will also not elude us.”

Analytical chemistry has always been concerned with the nature of the chemical forces that unite elements into compounds. The clearest approach is derived from the periodic table, as in the example below, which shows the series of compounds formed from the elements in period 3 (from *Holleman & Wiberg* 1955).

ionic bonding **covalent bonding**
(heteropolar) **(homopolar)**

$NaCl$ MgC_{l2} $AlCl_3$ $SiCl_4$ PCl_3 SCl_2 $ClCl$
Na_2S SS
Na_3P PP
Na_xSi $SiSi$
Na_xAl $AlAl$
Na_xMg $MgMg$
$NaNa$

metallic bonding

This chart reveals the three main types of bonds and makes us aware of all the transitional types. Clearly, pure heteropolar, pure homopolar, and pure metallic bonding occur only in the extreme cases. Intermediate states are the norm. The following sequence of compounds also illustrates the transition from ionic to covalent bonding:

LiF BeO BN CC

If we look at the chemical properties and activity of lithium fluoride, beryllium oxide, boron nitride, and carbon, we see a progressive decrease in the compounds’ salt-like character and an increase in polymeric capacity. At one pole, *dissociation* processes occur readily in water, generating electrical activity; at the other, *association* tends to occur, resulting in electrically neutral substances.

When we look at the theoretical model of bonding types, we are struck by the fact that very characteristic inorganic compounds such as salts, acids, and bases – in other words, all electrolytes – are easiest to explain in terms of the classical electrophysical attraction of oppositely charged ions, which can be interpreted as the donation and acceptance of particulate, separated electrons to complete the electron octet for each of the combining elements, held together by simple electrostatic attraction of the resulting ions. But as the bonding approaches covalency, which is responsible for the polymers that support life, the point-wise distribution of electrons imagined as particles no longer applies. How can a covalent bond possibly hold together when both electrons have the same charge? This phenomenon can be interpreted only in terms of quantum theory – that is, by “relaxing” the laws of classical physics so that the space vector and impulse (or temporal axis and energy) become undefined. Location and time can no longer be pinpointed, becoming nothing more than probabilities or potentials that cannot be conceived precisely. It is very interesting to note that such limit-experiences inevitably appear when dynamized forms of thinking approach organic substances and thus the biochemistry of living matter.

This is all the more true of the *mesomerism* that almost all organic compounds exhibit: the type of bonding falls somewhere between two structural formulas with covalent bonds. Even in any carboxyl group, the hydrogen belongs to both of its oxygen partners. The single hydrogen bond is generally broken down into two half-bonds, and where is the covalent bonding in that arrangement? In either covalent bonding or mesomerism, quantum relationships apply that do not describe any identifiable state of affairs but only probabilities or potentials. The wave theory of electrons that is applied here also deals only with probable waves rather than factual ones.

Inorganic matter with its characteristic electrolytes can be explained in terms of sums of particulate entities, whereas the world of living matter, like life itself, cannot. Of course highly polymeric minerals also exist, especially among the silicates, but this is no contradiction if they are understood as the Earth's "biochemistry" or the geochemistry of the Earth's life.

In his own way, Rudolf Steiner had the "relaxation" of rigid conceptions of molecules in mind when he spoke in 1921 about the step from inorganic crystalline structures to the inherent configurations of living matter:

"Here, however, substances are constantly forming for chemists to investigate, substances that do not always exhibit outer crystallization. Instead, their configuration is internal. Even the recent trend toward structural formulas in chemistry hints at this internal configuration. […] But here is the mystery: The more organic the connection between substances, the less they bond chemically and the more chaotic the intermixture of substances becomes." (*Steiner*, GA 205: 88/89, June 1, 1921)

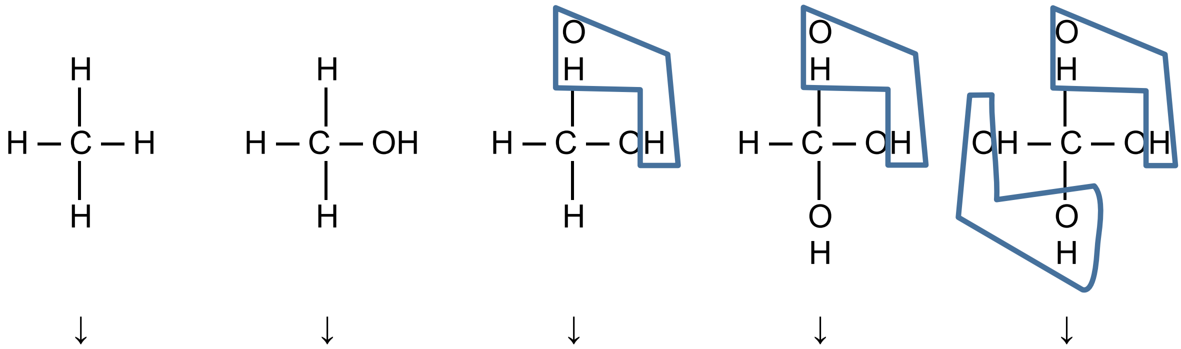
In life, formerly inorganic substances relinquish their forces of crystallization. This speaks qualitatively to the transition from ionogenic to merely covalent bonding, which can be described only in terms of chaos or quantum theory. Acceptance of the theory of covalent bonding was the subject of dramatic discussion among leading experts as late as the 1930s. At issue were Einstein's objectivistic determinism versus Bohr's probabilistic indeterminism. The latter was victorious, and Einstein at least conceded, as William Bragg is purported to have said, that everything that has already happened is particulate, and everything in the future is waves. In 1970, Bragg's son Lawrence formulated it like this: "The advancing sieve of time coagulates waves into particles at the moment 'Now.'" (*Clark* 1973) Clearly, the physical reality of substances is incomprehensible if time is excluded, since substances are also constantly coagulating out of the nascent state into reality.

At this point, the problem with chemistry as taught in our schools is that chemistry teachers themselves generally have not had the opportunity to delve into the fundamental contents of quantum theory with any degree of understanding. Ideally, however, what fundamental principles of quantum theory should a Waldorf upper school teachers have grasped? There is an urgent need here. In the long run, it makes no sense for teachers to respond to the probing questions of twelfth and thirteenth graders if all they can say is that they themselves also do not fully understand the quantum theory behind the octet rule, covalent bonding, mesomerism, and the benzene ring but that the students must be able to replicate the customary wording on exams. Unfortunately, the same situation applies in public schools. We must make the effort to acquire at least a beginner's understanding of the principles, as Steiner intended. We would find it well worth our while to take this step toward achieving the working goal of the chemistry of the future, a goal that Goethe himself already foresaw in his later years:

“In this field (i.e., teaching about organic nature), we owe a great deal to chemists, who bypass the content and structure (of an organism) and devote their attention entirely to the properties of substances and the ratios of their mixtures. We will become even more indebted to them because recent discoveries permit very subtle analyses and syntheses, giving us hope that we may approach the infinitely delicate workings of a living organic body. Just as we have been able to achieve an anatomical physiology through precise observation of structures, we aspire in time to develop a physical/chemical physiology, and it is to be hoped that both sciences will continue to advance as if each one alone were to bring the entire matter to its conclusion.” (*Walden* 1943: 81/82)

Here we are interested primarily in the *process* character of bonding types, i.e., with their temporal configurations. In this respect, heteropolar and homopolar bonding are true polarities. Ions bond with incalculable rapidity. When we mix caustic soda and hydrochloric acid, most of the hydrogen and hydroxyl ions form water instantly. The opposite is true of bonds between electrically uncharged partners (i.e., atoms or molecules rather than ions): In classic instances, this type of bonding occurs very slowly. Charcoal from the first fires used by prehistoric humans (> 1 million years) is still being found embedded in sediments, and petroleum, for example, has remained practically unchanged from the Paleozoic Era until today. Graphite, which surely passed through the photosynthetic process at one time, is found even in the oldest rocks on Earth (3.8 billion years). (*Pflug* 1984) Carbon compounds move into the world of living processes only by passing through heteropolarizing stages.

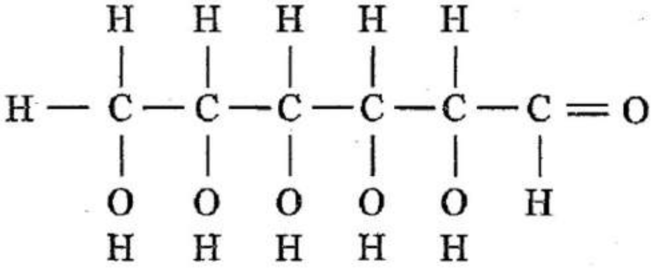
It is the temporal aspect that makes the oxidation series of aliphatic hydrocarbons (commonly used as an introduction to organic chemistry) so instructive on an ongoing basis. We begin with the four stages in the oxidation of methane, the simplest of these compounds; the end product, carbon dioxide, is the lowest in energy of the compounds in the sequence.



CH_4 methane — $H_3C\text{-}OH$ Methanol — $H_2C{=}O$ formaldehyde — HCOOH formic acid — CO2 carbon dioxide

Because methane’s bonds are all covalent; it is relatively inert unless activated by the addition of energy. Methanol is more chemically active and formaldehyde even more so. Formic or methanoic acid, however, dissociates into ions and is therefore highly reactive, readily entering into ionic reactions. The same is true of the carbonic acid ions that develop out of carbon dioxide. If we consider the alkane, alkanol, alkanal, and carboxylic acid series in a very general way, simply with regard to their suitability for life, it soon becomes clear that an organism composed entirely of compounds with ionic bonds would rapidly reach the end of its life due to the speed of the reactions that would take place within it. Conversely, if it consisted entirely of covalently bonded substances, necessary reactions would never even begin and the organism and it would remain metastable, at its initial high energy potential, with no means of changing. Obviously, therefore, real life often makes use of intermediate-stage compounds. If we take a not overly long carbon chain with a few oxygen bonds as an energy source, several alcohol groups as weakly reactive potentials, and at least one aldehyde group as a more reactive component (but less reactive than an ionogenic alkanoic acid), the natural outcome is a compound well suited to supporting life – a simple sugar such as glucose, which is the product of photosynthesis. Only now does it begin to make sense why such an important metabolite consists of a multivalent alcohol and a monovalent aldehyde (e.g., a ketone): It needs to occupy the moderate middle ground between extreme temporal patterns.

Thus we can (and should) read not only the compound's spatial structure but also its temporal gesture. By doing so, we move from the chemistry of individual substances to the chemistry of processes, which makes chemical reaction kinetics one of the most interesting aspects of modern chemistry.



Amino acids, the building blocks of proteins, also incorporate both alkalinity and acidity into their molecular structures. Amino acids are *zwitterions*, molecules with both positive and negative centers. They are designed for rapid reactivity, since both their amino groups and their carboxyl groups are ionogenic, the former through proton acceptance, yielding $R\text{-}NH_3^+$, the latter through proton release, yielding $R\text{-}COO^-$. In qualitative terms, it is not surprising that the plant kingdom consists predominantly of carbohydrates and mobile animals primarily of proteins. It is equally interesting to note that in water, which is so essential to life, the elements hydrogen and oxygen are held together primarily but not exclusively by covalent bonds. Water is weakly capable of dissociation; the ionized product $[H^+] \times [OH^-] = 10^{-14}$ accounts for its reactivity – in hydration, for example – and thus as a solvent of all water soluble ions. On the other hand, the predominance of covalent bonds means dilution retards many reactions that would otherwise occur too quickly in water. Even simply in terms of the gradient between homopolar and heteropolar bonding qualities, however, the chemistry of water has certainly not been exhaustively explored, because additional, weaker types of bonding also come into play – the hydrogen bridge bonding that results from the dipolar effect of water's imbalanced (angled) structure, or van der Waals forces that can be explained only in terms of quantum theory, to give just a few examples. Because water has access to a rich spectrum of graduated bonding types, it is capably of many subtly structured combining forms and reaction speeds, much to the benefit of life. Every good chemist knows that water is more than just $(H_20)_x$.

Most physiologically active organic compounds slowly lose reactivity, either by condensing into long-chain macromolecules (i.e., by releasing water) or through polymerization (without releasing water). For example, glucose can transform into cellulose, n-acetylglucosamine into chitin, the phenylpropanoles into lignins, acetic acid into fatty acids or isoprenoids such as caoutchouc, simple alkanes into waxes, amino acids into scleroproteins (horn). Structural compounds are not the only products of this phenomenon, however. Even energy sources such as starches, hemilcelluloses, long-chain fats, etc. can develop in the same way. All of these condensates or polymers are primarily covalently bonded, energy-rich, and contribute structure and bulk to the organism. In contrast, fully ionizable substances present the opposite picture: These compounds become physiologically active through dissociation rather than association and are characterized by electrical polarization, not electrical neutrality as in the polymers. Where fully ionizable compounds play a role in the organism, lower energy levels are achieved through rapid ionic reactions. All neurological rhythms are based on rapid ion migration.

The protein fraction of a living cell receives its internal structure from the cytoskeleton (with predominantly covalent bonds) and its reactivity from the supply of ions in the cytosol. In living proteins – whether gels or colloids – these two features always collaborate closely: Long chains contain the potential energy developed through anabolism, while weakly ionogenic amino and carboxyl groups initiate catabolic reaction cascades and alter electrical potentials by releasing energy. In most amino acids, the α-position of the amino group in relation to the carboxyl group prevents the possibility of mere salinization of the cell content. Any other position would rapidly lead to “intrinsic salinization” even within the molecule. *Life, even when described in chemical terms, consists not in eliminating tension but in preserving it in moderated form by partially (!) balancing out differences in potentials.* We arrive, therefore, at the following comparison of the basic polar bonding types:

homopolar = covalent = atomic bonding	Bonding	heteropolar = ionogenic = ionic bonding
polymerization condensation association	molecular structure	electrolytic dissociation
energy-rich	Energy	energy-poor
build-up of organic substance including structural matter	Metabolism	breakdown into lower molecular or Inorganic compounds
development of the body, biography, incarnation	Configuration	dissolution of life processes; excarnation

To those who understand nature in anthroposophical terms, it soon becomes evident that this contrast involves the vehicles of the two polar activities of the etheric. On the one hand, the etheric body of every living entity is devoted to building up its physical body. This is the domain of the plant kingdom. Ever since plants first dominated the landscape in the Devonian period, increasingly dramatic tree forms have developed. Today, giant redwoods and eucalyptus trees are the tallest living things on earth. The development of bodily mass, therefore, is also the "plant" aspect in animals and humans. Conversely, breakdown processes move from substances of high molecular weight to those of lower molecular weight, accompanied by the release of energy. This physiological breakdown makes perception possible on the soul level in animal and human bodies (*Fortlage* 1869). (With regard to breakdown processes in the plant kingdom, Rudolf Steiner pointed out that in that kingdom, sensory activity belongs to the entire landscape – the "earth soul" – rather than to individual plants. See GA 60, lecture of December 8, 1910.) Rapid ion reactions are necessary if the astral element is to take hold. In the spectrum of human rhythms, the most rapid physiological alternation is the neurological rhythm of polarization and depolarization via the migration of Na^+/K^+ ions within the cell membranes. The etheric approaches the physical and astral members of the constitution by utilizing covalent and ionogenic bonding, respectively. On the chemical level, this dual aspect of the etheric is graphically expressed in the antagonism between homopolar and heteropolar bonds.

It is also worth taking a look at metallic bonding and actual metal compounds (alloys, coordination complexes, and metallic salts). We are initially struck by the fact that the majority of chemical elements are metals. The flowing transition from heteropolar to metallic bonds takes place from the light metals to the precious metals, based on the broad spectrum of their redox performance, which forms the basis of electrochemistry, for example. *Between* the light and precious metals, the middle ground is occupied by most of the heavy metals, whose compounds display a superabundance of colors, hence the beauty of many ores. These metals are the most stable in terms of their nuclear chemistry and are physiologically active in a great variety of ways. Their coordination complexes in particular illustrate the transition to homopolar bonding in organic chemistry.

Life's circumstances never consist only in opposites but rather in the enhanced dynamic between opposites. On the soul level, our most direct connection to our body chemistry is through eating for the sake of nourishment. Which substances do we especially enjoy tasting? Sugar is an intermediary between starch on the one hand and carbon dioxide and water on the other. Both of these poles are relatively tasteless; only the mono- and disaccharides in the transitional range taste sweet! Something similar is true of proteins. Their parent materials – carbon, hydrogen, oxygen, nitrogen, and water – have neither flavor nor odor, and the same is true of high-value proteins such as egg white or pure, untreated meat. They taste good to us only in the intermediate stages, on the boundary between buildup and breakdown. The tasteless plant proteins used in making soy sauce, for example, develop their savory flavor only through partial fermentation that breaks them down into amino acids. Pure fats and oils taste like nothing, so we spice them up with ions, adding table salt to solid fats and vinegar to salad oils. Relatively short-chain fatty acids esterified with short-chain alcohols, however, yield the wonderful fruity aromas of strawberries, raspberries, peaches, pears, and bananas. Here again we see an enhanced chemical middle ground between substances of high and low molecular weight, neither of which is especially appealing to us. Goethe's "colored seam," presented in his theory of colors as the archetype of dynamic enhancement between darkness and light, has its counterpart in the world of chemicals as a “seam” of flavors and odors centered between opposite poles.

Chemistry as a Reaction to Formative Forces?

What has become of chemical reactions and tests for formative forces – for example, the “sensitive flame” test, copper chloride crystallization, the *Steigbild* technique, or the drop picture method – that initially claimed to be able to distinguish among and record supersensible influences in the lab? None of these imaging techniques has stood up to even well-meaning critiques. Copper chloride crystallization imaging has the best record with regard to replicability, achieved through standardization of all parameters. Characteristically structured images have even been produced using purely synthetic polymers. (*Hummel* 1992) In the *Steigbild* technique, standardization is limited by the type of paper, because cellulose fibers are always a mixture of different lengths and each batch of paper – even of the same type and brand – is always slightly different. For this reason, modern thin-layer chromatography on silica gel offers greater replicability

For many years, scientific exchange among experimenters using the *Steigbild* technique – or rather the notable lack of exchange – was an overt problem. It took this author ten years to bring about unrestricted sharing in a meeting held in the Scientific Section of the Goetheanum in Dornach. Results of that meeting were published in issue 46 of “Elemente der Naturwissenschaft” [Elements of Natural Science] in 1987. The unanimous conclusion was that anthroposophical imaging methods do not reflect the direct effects of etheric formative forces but rather the characteristic features of groups of substances previously arranged by formative forces within the living body. In each case, the end result is a reductionist phenomenon because the plant in question is killed, chopped, and pressed to extract its juice, which then undergoes preliminary refining before testing. In other words, the test substance is extracted from the holistic context of life. Even identifying the connection between the crystallization image and the plant in question – its organs, its harvest date, etc. – takes considerable effort. Jochen Bockemühl is right in saying that much more is visible in the morphology of an intact, living plant and its dynamic transformations than in any laboratory treatment.

And yet laboratory imaging techniques do have a certain relevance, especially if we consider multiple methods. The working group of Ruth Mandera and Hans-Joachim Strüh of the Wala research lab (*Mandera* 1987, *Strüh* 1987) took a fresh approach to working with the *Steigbild* and identified three conspicuous types, which they named the “loose” type, the “sugar” type, and the “colloid” type.

These three types relate to the observed rate of speed at which the juice rises in the absorbent paper: slowly, remaining in the lower portion of the paper; at a moderate rate; or distinctly fast and high-rising. From the Goethean view of bonding theory described above, it soon becomes obvious that the colloid type encompasses all organic mucilaginous substances that are highly condensed or polymerized yet still marginally water-soluble. Conversely, ionogenic substances – for example, the anthocyanins that color cherry juice – rise easily and quickly to form the upper colored bands of the “loose” type. Between these extremes are the more balanced, substances that have access to both poles and whose action is harmonizing, mediating, and balancing – sugars, for example! If the organic fractions themselves are not colored, they can be made visible or “developed” after the fact with metal complex salts, as Friedrich Ferdinand Runge (1795-1867) had already discovered during Goethe’s time (*Harsch/Bussema* 1985).

This interpretation of *Steigbild* testing of organic juices in connection with the spectrum of bonds from homopolar to heteropolar can elicit two diametrically opposed reactions. The first is disappointment: We see something explained that we would rather not see explained, and so we evoke the bogeymen of materialism and rationalism in an attempt to discredit it. The other possible response is that if we hope to achieve qualitative augmentation of explicability, we must accept it rather than reject it. The spiritual aspect should never be a gap-filler for what remains unexplained. Quite the contrary: It leaves its most telling expressions in the world of effects and needs to be celebrated there. How did Rudolf Steiner put it to the first Waldorf teachers?

> “Similarly, we must not encourage the much-loved notion that the unknown is proof of presence of spirit. After all, don’t people say, ‘Oh, that’s impossible to know, so spirit must be revealing itself there!’? Instead of sensing that spirit is knowable and reveals itself in matter, people are distracted into thinking that any unexplainable event is evidence of the divine.” (*Steiner*, GA 300/I: 100, lecture of September 26, 1919)

Thomas Aquinas was one of the first to speak out against the misuse of the spiritual world as a “refuge of ignorance,” a mere *asylum ignorantiae*, in our thought practices.

Dynamic Equilibriums

Transformation always takes place in the intervening field between opposites. As we have already seen, ideal covalent bonds are just as uncommon as pure ionogenic bonds, and intermediate stages account for the plethora of remaining compounds. Although these transformed substances may appear outwardly stable, they are not; rather, they are in states of *dynamic equilibrium*. For example, think of all the buffer systems in intracellular and extracellular biochemistry, or even simply the blood’s pH buffer. These systems are always based on *intermediate-stage bonding* of the substances involved, especially weak acids and weak bases. Thus all carboxyl acids and amino compounds are capable of buffering activity, modulating excessive acidity or alkalinity whenever it occurs. The “law of mass action,” discovered in 1867 by two Norwegians – the chemist Peter Waage (1833-1900) and the mathematician Cato Maximilian Guldberg (1836-1900) – describes this phenomenon exactly. The name is worse than unfortunate, however, because what is involved here is not the effect of *mass* but the effect of *concentration*, as we realize as soon as we understood that the size of the dose determines its effect.

The law of mass action itself, however, is just a special instance of *Le Chatelier’s principle*, a much more comprehensive principle that encompasses such adjustments in dynamic equilibrium while also including energetic processes. As the energy supply increases, endothermic combinations occur, reducing the amount of energy. Conversely, when the supply of energy is low, exothermic reactions are more likely to occur, releasing energy. This applies not only to chemical changes but also to physical changes, if we do not count transitions to different states of matter as chemical changes (which they actually are, since bonding forces and gradations of heat are just as involved in the reorganization of molecular structures during changes of state as they are in most “chemical” reactions).

This principle governs all of the weather patterns that make up climate. As heat is added, energy-binding processes such as melting and evaporation occur. As available heat decreases, it redevelops through condensation and crystallization. Water, therefore, is capable of any type of adjustment, which is what makes the Earth’s biosphere possible. Thus Le Chatelier’s principle is at work in all compensatory processes, and life can be achieved only by balancing opposites without ever coming to complete equilibrium. The latter is possible only after death and in the inorganic realm, and to this extent the principle of “minimized external forcing” in its mathematical form applies to the chemistry and physics of dead matter. For our purposes, however, it also reflects something characteristic of life, because it forms an enhanced middle ground – in this case, between polar bonding types, for example – in order to develop fully. Buffer solutions can be produced only with weak acids, not with strong ones. We might even say that Le Chatelier’s principle is a fundamental biological law that has found its way into the world of physics and chemistry. Does inorganic matter, including its laws, originate in organic matter? The anthroposophical understanding of evolution answers this question in the affirmative.

The capacity for constant compensatory adjustment resides in the etheric. Goethe himself discovered the compensation principle in living bodies, which governs the organization of our senses, for example. After looking at intense light, the eyes become less sensitive and see only relative darkness, but when we walk outside at night, we see the faintest traces of light. Our eyes are sensitized to red when we see green and to yellow when we see purple. When we extend our limbs, the flexor muscles prepare for action, and so on. Colored shadows are neither objective nor subjective but a consequence of our sensory physiology, which – like all etheric life – transcends objectivity and subjectivity and takes up residence where the dualistic gap between body and soul is bridged, namely, in life, the link that connects them. The existential legality of Le Chatelier’s principle emerges when projected from life into the inorganic realm, which is why that principle is indispensable to the physical existence of life.

Stereoisomerism

Stereoisomerism was discovered by Louis Pasteur (1822-1895), Jacobus Henricus van’t Hoff (1852-1911), and Joseph Achille Le Bel ((1847-1930), among others, and has proved to be one of the most significant discoveries in all of biochemistry: *How* a substance is constituted is as noteworthy as *what* it consists of. In addition to the actual elements involved, their spatial configuration also determines the properties of their compounds. Configuration, not mass, is the primary determining factor. This discovery transformed chemistry, formerly the mere study of matter, into molecular morphology. We should not say that structural chemistry is simply a “theoretical construct.” Until satellite photos became available, the same was true of maps, which did not make them any less reliable for planning trips. Meanwhile, good comparable photos of molecular morphology are also available to make the theoretical discovery perceptible. Steiner advised the first Waldorf teachers that if formulas had to be used in chemistry, it was preferable to introduce spatial formulas from the beginning. (*Steiner* GA 300/111:32). C_2H_6O can be either ethanol or dimethyl ether – two vastly different substances with the same components. Matter alone is not the essential factor; *how* it is put together is more important. This is the essence of any understanding of structure.

The most impressive stereochemical phenomenon in biochemistry is *chirality*. There are almost no organic compounds that are not chiral, and in fact their physiological effects essentially depend on their clearly asymmetrical directions of rotation. Pasteur discovered this phenomenon in dextrorotatory and levorotatory lactic acid. Le Bel and van't Hoff, working independent of each other, discovered that in most cases the asymmetry of the four carbon ligands is the deciding factor. In many cases, the human nose can smell the difference: One of the two entianomers (mirror image forms) of *carvone* smells like caraway, the other like spearmint; they are structurally identical but mirror-image reversed. By using two polarizing films, it is easy to make the difference in the spiral structures of dextrorotatory (e.g. glucose, saccharose) and levorotatory sugars (e.g. fructose) visible. (*Wenger* instructional materials) All chemical microstructures important to life are clearly asymmetrical. It is all the more astonishing that macroscopic symmetries are possible in the bodily structures of living things. Regardless of the organism's radial or bilateral symmetry (e.g. sea urchin versus fish), the centrally located vital organs of metabolism tend to be asymmetrical. The midgut glands that regulate digestion are located in the center of every spiral snail shell, and the majority of snail shells (helicid species) are dextral-coiling, although sinistral coiling is obligate in clausiliid species.

Chirality is almost unknown in inorganic chemistry (*Schad* 2000: 107), which makes the exception all the more surprising: Rock crystal and related silicates, which make up the greater part of the earth's crust (the part of the Earth closest to the biosphere) and are familiar to us as *plutonites* or intrusive igneous rocks, are chiral. There are dextral and sinistral quartzes (see *Schad* 1981a). Might they also be physiologically active, and in different ways?

This idea suggests itself readily to anthroposophical thinking, which understands every living organism as an entity unto itself, albeit an open one. As early as 1886, in his "Fundamentals of the Goethean World View with Special Reference to Schiller," Rudolf Steiner, then still a student, looked for the comparable whole in the inorganic realm and found it, not in any detail, but in the "totality of inorganic matter as a system," which is the entire cosmos. (*Steiner*, GA 2, 1886) To a certain extent, therefore, each individual living thing, as an entirety, is a reproduction in miniature of the entire cosmos. To our geometrical everyday consciousness, the external cosmos appears to be homogeneous and equivalent in all directions. Steiner took a stand against this view, stating that the cosmos has non-equivalent directions: If we insist on visualizing it in geometrical terms, we should imagine it as egg-shaped, not spherical. (*Steiner*, GA 136, lecture of April 11, 1912; GA 205: 90-91, lecture of July 1, 1921) Embryologists know that in the earliest stages of a chick's development, the body axis is perpendicular to axis of the egg. In 70 percent of cases, the head pole points away from and the head pole toward an observer looking at the egg with the blunt end on the left and the pointed end on the right. The chick's original position in the egg, therefore, is always asymmetrical and its orientation also varies unequally. Seen from this perspective, the fact that all complex organic products of metabolism are asymmetrical even in the details of their structure is an expression of the holistic, cosmic nature of life processes.

In physics, the first inherent dissymmetry (in beta decay) in the physical world was discovered in 1956. (*Lee and Yang* 1956) In 1997, the America astronomers

Nodland and Ralston discovered the asymmetrical spiral structure of the physical universe experimentally, based on radio signals from 160 distant galaxies displaying asymmetrical changes in their diameters. All previous work in this field had been based upon the strict assumption of isotropy in all directions of space.

An obvious idea, first suggested years ago by the anthroposophical physician Otto Wolff (1921-2003) is that the chirality of quartz is responsible for the efficacy of the biodynamic horn-silica preparation (produced in a cow horn that is an asymmetrical spiral, by the way). In 1982, together with Rainer Dietrich, I conducted the first experiments using separate sprayings of dextrorotatory and levorotatory quartzes in the experimental garden at the Institute for Waldorf Education in Witten-Annen. In most instances, pole beans responded better in terms of size and depth of leaf color to d-rotatory rather than l-rotatory quartz. Ms. Christina Senger, under the aegis of Professor Wolfram Achtnich, confirmed these findings in a dissertation based on field crop experiments in Göttingen. In spite of multiple attempts, however, the biodynamic research circle has not achieved conclusive results. We can only admire Rudolf Steiner's masterful grasp of the subject in choosing quartz, a mineral so closely associated with the physiology of life, for the horn-silica preparation. As Goethe said in his Maxims and Reflections (no. 839):

> If Nature in her lifeless beginnings had not been so fundamentally stereometric, how is she ultimately supposed to have achieved incalculable and immeasurable life?

And how did the wise man of Weimar already know about this?

The Image of the Divine in Matter

Rudolf Steiner once predicted that people of the future would learn to identify the working of Christ even in the laws of chemistry. (*Steiner*, GA 15: 66) When that happens, spiritualism and materialism will no longer be irreconcilable opposites. The future always has seeds in the present – such as this statement by Steiner, for example. Are such seeds also already present in the content of the inorganic sciences? Probably only as the first inconspicuous approximations. How do nuclear physics and nuclear chemistry describe of the submicroscopic structure of matter? The over one hundred elements are explained in terms of significantly fewer elementary particles. At least three characteristic properties are attributed to each elementary particle. One is *mass*: The particles is concentrated and centered in a very small space and is therefore also surrounded by a minimal gravitational field. In addition, most elementary particles carry specific *electrical charges*, and the electrical field that surrounds each one is much stronger than its gravitational field. In principle, these electrical fields extend out into space indefinitely, although their strength decreases rapidly, with the square of the distance. These are the principle opposing gestures in the structure of matter.

Mass number and charge by themselves, however, are not enough to completely characterize an elementary particle. That requires a third quantifiable factor, its *spin*. Spin is an asymmetrical torque that incorporates the direction of rotation of both the mass and the charge. Here we encounter a unifying, rhythmically oscillating characteristic that is just as fundamental and essential as mass and charge. Only all three quantities taken together describe an individual elementary particle.

Similar dynamics are inherent in the configuration of every atom. The nucleons that contribute to the atom's mass are clustered together in the nucleus. The neutrons among them contribute only to the atom's mass while not affecting its charge. Neutrons are often needed to prevent the protons, all positively charged, from repelling each other. In other words, the neutrons counteract the effects of the protons' charges. In contrast, the atomic shell consists of low mass, highly negatively charged electrons that determine the strength of the surrounding electrical field. The electron "shell" (an overly mechanical and therefore poor choice of words) that lies between the nucleus and the outer shell are characterized by rhythmical activity, full of "quantum leaps," that can be interpreted only in terms of wave theory. In 1895, Johann Jakob Balmer (1825-1898) was the first to discover the mathematical formula for computing this rhythmical sequence, the wavelengths of the visible hydrogen emission spectrum (the Balmer series). Balmer saw a pronounced Pythagorean character in the relationship he discovered. (Cf. *Hagenbach* 1941, *Hartmann* 1949)

Any further interpretation of this description seems unnecessary at this point. Clearly, however, the structure of all matter is ultimately threefold in the sense of polarity and dynamic enhancement. As revealed by anthroposophically illuminated Goetheanism, this trinitarian aspect gives meaning to data that are otherwise only technologically interesting, allowing them to serve as an aid to our human self-conception as it orients itself in the natural order that surrounds us.

Herder poked fun at Goethe for subscribing to this approach: "One of the most ridiculous periods in the history of genius was the period in Weimar when the mines in Ilmenau were to be put back into operation. Human beings were nothing; rock was everything. In the structure of granite, Goethe discovered the divine trinity, which only a mystery could explain." (Herder, conversation with Falk) Herder is referring here to the essay "On Granite," which emerged from Goethe's geological observations on a walking tour of the Harz Mountains. Rudolf Steiner, however, spoke of this essay with great admiration and recommended it in the Supplementary Course for teachers (GA 302: 36):

> Above all, we must always present history, geography, geology, and so on with true feeling. Geology is especially interesting if we present it with deep feeling for the rock formations under the earth. In this connection, a sympathetic read-through of Goethe's treatise on granite should be recommended to all educators. It illustrates how immersing ourselves in nature with our whole being rather than merely through conceptual activity allows us to develop a human relationship to the archetypal father that is ancient, holy granite. And of course this process must be extended to other features of nature as well. (*Steiner*, lecture of June 13, 1921)

In Rudolf Steiner's work, the threefold aspect of granite even finds therapeutic applications in the threefold human body. (*Steiner*, GA 349:19; lecture of February 17, 1923)

Goethe had access to all the geological expertise of his time, having been introduced to it by his personal friend Heinrich von Treba, assistant director of the Clausthal-Zellerfeld mining authority. In their relationship to light, quartz and mica illustrate the polarity of transparency and reflectivity, feldspar the dynamic enhancement to color. Goethe's entire theory of color, therefore, is also an attempt to grasp this branch of physics in terms of trinitarian qualities.

Today our knowledge of almost all natural phenomena is incomparably greater, more precise, more multifaceted, and more differentiated. In terms of both its educational value and our understanding and appreciation of nature, however, it is sadly lacking. Natural science remains unintegrated into spiritual culture because our educated, spiritually inclined contemporaries turn up their noses and purse their lips at science, distaining it as mere reductionism and materialism. And yet the natural sciences, far from being the work of the devil, are full of good spirit that we should continue to discover. The methodology has been available for a long time, but the discovery must be actively desired and pursued. The alternative is that a detached, ivory-tower form of spiritualism will misconstrue its task and give rise to an increasingly degenerate and negative materialism. (*Steiner*, GA 295:167) Now, however, we finally have the opportunity to free ourselves from the tragic centuries-old tradition described at the beginning of this article.

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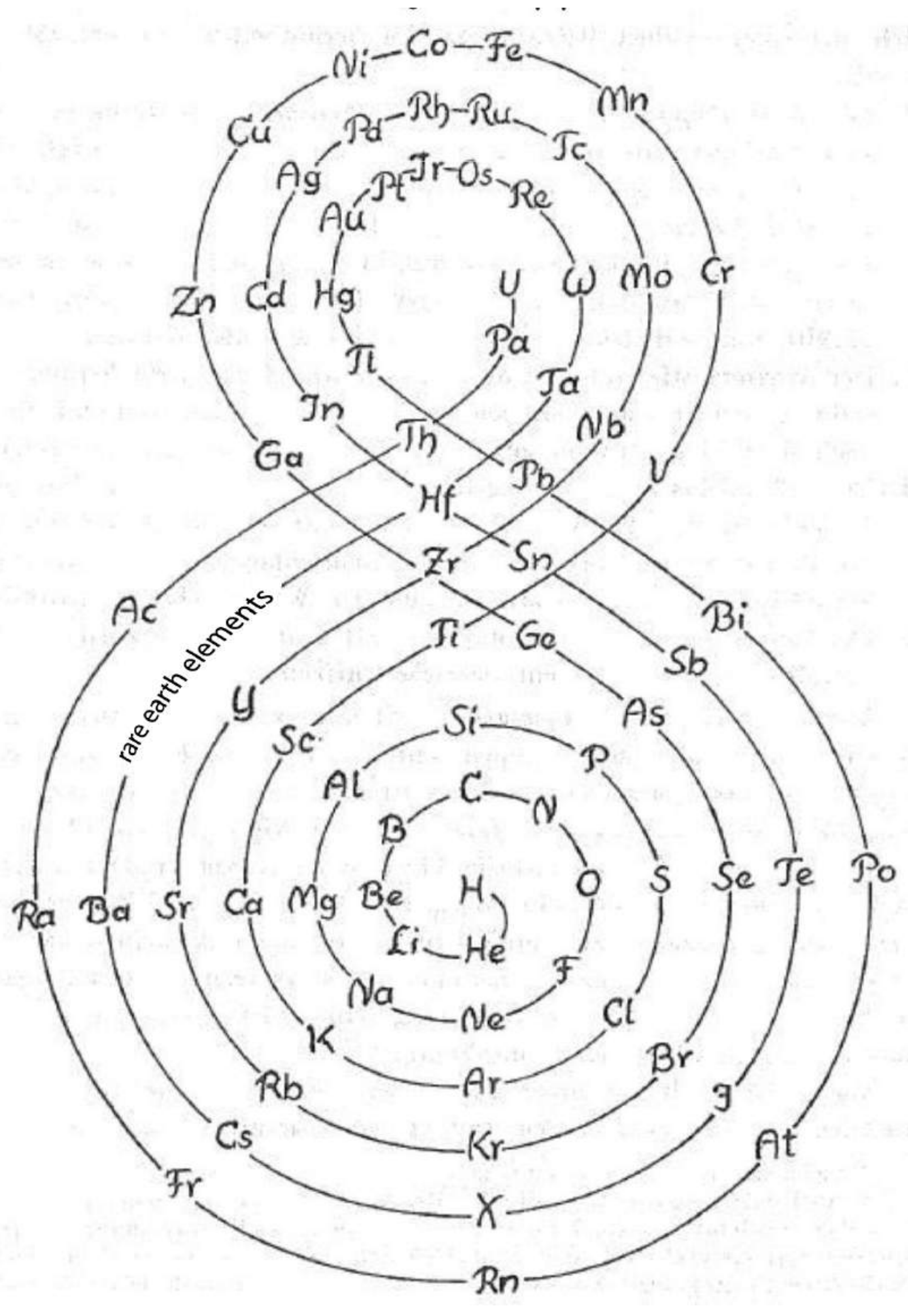
Lemniscatic Periodic Table of the Elements



A model free introduction of chemical formulas

Manfred von Mackensen, 'Prozesschemie', 2001

1. The transition class 10 – class 11

Reflection on class 10. In the 10th class we give a survey of the manifold and structured expressions of the salts and their symmetries. We got to know transforming forces of the acids, the absorbing action of alkalis and the mineralising action of bases. Within the plant world alkaline processes are characterised by weight and over-ripeness, acidic processes by freshness and growth. The internal processes of the animal, not directly accessible from outside of the body, are alkaline in character; those processes however, which are accessible without resorting to incisions, are acidic in character, i.e. gastric juices and feeding juice of the bees. When teaching about salts, alkaline and acidic phenomena are reviewed in minerals, natural water and juices of living organisms. Different directions in processes may be discerned, which are represented in the most varied way through different substances – even within the crystal form.

Preview class 11. At times it will happen that one or another chemical formula for a salt, an acid or a base, will be used in class 10, declared in anticipation of what's to come; possibly even encouraged to remember it for next year. However, how the innumerable substances of the world can be reduced to a small number of chemical elements, in what densification, concentration and finally decay of the change- and emerging-impulses of the material abundance are present in nature, this process of identifying, of narrowing down and individualising to the extreme, to an element, that belongs to class 11. In class 11 this is didactically appropriate, as it requires an overview of chemical possibilities, presented in class 10, to notice the focussing and one-sidedness.

2. Laws and atoms

Actions of elements? Only in compounds. Firstly, irrespective of whether one starts the mainlesson with calcium, nitrogen, sodium or sulphur, we have to establish the fact that such an element, seen as the concentration of that specific substance impulse, has the smallest weight of all its derivatives. All compounds of the element weigh more than the portion of the element used to make them. Every time something was added. The element stands as the concentration in the centre of its derivatives (compounds). Only through the compound does the element act in a process of nature and leaves its mark because it is bound differently or in a different manner. Isolated, as pure elements, mostly prepared in the laboratory, they have little influence in nature's processes. An element doesn't realise its impulse, its driving force on its own but only in conjunction with other elements. Only in that manner can our world exist: aiming for innumerable new qualities, with unlimited flowing forces. These do emerge monotonously from the elements as building blocks of the substances. Every compound exhibits new, *particular, own* qualities. The elements only indicate these. They themselves are poorer.

No material world-building blocks! We should not speak trivially of elements in a material constitutional manner, as mystical invisible beings, before we have demonstrated their impoverishment. Even if conventional school chemistry admires them as much as it wants as building blocks of the universe, as root causes or simply as the only reality: we have no reason to introduce the elements before class 11.

Proportions. The so called law of constant proportions is an early, unspoken experience of children from the first melting icicle running away. From nothing comes nothing, from little little, mostly something is in surplus. But a lot of acid given to a base forms the same salt as a little acid, only one or the other remains unchanged. Substances have their own property identity, just as they have their fixed proportions when reacting initially; there is no way changing that. In class, therefore, we don´t have to discuss the laws of constant proportions and of conservation of mass too much.

Conservation of mass of the element. It is just as obvious, that the substances or elements reappear when destroying the substance, in the same quantity, as long as nothing is lost. Otherwise one of the initial substances would be changed into the other when repeatedly producing and destroying a compound. However, they are something different! The so called law of the conservation of (elemental) mass can be put to the pupils, without much introduction or proof.

Consequences, not definitions characterise laws. What we need in education is not an extensive *measuring,* but an experience and a judgement how laws present themselves, what aspect of experience *points to them*. For example, that is the point of the experiment producing iron-sulphide. We base the use of formulas on that or similar experiments – not on laws, much less on atoms. Even the explanatory satisfaction derived from using 'atoms' arises from an even deeper layer of half-conscious pre-existing wish to have elements as building blocks; this leads even more strongly away from the personally strengthened meeting with the world and one's own judgement. We must protect ourselves from both. We all have the intuitive feeling, even the particular thoughts, to consider everything in the world to be caused by matter.

Experiencing the boundaries of particles. Mainstream laboratory and industrial chemistry is based on the conservation of mass, on number ratios, constant and graded proportions, conservation of the elementary mass, and finally: the conservation of particles, those particles which are eternal and make everything! One feels life on earth as a cage, wherein the particles actively and bring forth the world – and simultaneously restrict it. Reaching to the particles is felt as the great empowerment in the cage, the formula becomes its image and all the qualities of the phenomena of the world become uniform: It is as if we are engaging with and manipulating eternal reality. Here we do not need qualitative observation, no empathy with living nature and the substances it produces, and in particular: one need not form self-generated, self-evaluated thoughts in conjunction with this empathy and phenomenon. One has one's ready concepts (the molecules, electrons and ions), which are strongly founded in physics: on the eternal, static world, to which everything in the opening questions is ultimately reduced.

Basic attitudes. The present approach is not to be seen as a philosophical programme, but more as an accessible presentation; also in the soul of the pupils. We can summarise this as follows: chemical knowledge based on atomic conceptions and a few experimental signals, combined with 'make-ability' and power-instinct results in a non-verbalised credo: “Greetings atoms! We thank you for everything, the structure of nature, our bodies, our brain processes: we in you and you in us!”.

Didactic switches. Initially we'll let the atoms be. Just as they are unchangeable, so too are the basic attitudes and preconceptions with which we experience them; in this instance we cannot develop anything spiritual for the students. We can mention, 'praise' and lightly cover the atoms, and demonstrate that we know how to use the system, that we admire the system's overwhelming intelligence and power opportunities and consider it scientific, but do not expect wisdom or salvation from it. Because these we only acquire from experience, not from conception.

No final judgement. The previous remarks regarding the problem of atomism are intended to enlighten our daily consciousness with a view to making it receptive for the obvious, for what is appropriate for life so it can find its way. A historical, philosophical, scientific theoretical, or let alone a specialist appreciation will not be achieved. To present the fundamental problem inherent to the materialistic, causal-analytic cognition of nature, let us mention a few short essays from 1882 and 1890 by R. Steiner ('The only possible criticism of the atomic concepts' and 'Atomism and its refutation')[1].

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[1] Steiner, R (1882....) Einzig mögliche Kritik de atomistischen Begriffe; Die Atomistik und ihre Widerlegung. In 'Beiträge zur R. Steiner Gesamtaufgabe ' Nr. 63, Michaeli 1978, R. Steiner Nachlassverwaltung CH 4143 Dornach (Contributions to Steiner's complete works)

3. Manner of perception

Steps to arrive at chemical formulas. Chemical formulas have to be introduced en passant; developed from observation yes, but not by spending time on special experiments. In the end Hofmann's apparatus may be the only demonstration experiment used. The formation of iron sulphide would be a key experiment. It can demonstrate in a wonderful manner what it means to have a surplus of sulphur or iron. Burning of steel wool in air or the reduction of copper oxide with ammonia – experiments that could all be demonstrated – are suitable to demonstrate the proportions, the changes and the residues of the substances one started with.

The choice of the molar-mass. After the proportions the problem of abbreviations raises it head. We define a unit of mass specific to each element, in the case of hydrogen this is 1 gram. Thus the basic definition for the whole system is

$$1 \text{ g Hydrogen} = 1 \text{ H}$$

The element specific mass, in the above example 1 g, is also known as the molar-mass. Under normal conditions (i.e. standard pressure of 100 kPa (=1 atm) and standard temperature of 0°C, or STP) 1 mole of hydrogen has a mass of 2 g, because of its bimolecular nature, therefore it is written as H_2 and the molar-mass is 2. In contrast here a mole of atomic hydrogen is meant. A mole of hydrogen is therefore a proportion of this species with a mass of 1 g (that does not contradict the atomistic definition of the mole; distant digits after the comma don't have any meaning in the introduction of the mole). The mass of 1 g was chosen because hydrogen is the 'lightest substance', i.e. under standard circumstances (STP) it has the smallest density; and because all compounds that can be made with it have less hydrogen mass than of the reaction partners. Hydrogen is physically and chemically the lightest element.

In principal we could choose the molar mass of other elements, which will also be represented by one letter, by any number, at least in the simplest cases. However, the use of formulas only has an advantage if you take the mass proportions into account with which compounds are formed, so that we don't end up with complicated fractions of molar masses and of the representative letters. Thus we allocated the number of grams of chlorine that reacts with 1 gram of hydrogen, which is (rounded) 35, as its molar mass. We can then write:

$$1\,H + 1\,Cl \text{ ---------->} 1\,HCl \quad \text{or} \quad H + Cl \text{ ------------>} HCl$$

The formula for water from the mole volumes. Interestingly Gay-Lussac found in 1808 that equal volumes of hydrogen and chlorine react to form hydrogen chloride, thus indicating that molar masses relate to a unitary volume. This volume is set to roughly 24 l at room temperature. It is the same for all (gaseous) elements. We can thus ascribe the mole volume to one letter of each element. The number of letters for the elements are in proportion to the number of mole volumes participating in forming the compound, at least in simple cases. For example when we electrolyse water we find that for every mole volume (~24 l) of oxygen we get 2 mole volumes (~ 48 l) of hydrogen gas. Thus the formula for water is H_2O and it follows – with a mass ratio of 1 to 8 – that the molar mass of oxygen is 16 g.

$$H_2O \text{ ---->} \; 2\,H + 1\,O$$

First advantage. What have we gained by such formulas?

- Firstly, in an abbreviated form, they represent quantities of used or produced substances during reactions, so that we don't need to weigh but only need to write letters, which, at the most, will be accompanied by small whole numbers. Formula writing is thus initially an adequate protocol for quantities, for example production.
- If we boldly state that we could retrieve, in a roundabout way, the elements which disappeared in a substance we can predict reaction possibilities and exclude others. We get an overview of the whole.

4. The great discovery

A universal system “falls from heaven”. The last advantage mentioned follows from a circumstance, which is difficult to grasp. In all compounds of an element with the *most different* other elements, it always “uses” the same molar mass and all other elements use the same molar mass amongst themselves as with the first. That goes beyond constant and graded proportions of a single combination of elements. The molar mass calculated from a dual combination of elements, if necessary supplemented with small whole numbers, suddenly shows itself applicable over a large range in chemistry for all combinations of elements. We could call this a law of *universal proportions.* An example:

- Sulphur dioxide uses once 32 g and twice 16 g (sulphur respectively oxygen);
- Water uses once 16 g and twice 1 g (oxygen respectively hydrogen);
- Hydrogen sulphide uses once 32 g and twice 1 g (sulphur respectively hydrogen).

The same molar masses apply generally. All proportions in the net of countless combinations fit into this rule. That is the implication of Richter's law (Jeremias Benjamin Richter, 1791). Imagine one compound: its composition is governed by a universal proportion of molar masses of innumerable other combinations of elements; as if only particular mass intervals — i.e. just those of the molar masses — were possible in the universe. We only wanted to produce a shorthand for the mass proportions, however, as if by magic, the element specific 'mass-parcels', initially simply chosen on practical grounds, turn out to be universally applicable for all imaginable pure compounds! Conventionally this is called the law of equivalent proportions[2]. It would be more correctly to speak of the “universality of proportions”, a concept based on a concept; not a fact.

Mysterious properties of the volume of the mole. How did universal wisdom become embedded in our system, initially started spontaneously? Because we calculate theoretically the molar masses for all elements from the same *volume*. As only a few of the elements are gaseous, the others would need to be brought into the gaseous state before being weighed, and then recalculated, using the gas laws, to standard conditions[3]. It would be necessary to heat nearly all elements and bring them in a state of low pressure. That means to bring them out of the current densified earth condition. They have to be thought of as being at a maximum state of rarefaction and at the highest temperature, i.e. in a more cosmic, perhaps an ancient state[4]. By basing ourselves on a single mole volume (or molar-volume) we are as it were connecting with the cosmic origin of substances. Out of that the wisdom-filled universal ratio streams into our system, unthinkingly begun, and makes it successful, because it is universal. Formulas get their natural lawfulness out of a world of warmth and light, as if out of another world, the universe[5].

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2 Hollemann, Wiberg: Lehrbuch der anorganischen Chemie, (1985), p 22; (Diederic Ruarus: see also Partington, General and Inorganic Chemistry, (1946), p 4 ff; and Parkes, G (ed) Mellor's modern inorganic Chemistry (1967), p 63 ff)

3 The so called 2 atomic gasses, such as H_2, O_2, N_2 etc, would also need to be brought, through temperature increase, to give up this earthly heaviness and consolidation softly introducing densification, as exemplified by 2H ---> H_2. They have to be made ´1-atomic' to have the molar volume as indicated by the underlying mole masses.

4 It is possible to circumvent the difficult to achieve gaseous states, particularly through the use of Richter's law and through other measurements of collative properties; people did this with the known system and encircled what couldn't very well be measured. (Collative properties = rising of boiling point, lowering of freezing point, osmotic pressure, vapour pressure and the like).

5 As the discussion ends with the initially nebulous concept “cosmos”, which is neither based on a substance nor on an instruction for measurement, yes, even shouldn't, the willing reader is invited to take something, initially considered a flaw, as a reason for further research. Because the 'open' concept 'cosmos' and `cosmic past´, which leads away from only ordering what is tactile, can generate interest and reverence which make it possible to touch something larger, whole that unites with the origin of humanity and the earth – the only source of effective understanding. In contrast the cool ordering of the world leads, as is well known, only to exploitation of that which is produced rationally. The concept 'cosmos', which cannot be adequately discussed here, is therefore not a flaw, but a gem which it is worth writing this article. Rudolf Steiner describes the source of the above complex, the 'chemical ether' (ether in the sense of the field of formative forces), as a boundary to the endless physical occurrence of changes of substances. It seems that Steiner saw the law of the conservation of elemental masses as the reason for the universal proportions.

Steiner indicates the generation of the chemical ether from the life ether, which manifests itself in permanent differentiated element activity, in Akasha chronic (GA/CW 11, p 113 ff, 1904 – 8/1973); in the Agricultural course the action on earth of the life- and chemical-etheric from the region of the universe of the 'outer' planets, about the reflection by silica (GA/CW 327, lecture II p 30 ff, 1924/1984); in the 2nd medical course the conservation of the element mass (mole-mass in this article; Diederic Ruarus) through the continued existence of etheric substances in the chemical ether, in contrast to the varying chemical turnover (GA/CW 313 lecture II, p 29, 1921/1963).

Atoms as thought models

If one rejects the origin of heat and dilution and insists on having something that doesn't depend upon its surrounding but rather relates centrally to itself (based on simple matter), then one imagines atoms (Dalton). One goes therefore to the opposite position and leaves the world of objects (e.g. that of classic physics). One delves with one's thoughts into "causal" material structures. Daniel Bernoulli's kinetic gas theory from 1738 starts with something of this kind, fully in modern materialistic consciousness in such an ingenious way, drawing on Mariott's empirical gas theory, that one forgets the original fundamental decision.

Keeping the interest of the pupil. It is advantageous not to follow Bernoulli[6], but to introduce the formulas without reverting to a model. Because everything that rests on invisible, but clearly conceptualised but reductionistic entities, turns the initially thinking student off. That is demonstrated by the ongoing powerless bemoaning about the loss of student interest (powerless, as the complaint is reductionistic) at senior High school level, lately described by Hörner and Greiwe: Chemistry – No thank you?[7]

The cult of phenomena. Pupils are only attracted by a thinking based on phenomena: to wit - that engages the pupils to judge for themselves. If we do not swim, as many excellent authors, who are looking for a phenomenological approach, also with our thinking outside the reductionistic frame, then we cannot keep the interest of the pupils over time. For example the following two authors:

Mins Minssen describes the "essential difference between possible goals of a phenomenology of nature and of science: science tries, *in the long run, to banish mysteries from the world,* by reducing them to relations between numbers, structural units and their chains of development.... A phenomenology of nature tries, without adding mystification, to describe an appearance in nature knowing that, in principal, the phenomenon remains more complex than the description, which goes beyond the descriptive powers of the observer." Wender writes about describing a substance: "I let pupils hear how it can mummer and bang, observe how the wonderful colours and forms appear, let them smell how awful or heavenly substances can present themselves, feel how warm and smooth something is, let them taste how acidic and bitter they are. I devote all my attention to making sure that they can really observe and that this becomes a real experience. I notice that their emotional life is engaged through the senses and that in this way they can

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[6] Bernoulli, D. (1700 – 1782) 1738 beginnings of a kinetic theory of gasses

[7] Hörner & Greiwe (2000) chimica didactica 26(1) p 25 & 26 (2000)

participate in the beauty of life, that their morality also develops".[8]

Boundaries to observation only. It should be in the nature of adolescents, that after the richest observation *some form of thinking* occurs. We encounter the deficit of phenomenological aspiring modern chemical didactics. We must - in complete opposition to using models - find the spiritual transition from the nice, separate experience to the whole of living nature and the human.-——Where else can moral freedom come from? Only a personal idea can give force to thinking, because we can nurture it in our inner life, even subscribe to it. In contrast concepts, embedded in a thinking, which as a reductionistic consequence declares molecular processes as epiphenomena of our nervous system and just considers itself to be an impartial registrar of a world inventory independent from itself — a registrar, in which any thrust to cognition is levelled — cannot be worthy of the interest of the adolescent in the long run.

Previous goetheanists. We should add that Frits Julius also extensively discusses and recognises the phenomenal, i.e. the real phenomena underlying the fixture of molar masses in gas volumes[9]. Julius describes the net of universal proportions or, as we say, the universality of the proportions as follows: "When some substances form compounds with each other, the involved mass ratios draw a fragment of this net into our view".

5. Teaching practice

A table of rounded mole-masses of elements (previously so called 'atomic weights', nowadays 'relative atomic weights in gram') enables pupils to manage the following exercise; the relevant formulas of the compounds, which may be calculated at any time from the weight proportions of the elements involved, are given.

— How large is the molar mass of carbon dioxide, formula CO_2? (44 g)

— How much carbon is used to produce 88 g of carbon dioxide? (24 g)

— How much carbon is used to produce 88 g of carbon monoxide? (37.7 g)

If such stoichiometric calculus becomes too complicated and practised too long, one only achieves a separation in emotionally interested pupils, who now drop out, and intellectually capable, who learn to view a passing skill as the essence of chemistry.

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[8] Both quoted from chimica didactica 26(2/3), p 91 resp 92 (2000)

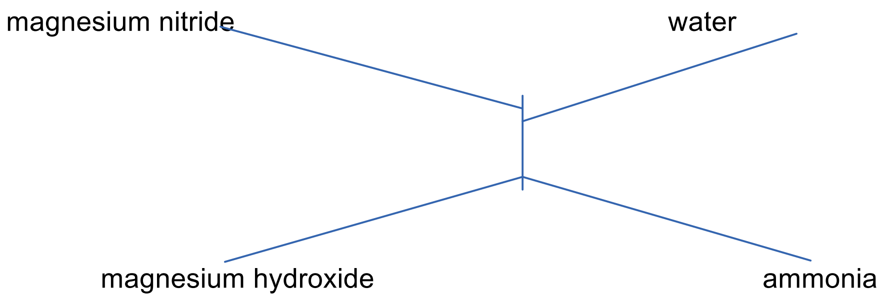
[9] Julius, F. (1965) Grundlagen einer phänomenologischen Chemie, Verlag Freies Geistesleben; English: Fundamentals of a phenomenological study of Chemistry, AWSNA USA (2000)

After writing correct formulas for compounds (CO, CO_2, H_2O) we can now proceed with another result from our discussion of formulas, the possibility to practice precise reaction equations. Having made magnesium nitride and given the formula Mg_3N_2, we can now write

$$3Mg + 2N \text{ -----> } Mg_3N_2$$

Initially we say 'three mole-masses of magnesium', not 'three magnesium' or 'three Mg'. Mg is thus not a general abbreviation for magnesium. Because Mg doesn't mean 'substance of the sort magnesium', but '24 g magnesium'. The same applies for example to carbon dioxide, which I in general abbreviate with 'Kd' and not by CO_2, copper with 'Ku'[10] etc. Universal abbreviations seem to automate cognition: however they also repress cognition by subjugating the concrete – therefore the use of Kd and Ku which are not theory laden.

What happens when we let the nitride react with water? We start by writing a reaction scheme. From the nature of the substances we have deduced that the gaseous reaction product is most likely to be a nitrogen compound, the mineral solid residue is a metal compound. The combustibility of magnesium, which in the case of the nitride has only partially been spent (mild glowing instead of a bright burning as with oxygen), transforms into the gaseous compound, i.e. a hydrogen compound, which further experiments show to be combustible. We therefore restrict substance to:



After the formulas NH_3 and $Mg(OH)_2$ have been given, the students can write

$$Mg_3N_2 + 6\,H_2O \longrightarrow 2\,NH_3 + 3\,Mg(OH)_2$$

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[10] In German carbon dioxide is Kohlendioxid or Kd, a non existing chemical abbreviation; Copper in German is Kupfer, which abbreviates to Ku.

The principle followed here is: 'that we don't miss out on even one', because of the element masses being constant, all the letters on the left must equal those on the right. This principle allows us to write unknown reaction equations just by using the formulas; for example 24 g of carbon have consumed 48 g of oxygen, what kind of gas will come about? Using what we have learnt and knowing of the possibility of carbon monoxide, we can write:

$$2\,C + 3\,O \text{ --------->} CO_2 + CO$$

Indeed, (poisonous) carbon monoxide is also formed, which we have 'discovered' by writing our reaction equation — a triumph of using formulas.

Before we continue with looking at the way the reaction proceeds (the so called reaction equations) as depicted in formulas, what we can predict or after the event can understand, we look once more at the advantages and dangers the single formula can have for cognition (as started above on page 4). Take CO_2 for example. We have a heavy gas, catch 44 g in a container and call this proportion CO_2. What do we know from that?

1. The proportion is given with the formula CO_2: for every 12 g of carbon 32 g of oxygen are used. These amounts, even if in a roundabout way, have been used; and just by these substances and none others!
2. When carbon dioxide loses carbon or oxygen, i.e. when it disappears, only carbon and oxygen are produced (often caught in new compounds) in the original amounts, and nothing else.

The formula thus presents an unambiguous past and a certain future. What does it tell us about the present?

3. The formula of the substances forces you to think that to be an addition; as if carbon dioxide were active and stimulating (exiting, rousing), water explosive and rust weldable. The depicted elements are either only past or only future, not the present! That there is something new now makes life and change on earth possible. The formula negates this. Cognition blocks itself right there, nicely said: a disadvantage of the formula.

4. However, something of the element combination remains a reality in the present: and that is the mass. Its conservation suggests a continuation of the components; with respect to change mass has nothing to say. It is only conserved.

5. There is something else of the elements which remains in the present: the propensity for qualities. The qualities are gone, but some return changed, more for a qualitative thinking than as measurable data. Solely as tendencies, inclinations, only accessible to a phenomenological overview. But these inclinations do order nature.

We thus have four advantages and only one, but a very seductive disadvantage (above #3). If one succumbs to this disadvantage, i.e. the assumption of a physical continuing existence of the elements in the compound — and it is nowadays difficult to disregard this —, we then subsequently need to ask: How do the dispersing elements hold together? And if the elements are simply there why don't we see them in the compound? This last question leads to the 'most fine dispersion' as atomic granulation, this leads initially to a theory of bonding, to the electrons. The decisive searches for models in modern chemistry have their origins in the problems related to the formulas; which is only one variant of the problems associated with materialism.

We could interject: “Let’s keep materialism, if it does us such a lot of good and has built the whole impressive edifice of modern chemistry”. However, we don't reach the pupils! And what's happening with nature, the environment; with the health of our children which is declining continuously? - These comments are from the field, from practice and as such are unscientific.

However, initial understanding and education start from basic experiences. Based on an original understanding of the phenomena, they seek to demonstrate comprehensive relationships, without postulating from the start such a comprehensive relationship, which is embedded in particles. It is possible, based on life and related to humans to find such relationships, if we are prepared to extend observation beyond the external maintenance of substance. Of course we cannot immediately dismiss the 200 years since Dalton. But it is sufficient if we in the first instance focus on the advantages 1, 2 and 5 above, leave the rest (the whole model work) behind; at any rate for class 11. — Let us turn our attention to an old problem, to that of valency. How does one solve this without electrons?

6. Oxidative and reductive valency

A first suspicion of valency. When formulating the reaction (setting up the reaction equation) — as mentioned above — the number of letters (symbols) is the same on the left and right, i.e.

$$3\,CuO + 2\,NH_3 \text{ -------> } 3\,Cu + 3\,H_2O + 2\,N$$

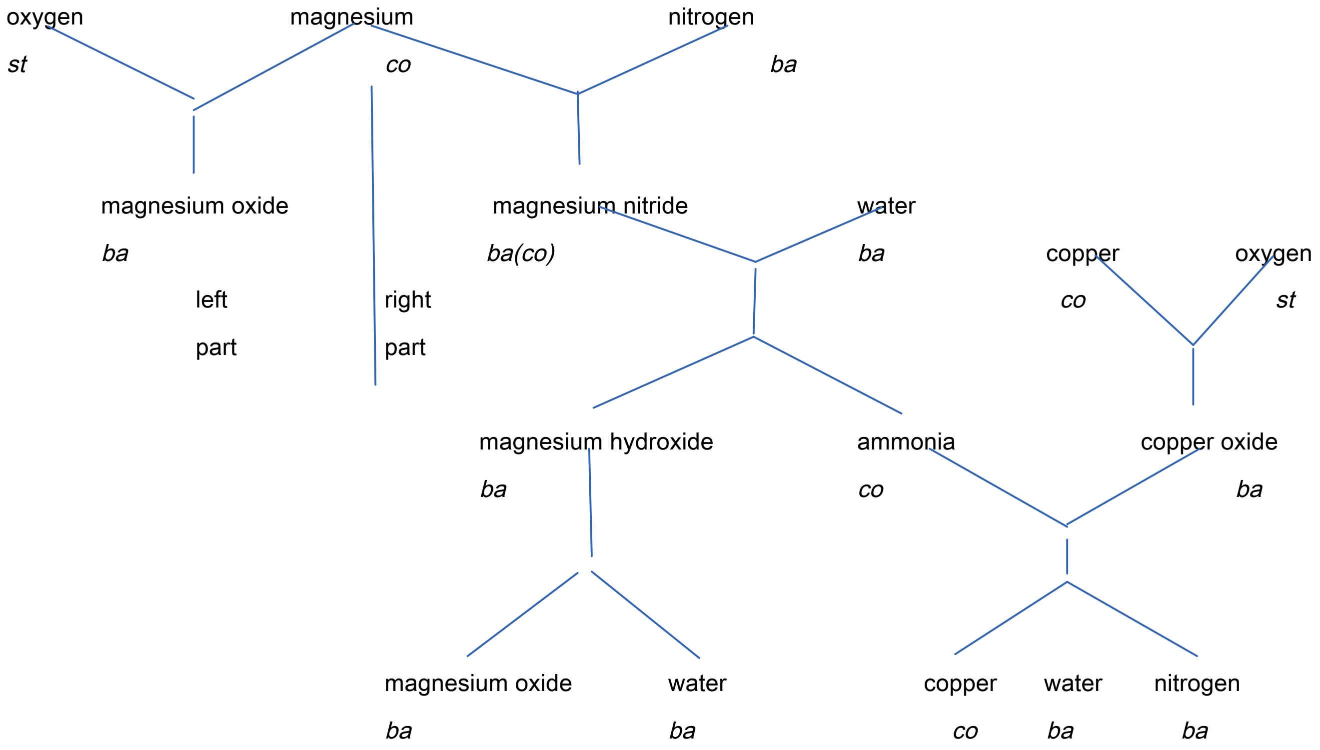
In teaching one can initially use a table, such as the following, for complicated reaction equations:

symbol	numbers left	numbers right
Cu	3	3
O	3	3
H	6	6
N	2	2

Even if the students use this sort of table, it remains unsatisfactory for them that they must be given the formulas. You can point out that these can always be derived from precise weightings (measurements of weight). However the students notice that the teacher not only knows the results of previous weightings, but also that he derives the small whole numbers form an element specific stock of numbers, which he, because he is an expert, knows about. The stock contains 'valencies'.

Stepped proportions, stepped properties. The valency describes the steps by which elements participate in the stream of transformation of the others. An element is not only determined by numbers or quantities but also shows qualitative grades, for example bivalent iron; one finds a unique, typical complex of tendencies to certain properties (see above point 5). If one changes the valency, then a new related complex arises, a new force effective in nature. Therefore the valencies have to be drawn from pathways of qualitative change of matter in nature rather than from imagined numbers of electrons, that are only based on systems of physical measurements and the reification of quantities.

The Polarity of forces of transformation. Firstly one has to explain qualitatively, drawing on the natural impulses of the reactions, that there are two transformational directions, oxidation and reduction. These are forces of open nature, of the emerging and decaying of living organisms and their materials. We observe a tableau of schemas of the linked reactions (that were demonstrated over several days):



combustible = *co*

stimulate (fuel, inflame, foment) = *st*

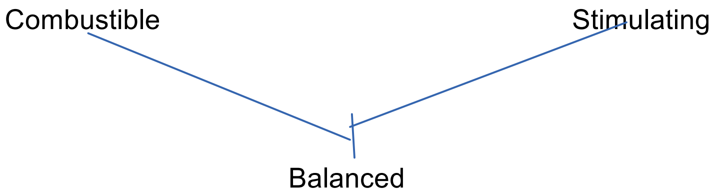
balanced = *ba*

Students recognise amongst other things that the result of magnesium's transformation in the left part is the same as in the right part, as all other substances on the right appear as they were used (water in 2 parts).

Which forces are involved in the reactions? We need to state firstly that producing magnesium is an act of violence: magnesium oxide and carbon have to be heated to 1800°C and then the magnesium vaporises.

Imponderables as driving forces. The imponderables of carbon, i.e. the all moving force, which in the end derives from the universe, is impressed forcibly on magnesia (magnesium oxide), while carbon is being converted to its highest state of oxidation through the intense heat. The imponderables, or more precisely, the disposition of a substance to bring actions of imponderables to the fore is the driving force for all changes on earth from the universe (sun, planetary system); it continuously brings forth life and chemistry. In the end, the idea of imponderables suggests ways of understanding how the universe works.

Combustible and stimulating. In school the descriptive part of the idea of imponderables has its place. We can divide substances as: *combustible, stimulating* and *balanced:*



These qualities have been inserted in the previous scheme in *italics.* We see that nitrogen is forced into the role of stimulator: through the extraordinary combustibility of magnesium. It therefore is not adequately balanced, because nitrogen doesn't have any balancing qualities. The uncompensated combustibility emerges in a repressed form in ammonia, it maintains itself even in copper (last reaction), because that is fairly oxidisable. We learn that it depends on the conditions and the partner in the reaction, if a combustible or stimulating property is used, i.e. in which direction a substance, in this case nitrogen, is pushed. Everything is interchangeable with everything else, nothing stands on its own. (In reductionistic chemistry that is expressed in the table of redox potentials).

Oxidation and reduction. We don't need to show how students now train in the use of the conventional statements “no oxidation without reduction” (= no disappearance of combustibility without disappearance of stimulation) and “the oxidiser is reduced and the reducer is oxidised” etc. from many examples. The expression 'redox reaction' will then become familiar and obvious. Examples of such substances are:

Combustible substances	**Stimulating substances**
Wood, straw, hay	Air, oxygen
Resin, wax, oil	Nitrate, chromate, permanganate
Carbon (coal), peat, tar	Oxides of: lead(II), lead (IV), manganese; sodium peroxide
Oil, asphalt, natural gas	Chlorine, Bromine, nitric acid
Alcohols, sugar,	under certain conditions sulphate,
aromatic liquids	carbonate

A concept, related to the large number of substances, to the totality of nature, even in regard to the openness of the earth to the universe, such as combustibility and giving off imponderables replaces a concept of losing electrons — a goethean turn, which can free us from an underlying pressure and ultimately from naïve realistic mental images.

Twofold valencies. Once we've developed a qualitative notion of redox forces we can quickly order the valencies. The reductive valency of hydrogen is set to +1. In hydrochloric acid hydrogen (here and always) has the reductive valency of 1 (it acts as a reductor), chlorine of course the oxidative valency of also 1, but negative; in shorthand:

H: +1 Cl: -1

It is now possible to determine the valency as oxidation (+) or reduction (-) number (read x= times):

2x1,-2	2x1,6,4x-2	2x3, 3x-2	2, -2	2, (5,3x-2)x2	
H_2S	H_2SO_4	Fe_2O_3	FeS	$Cu(NO_3)_2$	etc.

[Diederic Ruarus: I find the above not very obvious, and you do need to know the oxidation numbers; these can be deduced much easier using the mole concept.

1. *Oxidation can be defined as a reaction of an element with oxygen (or in von Mackensens terminology with stimulating agencies);*

2. *the reaction:*

hydrogen	*+*	*oxygen*	*----->*	*water*
$2\ H_2$		O_2		$2\ H_2O$
2 mole-masses		*1 mole-mass*		*2 mole-masses*

2 moles H <-------> 1 mole O

and by consensus hydrogen has the valency +1 (or the oxidative valency) and oxygen has the valency -2 (or the reductive valency -2)]

Every change of valency (elements have valency 0) is a redox reaction. Writing redox-reactions will probably start in class 12 with exercises to train the students to become competent. Initially the following statement may be helpful: Hydrogen and hydrogen representatives have the valency +1, their partners, when they react with 1 mole, have the valency -1; oxygen and its representatives have valency -2. It is incumbent on the chemist and to some degree on the students too, to memorise the most occurring valencies of the elements.

What expresses itself in the valency? A derivation of the valencies from physical data (spectroscopy) from quantum values is initially beyond the scope of a general introductory chemistry curriculum to attain the necessary level of knowledge to judge. However, the origin of the valencies can be shown as follows phenomenologically. Hydrogen, as the element with the smallest specific gravity and the lowest temperature of condensation signifies, for all practical purposes, a permanent gas and the transition between the earth atmosphere and outer space, where it is found as a gas fleeing the earth. As such it is furthest removed from terrestrial qualities like solidification and weight. Amongst other things that is expressed in its very small mole-mass. Significantly it has the smallest valency. With the other elements substantiality increases, the mole-masses increase. Then the influence of the earth acts; ever more valency states come about. In particular with respect to oxygen, the element which doesn't flee the earth, rather a binding, mineralising element, it even has valency eight when reacting with the heaviest elements (osmiumtetraoxide). In that light the sequence of elements in a period with their increasing oxidative valency is a pathway of increasing compound forming, a submerging of one substance into another (and an increasing openness of a substance for another).

Whereto with the periodic system? From a phenomenological point of view the periodic system can only be introduced as a system of diversification and valency. We only need to remind ourselves that the much highlighted similarity of properties between elements of a group already with the showcases at the outer wings of the system (Na/K and Cl/Br), are absent in life processes. However tempting a periodic ordering of the elements on the principle of mole-masses may seem, so difficult is the interpretation based on the physical manner of measuring, taking the level of knowledge of the students into account; not to mention the overloading with all the presented elements. It is better to forget the periodic table (system) or just to mention it in passing.

7. What is achievable?

Conclusion. The students know: the initials of an element represent a mass, which has been determined skilfully for each element. In the case of gaseous elements the mole-masses have the same volume. However that is already taken into account when setting the mole-masses, the students only need to think of masses when they write formulas. Initially all formula intricacies can be restricted to this. — Do they have to?

Goetheanism as a professional advantage. Everything calls for formal education, scientific reductionism, abstraction: “Internet in the Kindergarten” — because of assumed advantages for later work life. However, these sorts of jobs are not available for many, 80% must do something else. Phenomenological chemistry qualifies people to take leading roles in agriculture, natural medicine and pharmaceutical industry, nutrition and health, environment and natural history, in industries such as the textile industry, the production of cleaning materials, dyes, building materials and many others. That will be the future task for part of the workforce, there, where mainstream sciences fail.

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The Agriculture Course

GA 327

Agriculture Course: Lecture 3

Lecture Three

KOBERWITZ,
***11th June*, 1924.**

MY DEAR FRIENDS,

The earthly and cosmic forces, of which I have spoken, work in the farm through the substances of the Earth, needless to say. In the next lectures we shall pass on to various practical aspects, but before we can do so we must enter a little more precisely into the question: How do these forces work through the substances of the Earth? In the present lecture we shall consider Nature's activity quite generally speaking.

One of the most important questions in agriculture is that of the significance of *nitrogen* — its influence in all farm-production. This is generally recognised; nevertheless the question, what is the essence of nitrogen's activity, has fallen into great confusion nowadays. Wherever nitrogen is active, men only recognise, as it were, the last excrescence of its activities — the most superficial aspects in which it finds expression. They do not penetrate to the relationships of Nature wherein nitrogen is working, nor can they do so, so long as they remain within restricted spheres. We must look out into the wide spaces, into the wider aspects of Nature, and study the activities of nitrogen in the Universe as a whole. We might even say — and this indeed will presently emerge — that nitrogen as such does not play the first and foremost part in the life of plants. Nevertheless, to understand plant-life it is of the first importance for us to learn to know the part which nitrogen does play.

Nitrogen, as she works in the life of Nature, has so to speak four sisters, whose working we must learn to know at the same time if we would understand the functions and significance of nitrogen herself in Nature's so-called household. The four sisters of nitrogen are those that are united with her in plant and animal protein, in a way that is not yet clear to the outer science of to-day. I mean the four sisters, carbon, oxygen, hydrogen and sulphur.

To know the full significance of protein it will not suffice us to enumerate as its main ingredients hydrogen, oxygen, nitrogen and carbon. We must include another substance, of the profoundest importance for protein, and that is sulphur. Sulphur in protein is the very element which acts as mediator between the Spiritual that is spread throughout the Universe — the formative power of the Spiritual — and the physical.

Truly we may say, whoever would trace the tracks which the Spiritual marks out in the material world, must follow the activity of sulphur. Though this activity appears less obvious than that of other substances, nevertheless it is of great importance; for it is along the paths of sulphur that the Spiritual works into the physical domain of Nature. Sulphur is actually the carrier of the Spiritual. Hence the ancient name, "*sulphur*," which is closely akin to the name "*phosphorus*." The name is due to the fact that in olden time they recognised in the out-spreading, sun-filled light, the Spiritual itself as it spreads far and wide. Therefore they named "light-bearers" these substances — like sulphur and phosphorus — which have to do with the working of light into matter.

Seeing that sulphur's activity in the economy of Nature is so very fine and delicate, we shall, however, best approach it by first considering the four other sisters: carbon, hydrogen, nitrogen and oxygen. These we must first learn to understand; we shall see what they signify in the whole being of the Universe. The chemist of to-day knows little of these substances. He knows what they look like when he has them in his laboratory, but he knows practically nothing of their inner significance in the working of the Cosmos as a whole. The knowledge of modern chemistry about them is scarcely more than our knowledge of a man of whose outer form we caught a glimpse as we passed by him in the street — or maybe we took a snapshot of him, and with the help of the photograph we can now call him to mind. We must learn to know the deeper essence of these substances. What science does is scarcely more than to take snapshots of them with a camera. All that is said of them in scientific books and lectures is scarcely more than that.

Let us begin with *carbon*. (The application of these matters to plant-life will presently emerge). Carbon indeed has fallen in our time from a highly aristocratic status to a very plebeian one. Alas, how many other beings of the Universe have followed it along the same sad way! What do we see in carbon nowadays? That which we use, as coal, to heat our ovens! That which we use, as graphite, for our writing. True, we still assign an aristocratic value to one modification of carbon, namely diamond, but we have little opportunity to value even that, for we can no longer afford to buy it!

What is known about carbon nowadays is very little when you consider its infinite significance in the Universe. The time is not so very long ago — only a few centuries — when this black fellow, carbon, was so highly esteemed as to be called by a very noble name. They called it the Stone of the Wise — the *Philosopher's Stone*. There has been much chatter es to what the "Stone of the Wise" may be. Very little has emerged from it. When the old alchemists and such people spoke of the Stone of the Wise, they meant carbon — in the various modifications in which it occurs. They held the name so secret and occult, only because if they had not done so, anyone and everyone would have possessed it — for it was only carbon. Why then was carbon the "Stone of the Wise?"

Here we can answer, with an idea from olden time, a point we need to understand again in our time when speaking about carbon. It is quite true, carbon occurs to-day in Nature in a broken, crumbled form, as coal or even graphite — broken and crumbled, owing to certain processes which it has undergone. How different it appears, however, when we perceive it in its living activity, passing through the human or animal body, or building up the plant-body out of its peculiar conditions. Then the amorphous, formless substance which we see as coal or carbon proves to be only the last excrescence — the corpse of that which coal or carbon truly is in Nature's household.

Carbon, in effect, is the bearer of all the creatively formative processes in Nature. Whatever in Nature is formed and shaped be it the form of the plant persisting for a comparatively short time, or the eternally changing configuration of the animal body — carbon is everywhere the great plastician. It does not only carry in itself its black substantiality. Wherever we find it in full action and inner mobility, it bears within it the creative and formative cosmic pictures — the sublime cosmic Imaginations, out of which all that is formed in Nature must ultimately proceed.

There is a hidden plastic artist in carbon, and this plastician building the manifold forms that are built up in Nature — makes use of sulphur in the process. Truly to see the carbon as it works in Nature, we must behold the Spirit-activity of the great Universe, moistening itself so-to-speak with sulphur, and working as a plastic artist — building with the help of carbon the more firm and well-defined form of the plant, or again, building the form in man, which passes away again the very moment it comes into being.

For it is thus that man is not plant, but man. He has the faculty, time and again to destroy the form as soon as it arises; for he excretes the carbon, bound to the oxygen, as *carbonic acid*. Carbon in the human body would form us too stiffly and firmly — it would stiffen our form like a palm. Carbon is constantly about to make us still and firm in this way, and for this very reason our breathing must constantly dismantle what the carbon builds. Our breathing tears the carbon out of its rigidity, unites it with the oxygen and carries it outward. So we are formed in the mobility which we as human beings need. In plants, the carbon is present in a very different way. To a certain degree it is fastened — even in annual plants — in firm configuration.

There is an old saying in respect of man: "Blood is a very special fluid" — and we can truly say: the human Ego, pulsating in the blood, finds there its physical expression. More accurately speaking, however, it is in the carbon — weaving and wielding, forming itself, dissolving the form again. It is on the paths of this carbon — moistened with sulphur — that that spiritual Being which we call the Ego of man moves through the blood. And as the human Ego — the essential Spirit of man — lives in the carbon, so in a manner of speaking the Ego of the Universe lives as the Spirit of the Universe — lives via the sulphur in the carbon as it forms itself and ever again dissolves the form.

In bygone epochs of Earth-evolution carbon alone was deposited or precipitated. Only at a later stage was there added to it, for example, the limestone nature which man makes use of to create something more solid as a basis and support — a solid scaffolding for his existence. Precisely in order to enable what is living in the carbon to remain in perpetual movement, man creates an underlying framework in his limestone-bony skeleton. So does the animal, at any rate the higher animal. Thus, in his ever-mobile carbon-formative process, man lifts himself out of the merely mineral and rigid limestone-formation which the Earth possesses and which he too incorporates in order to have some solid Earth within him. For in the limestone form of the skeleton he has the solid Earth within him.

So you can have the following idea. Underlying all living things is a carbon-like scaffolding or framework — more or less rigid or fluctuating as the case may be — and along the paths of this framework the Spiritual moves through the World. Let me now make a drawing (purely diagrammatic) so that we have it before us visibly and graphically. **(Diagram 6)**. I will here draw a scaffolding or framework such as the Spirit builds, working always with the help of sulphur. This, therefore, is either the ever-changing carbon constantly moving in the sulphur, in its very fine dilution — or, as in plants, it is a carbon-frame-work more or less hard and fast, having become solidified, mingled with other ingredients.

Now whether it be man or any other living being, the living being must always be permeated by an *ethereal* — for the ethereal is the true bearer of life, as we have often emphasised. This, therefore, which represents the carbonaceous framework of a living entity, must in its turn be permeated by an ethereal. The latter will either stay still — holding fast to the beams of the framework — or it will also be involved in more or less fluctuating movement. In either case, the ethereal must be spread out, wherever the framework is. Once more, there must be something ethereal wherever the framework is. Now this ethereal, if it remained alone, could certainly not exist as such within our physical and earthly world. It would, so to speak, always slide through into the empty void. It could not hold what it must take hold of in the physical, earthly world, if it had not a physical carrier.

This, after all, is the peculiarity of all that we have on Earth: the Spiritual here must always have physical carriers. Then the materialists come, and take only the physical carrier into account, forgetting the Spiritual which it carries. And they are always in the right — for the first thing that meets us is the physical carrier. They only leave out of account that it is the *Spiritual* which must have a physical carrier everywhere.

What then is the physical carrier of that Spiritual which works in the ethereal? (For we may say, the ethereal represents the lowest kind of spiritual working). What is the physical carrier which is so permeated by the ethereal that the ethereal, moistened once more with sulphur, brings into it what it has to carry — not in Formation this time, not in the building of the framework — but in eternal quickness and mobility into the midst of the framework? This physical element which with the help of sulphur carries the influences of life out of the universal ether into the physical, is none other than *oxygen*. I have sketched it here in green. if you regard it physically, it represents the oxygen. It is the weaving, vibrant and pulsating essence that moves along the paths of the oxygen. For the ethereal moves with the help of sulphur along the paths of oxygen.

Only now does the *breathing* process reveal its meaning. In breathing we absorb the oxygen. A modern materialist will only speak of oxygen such as he has in his retort when he accomplishes, say, an electrolysis of water. But in this oxygen the lowest of the supersensible, that is the ethereal, is living — unless indeed it has been killed or driven out, as it must be in the air we have around us. In the air of our breathing the living quality is killed, is driven out, for the living oxygen would make us faint Whenever anything more highly living enters into us we become faint. Even an ordinary hypertrophy of growth — if it occurs at a place where it ought not to occur — will make us faint, nay even more than faint. If we were surrounded by living air in which the living oxygen were present, we should go about stunned and benumbed. The oxygen around us must be killed. Nevertheless, by virtue of its native essence it is the bearer of life — that is, of the ethereal. And it becomes the bearer of life the moment it escapes from the sphere of those tasks which are allotted to it inasmuch as it surrounds the human being outwardly, around the senses. As soon as it enters into us through our breathing it becomes alive again. Inside us it must be alive.

Circulating inside us, the oxygen is not the same as it is where it surrounds us externally. Within us, it is living oxygen, and in like manner it becomes living oxygen the moment it passes, from the atmosphere we breathe, into the soil of the Earth. Albeit it is not so highly living there as it is in us and in the animals, nevertheless, there too it becomes *living oxygen*. Oxygen under the earth is not the same as oxygen above the earth.

It is difficult to come to an understanding an these matters which the physicists and chemists, for — by the methods they apply — from the very outset the oxygen must always be drawn *out* of the earth realm; hence they can only have dead oxygen before them. There is no other possibility for them. That is the fate of every science that only considers the physical. It can only understand the corpse. In reality, oxygen is the bearer of the living ether, and the living ether holds sway in it by using sulphur as its way of access.

But we must now go farther. I have placed two things side by side; on the one hand the carbon framework, wherein are manifested the workings of the highest spiritual essence which is accessible to us on Earth: the human Ego, or the cosmic spiritual Being which is working in the plants. Observe the human process: we have the breathing before us — the living oxygen as it occurs inside the human being, the living oxygen carrying the ether. And in the background we have the carbon-framework, which in the human being is in perpetual movement. These two must come together. The oxygen must somehow find its way along the paths mapped out by the framework. Wherever any line, or the like, is drawn by the carbon — by the spirit of the carbon — whether in man or anywhere in Nature there the ethereal oxygen-principle must somehow find its way. It must find access to the spiritual carbon-principle. Flow does it do so? Where is the mediator in this process?

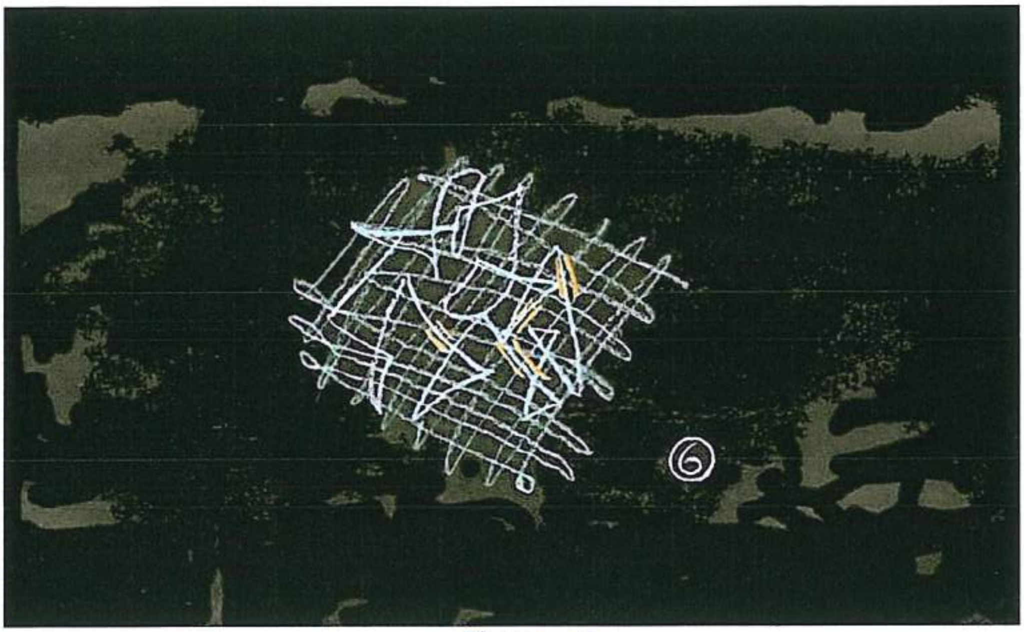

Figure 6

The mediator is none other than *nitrogen.* Nitrogen guides the *life* into the *form* or configuration which is embodied in the carbon. Wherever nitrogen occurs, its task is to mediate between the life and the spiritual essence which to begin with is in the carbon-nature. Everywhere — in the animal kingdom and in the plant and even in the Earth — the bridge between carbon and oxygen is built by nitrogen. And the spirituality which — once again with the help of sulphur is working thus in nitrogen, is that which we are wont to describe as the *astral.* It is the astral spirituality in the human astral body. It is the astral spirituality in the Earth's environment. For as you know, there too the astral is working — in the life of plants and animals, and so on.

Thus, spiritually speaking we have the astral placed between the oxygen and the carbon, and this astral impresses itself upon the physical by making use of nitrogen. Nitrogen enables it to work physically. Wherever nitrogen is, thither the astral extends. The ethereal principle of life would flow away everywhere like a cloud, it would take no account of the carbon-framework were it not for the nitrogen. The nitrogen has an immense power of attraction for the carbon-framework. Wherever the lines are traced and the paths mapped out in the carbon, thither the nitrogen carries the oxygen — thither the astral in the nitrogen drags the ethereal.

Nitrogen is for ever dragging the living to the spiritual principle. Therefore, in man, nitrogen is so essential to the life of the soul. For the soul itself is the mediator between the Spirit and the mere principle of life. Truly, this nitrogen is a most wonderful thing. If we could trace its paths in the human organism, we should perceive in it once more a complete human being. This "nitrogen-man" actually exists. If we could peal him out of the body he would be the finest ghost you could imagine. For the nitrogen-man imitates to perfection whatever is there in the solid human framework, while on the other hand it flows perpetually into the element of life.

Now you can see into the human breathing process. Through it man receives into himself the oxygen — that is, the ethereal life. Then comes the internal nitrogen, and carries the oxygen everywhere — wherever there is carbon, *i.e.*, wherever there is something formed and figured, albeit in everlasting change and movement. Thither the nitrogen carries the oxygen, so that it may fetch the carbon and get rid of it. Nitrogen is the real mediator, for the oxygen to be turned into carbonic acid and so to be breathed out.

This nitrogen surrounds us on all hands. As you know, we have around us only a small proportion of oxygen, which is the bearer of life, and a far larger proportion of nitrogen—the bearer of the astral spirit. By day we have great need of the oxygen, and by night too we need this oxygen in our environment. But we pay far less attention, whether by day or by night, to the nitrogen. We imagine that we are less in need of it—I mean now the nitrogen in the air we breathe. But it is precisely the nitrogen which has a spiritual relation to us. You might undertake the following experiment.

Put a human being in a given space filled with air, and then remove a small quantity of nitrogen from the air that fills the space, thus making the air around him slightly poorer in nitrogen than it is in normal life. If the experiment could be done carefully enough, you would convince yourselves that the nitrogen is immediately replaced. If not from without, then, as you could prove, it would be replaced from *within* the human being. He himself would have to give it off, in order to bring it back again into that quantitative condition to which, as nitrogen, it is accustomed. As human beings we must establish the right percentage-relationship between our whole inner nature and the nitrogen that surrounds us. It will not do for the nitrogen around us to be decreased. True, in a certain Sense it would still suffice us. We do not actually need to breathe nitrogen. But for the spiritual relation, which is no less a reality, only the quantity of nitrogen to which we are accustomed in the air is right and proper. You see from this how strongly nitrogen plays over into the spiritual realm.

At this point I think you will have a true idea, of the necessity of nitrogen for the life of plants. The plant as it stands before us in the soul has only a physical and an ether-body; unlike the animal, it has not an astral body within it. Nevertheless, outside it the astral must be there on all hands. The plant would never blossom if the astral did not touch it from outside. Though it does not absorb it (as man and the animals do) nevertheless, the plant must be touched by the astral from outside. The astral is everywhere, and nitrogen itself — the bearer of the astral — is everywhere, moving about as a corpse in the air. But the moment it comes into the Earth, it is alive again. Just as the oxygen does, so too the nitrogen becomes alive; nay more it becomes sentient and sensitive inside the Earth. Strange as it may sound to the materialist madcaps of to-day, nitrogen not only becomes alive but *sensitive* inside the Earth; and this is of the greatest importance for agriculture. Nitrogen becomes the bearer of that mysterious sensitiveness which is poured out over the whole life of the Earth.

It is the nitrogen which senses whether there is the proper quantity of water in a given district of the Earth. If so, it has a sympathetic feeling. If there is too little water, it has a feeling of antipathy. It has a sympathetic feeling if the right plants are there for the given soil. In a word, nitrogen pours out over all things a kind of sensitive life. And above all, you will remember what I told you yesterday and in the previous lectures: how the planets, Saturn, Sun, Moon, etc., have an influence an the formation and life of plants. You might say, nobody knows of that! It is quite true, for ordinary life you can say so. Nobody knows! But the nitrogen that is everywhere present — the nitrogen knows very well indeed, and knows it quite correctly. Nitrogen is not unconscious of that which comes from the Stars and works itself out in the life of plants, in tim life of Earth. Nitrogen is the sensitive mediator, even as in our human nerves-and-senses system it is the nitrogen which mediates for our sensation. Nitrogen is verily *the bearer of sensation*. So you can penetrate into the intimate life of Nature if you can see the nitrogen everywhere, moving about like flowing, fluctuating feelings. We shall find the Treatment of nitrogen, above all, infinitely important for the life of plants. These things we shall enter into later. Now, however, one thing more is necessary.

You have seen how there is a living interplay. On the one hand there is that which works out of the Spirit in the *carbon-principle*, taking an forms as of a scaffolding or framework. This is in constant interplay with what works out of the astral in the *nitrogen-principle*, permeating the framework with inner life, making it sentient. And in all this, life itself is working through the *oxygen-principle*. But these things can only work together in the earthly realm inasmuch as it is permeated by yet another principle, which for our physical world establishes the connection with the wide spaces of the Cosmos.

For earthly life it is impossible that the Earth should wander through the Cosmos as a solid thing, separate from the surrounding Universe. If the Earth did so, it would be like a man who lived on a farm but wanted to remain independent, leaving outside him all is growing in the fields. If he is sensible, he will not do so! There are many things out in the fields to-day, which in the near future will be in the stomachs of this honoured company, and — thence in one way or another — it will find its way back again on to the fields. As human beings we cannot truly say that we are separate. We cannot sever ourselves. We are united with our surroundings — we belong to our environment. As my little finger belongs to me, so do the things that are around us naturally belong to the whole human being. There must be constant interchange of substance, and so it must be between the Earth — with all its creatures —and the entire Universe. All that is living in physical forms upon the Earth must eventually be led back again into the great Universe. It must be able to be purified and cleansed, so to speak, in the universal All. So now we have the following:—

To begin with, we have what I sketched before in blue **(Diagram 6)**, the carbon-framework. Then there is that which you see here the green—the ethereal, oxygen principle. And then — everywhere emerging from the oxygen, carried by nitrogen to all these lines there is that which develops as the astral, as the transition between the carbonaceous and the oxygen principle. I could show you everywhere, how the nitrogen carries into these blue lines what is indicated diagrammatically in the green.

But now, all that is thus developed in the living creature, structurally as in a fine and delicate design, must eventually be able to vanish again. It is not the Spirit that vanishes, but that which the Spirit has built into the carbon, drawing the life to itself out of the oxygen as it does so. This must be able once more to disappear. Not only in the sense that it vanishes on Earth; it must be able to vanish *into the Cosmos*, into the universal All.

This is achieved by a substance which is as nearly as possible akin to the physical and yet again as nearly akin to the spiritualand that is *hydrogen*. Truly, in hydrogen — although it is itself the finest of physical elements — the physical flows outward, utterly broken and scattered, and carried once more by the sulphur out into the void, into the indistinguishable realms of the Cosmos.

We may describe the process thus: In all these structures, the Spiritual has become physical. There it is living in the body astrally, there it is living in its image, as the Spirit or the Ego — living in a physical way as Spirit transmuted into the physical. After a time, however, it no longer feels comfortable there. It wants to dissolve again. And now once more — moistening itself with sulphur — it needs a substance wherein it can take its leave of all structure and definition, and find its way outward into the undefined chaos of the universal All, where there is nothing more of this organisation or that.

Now the substance which is so near to the Spiritual an the one hand and to the substantial on the other, is hydrogen. Hydrogen carries out again into the far spaces of the Universe all that is *formed*, and *alive*, and *astral*. Hydrogen carries it upward and outward, till it becomes of such a nature that it can be received out of the Universe once more, as we described above. It is hydrogen which dissolves everything away.

So then we have these five substances. They, to begin with, represent what works and weaves in the living — and in the apparently dead, which after all is only transiently dead. Sulphur, carbon, hydrogen, oxygen, nitrogen: each of these materials is inwardly related to a specific spiritual principle. They are therefore very different from what our modern chemists would relate. Our chemists speak only of the corpses of the substances — not of the real substances, which we must rather learn to know as sentient and living entities, with the single exception of hydrogen. Precisely because hydrogen is apparently the thinnest element — with the least atomic weight —it is really the least spiritual of all.

Formic acid and oxalic acid

Manfred von Mackensen, 2003

The ‘alchemist experiment’

As we have seen formic acid and oxalic acid represent major processes that occur both in nature and in living organisms. In both cases there are similar processes, though at different levels. In nature and in human beings there are constant transition processes between these levels and between these substances. One of these can be carried out in the laboratory. These processes were understood by the alchemists as having to do with healing processes in the human being and were therefore revered. Oxalic acid is thereby transformed into the next higher form of formic acid. If one wants to create an appropriate mood through outer factors one can use a medieval retort in which oxalic acid is slowly and moderately heated in glycerine. Formic acid forms in fluid form and carbon dioxide is given off (experiment 3).

In the lectures previously referred to, Steiner describes this chemical reaction as ‘total mirroring’ of that ‘which can be experienced as living’, not only in human beings but also ‘in the life and activity of nature’ (e.g. in plants and insects).

What does the term ‘mirroring’ tell us? In a mirror we see the external situation similar to the original, though the perspective is reversed. Every is also reduced - we can’t grasp it with our hands, but rather bump into the mirror, that is, all sense impressions are reduced to the sense of sight. If one considers these aspects, then one can engage further with Steiner’s suggestions that in this lab experiment we have a picture of inner processes in the human body (digestion and lungs), as everywhere in nature (decaying wood and insect life). Everywhere the emergence of these two acids is the precondition for that, which we call life and health.

Formic acid in chemical comparison

Just as we have used the comparison of oxalic acid with citric acid in order to make their appearance as clear as possible, so we can place another acid – that also arises from life transformations and that can also become perceptible outside of natural beings – alongside formic acid: acetic acid, which emerges at the end of the sweet fermentation process.

Acetic acid, like formic acid is a clear, water-like liquid that can be mixed with water but is hard to dehydrate. When cold it cannot be ignited and only burns when heated. It gives off a smell even when cold but is not as overwhelming and acrid as formic acid, being somewhat more penetratingly aromatic. Both acids taste, when diluted in water, strongly sour and eat into chalk.

Like water both acids have the possibility of quickly vaporizing and can be distilled. Likewise they lack the ability to be mixed with carbon disulfide, which is a particularly water-resistant substance. They are also similar in that both acetic acid (glacial acetic acid) and formic acid in concentrated, pure form become ice at 17 ˚C respectively 8˚C.

Thus in both acids we have two water variants derived from life processes, however they differ from water and reveal their origin in the possibility of combustion. Thus here appear the differences between them: formic acid burns with a quiet, blue and lightly extinguishable flame, whilst acetic acid burns in a glass beaker, by boiling, with an orange coloured ring that sinks below the rim of the glass, thus demonstrating a certain weight. Formic acid is more volatile and boils at 100.5 ˚C, whilst acetic acid boils at 118 ˚C. Formic acid shows itself to be more similar to water because it doesn't mix with benzene, whereas acetic acid dilutes with benzene, but not with carbon disulfide. Acetic acid is therefore more liable to solidify and is nearer to carbon, like wax. Its lowest pH value is 2.4. Formic acid is more unstable and closer to hydrogen, is more similar to water and more acidic. That is also shown by other properties: formic acid, for example has a reducing effect on ammonic silver nitrate, whilst acetic acid has not. Formic acid breaks down on heating its steam at 120 ˚C; also when combined with a concentration of sulphuric acid, only the formic acid is destroyed. It is more unstable and reacts more easily.

Acetic acid arises out of the aeration of fermentation products. The inebriating effects are overcome and sober, refreshing effects occur through the processes of oxidation. The ability to counter decay already presents acetic acid's past - that's how it arose. Thus it retains a conserving quality, as shown by foodstuffs conserved in acetic acid/vinegar. Formic acid develops an even stronger preservative force. It works above all in the landscape and into the future. Isolated, it also shows in the moment with great disinfectant effects, even 2.5‰ addition to fruit juice works in a conserving way.

Acetic acid embodies aerated, consolidating fruit forces. Formic acid embodies volatile, reactive – that is, effective in all directions – much more generalised earth forces. It bears the effects of its origins in the 'necessary' dealings of ground animals with earthy remains, as its direction of activity with it. This reveals itself in the greater density of it: 1.22 g/cm^3, as opposed to 1.05 g/cm^3 for acetic acid. Thus formic acid is the crowning glory of the acids in nature through its chemical force and through its density. It appears, somewhat emphatically expressed, as a peak of earthy saturation.

Thus we see in formic acid:

- A watery substance that is intensified and permeated to acidity that works broadly in nature,
- A force typical to all acids but here in strengthened form as something that protects life from decay,
- One of the imponderables[1] of life forms that express themselves in chemistry as inflammable and thus a substance that stands close to life transformations,
- An earthly concentrating force.

Let us now put two acids – formic acid and oxalic acid –, that could be easily transformed into each other in the lab, alongside each other, then the differences are raised to the level of polarity: Here a strongly smelling liquid - there a firm substance that even in crystal form in water only dissolves to an extent, that tends to sublimate rather than melt. Here rapid inflammability - there slow to burn only at higher

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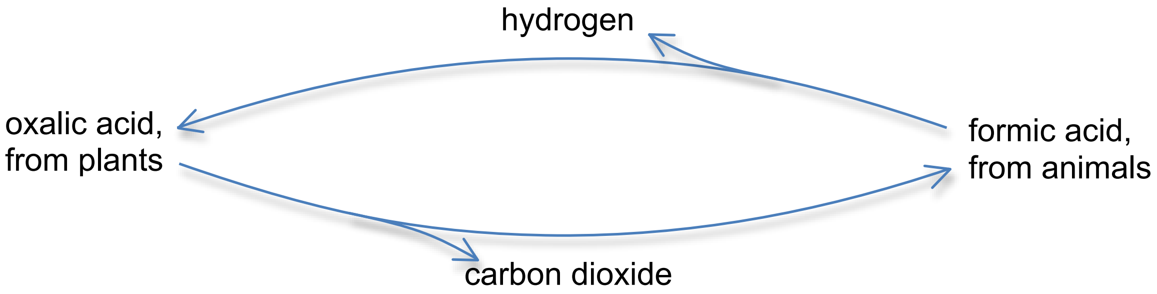
[1] See v Mackensen (2001, p. 9ff) 'Prozesschemistry' for a description of imponderables as mobile forces derived ultimately from the cosmos.

temperatures. In oxalic acid we see an expression of solidifying plant life, bound to a particular location out of which it arose. The extreme insolubility of its calcium salt is well known and frequently used, whilst formic acid is used as a lime-dissolver. On the other hand, when the resilience of oxalic acid is overcome through watery solution it develops a stronger acidic effect than formic acid (pH down to 0.7).

In the transforming of formate into oxalate hydrogen escapes, in the transformation of oxalic acid into formic acid carbon dioxide is produced. Something is expressed in the character of these two gases that reveals the difference between their original substances: warmth that streams towards the cosmos on the one hand and earth-bound isolating consolidation forces on the other. Formic acid appears to us as something dissolving, mobile, setting things in motion. These movement-generating imponderables appear in many aspects of formic acid, above all in the capacity to reduce (silver experiment), in the capacity to burn and in the etheric solubility; but slightly also in the fruity smells of its esters and in their stability.

As acid, formic acid has power and aggression, but in the realm of the salts it is not consolidating and mineralizing. As substance against rheumatism it shows a dissolving effect that mobilizes sediments in life processes. Formic acid brings what has halted, into motion. The ant that can transport heavy objects on the forest floor is an image of such a process. A force coming tirelessly from within becomes active and begins to move that which has become a solid and physical object.

Overview of relationships:



Experiment 1: Sulphuric acid drives formic acid out of its salts

Experiment lasts about 3 minutes.

As stronger and less volatile acid, sulphuric acid can attack formic acid salts and free formic acid.

Procedure: fill a test tube with about 2 cm^3 natriumformiate (= sodiumformiate) and cover with diluted sulphuric acid. On heating one can identify the typical formic acid smell.

Experiment 2: Esterification of formic acid

Experiment lasts about 7 minutes.

As in experiment 1, natriumformiate (= sodiumformiate) can also be used as starting material for combining formic acid and ethanol.

Procedure: The salt and the alcohol, each about 2 cm^3, are put into a test tube. About 1 ml of concentrated sulphuric acid is added and the tube well shaken. The formation of ester is soon apparent through the fine smell of arrack. On warming (about 1 minute at 50 ˚C) the smell grows stronger. After pouring into another glass half full of water and ensuring that the salt is dissolved completely by shaking, the ester forms as an oily film on the surface.

Experiment 3: The alchemist experiment

The transformation of oxalic acid into formic acid and carbon dioxide occurs through heating in glycerine.

Procedure: Into a retort or round-bottomed flask 50 g of oxalic acid dihydrate crystals are filled, then 50 g glycerine are added. The thermometer should reach into the mixture. A suction flask is attached gas-tight to the retort. From the suction flask a rubber tube passes to a beaker with about 5 cm depth of calcium hydroxide solution. The retort is placed on a tripod with a mesh and fixed there. The neck of the retort can be cooled with a wet cloth. The mixture is quickly heated until the thermometer shows 110 ˚C. By then all the crystals should have dissolved and gas bubbles are rising through the calcium hydroxide solution. Now the temperature is raised slowly to 140 ˚C. Then a clear distillate should drop into the suction flask, and the calcium hydroxide solution should become cloudy through the gas and then later maybe clear up again. After about 5 - 7 minutes the burner is extinguished and all connections are disconnected. Then the distillate can be tested regarding smell, taste, pH value and ability to reduce using an ammoniac silver nitrate solution.

Anthroposophic Press, Hudson, USA 1998

with Rudolf Steiner"

Tuesday, February 6, 1923, 4:00 p.m.

Dr. Steiner: Today, we want to have our agreed-upon discussion with Dr. Kolisko on health in the school. I will not go into the details of treating students because there are a number of principle things we need to present first. They will form the basis for further work that must also occur. We will proceed, then, by selecting some typical cases that could arise here. You will also have an opportunity to ask questions about specific cases.

I would first like to draw your attention to the fact that all of our Waldorf School pedagogy has a therapeutic character. The entire teaching method is itself oriented toward healing the child. If you create a pedagogy that does the proper thing during childhood, then educating children takes on a healing aspect. In particular, if we properly handle the child as an imitative being before the change of teeth, then use authority properly, and then appropriately prepare the child to form judgments, all of that will have a thoroughly health-giving effect upon the child's organism.

It is fundamentally necessary that the direction of our behavior at school be hygienic. That is, that the teacher, in flesh and blood, has penetrated the three aspects of the human organism. The teacher should have an instinctive feeling for each child, that is, for whether one of the three aspects of the human organism, the nerve-sense system or the rhythmic system or the metabolic-limb system, predominates, and for whether we need to stimulate one of the other systems in order to balance a harmful lack of balance in the other systems.

For that reason, we will look at the threefold human being in a way particularly important for the teacher. We have the nerve-sense system. We can properly understand that only if we are aware that there is a regularity in the nerve-sense system that is not subject to the physical and chemical laws of earthly matter.

We need to be aware that the human being rises above the laws of earthly matter through the nerve-sense system. The form of the nerve-sense system is completely the result of prenatal life. The human nerve-sense system is received by the human being in accordance with pre-earthly life. The nerve-sense system is thus capable of independently developing all activities related to the spirit-soul, because all material laws of the nerve-sense system are removed from earthly matter.

The case is exactly the opposite with the metabolic-limb system. Of the three human systems, the metabolic-limb system depends most upon external material processes. When people understand the earthly processes playing out in physics and chemistry, they also understand which processes continue within the human being, at least to the extent that human beings have a metabolic-limb system. However, they learn nothing about the laws of the nerve-sense system.

The rhythmic system lies between these two and, in a certain way, naturally balances the two extremes.

These things form quite individually within every human being. This is particularly true of children. The activity of one system always predominates over the others, and we need to do what is necessary to create a balance. For that, we must have a capacity to really listen to how children express themselves, so that expression can become a revelation of what we need to do with the child in order to help it achieve a completely harmonious health.

It is important that we become clear about the fact that, for example, we can have a beneficial effect upon the nerve-sense system by adding the proper amount of salt to the foods the children eat. Thus, if we notice that a child tends to be inattentive, to be flighty and turn away from what you present, that the child is what we might call too sanguine or too phlegmatic, we will need to see to it that we strengthen the child's pictorial forces so that he or she becomes better able to pay attention to the outer world. We can do that by providing the child with more salt. If you have, for instance, children who are inattentive or who tend to wander, then, if you look into the matter, you will find that the child's organism does not properly process salt.

In more severe cases, it will often not be enough to simply suggest putting more salt into the child's food. You will notice that because of some lack of knowledge, or perhaps inattentiveness, the parents salt the food too little. There, you can help with such suggestions. It is, on the other hand, also possible that the child's organism refuses to accept salt. In such cases, you can help achieve the proper intake of salt by using a very dilute dosage of lead compounds. Lead is what, to a certain extent, enlivens the human organism to properly process salt. Of course, if you go beyond that boundary, the organism will become ill. What is important is to achieve the proper limit, which you may notice when a child has the first traces of a tendency for mental dysfunction. That is something many children have. You will then see that you will have to bring the whole healing process into line with what I have just described.

It is certainly a major deficiency that many educational systems pay no attention to such things as, for example, the external appearance of the children. You can stand in front of a school and see both large and small-headed children. We should treat those children with larger heads, in general, in the way I just presented. Those with small heads should not be treated that way, but in a way I will shortly describe. In those children with a physically oversized head, you will be able to find what I have just described as deficiencies, namely, lack of attention or a too-strongly developed phlegma. Now, however, we have all those children who have the contrasting tendency, that is, those whose limb-metabolic system is not sufficiently active throughout their being. Of course, such children feed their organic metabolism, but what the metabolism should be for the human organism does not sufficiently extend throughout their entire being. External observation of such children shows that they like to brood over things, but

that they are also very strongly irritated by external impressions, that is, they react too strongly to external impressions. We can help such children improve throughout their entire organic system by taking care that they receive the proper amount of sugar.

You should also study the development of children in the following way. There are parents who overfeed their young children with all kinds of candy and so forth. When such children come to school, from the perspective of the soul and spirit, and thus also physically, they are concerned only with themselves. They sit and brood when they do not feel enough sugar in their organism. They become nervous and irritated when they have not had enough sugar. You need to pay attention, because when such children have too little sugar for a period of time, their organism slowly decays. The organism becomes fragile, the tissue becomes brittle, and they slowly lose the capacity to properly process even the sugar in their food. For that, you need to take care to properly add sugar to their food. Nevertheless, the organism may, in a sense, refuse to properly process sugars. In that case, you again need to assist the organism by giving a small dose of silver.

Now you see how, for the teacher, the spirit-soul life of the child can become a kind of symptomatology for the proper or improper functioning of the body. If a child shows little tendency for differing imaginations, if the child simply tosses everything together in a fantasy, if it cannot properly differentiate, then the nerve-sense system is not in order. In your attempts to teach the child to differentiate, you have at the same time a symptom indicating that the nerve-sense system is not in order, and you must, therefore, do what I just described.

If a child shows too little capacity for synthetic imagining, that is, for constructive imagining where the child cannot properly picture things, if he or she is a little barbarian in art, something common in today's children, that is a symptom that the metabolic-limb system is not in order. You must, therefore, provide assistance in the other direction, in the area of sugar. From a hygienic therapy perspective, it is very important that you look at whether differentiating imagination or analytical imagination or artistic synthetic imagination is missing in the child.

There is now something else. Imagine you have a child whose analytical imagination is clearly missing. That could also be a sign that the child is directing his or her astral body and I too much away from the nerve-sense functions. You must, therefore, see to it that the child's head is cooled in some way, for instance, that you give the child a cool wash in the morning.

You should not underestimate such things. They are extremely important. You should certainly not see it as a kind of deviation into materialism to advise the parents of a child who shows no capacity for painting or music to give the child a warm stomach wrap two or three times per week, so that the child has it on overnight.

People today have too little respect for material measures, and they overestimate abstract intellectual measures. We can attempt to correct that modern, but incorrect, perspective, by attempting to show that the divine powers have used their spirit for the Earth in order to fulfill everything materially. Godly powers allow it to be warm in summer and cold in winter. Those are spiritual activities accomplished by divine powers through material means. Were the gods to attempt to achieve through human education, through an intellectual or moral instruction, what they can achieve by having human beings sweat in the summer and freeze in the winter, then they would be incorrect. You should never underestimate the effects of material means upon children. You should always keep them in mind.

There is also another symptom for the same organic problem that arises when there is a deficiency in synthetic thinking, namely, children become pale. Children are often pale in school. We can handle that similarly to the condition of the astral body not being properly integrated into the metabolic-limb system. You can improve the paleness of children through the same means, because when you give a child, say, a warm stomach wrap, it sets the entire metabolic-limb system into motion so that the full metabolism develops greater activity throughout all systems of the organism.

If that system develops too strongly, so that you need to make only a small remark to a child and he or she immediately gets a red face and is terribly annoyed, treat that in exactly in the same way as when the astral body and the I are not properly integrated into the nerve-sense system. In that case, you need to give the child's head a cool washing in the morning.

It is extremely important for the teacher to be able, in a sense, to foresee the child's state of health and act preventively. Of course, there is much less thanks for that than when you heal when the illness already exists, but for children it is much more important.

Now, of course, things that have been used upon a child's organism to direct a process in one direction or another may need to be subdued. If you treat a child for a time with lead in the way I described, you will need to stop the process at a later time. If you have, for instance, treated a child for a time with lead and have accomplished what you wanted, it would be good to treat that child with some copper compound for a short time, so that nothing remains of the lead process. If you found it necessary to treat a child with silver for a period, you should later treat him or her with iron, so that the inner process is arrested.

There is one more thing I want to say. If you notice a child is, in a sense, lost in its organism, that is, does not have the requisite inner firmness—for example, the child suffers a great deal from diarrhea or is clumsy when moving its limbs, so that it dangles its arms and legs when picking up things and then lets them fall again—such things are the first symptoms of what will develop into processes that strongly affect the person's health later in life. You should never ignore it when a child often has diarrhea or urinates too much or picks things up so clumsily that they fall again or shows any kind of clumsiness in grasping objects. You should never simply ignore such things. A teacher should always keep a sharp eye open for such things as, for example, whether a child dexterously or clumsily holds a pencil or chalk when writing upon the board. In that way, you can act as a hygienic doctor. I mention these things because you cannot accomplish very much by simply reprimanding the child. Only someone who is always active in the class can affect anything. On the other hand, you can achieve a great deal through external therapeutic means. If you give the child in such a case a small dose of phosphorus, you will see that it will become relatively easy to reach the child with reprimands about clumsiness, even with organic weaknesses of the sort I just described. Give the child phosphorus, or if the problem is deeper, for example, when the child tends toward flatulence, use sulfur. If the problem is more visible outwardly, then phosphorus. In such cases, suggest to the parents that they should feed the child foods connected with colorfully flowering plant blossoms. Speaking in an extreme case, suppose a child often wets the bed. Then you can accomplish a great deal through a therapeutic treatment with phosphorus, but still more by working with the diet. Suggest adding some paprika or pepper to the food as long as the condition persists. You will need to determine that based upon the child's further development.

In such questions, it is absolutely necessary that members of the faculty work together properly. We are in the fortunate situation of having Dr. Kolisko as the medical member of our faculty, and we should not undertake such therapies without speaking with him first, since a certain understanding of chemical and physiological things is necessary to arrive at the correct opinion. Nevertheless, every teacher needs to develop an eye for such things.

I once again need to take this opportunity of mentioning that in teaching it is of primary importance to take care to bring the nerve-sense system and the metabolic-limb system into a proper balance. When that is not done, it shows up as irregularities of the rhythmic system. If you notice the slightest inclination toward irregularity in breathing or in the circulation, then you should immediately pay attention to it. The rhythmic system is the organic barometer of improper interaction between the head and the limb-metabolic system. If you notice something, you should immediately ask what is not in order in the interaction of these two systems, and second, you should be clear that in teaching you need to alternate between an element that brings the child to his or her periphery, to the periphery of the child's body, with another element that causes the child to withdraw within. Today, I cannot go into all the details of a hygienic schoolroom; that is something we can speak of next time.[1]

A teacher who teaches for two hours without in some way causing the children to laugh is a poor teacher, because the children never have cause to go to the surface of their bodies. A teacher who can never move the children in such a way as to cause them to withdraw into themselves is also a poor teacher. There must be an alternation, grossly expressed, between a humorous mood when the children laugh, although they need not actually laugh, but they must have some inner humorous feeling, and the tragic, moving feeling when they cry, although they do not need burst into tears, but they must move into themselves. You must bring some life into teaching. That is a hygienic rule. You must be able to bring humor into the instruction.

If you bring your own heaviness into class, justified as it may be in your private life, you should actually not be a teacher. You really must be able to bring the children to experience the periphery of their body. If you can do it in no other way, you should try to at least tell some funny story at the end of the period. If you have caused them to work hard during the period on something serious, so that their faces are physically cramped from the strain on their brains, you should at least conclude with some funny story. That is very necessary.

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[1] The discussion never occurred.

There are, of course, all kinds of possibilities for error in this regard. You could, for example, seriously damage the children's health if you have them work for an entire period upon what is normally called grammar. You might have children work only with the differences between subject, object, adjective, indicative, and subjunctive cases, and so forth, that is, with all kinds of things in which the child is only half-interested. You would then put the child in the position that, while determining whether something is in the indicative or the subjunctive case, the child's breakfast cooks within the child, uninfluenced by his or her soul. You would, therefore, prepare for a time, perhaps fifteen or twenty years later, when genuine digestive disturbances or intestinal illnesses, and so forth, could occur. Intestinal illnesses are often caused by grammar instruction. That is something that is extremely important. Certainly, the whole mood the teacher brings into school transfers to the children through a tremendous number of very subtle connections.

A great deal has been said on various occasions during our earlier discussions on this topic. The inner enlivening of our Waldorf School teaching still requires considerable improvement in that direction. Even though I might say something positive, I would nevertheless emphasize that it is highly desirable, even though I am aware that we cannot always achieve ideals immediately, for Waldorf teachers to teach without preconceptions. teachers should really be so prepared that they can give their classes without preconceptions, that is, that the teacher does not need to resort to prepared notes during class. If the teacher needs to look at prepared notes to see what to do, the necessary contact with the students is interrupted. That should never occur. That is the ideal. I am not saying this just to complain, but to make you aware of something fundamental. All these things are hygienically important. The mood of the teacher lives on in the mood of the children, and for that reason, you need to have a very clear picture of what you want to present to the class. In that way, you can more easily help children who have metabolic difficulties than if you had the children sit in a classroom and taught them everything from a book.

It is a fact that in earlier periods of human development, teaching was generally understood as healing. At that time, people understood the human organism as tending to cause illness itself and knew that teaching brought a continual healing. It is extraordinarily good to become aware that, in a certain sense, every teacher is a doctor for the child.

In order to have healthy children in school, teachers must know how to overcome themselves. You should actually attempt to keep your private self out of the class. Instead, you should picture the material you want to present during a given class. In that way, you will become the material, and what you are as the material will have an extraordinarily enlivening effect upon the entire class. teachers should feel that when they are not feeling well, they should, at least when they are teaching, overcome their ill feeling as far as possible. That will have a very favorable effect upon the children. In such a situation, teachers should believe that teaching is health-giving for themselves. They should think to themselves that while teaching, they can move away from being morose and toward becoming lively.

Imagine for a moment you go into a classroom, and a child is sitting there. After school, the child goes home. At home—of course, I am referring to a different cause, I am not saying the teaching would cause this—the child needs to be given an emetic by the parents. Of course, that could not have been caused by the instruction given by Waldorf teachers, that would only occur in other schools. However, if you went into a class with the attitude that teaching enlivens me and brings me out of my morose state, you could spare the child the medicine. The child can digest better when you have the right attitude in the classroom. In general, a moral attitude of the teacher is significantly hygienic.