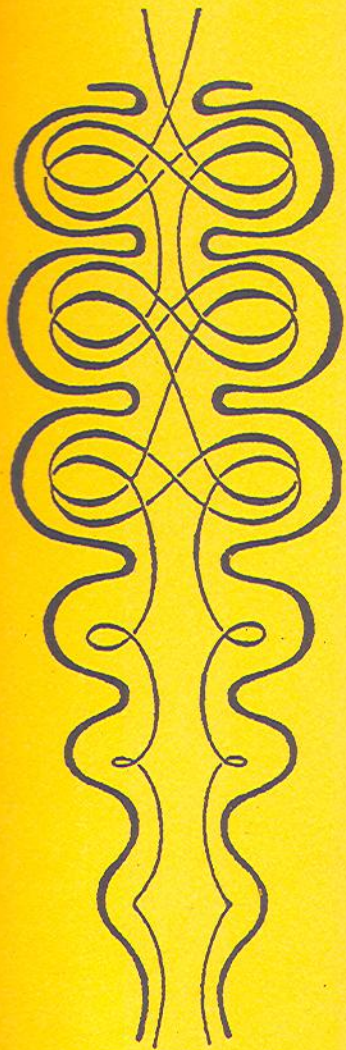




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# WALDORF SCIENCE NEWSLETTER

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A  
Selection  
from

**“A Chemistry of Process”**

by

Manfred von Mackensen

**TOWARDS A RENEWAL OF CHEMISTRY**

The thoughts formulated here were originally conceived as an introduction for the whole of the present work. However as this edition was finalized, the accent shifted and another entry-point arose [the “imponderables”]. I felt the material presented here might further kindle the main ideas presented in this book—for one or another reader. Thus, the “related topics” worked though here echo the themes which appeared in the earlier chapters in a somewhat different form. However, two sections appear here for the first time: Steiner’s curriculum indications and the review of how other authors took process-chemistry as a starting point.

**PROBLEM, STATE OF RESEARCH—WHAT’S DESIRED**

Chemistry, in the eyes of many, is in a hopeless state: stuff about formulas, invisible molecules, and poisons—an endless production of toxic materials which slowly seep into everything. Dangerous substances float right up to the sun. Can it be different? Is there some sort of “eco-chemistry?” A change must begin with a search for a new understanding. Can chemistry also be taken up in a phenomenological way? A way like Goethe’s *Color Theory*, or a Goetheanistic study of animals, wherein the animal world is considered as some kind of spread-out human organization, and every animal as a one-sided specialization? Can we also see the chemical elements in this way?

**THE ETERNAL SEARCH FOR FOUNDATIONS**

People constantly search for columns to support a building of knowledge. Just as a few columns in a subterranean crypt will carry a many-membered giant body, whose streams of force converge in crucial footings, so basic elements and foundational laws should bind together our knowledge.

In chemistry people extracted out the elements. They viewed “elements” like primal forces working in substances. However, as people became accustomed

to thinking in terms of elements, they were forced to step outside the boundaries of their knowledge. Basic, powerful principles would show up in chemistry to those who possessed a broad, deeply worked-through, knowledge. In order to experience their force, a person needs to achieve a broad overview.

Since Boyle and Lavoisier, chemical elements have been the underpinning not only of chemistry but also basically for the whole of natural science. Physics, geology, biology, and medicine all work with chemical categories. In the everyday world of modern people—especially in the preparation of dangerous materials in chemical and radiation biology—chemistry is permeated by elements.

When we ask, in a new way, about the foundational forces in chemistry, about something which would replace mere tangibly-conceived “elements” with spiritually-rich, less physically-dark principles, i.e., with some sort of “process,” then it will be completely necessary to penetrate once again nature’s entirety in a thought-through way. We mean *all* the widths of the whole of nature-knowledge. Whoever wants to judge something as fundamental, which could be a foundation for such a building, must also explore the *whole* domain of nature.

### RULING/DOMINATING KNOWLEDGE

Every stage in the history of science follows a particular scientific theory—a particular world-view. It is as if each dynasty of researchers unconsciously practice a certain orientation. They develop knowledge only out of their personal development and eventually bring about their particular world-view. This is especially true when it starts to indisputably dominate things under the word “science.” Whoever wants to show they “understand,” must recognize a particular world view. This is increasingly recognized in the history of science since Thomas Kuhn’s *Structure of Scientific Revolutions*—a sequence of paradigms rather than an ascent approaching one truth.

The core concept of modern science is *the idea of the observer*. In their experiences, scientists want to hold themselves free in their sympathy and their moral commitment. They want to remain free in cool, rational activity for the sake of self-fulfillment. But do they penetrate into the world in this way? Of course they penetrate, but distanced, *subjugated*. Although spectator-knowledge makes laws available in the impersonal case, it is always arbitrary knowledge about power or domination because it is grasped from a distance. (See Owen Barfield—“instrumental knowing” rather than “sacramental knowing.”)

The Goetheanist, in contrast, will constantly strive to set aside the role of the observer. He will first participate in sensory, completely human experiences. He will go completely into a thing in the sensory realm and thereby feel it first as a human being, rather than in terms of its technical value or profit. Thereby, he is involved and increasingly committed to qualities, forces, to essence (beingness). No longer does he have arbitrarily manipulated subject matter before him, which he only understands in the domination of his knowing, since he has no other way to understand things. In the end, out of spectator-knowing grows a **[new] moral, participatory-knowing**. One asks anew, what “it” is on an artistic scale, in terms of human worth.

Consequences arise from this—we can definitely assume the need for a new starting point. I will candidly try to present this.

Although we have only just begun to expand Goetheanistic natural science into chemistry, a wealth of practical-commercial applications has arisen (as also happens with conventional reductionistic chemistry). In such cases it is more a reverent task and less a prize to be seized, tasks in nature, for example in agriculture and forestry, in pharmacy and medicine, production of nutrition, clothing, housing—very simply, tasks involving making use of the world. That such tasks arise comes from the fact that chemistry *can never* be merely observed. It interacts beyond itself just as it acts into substances. Every science of materials is, in itself, *an interactive science*. Perhaps, in general, it is dangerous to let one's self get "mixed up with" chemistry, since *we also take part* as instruments in this whirlpool of activity. We must pursue chemistry in such a way that, in our scientific knowing, morally-productive paths become visible, where everything remains connected with the human being.

### SCHOOL CURRICULUM — STIMULUS FOR A CHANGE IN CHEMISTRY

Practically all chemistry teachers in Waldorf schools allow their preparations to be led by Rudolf Steiner's indications in *The Conferences with Teachers*, first edited in 1955 by Karl Stockmeyer, and also available since 1975 in the German Collected Works, GA volume 300.<sup>1</sup> The indication relating to the 11th class occurs in a teacher's conference of the first Waldorf school in Stuttgart on June 21, 1922; it indicates the structure of the three to four week main lesson block in 11th class. (This was the first time the school had grown to include an 11th class.) It includes the following stenographic record of statements by Steiner:

"(1) In chemistry, it would be necessary to develop the leading concepts—acid, salt, base, as fully as possible, so that they know what is an alcohol and what is an aldehyde. (2) The traditional situation, the division between organic and inorganic chemistry, we will only take slightly into account. (3) It seems to me that this is the right moment when an overview of chemical substances can be woven in. (4) I would not think it right if we developed a kind of chemistry on the basis of materials first. (5) It is better to develop processes—and there the substances and the metals must be 'taken up'—so that in your teaching the feeling will be called forth that, when dealing with substances, you are dealing only with arrested processes; that the picture should emerge how the substances are processes which have been brought to rest. (6) If I have a piece of sulfur before me, we have a frozen process here. (7) When I stand here and it rains tremendously, then I have a process *in which I am directly involved*. (8) If, however, I look at the cloud from a distance, this cloud appears as an outer object. (9) If I consider certain processes, it is as though I consider the cloud from a distance. (10) If I look at sulfur, I am in a similar situation as if I were looking at a cloud outside me. (11) Substances are frozen observed processes." (2/6/22)<sup>2</sup>

The passages in sentence (3) about "an overview of substances" and in sentence (6) speaking about sulfur have led many Waldorf schools to weave a tradition for Grade 11 chemistry, to treat a selection of chemical elements, starting with sulfur, and allow them to flow into a periodic system of the elements. However, sentence (4) warns expressively about a kind of chemistry developed on the basis of

substances. It suggests instead (5) to *develop processes* in such a way that the substances can "be gotten into."

This indication has been taken up by some researchers and has led them to considerations where with just a few processes (such as burning or digestion, or those meant by the "Tria Principia"), they attempted to make them into "leading threads" for the phenomena of substances.

However, it must be questioned, do such "reaction types" really present archetypal processes, and do these reaction processes call forth the feeling meant in sentence (5), that "with substances, you are dealing only with arrested processes?" Taken to heart, with such an arrangement we do not remain with "objectively conceived essence of substance," and thereby ultimately relate to sense experiences by working through them in a naive-realistic way, and then we merely clothe them with an overlay of thoughts. It would then be of little help (as is self-evidently thinkable) to describe processes with words and rename the otherwise already known. If we take up the help Steiner gives, *substance should relate itself to process, just as a cloud seen from outside relates to the experience of standing in the rain.*<sup>3</sup> A process which is only described is like becoming completely drenched in one's own personal experience, and through the description replaced by another's experience of process. Thereby, no intensive feeling arises. Here, the only helpful hint we can give is by indicating, "Go over there, where it's raining and let yourself get wet." Where and when it is already raining can perhaps be given as a hint; all other indications do not get one any further. For **chemistry**, this means that the **possibilities which lie in the substances must first be developed in their manifold variety and the experiences allowed to run over us like the rain from the cloud.** Without being first outwardly and then inwardly touched by them, without the stimulus of experience, the student cannot progress to a knowledge of process. In teaching, that can be taken quite literally, to experiences of touch, smell, taste, which modern people are usually afraid of in chemistry.

The lessons proceed initially from one or another ordered experience of substance. Initially, the concept (mental picture) of a particular substance should be developed through the sequence of phenomena, made perceptual but un verbalized. For the development towards process, i.e., for individual understanding, the question remains open: what could be meant on the one hand by the 'task' of not developing chemistry on the basis of substance (4), but on the other hand (5) how to develop a process in such a way that a feeling is engendered: "Substance is frozen observed processes." The first part of this assignment certainly does not ask us to show experiments with substances from the first day of the main lesson. It is only important *which direction of thought* we chose. It ought to be one which attempts to penetrate—like a microscope into the invisibly small—and construct models of the "inside" of substances and use them to explain the "outer" reality we experience. Or it ought to be another contrasting attempt which pushes into ever larger and wider connections in order that in a sense-filled way, the present, experienced phenomena of substance would be embedded in the ordering and the processes (which point beyond themselves just as much spatially as temporally). Physical-causal thinking should be overcome with an evolutionary-holistic series of thoughts.

In order to come closer to the indications by Steiner in (5) and (11) - frozen processes, perhaps the following simplified image can be of help. A person walks in a particular way across the landscape and leaves behind his footprints. Only these remain to meet our gaze, while nothing is seen of the person responsible. Now, as a first way of looking at them, we could investigate the footsteps left behind (length, depth, symmetry, etc.) and describe their characteristics without thinking about how they arose—the steps of a human being. Secondly, out of an investigation of individual features of the conditions that caused them, we could connect the descent of the shoe with how the foot was held. However, thirdly, we could allow the overall orientation of the traces to be perceived as impressions, picture to ourselves the footprints of a person, and put ourselves in their shoes, let the forces of their activity be re-imagined and come to light in us.

What we have here termed “steps” can also be seen as the progress of evolution, which brings us nearer to the idea of a great process whose traces today are the whole world and in which we are actually “stretched out” as Steiner indicated in his comments.

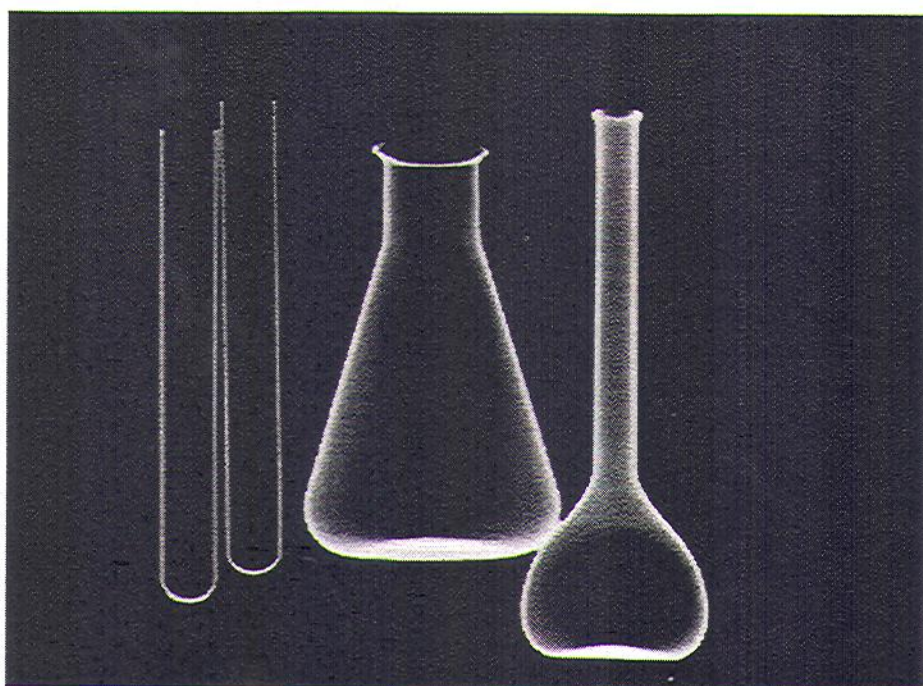
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## Endnotes

<sup>1</sup> *Faculty Meetings with Rudolf Steiner*, Anthroposophic Press, Hudson NY, 1998; Vol. I, p. 358.

<sup>2</sup> Numbering and punctuation by the author.

<sup>3</sup> See also Manfred von Mackensen “An Indication for a Chemistry of Process” in *Elemente der Naturwissenschaft*, Vol. I, No. 18, p. 29, 1993.



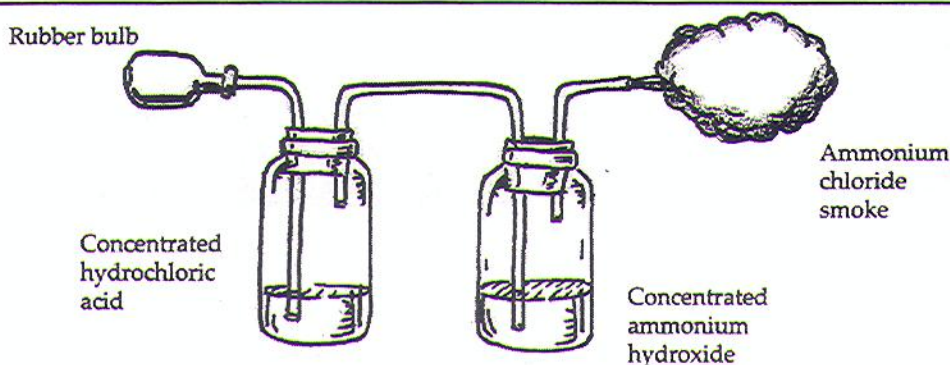
# Sponges and Sinks and Rags, Oh My!

*Where microbes lurk  
and how to rout them*

By Janet Ralof

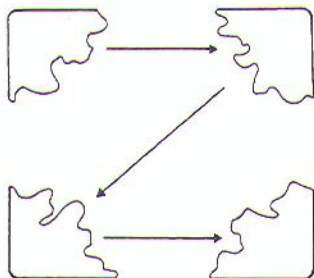
Think household germs, and chances are you'll think of the bathroom. Yet when scientists from the University of Arizona in Tucson sample surfaces from kitchens and bathrooms in the same house, "consistently, kitchens come up dirtier," notes microbiologist Carlos Enriquez. This trend holds even for disease-causing germs spread by fecal contamination, such as the *Escherichia coli* coliform bacteria. "We have swabbed the toilet rim, for instance, and seldom do we find fecal coliform bacteria there, surprising as that may sound," he observes. Enter the kitchen, though, and they're everywhere—in the sponges, dish towels, sink, even on countertops. "So my boss usually jokes about it being safer eating dinner in the bathroom," he says. But kitchen pathogens are no laughing matter. In the United States the diseases they cause kill an estimated 9,000 persons each year—mostly the very young, the very old, and those with severely weakened immune systems. The cost of treating foodborne infections ranges from \$5 billion to \$22 billion annually, according to an analysis released in May by the U.S. General Accounting Office. Though state and federal agencies compile records on widespread or highly publicized cases—like the *E. coli* deaths traced to hamburger served at Jack-in-the-Box restaurants in early 1993—they have little information on cases involving just one or two individuals, especially when the ensuing stomach cramps, vomiting, or diarrhea don't lead to hospitalization. However, when researchers have attempted to tally homespun outbreaks, the numbers have proved staggering, notes food safety expert Elizabeth Scott of Newton, Mass. In the January *Journal of Applied Bacteriology*, she reviewed European data on disease that could be traced to food eaten at home. For 1989 to 1991 in England and Wales, for instance, 86 percent of the 2,766 reported outbreaks of salmonella infection involving one or more persons appeared to stem from household exposure. Says Enriquez, these data indicate that "even though we usually feel more secure eating at home, it doesn't necessarily mean it's safer." He and researchers in a few other labs around the country are now investigating where kitchen bugs lurk, with an eye toward

making home cooking safer. Sponges provide an ideal way to spread disease, a discovery the Arizona researchers stumbled upon while swabbing kitchen surfaces daily in several homes. Bacteria tend to be concentrated in the sink, its drain, and the sponge, Enriquez and his colleagues found. In one home they examined, however, everything from the countertops to refrigerator handles bore consistently heavy contamination—until the sixth day, when most surfaces suddenly turned up virtually germ free. It turned out the family had simply begun using a new sponge. That was a few years ago. At the American Society for Microbiology meeting in New Orleans last May, Enriquez and his coworkers reported finding that most of the 75 dish rags and 325 sponges from home kitchens that they have sampled harbor large numbers of virulent bacteria (SN: 5/25/96, p. 326), including *E. coli* and strains of salmonella, pseudomonas, and staphylococcus. They measure bacteria in colony-forming units—one or more cells that, when cultured, generates a clump of bacteria. In wet areas around the sink, and especially its drain, Enriquez's group has measured up to 10,000 colony-forming units per milliliter of moisture sampled. "And we've found up to 10 million colony-forming units in 1 ml of the liquid wrung from a sponge," he told *Science News*. "Initially we were surprised," he says. In retrospect, the microbiologists realized that continually moist cellulose sponges provide "a very hospitable environment" for bacteria. Key to their survival is a surface easy to cling to, a steady supply of nutrients—even microscopic scraps of food—and moisture. If a sponge stays moist, the number of live microbes doesn't decrease for two weeks. Bacteria can even survive for at least two days, Enriquez finds, in a damp sponge gradually drying in the air. On dry surfaces, resident bacteria survive no more than a few hours. However, Enriquez points out, that's long enough to infect another source of food, or a person's hands during meal preparation. Though bacteria may love sponges, they happily colonize even stainless steel, notes Edmund A. Zottola of the University of Minnesota in St. Paul. Metal that appears smooth to the naked eye is, from a microbe's perspective, "full of all kinds of nooks and crannies, canyons, gullies, and hills," he observes. Whenever bacteria find a site harboring moisture and food, he says, "they will set up housekeeping and grow." His studies have shown that if they aren't sent packing quickly, the microbes produce an organic goo with threadlike tendrils "that literally cements the cells to the surface." This allows them to weather the elements—fast-flowing sprays of water, a little rubbing, or a weak detergent solution. Eventually, unrelated families of microbes move in. The resulting cosmopolitan community forms biofilms that further protect its inhabitants. Cutting boards, with their accumulations of scars, also prove hospitable to bacteria.



## HOW TO READ SCIENCE\*

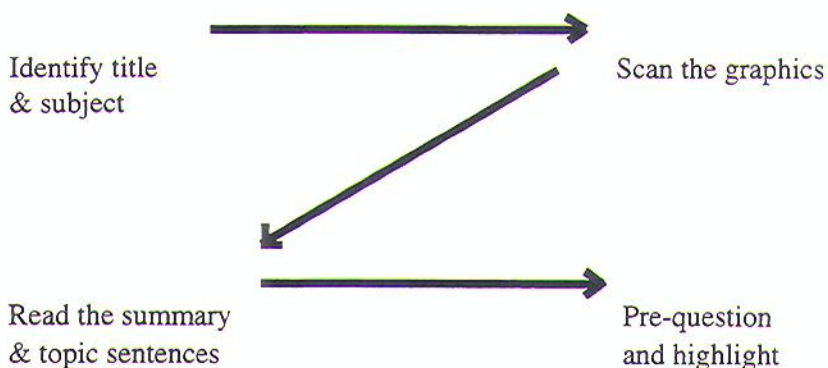
Reading science is unlike reading a novel where clear images come forward to entertain you. Reading an article, paragraph, magazine or book on a scientific topic requires a strategy. First, imagine that you are being confronted with a picture puzzle. What is it you look for first? Usually you try to find the four corners to give a boundary to the puzzle. You can attack your science reading in the same manner.



Before you start to read you have to familiarize yourself with the article and recognize that the author is trying to point out his or her observations to you. The following four steps, preliminary to actually reading the text, will help you.

1. Read the title and ask yourself what you already know about the subject?
2. Then thumb through the reading and acquaint yourself with the chapter or paragraph headings, the graphs, the pictures and illustrations. Familiarize yourself with the graphics and ask what the author is trying to get across.
3. Go to the end of the article or book and read the final paragraph or summary. This will give you a clear idea of where the article is heading. Then glance at the topic sentences from a few of the paragraphs.
4. Finally ask yourself questions that you hope to find the answers to as you are reading and then start to read with a highlighter in hand (or a pencil to underline or a notebook to make notes in as you read).

This strategy will save you a great deal of time as you read and will improve your comprehension.



These are the four corners of the puzzle which will give you a strategy to master difficult scientific readings.

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\* Taken from *The Wonder of Chemistry*—7, 8, and 9, by David Mitchell, available in Spring 2000 from AWSNA Publications.

## EXPERIENCES AND SUGGESTIONS FOR CHEMISTRY TEACHING IN WALDORF SCHOOLS

(Published in *Erziehungskunst* 62 Jg. Heft 3, March 1998—revised by the author November 1999)

by

Wolfgang Schad

*Chemistry in Waldorf schools is a controversial subject. On the one hand, the students should be led into substances and processes in a living, experiential way. On the other hand, knowledge of formulas is a requirement for standard exams evaluating high school students. Rightfully, parents don't want their children to master standard chemistry formulas just prior to these final exams. Even among college-educated chemistry teachers, there are very divergent starting positions, between which too little dialogue has occurred up to now. In order to open a forum concerning this dilemma and activate a dialogue between colleagues of different opinion, Wolfgang Schad was asked to give a lecture at a scientific symposium at the Goetheanum in Dornach on April 10, 1997. Schad was a Waldorf pupil, then a Waldorf high school chemistry teacher, later a lecturer in Waldorf training seminars, and now is involved in research at the University of Herdecke. His lecture was conceived as a contribution for promoting discussion on the unique teaching methods in Waldorf high schools.*

### BACKGROUND

As is well known, Rudolf Steiner entrusted Eugen Kolisko, the first school doctor at the “mother school” in Stuttgart, to work out the details of a Waldorf chemistry curriculum for the middle and upper grades. Kolisko wrote up his attempt and the experiences he had with it in an essay “On the First Lessons in Chemistry,” in 1929 and issued it as a brochure in 1932. In order to establish ties between this beginning, which remains a well-known classic today, and other attempts (such as the approach of the Dutch Waldorf educator Frits Julius),<sup>1</sup> an intense internal discussion occurred in 1934 in the first teacher's Collegium about whether it was in fact the right thing to say to students, for example “the metals don't actually originate from the earth but rather stream in from the cosmos.” Kolisko then withdrew it from public sales. This “Kolisko's chemistry” was afterwards controversial also because the government school inspector did not appreciate it. In pre-war 1930s there was, naturally, quite a bit of worry about what the government did.

Steiner held "Kolisko's chemistry" (as he liked to refer to it) in high regard. After the General Anthroposophical-science course in the Haag<sup>2</sup> he made comments expressing greatest respect for "the natural-scientific phenomenalism of Kolisko." On the other hand, he carefully avoided the discussion pursued by Kolisko, Hans Theberath, and Franz Halla, about whether atoms existed or not, in the inaugural 1921 volume of the newly-formed newsletter *Die Drei*. Steiner felt this should be ended quickly, in order to avoid inflicting damage to the reputation of Anthroposophy, "and under the circumstances, given its importance, even opponents have some justification." This concerns "for example, the facts of physical science, which—if one takes them as they are, without getting into polemics against them—provide a most important basis for the Anthroposophical view, while polemics ... lead to a dead end."<sup>3</sup>

In discussions at the teachers faculty meetings (4/24/23), Steiner commented about the question of formulas in chemistry teaching:

"Isn't it so, there would be at least some sense in using stereometric formulae, but mostly planar formulas are used, which is senseless."<sup>4</sup>

In 9th grade astronomy, Steiner indicated he wanted the issue of the depth of the universe to be handled in connection with the Doppler principle<sup>5</sup>, and in geography the lateral movement of the continents could be discussed in connection with Alfred Wegner's theory, recently published in 1915 in a book Walter Johannes Stein had purchased for the faculty library—at Steiner's suggestion.<sup>6</sup> So, Steiner was keenly interested in Waldorf students being exposed in high school to the most modern developments in natural science.<sup>7</sup> Steiner spoke with great respect for the significance of atomic structure of matter: in the atom rests the seeds of a future Jupiter-condition of the Earth.<sup>8</sup>

Just after the opening of the first Goetheanum, Kolisko gave three lectures (October 1920) in which he explained how Avogadro's Law and all atomism was worthless, using a complicated sequence of arguments. With other contributions, and likely also with this one, Steiner was not in agreement; it was a note of dissonance with the forms of the building.<sup>9</sup> He also turned against similar methods of argument in the above-cited first issue of *Die Drei*. The lecture reference which appeared in 1922 was never again reprinted.

Already in this early phase of "Waldorf chemistry," the dissonance is there. And, the differences of opinion connected with it have not been resolved right up to today. Now, there is nothing wrong with a positive discussion; in fact, it should be welcomed. However, this particular debate has lasted for decades and has not been as fruitful as we might have wished. Try to find a former Waldorf student who was so enthused by chemistry in school that he focused on chemistry in university and then became a successful Waldorf chemistry teacher. I know only *very* few examples, and those can be counted on one hand! [Note: Schad himself *is* an example.] This is an important fact: Waldorf chemistry—and all that is understood under this heading—has not been fruitful.

This situation challenges us to look at the reasons. The discussion on chemistry needs to be pursued on three distinct levels:

- 1) on a scientific-historical level,
- 2) on a history of chemistry in Waldorf pedagogy level, and
- 3) on the particular nature of chemistry as such.



*Johann Wolfgang Döbereiner (1780 - 1849). In 1810 Döbereiner was called by Goethe to be professor of chemistry in Jena. His discovery of the Triad-rule paved the path for the Periodic system. (from: H. Wahl and A. Kippenberg, Goethe and his World, Leipzig, 1912)*



*Jacobus Henricus van't Hoff (1852 - 1911). Van't Hoff was a student at the University of Bonn. At age 21, he discovered the fundamentals of stereo-isomers and paved the way for modern biochemistry. (from: E. Cohen, J.H. van't Hoff: His Life and Work, Leipzig, 1932)*

## ABOUT THE HISTORY OF SCIENCE & CHEMISTRY

At the scientific-historical level, just as botany developed from the lore of medicinal plants, so chemistry was born during the Middle Ages out of practical studies in metallurgy. During the transition from the 18th to the 19th century, methods of quantitative measuring led to the discovery of stoichiometry<sup>10</sup> and its interpretation through atomism. During the second half of the 19th century, the analysis into elements and their synthesis was carried so far as to achieve both of the "Goethean"<sup>11</sup> discoveries of chemistry—the periodic system and stereo-isomers.<sup>12</sup>

The first of these (periodicity) not only expresses polarity, degrees of intensification and climax, seven stages of intensification, and transformation of substance, but also the four steps in world-evolution (pointed out by Bindel and Blicke 1984),<sup>13</sup> if I may read their interpretation about an orientation in time in the reverse sense. Moreover, from its side, stereoisometry provided the insight that the qualities of compounds not only depend on *what* elements are involved in their formation, but also *how* these elements are arranged spatially. In fact, this discovery says the overall configuration can be of greater importance than the mere quantity of elements present! The profound physiological significance of asymmetry in the chemistry of living things—in biochemistry—was first made understandable through this discovery. Just as it is abstract for a map of Italy to represent the actual country and landscape, so is it difficult to comprehend the true essence of a substance with a stereo-formula. However, with the help of a map, I do know my surroundings better than without it. Whether or not I can see the sea from Genoa, the boot shape of Italy has not been questioned by anyone, even before satellite pictures provided confirming images.

Spatial-structural formulae are not themselves the true reality of substances. However, it does not help to push them aside either, as artificial constructs which have absolutely nothing to do with the reality of the substance; particularly since the spatial structure of macro-molecules, developed up to now on the basis of indirect inference, has today been captured with new imaging techniques. (See Figures 1, 2, and 3.) Permit me a related comparison. Even Goethe did more Goetheanizing with animal skeletons than with living animals. Most of his travels were made sitting on a horse's back (for 500 km during his first journey into the Harz Mountains!) or riding in a horse-drawn carriage (during his famous Italian journey). Nevertheless, there is no mention of using the living animals that carried or pulled him. Only the reduced phenomenon (its skeletal forms) allowed him to gain the cognitive distance. He was more interested in knowing how life and spirit had formed itself in the most material realm than in where the supersensible allows itself to be separated from the sensible. Much too often we think of Goethe as a synthetic and holistic scientist, and too seldom note that he considered analysis of equal importance to synthesis in research. His position concerning the interplay between analysis and synthesis becomes very clear looking at his statement about the Parisian Academy discussion during the last year of his life.<sup>14</sup>

During our century, models of atoms have become increasingly insubstantial (ball-and-stick, to quantum cloud, and finally to wave-equations) and have paved the way for bonding theories and reaction kinetics.<sup>15</sup> Even from these "skeletons" we can extract plenty of Goethean science.

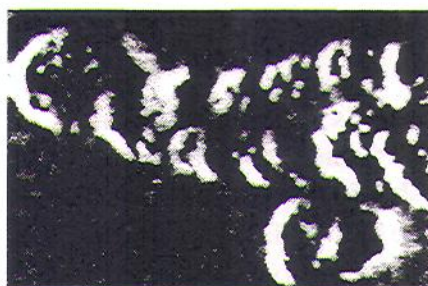
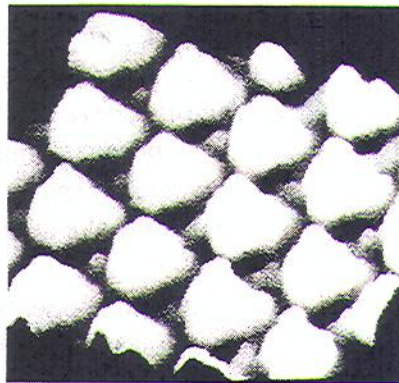


Figure 1

A chromosome and a model of DNA (deoxyribonucleic acid) double helix, 106x scanning tunnel microscope picture, 1989, by B. Kobbe in Berkeley, CA, "The First Photograph of the Building Blocks of Life," *Images of Science*, 22(4), p12, 1989.

Figure 2

The first picture of the benzene ring, B. Kobbe, in *Images of Science*, 24(10), p34, 1988.



In the realm of anthroposophically-oriented science, people tried to grasp or record the etheric formative-forces<sup>16</sup> with physical and chemical means such as the Steigbilder (capillary dynamolysis) method, begun by Lili Kolisko, the copper-chloride crystallization started by Ehrenfried Pfeifer, and the Drop-picture method developed by Theodor Schwenk. Looking at such results, it becomes clear that these image-forming methods are not reagents for etheric formative-forces, but reagents to material structures, even the chemical forms, which the formative-forces had

shaped beforehand. Whatever is discovered in a laboratory experiment is already part of a technical world. And this is a clarification that could have been recognized from the beginning. Spiritual things can only be captured by spiritual, not with material means. Steiner characterized this latter as the danger of spiritualists: wanting to discuss the spiritual in a material way.<sup>17</sup> From this laboratory-style “formative-forces research,” **over the last 60 years, no useful school experiments have emerged to establish themselves securely**, since they have not withstood the natural critique of our Waldorf high school students. They should be archetypal phenomena and must also be reproducible.

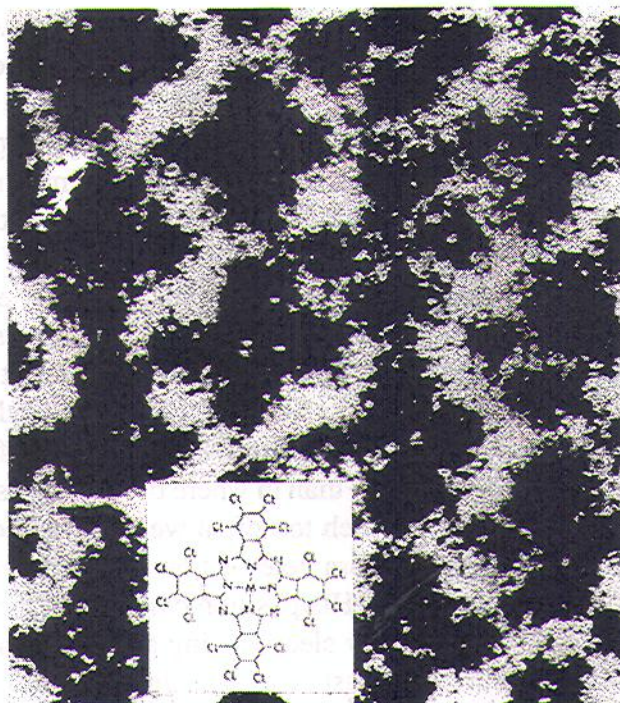


Figure 3  
Copper hexa-deca-chloro phthalocyanin. An electron microscope picture taken at Kyoto University, Japan, by N. Uyeda.

#### VIEWS ABOUT CHEMISTRY IN WALDORF EDUCATION

The landscape of Waldorf school chemistry today is marked by diverse methods and schools of thought. This diversity itself does not need to be a negative attribute. Nevertheless, not all methods are understandable for everyone. It is the easiest to teach chemistry in the middle grades. There, we know it is important that the 4th grade curriculum will encompass physiology and zoology, botany in 5th grade, and geology and physics in 6th grade. It is then only in 7th grade when we start with the first lessons specifically in chemistry. Clearly, these natural science subjects mark the entrance of the child from the pre-birth world into earthly relationships, passing through various levels of the natural-organic world, over the spectrum from the natural into the inorganic, material world. If physics is the science of interactions of matter and energies *in space*, then chemistry leads the student through the *study of processes in time*, into the qualities of substances, as well as in to their quantitative aspects.

How should one work with students developmentally as well as spiritually, on the mysteries of the material world? Again, in the **middle grades** there is a consensus, following the didactic and methodological instructions of Eugen Kolisko and Frits Julius.<sup>18</sup> We teach meaningful-sensible phenomenology, lively characterized, like personalities who stand out in history — now, sulfur or then, iron — allowing new pictures to flow into the realm of our daily lives. For the class teacher, who is initially not trained as a chemist, it is often a greater challenge than for the students. Therefore, he often seems to get more enthusiastic than the students.

In **high school** the capacity for causal thinking awakens fully and, according to Rudolf Steiner, especially in Waldorf schools, should be reinforced through natural sciences rather than the study of ancient languages.<sup>19</sup> **But here the**

**dissonance begins.** In one Waldorf school, depending on the teacher's personality, throughout all the upper grades the students receive more or less continually a *methodological extension of the middle-school approach to chemistry [pictorial-anecdotal lore]*. The phenomena of impressively colorful, smelly, steaming and explosive experiments should fascinate them, everything is explained with humor, and connections to everyday life experiences are served. However, causal necessity and correlative understanding stay unanswered. At best, this type of teaching asks the question, "Where can such knowledge be used?" The curious and interested student will quickly look further in some conventional chemistry books and read about atoms and molecules, is given an experimental chemistry kit, or finds a high school chemistry text book. This kind of Waldorf chemistry in the upper grades is experienced with ambivalent feelings.

At another Waldorf school—perhaps because of a shortage of Waldorf-trained teachers—a teacher presents chemistry as it would be taught in public schools. The experiments work, the lectures are built up systematically. However, always reducing things to smallest particles has an affect as abstract as paper-maché; the students are supposed to learn about the chemistry of chalk (calcium cycle) "on the chalk-board," and many inquisitive questions often unmask the teacher, who seems not to have a deep understanding of the breadth of the topic. Where does the octet tendency (of the periodic table) or the Pauli exclusion principle come from?<sup>20</sup> Quantum chemistry is not completely mastered by a college-level chemist, they simply learn to believe it through their studies.

The eagerness to believe in things can also be found in Waldorf teachers—no one is immune to that. But the Anthroposophic ideal is to believe in only that which one has come to recognize and know by oneself—to take responsibility only for the known. Only then does the cleft between knowledge and belief disappear.

## DOUBTING THE EXISTENCE OF MATTER

How can a Waldorf student relate to the demonstrations of a chemistry teacher who denies the existence of matter? Here I would like to mention a quote from Rudolf Steiner's first publication. "Without matter, the manifest world picture is merely a sum of changing perceptions without anything material lying at the basis."<sup>21</sup> He continues in the same publication, several lines below, "The above mentioned term surely only refers to matter as defined by physics [already in 1890!, eds.]; when physics often identified with the old, generally incorrect concept for substances from metaphysics [probably meaning Spinoza, eds.] matter as phenomena or percept is something completely different." This tangible, graspable characterization of matter, which is often the way naïve students describe it, is not criticized by Steiner. (The denial of matter exists today, at least in the writings of Mary Baker Eddy in *Christian Science*.) The first quote is often used pointlessly as a fundament for chemistry lessons, which in their extreme phenomenism do not permit generalizations. However, all concepts are generalizations, and starting in 9th grade, students rightfully want to understand, comprehend and grasp things conceptually.

Yet a third school of approach consists in starting by connecting to pre-scientific antiquity and the medieval study of nature. If there is any conceptualizing, then it is with the elements of Aristotle, who formed a classification system based on *qualities* such as "wet," "dry," "warm" and "cold," and their aggregate conditions of solid, fluid, gaseous and fiery-energetic. Or perhaps the "Tria Principia"

of Paracelsus' medical studies is used to further understanding. Steiner has given helpful pictures for bridging these two classical approaches. But Steiner did not gain his understanding of the world from this source, on the contrary, it was out of his own independent inner research that he unlocked a deeper understanding of these ancient and medieval thought forms. With the students we should follow Steiner's path. The upper grade students are quickly sensitized and develop a professed aversion to that which they cannot connect to by way of their own observation.

Nevertheless, there also exists a fourth school contrary to all this, which thankfully is in the minority. One does not look or listen to anyone else, but seeks the bridge to understanding chemistry out of one's own completely personal, subjective, private inner soul forces. There, out of the "being" or character of carbon and that of oxygen, we are told that their compounds can only be gasses, and out of the character of silica that its oxygen-compounds are solid. One certainly makes one's mark as an impressive, self-sufficient original. However, the definition remains rhetoric—comprehensible to no one. This causes acute senseless damage, and it passes right by the people concerned.

Especially in Waldorf schools, each teacher has an exceptional degree of freedom with curriculum and lessons. This is good only as long as the inner substance rings true, and only will rightfully stand as a principle if the subjective misuse is not ruled out, for the vestige of an equalizing regimentation in pedagogical praxis is even more frightful. Personally I give an unequivocal "yes" to variety and diversity, but only as long as it does not backfire and the heterogeneous situation cannot bear fruit. And, in the case of chemistry in Waldorf schools, that has been the situation for too long. My thesis is that in no other science taught in Waldorf schools is the dissonance as great over what and how to teach as it is in chemistry.

This must be acknowledged and factually taken up without emotion, polarized factions or suppression. Then the fact becomes an anthroposophical impression or even a phenomenon worth consideration. What does this fact say? The problem cannot be especially the fault of individual personalities of chemistry teachers. The source lies much more beyond the personal. Here, we come to the third level, the subject itself, the nature of chemistry as such.

### THE UNIQUE NATURE OF CHEMISTRY

Physical science considers physical substances in their spatial behaviors and interactions. Chemistry, in contrast, focuses on their transformations: how one element can become another one, always accompanied by conversions of energy. In this respect, the study of changes in aggregate condition, strictly speaking, belongs within the area of chemistry, since the chemical bonding forces involve shades of warmth. Of course, physics also recognizes temporal changes, e.g., the movement of masses or loading, etc. However, only *spatial* changes actually take place in that case, not a transformation of material *in itself*; that, in contrast, involves yet another relationship to time. Characterizing physics, then, as the *spatial* aspect of physical entities and chemistry as the examination of physical *processes in progress* within qualitatively-changing *time*, this still leaves a third comparative "tertium comparationis": matter in itself, without spatial or temporal changes. Actually, there should be such a *third* subject area in the physical world—pure understanding of physical matter. The following quote from Goethe illuminates this:

"One shall not study the works of nature or art only when they are

finished: one needs to capture their process of emergence in order to understand them to some degree.”<sup>22</sup>

If we take the study of matter into a study of process, this also includes chemistry. Chemistry, then, explores the riddle of matter in its manifold being and its variations.

Whoever has pursued both the fields of physics and chemistry to some degree recognizes the obvious difference in learning. Generally, physical processes can be led back to just a few basic regularities from which we can derive far-reaching mathematical formulas. In chemistry, there is little or nothing to calculate. In fact, calculations seem superfluous when we want to deduce why, on the one hand, under normal circumstances calcium carbonate appears as a solid in water, and on the other hand, calcium chloride is soluble, why silver phosphate appears bright yellow and copper-hydrate compounds appear blue. Those characteristics just have to be learned, and in this respect the chemist needs to recall much more factual knowledge than the physicist.

Since physics has been considered a more exact science for these reasons, people have not stopped making chemistry into physics—a physical chemistry. As long as one does not deal with the quantum effects, one is able to reconstruct the material world into models of small particles within Euclidean space and Newtonian time.

However, once we recognize the special affinity of chemical processes to time, the subject of chemistry then becomes interesting, when metabolic and energetic exchanges can be observed in *living* time. As Rudolf Steiner once characterized succinctly:

“In the end there are only four sciences necessary:  
pneumatosophy,  
psychology,  
chemistry and  
physics.”

So he regarded chemistry as the central point of all life science, almost synonymous to biology.<sup>23</sup>

Conforming to current understanding, we use the term *biology* to refer to the phenomena of life and the term *chemistry* for the understanding of matter and material transformations. And the chemistry teacher needs to do the same in his lessons. What is the epistemological problem that lies at the root here?

The basic process of knowledge is provoked by the unfamiliarity of the sensory experience.

“Knowing would be in the worst case a useless process if the sensory experience gave us something completely finished.”<sup>24</sup>

For a **reductionist** consciousness, the mineral-dead world seems to be most easily grasped. Plant life is already more difficult, the subjectivity of the animal world even more so, and an understanding of the human world remains mostly a riddle. But, for uninhibited immediacy, the opposite holds true: a real understanding of human beings like us, when we engage in real human encounters, is the easiest. How much more the other human being is able to communicate about his *self*—

with or without words—than the other natural kingdoms! Already animals, even the higher developed ones, are more foreign to us. And to have a trusting relationship with the sort of animals like deer or llamas, one needs to work with them for a long time. And still, there remains an unbridgeable chasm to the real being in itself of even the most trusted family dog. The dog's "I," its group ego, is not individualized into the animal, rather it remains in the supersensible astral plane—the world of the "wisdom of the types." For the plant world the character of anonymity of being is even greater. Certainly the experience of a subjective personality, which still rays out from most animals, is absent in the encounter with plants in their world, which seem pleasantly supra-personal. However, the plant-ego is much more distant from us. For example, a dog can express and share "happiness" and excitement; a plant, however, stands there completely neutral, almost "numb."

If one's gaze, seeking some sort of meeting, now falls on the world of the stones, of minerals and substances, the empathic inaccessibility culminates to an incredible extent. Who actually talks to their chemicals? To whom do rocks and minerals actually whisper their secrets? In *Wilhelm Meister* Montanus says the following words, "The mountains are mute teachers and make dull students." Similarly, in the archives of *Makariens*: "Rocks are mute teachers, they make the observer dumb (perhaps in awe), and the best one can learn from them is to not communicate (remain silent)."<sup>25</sup> Consequently, we each invent our own language in order to discuss chemistry. In chemistry, more than in other areas of science, there is a gigantic chasm between directly observed phenomena, and the thought processes connected with them as well as their linguistic formulations. This lies in the nature of the world of substance itself.

Like can best be understood by like. Another human being can open himself to us and allow us a glimpse into his inner being as no other natural being can. Ego and Ego meet each other in the here and now, in the "I-Thou experience." Steiner indicated the group ego of animals is located in the atmospheric envelope of the earth—already distant but still a bit close. The plant-ego is described by Steiner as localized at the center of the earth—a world of incredible inaccessibility and yet still belonging to the earth. However, the ego-being of the minerals has its home in the fixed stars: light years removed from us.<sup>26</sup> That which still appears like a metaphor in such indications takes on its full spiritual reality when Anthroposophy lifts the veils of spatial metaphors and focuses the question on the world of hierarchies of spiritual beings. From there it is suggested that a full understanding of the animals is accessible to the third hierarchy above humankind (angels, archangels, time-spirits); correspondingly, the being of plants is understandable from the perspective of the spiritual beings of the second hierarchy. The mystery of matter, however, is only revealed to the highest Seraphim and Cherubim.

The most difficult area for the human being to understand is matter. This might be connected with the reason why we have a better methodology for anthroposophically-extended biology. New teaching methodologies have been developed in the fields of physics and mathematics as well. However, a renewal of chemistry, worth being handed down to posterity, has been most difficult. We can see anthroposophically why that is so, but we are too quick to take up this challenge if we follow the conviction that we can do it with the methods directly accessible to us today.

General chemistry—more so than physics—has posed the question of matter purely pragmatically. There are many philosophical physicists (Gustav Theodor

Fechner, Max Planck, Werner Heisenberg, and Carl Friedrich von Weizacker). Yet, philosophically productive chemists are always extremely rare. Perhaps, we could name the contemporary of Rudolf Steiner, Wilhelm Ostwald—but his works didn't reach many. Hence, the limitation of explanatory surrogates, i.e., models, is especially great when it comes to chemistry. We don't find this form of thinking amongst ourselves? This doesn't apply also to our own ranks? As long as we cannot agree on an agnostic phenomenology such as: "We take pleasure with all our senses in the material manifestations and treat that in the most practical way," the thought offerings of our chemists have their own "model-like" structure. As I have attempted to show, this lies in the nature of chemistry itself.

If our goal seems so unreachably far away, should we join Goethe in practicing "positive resignation?" Is it simply impossible to improve chemistry teaching? Or is there something we can do about it?

### HOW CAN CHEMISTRY TEACHING BE IMPROVED ?

First, the teacher needs to honor the **basic teacher's ethic** to bring nothing to the students which one has not thoroughly investigated oneself. Although this applies to all subjects, it is even more important to follow it in chemistry.

Because a spiritually-correct understanding of matter will only develop in far future stages of human consciousness, we are—anthroposophically speaking—continuously faced with the challenge to foresee the future. In fact, education is faced with the same problem. The teacher, as long as she takes her work seriously, has to convey not only the treasures of the past, and the essence of the present but also needs to be sensitive to the future mysteriously shining through in each and every one of his students, and he needs to find a way of laying seeds for the future, addressing their developing egos in an artistic manner.

New things are usually born out of great tensions—unless the debate becomes aggressive. It seems to me this is related to why, in the Waldorf curriculum, chemistry is deferred until later than physics and mathematics. Earlier I mentioned that middle-school physics is introduced in 6th grade and chemistry only in 7th grade. The onset of rational, or rather causal-thinking, abilities of the students, however, is really only in the upper grades and is called upon in mathematics, especially in the area of permutation-combinatorics theory (9th grade), and in physics in the area of mechanics (10th grade). In the 9th grade, however, phenomenological-organic [biogenic] chemistry remains the standard. Nevertheless, the systematizing and quantitative methods of inorganic chemistry should correspondingly be delayed and then enter the curriculum in full force during the 10th grade.

All efforts to initially bridge the hiatus between phenomenology and a quest for true understanding towards the end of the high school years remain stuck as mere initial attempts. Kolisko never discussed this problem publicly. Frits Julius discussed the 10th and 11th grades in detail.<sup>27</sup> His plans for the 12th grade, however, were only very sketchy. The important central indications of Rudolf Steiner received little attention overall and were taken to heart by only a few individuals.

Perhaps Steiner's concrete indication to discuss the occurrence of oxalic acid and formic acid in the human organism as part of the 12th grade chemistry curriculum<sup>28</sup> may serve as an example. On the one hand, a professional chemist was brought in to investigate everything available in the most recent technical publications about both organic acids in order to confirm or disprove the indication that both acids exist within the human body.<sup>29</sup> After researching 196 publications, it

was confirmed that nothing contradicted Steiner's indication—a reassuring, yet meaningless experience. Reinhard Schoppman proposed a sensible phenomenological methodology for this topic.<sup>30</sup> On the other hand, one of our young biochemists, working on the same question, found out that over the period over the last seventy years no advances have been made in this area because oxalic and formic acid occur in such trace amounts within the human body that their existence appears insignificant and can be compared to the level of free iron in the human body. When Steiner discussed such substances in life processes, he only dealt with their *organically-bound* forms. Today, we can find these and other substances in all cellular respiratory processes, surfacing in the form of di-carboxylic acid groups and carboxyl groups within the citric acid cycle. Steiner's indication that oxalic acid is connected to etheric decomposition and formic acid is connected to astral decomposition<sup>31</sup> allows a central process such as the citric acid cycle to be better understood. The citric acid cycle, in turn, sheds further light on Steiner's statement, so that we finally can explore the pedagogical presentation of these processes. (See the good attempt by Klaus Frisch).<sup>32</sup> Nevertheless, one still runs into a lack of understanding. One reason may be that "modern" biochemistry, with its instrumentality of structural forms, is considered as negative and suspicious. Another, very simplistic, reason may be that in being very understandable, it destroys the "numenosity."

Essential to the 12th grade is Steiner's advice to the teachers to review and summarize all the preceding chemistry classes and introduce the students to a wider consciousness of a four-folded concept of substances. A few scholars have made efforts in this direction (W. Schad, A. Scheffler, von Mackensen and Schoppman),<sup>33</sup> but none of them refer to or comment upon each other's efforts. And since individual efforts prevail, none of the results gets beyond the personal, and no overarching ideas develop to build a common ground. There are several easily detectable reasons for that, which could also be easily overcome. I suggest that the activists within this area of expertise meet and exchange their ideas until they produce more than their individual findings. Second, the solution is neither purely phenomenological nor does it follow conventional chemistry, but lies in the realm of *reconciling the gap between them both*, since it was given as a pedagogical task appropriate to be taken up in the 12th grade (finding a synthesis).

## SUGGESTIONS TO RECONCILE THE CONFLICT

What is the task for Waldorf chemistry teachers? First, if possible, the teacher needs to avoid frustrating the 18-year-old students, by being the only one with enthusiasm for the experiments which are in turn not understood by the students. Also the teacher should refrain from engaging in purely conventional chemistry, as it is taught in public schools, which students only study because of ambition and the pressure of exams. In the chemistry methodology of public schools, much has come to light in recent times which points towards overcoming this conflict.<sup>34</sup> (See German periodical *Natural-Science Teaching*, 1997). In either case, the elimination of either extreme position does not bring us any further.

However, the conflict can be made pedagogical, if the conflict that the teacher is facing is openly brought into discussion with the *upper grade* students, the fruitful tension shedding (new) light on the situation, allowing for the discussion to develop within a discourse. Here I am in complete agreement with Hans Müller-Wiedemann. That is mainly what I have done during my decades of Waldorf teaching.

We should not underestimate the students' ability to form opinions at this age. These maturing youngsters seem to identify easily the methodological tension between experiential and conventional (formal) chemistry as a particular problem of chemistry. They are also grateful when solutions are derived in a natural way (and do not appear artificial) or when no solution is offered (if the teacher really does not have one). The tension can be intensified methodologically by a very conscious effort to divide the weekly lesson plan: "We will do three days of qualitative chemistry and then three days of quantitative physical chemistry, in an alternating counterpoint" (like a swinging pendulum between two extreme points, capturing the entire spectrum of chemistry). This mental Roman sauna (alternating from a hot bath to a cold bath) not only feeds the different interest groups but also openly allows the older students to become rightfully introduced to the scientific historic problems with which their teacher lives. First the teacher can present structural chemistry, then follow this with demonstrative perceptual exercises with a Goethean ideal in mind. One can proceed with these two approaches alternately. The teacher can just do it and not talk about it. It is motivation for the future. And, this becomes even more effective in a great moment when both approaches seem to not negate one another but, rather, complement one another. Those students who experience this moment will be properly motivated for the future.

In that we show the contrasts without emotion, and work them out together, we will overcome a widespread polarization in the school movement—to either merely take naïve joy in the smells and explosions of the "chemical kitchen" and to demonize university chemistry as evil or else to only study and practice a chemistry of atomic models exclusively, since it is technically usable. This undesirable but all too common polarization to a single outcome should in the end no longer be pursued. This has brought too little over the last seventy years and will bring still less over the next hundred.

As a university professor for the last seven years, I have glimpsed the difficulty which today's pre-medical students have in the first semester of university-level chemistry. The difficulty for the majority of those coming from public high schools is just as massive as for the Waldorf graduates. It is only necessary that all of them have already received the capacity to make overcoming each transition personally productive; this alone will help them. However, this can hardly be said to them. At minimum, the development of the conceptual horizons of 20th century chemistry should not be cut out of the upper grades. If this is concealed from the students, we thereby pass by a pedagogical duty to make clear the history of this subject through the 20th century. The 17-19-year-olds want to be contemporary. That the students thereby experience the transition to 13th grade chemistry (preparation for the college entrance exam) without too much of a break, and even find a connection to chemistry in their studies is an additional pedagogical achievement.

With these comments, I want to open a forum on the assigned theme in a thoroughly methodical way, as well as point us toward meaningful, sensible educational directions. There, as is well-known and as I have said already, the chemist is not so much involved with insights but with what is manageable and workable. The question presumably remains, "What have you done in details in your chemistry teaching?" From this reality a conversation can arise.

## Endnotes

- <sup>1</sup> F. Julius: *The World of Matter and Human Education*. Part I: *Chemistry Demonstrated by Simple Phenomena*. Also, Part II: *Foundations of a Phenomenological Chemistry*. Stuttgart (Verlag Freies Geistesleben) 1960/ 1965. Translated by AWSNA Publications, 1999.
- <sup>2</sup> R. Steiner, *The Significance of Anthroposophy in Modern Spiritual Life*, April 7-12, 1922; GA 82.
- <sup>3</sup> R. Steiner, *Anthroposophical Community Building*, lecture on January 30, 1923, p. 41/ 42. GA 257.
- <sup>4</sup> R. Steiner, *Faculty Meetings with Rudolf Steiner*, vol. 3, April 24, 1923; GA 300c.
- <sup>5</sup> *Ibid.*, *Faculty Meeting* September 22, 1920; GA 300c.
- <sup>6</sup> Oral communication from Fredreich Kipp.
- <sup>7</sup> For example, in the field of Astronomy compare Thomas Schmidt: *Science in Astronomy Lessons*. in: *Erziehungskunst* 1998/ 1: 15-26.
- <sup>8</sup> R. Steiner: *The Temple Legend and the Golden Legend*, lecture on October 21, 1905, p. 195. GA 93.
- Also: *Myths and Sagas; Occult Symbols*, lecture on October 21, 1907, p. 133-134. GA 101.
- and E. Bindel and A. Blickle: *The Periodic System as Document for Creation* in: *Die Drei*: 1984, vol. 2 and 3, p. 90-107.
- <sup>9</sup> R. Steiner: *Anthroposophical Community Building*, January 30, 1923, p.41; GA 257.
- <sup>10</sup> Stoichiometry is the study of quantitative ratios seen in chemical combining and reactions.
- <sup>11</sup> The "Goethean" perspective follows Goethe's scientific viewpoint. One of his ideas centers around "polarity and intensification," where contrasting / opposition phenomena can interweave at a higher level.
- <sup>12</sup> Stereoisometry: isomers are chemical compounds with the same proportion of elements (same molecular formulae), yet show different characteristics; they differ in the spatial arrangement of atoms within the molecule; *stereoisomers* even have the same connectivities, but differ only in that their spatial arrangements are *mirror images* of each other. Living systems often show a preference for one form, designated the 'right-handed' form (ex: d-+-glucose).
- <sup>13</sup> Ernst Bindel and A. Blickle: *The Periodic System of Elements as Document for Creation*. in: *Die Drei*: 1984, vol. 2 and 3, p. 90-107.
- <sup>14</sup> J.W. Goethe: *Principles of the Philosophy of Zoology*. in: *Berliner Jahrbucher fur Wissenschaftliche Kritik*, September 1830, vol. 51, 52, March 1832, Hamburg edition, book 13: 219ff.
- <sup>15</sup> Bonding Theory: Chemistry distinguishes between several bonding types/ forms. Process kinetics: The recognition of time elements involved in chemical processes, therefore a time structure of chemical processes.
- <sup>16</sup> I refer here to those forces in the organism which fashion processes and forms of life, out of matter, and constantly renew them.
- <sup>17</sup> R. Steiner: *Foundational Impulses for Spiritual Science*, January 29, 1906, p. 24. GA 96.
- <sup>18</sup> E. Kolisko: About the first chemistry lessons. in: *Auf der Suche nach neuen Wahrheiten*. Verlag am Goetheanum, Dornach 1989. F. Julius: see footnote 1, above.
- <sup>19</sup> E.A. Stockmeyer: *Rudolf Steiner's Indications for Waldorf Education*, manuscript edition, Stuttgart 1988: pg. 14.
- <sup>20</sup> Octet tendency: When there are eight electrons together in the outer atom shell, it resembles high stability. The Physicist Wolfgang Pauli discovered the principle that two electrons within an atom shell can never have the same quantum numbers.
- <sup>21</sup> R. Steiner: *The Archetypal Phenomenon* (1890) in: GA 1, Dornach 1987, p. 247.
- <sup>22</sup> Goethe, 1803
- <sup>23</sup> R. Steiner: *The Birth of Natural Sciences in world history and their Subsequent Development*, lecture on January 6, 1923, p. 144. GA 326, Dornach 1977.
- <sup>24</sup> Steiner, GA 1, p111
- <sup>25</sup> J. W. Goethe: *Wilhelm Meister's Wandjahre II*, 9 and III from Makariens' archives 103. Hamburg, book 8, p. 260 and actual quote on p. 476.

26 Steiner GA 105

27 F. Julius: *The World of Matter and Human Education*, Part I: Chemistry demonstrated by Simple Phenomena; Part II: *Foundations of a Phenomenological Chemistry*, Stuttgart 1960/1965; English translation AWSNA 2000.

28 R. Steiner: *Faculty Meetings with Rudolf Steiner*, April 30, 1924; Vol.2. GA 300c, p. 748, Dornach 1975, Anthroposophic Press 1999. R. Steiner: *Creation of Mysteries*, GA 232, Dornach 1987, p. 193 ff (December 22nd 1923. R. Steiner: Meditative observations and instructions for the study of medicine. GA 316, Dornach 1987, lecture on March 1st 1924.

29 A. an Hooft: *Formic Acid in the Human Body and in Nature*, Kassel 1992.

30 R. Schoppman: *Formic acid and Oxalic acid; A Commentary on the 12th grade Chemistry Block, Erziehungskunst*, 1991/6, p. 559-571.

31 The etheric formative processes (11) build up the physical body, the astral (soul) forces eat away at it and break it down.

32 K. Frisch: *Oxalic and Formic acid. Understanding the Curriculum Choices of Rudolf Steiner for the 12th grade Chemistry Block*, in: *Erziehungskunst*, 1992/ 6,7, p.577-599.

33 W. Schad: About the particularity of astral substances - prerequisites for an understanding of veterinary/ animal remedies. Weleda correspondence notes for doctor 79, 1971, p. 52-60. revised print in: The human being and remedies, Weleda correspondence notes for doctors 100, 1981, p. 103-112.

A. Scheffler: *About the Creative/Changing Powers of Fire - for Chemistry Lessons*. Tycho de Brahe Jahrbuch für Goetheanismus, Niefern-Oschelbronn 1996, p. 373-410. M. von Mackensen and R. Schoppman: *Oxalic Acid, Formic Acid, Uric Acid. Chemistry as Effect not as Cause of World Substance*. manuscript copy Kassel (Pedagogical Institute), 1997.

34 Recently, new methodologies for chemistry developed in regular schools, working toward the surmounting of this conflict. Take a look at the publications within the last recent years of the journal: *Naturwissenschaften im Unterricht Chemie*. E. Friedrich Verlag, Seelze.

## IN SEARCH OF A CONSENSUS: ABOUT CHEMISTRY LESSONS AT WALDORF SCHOOLS

by  
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from: *Erziehungskunst*, Jan. 1999, No. 1, pp. 1095-1101.

In the introduction to Wolfgang Schad's article "Experiences and Suggestions for Chemistry Teaching in Waldorf Schools" the author called for a deeper discussion among Waldorf science teachers about the chemistry curriculum.<sup>1</sup> Since the founding of the first Waldorf School, the indications of Rudolf Steiner, especially those concerning the upper grades, have rarely been the focus of extensive inter-disciplinary discussions. Annual conferences, lectures, and seminars specifically designed for chemistry teachers have been offered for decades (mostly in Kassel). But these seminars did not bring about the hoped-for strengthening of the subject, because many of the chemistry teachers at Waldorf schools come from educational backgrounds where chemistry had been only a minor, next to physics and/or biology. And since chemistry had not been their focus of study, their energy remains more in the other subjects (physics and biology). Furthermore, conflicts of interests developed because all subject-specific conferences were scheduled in the autumn, usually around the same time. Consequently, conferences, seminars and lectures specifically designed for chemistry teachers were poorly attended. However, since 1996, subject-specific conferences have been scheduled in succession, so that a greater attendance can be expected.

These preliminary remarks should complete the picture about the reasons for "dissent" among Waldorf chemistry teachers as portrayed by Schad (1998). Although much of Schad's presentation is quite stimulating, yet, upon reflection, much appears still incomplete and lacking detail, especially with respect to the reconciliation of the so-called "chasm between phenomenology and the desire for systematic understanding that high school students experience toward the end of their school career." According to Schad, it appears as if particular pedagogical goals of Waldorf education are generally not met at all, or only met inadequately in Waldorf school chemistry classes. In order to take a closer look at these issues, we need to ask ourselves first what is the purpose for chemistry lessons in Waldorf schools? Only through such questions can we make distinctions between the current traditions. Rudolf Steiner clearly didn't include chemistry in his general curriculum because it had been an established natural science subject in elementary and secondary schools during the 19th century, not because it had

become a high school elective within the natural sciences, and was being included in the university entrance exams.

Furthermore, this touches the even more comprehensive question of why Waldorf schools developed their own methods in almost all subjects, differing from conventional ones? From one particular viewpoint, one could claim that the specific way Waldorf schools work to reach their educational goals is often not the easiest nor most direct, but to an extent is a detour along a more indirect path. At first sight one could say that the apparent goals are different from the actual ones. But such real educational goals have more depth and are often manifested in an entirely different area than might be conventionally defined for the subject.

For example, consider handwork: students learn to knit at an early age. It would be incorrect to assume that this happens because we want the students to become competent professional knitters. Rudolf Steiner said, "The main thing is that the cultivation of handwork will allow a person to become *practical in many different ways*," (italics by the author). Although it might seem paradox to some, I am convinced that one cannot be a good philosopher unless he/she is able to mend his/her own socks or clothes if necessary...<sup>2</sup> Much as handwork helps to develop thinking, other lessons—like book binding, land surveying and wood work—are not done primarily to lay a basis for future employment, but, rather, help serve the development of higher abilities—particularly the development of social relations. The attentive reader of this journal should be able to think of many other examples that have been described by different authors. Does not the positive reputation Waldorf schools have in the public opinion rest mainly on the fact that its developmental path does not lead directly to premature specialization but rather is always aiming to educate the harmonic development of the whole human being. Thus, Waldorf education finds a niche, developing key qualifications<sup>3</sup> highly sought and requested in today's labor market? What can chemistry lessons contribute to the practical life of a young person, today? Should the teacher try only to teach the knowledge needed for standardized tests and a study of chemistry as it stands today? In his recent article, Schad vividly described this type of lecture as "paper maché," and pointed out that actually, instead of understanding, only belief is cultivated. Would it not make more sense for the lessons to create a much more comprehensive foundation so that all students—even those who end up not going on to college—can form their own thoughts in a healthy independent way, allowing them to orient themselves and develop their own critical thinking in *all* areas of their lives? This sounds very idealistic and is, of course, not directly attainable only through chemistry lessons. However, chemistry—especially as a natural science—offers unique qualifications. To clarify this daring statement, we will attempt to consider chemistry from a somewhat unusual viewpoint.

## What is the Special Purpose of Chemistry?

All too often, even in Waldorf schools, chemistry is interwoven with physics without conscious reflection. If we want to be precise, only *transformation* of substance and, most generally, all processes and transformations in the widest sense belong to chemistry. *Descriptions* of matter and also its arrangement based on outer characteristics, and questions about the causes of such distinctions in the perceptual phenomena of matter (atomic structure), considering only the present situation, the status quo, belong essentially to physics. Physics is “the science of being (matter)” in which time is only of quantitative significance. (Schad specifically described this very well in the section of his article “The unique nature of Chemistry.”) In the sense we are striving for, chemistry lives *directly* in the difference between the before and after, where “time” is qualitatively and immutably part of what happens. Thus, chemistry is the “science of creation and passing away.” Chemical formulae are only correctly read and understood in this sense, when the notation “ $H_2O$ ” is understood as follows: totally homogeneous water *can*, through transformation, form two volumes of hydrogen and one volume of oxygen or could *be formed* by reacting these elements in the given proportions. All formulae, then, entail two unexpressed aspects: the future (analytic) and past (synthetic) aspects. They are expressions of processes that happen in time. The present, the only time in which we can experience the substance, is insufficiently described by a formula, because water *is* only water whenever we observe it and does *not* consist of two gases (such as “explosive-gas” a mixture of oxygen and hydrogen). Instead, water *in future* allows these two gases to form in a future experiment; it *was* formed using these two gases in a reaction in the past.

This type of “chemical thinking” is extremely important and should be completely internalized by chemistry teachers, so that he or she will consistently use different terminology without having to consciously focus on it. Then, the teacher would not talk about a substance *consisting of* different elements, but instead always speak about *arising* (or passing away). Also, “water arises out of hydrogen and oxygen (or: can be decomposed into hydrogen and oxygen),” etc.

Now, our human senses are formed in such a way that (chemical) becoming and passing away cannot be perceived *directly*—in the truest sense, this is *supersensible*. Because of the way our senses belong to the physical body, we can detect only the physical characteristics of substances before or after a transformation process takes place. Therefore, we have become accustomed to fill that “black hole” between observations with theories and (philosophical) models.

With “*what*” can we perceive processes which take their course in time? In order to do that, a thinking is necessary that to a certain degree interweaves the individual,

“timeless” observations into a continuum, and thereby inwardly creates a picture of that which outwardly is only observable as a beginning and an end.<sup>4</sup>

So, whenever we discuss a chemical transformation with students in such an intensive and broad way as possible, comparing the before and after of it, and attempt to reconstruct the chemical process in thought, then we are working on mobility of thinking! The frequently cited “phenomenological approach” used in Waldorf chemistry teaching only makes sense when approached this way; it cannot be sought in mere dramatic impressions of colorful, smelly, smoking or explosive experiments, as Schad also says in his article.

At this point, it makes sense to take a look at Goethean methods in other areas. Just as Goethe himself said, “Natural history relies mainly on comparisons,”<sup>5</sup> comparison is *the* method of choice in every science in which matter transforms in time. For example, Jochen Bockemühl demonstrated this beautifully in his “leaf metamorphosis series” and his work on plant landscapes.<sup>6</sup> Here also, the research goal remains in the intervening realm—the individual sensory observations that are bound up with moment-to-moment impressions. However, this interval can only be grasped through extensive practice. The same holds true for the so-called “picture-forming methods,”<sup>7</sup> where in a single picture is actually only the expression of a past effect—also an artificial (laboratory) world, as Schad emphasized. Only through *comparison* of several pictures can we, as spiritual beings, come closer to the creative powers that are hidden (with)in the artificial-technical world. The comparing and evaluating human being is the instrument for revealing images, not the pictures themselves. Some teachers have experimented with this with much success and approval from high school students.<sup>8</sup> (Viewed this way, the term “spiritual” includes *everything* which is active *within* the researcher.)

The often puzzling formulations by Steiner in his indications for the 12th grade chemistry curriculum about the four-fold nature of protein,<sup>9</sup> can only be understood through comparison of the before and after (past and future) of protein in the four different kingdoms of nature and not somehow from analytical differences between particular protein forms.

## Chemistry Lessons as Schooling for Living Thought Processes

I don’t have to emphasize the importance of living thought processes—in contrast to schematic thinking. Moreover, chemistry serves as a unique tool for schooling the flexibility of thinking. This then should convince and encourage many teachers to prepare their classes accordingly. The quantitative and systematic methods of inorganic chemistry often promoted starting in 10th grade appear counterproductive to

the development of flexible thinking. The need for students to know and understand why something happens (their “quest for causal understanding,” as Schad puts it) can be satisfied in those subjects where cause and effect relationships really take place, namely in the study of mechanics (as Steiner pointed out, “Mechanics is more important than Latin”), and in handwork techniques. Treating chemistry as a physical science because of the students’ natural curiosity for cause and effect relationships seems questionable. The “interval between phenomenology and the drive to discover causalities at the end of their school career” can be bridged in other ways. A brief outline of them follows.

Clearly, the students will and should notice the difference between “Waldorf chemistry” as outlined and conventional-school-chemistry. However, we can and should avoid their perceiving conventional chemistry as the “real chemistry.” Hans Rohrwacher describes vividly in *Erziehungskunst*, 1998:6, how this can be further complicated when (perhaps starting in 11th grade) the phrasing and explanations of the materialistic world-view, as *historically conditioned*, and constantly evolving, become increasingly interwoven into our observations and studies—as a gift [adding to or supporting the scientific theories] instead of being critically examined in contrast. This is how it should be expressed: “What we experienced right now has been explained in the following ways throughout the history of chemistry ...” By no means (not even in the teacher’s own thoughts!) should the student be exposed to comments like this: “Benzene is actually a ring of six carbon atoms.” Instead we should hear statements like: “Modern attempts to explain the reactions of benzene go back to August Kekule, who suggested a model that shows six carbon molecules configured in the following way...” But *before* we take that step, we need to make certain that an image such as the commonly used ball-and-stick molecular model will not be taken as simply realistic, no more so than they would look for a church, represented on a map by a cross, as actually a large statue of a cross. This is a clear indication (as Schad mentioned correctly) of how increasingly *de-materialized* mental pictures of models are necessary, leading up to the quantum wave-mechanics interpretation, rather than materialized as “bones”! Here the task of the physics teacher begins; he can usually only give an approximate description of the most modern concepts because a thorough treatment of quantum theory goes beyond the capacities of most high school students. The last mentioned fact furthers the impression that what we mean under the term “matter” is not easily solved by a sensory approach. Of course, we need to examine carefully at what age the students become capable of distinguishing between human concepts and naturally existing realities, so that we do not shake their confidence in life by leaving them standing at the edge of an “inter-corporeal” void. Rudolf Steiner indicated it was possible and even “pedagogically incredibly important” for physics [not chemistry!] teachers to “come as

far as talking about theories of ions and electrons, without talking about anything other than phenomena” during the main lesson block on electricity (*Conferences with Teachers*, Sept. 25, 1919).

From my own experience of many years, I can say it is not a problem for students who graduate from the 12th grade (and even less for those who continue with the German university admission exams in the 13th grade) to interrelate the phenomena experienced and mentally worked out in classes with current attempts at explanations, especially when their relationship was discussed—now and then with a wink of an eye. At times we can even note a sense of pride because the Waldorf schools pave their own way, independent of the mainstream, not blindly following those conventions that somewhat managed to drive chemistry into a sad state.

When Schad mentions Steiner’s indication that Waldorf high school students should meet the newest developments in natural sciences, this comment refers to physics and it does not involve teaching students the materialism which goes along with the newest theories and developments without questioning.<sup>10</sup> Those students who elected chemistry in high school are frequently able to transition well into the chemistry classes taught at universities because they have been exposed to flexible thinking and have practiced it throughout their school careers. The significance of flexible thinking is demonstrated continuously in the requirements placed on educational institutions by industry. Who is not aware of the dangers of overspecialization?

At last, I would like to make a comment that refers to a public opinion that assumes that Waldorf school students are reinforced in the view that “chemistry is evil.” Actually, quite the opposite takes place. Almost all of Steiner’s instructions for chemistry lessons at different grade levels include comments on physiological, i.e. living processes, which then in 12th grade culminate in the suggestion “to experience chemistry in connection with the human being.”<sup>11</sup> Through such a growing and ultimately specific knowledge that *all* living processes of the human being are accompanied by chemical transformations, students gain a new and positive attitude and relationship toward chemistry as a science—which otherwise is often perceived only negatively, viewed in the context of the widespread and often hazardous chemical industry.

Perhaps, on the basis of this interpretation, the unbiased reader can see how the subject of chemistry in Waldorf schools makes an important contribution to the overall educational goal, although, or, because, perhaps, it differs from conventional methods. The chemistry teachers will surely discover in this the consensus that Schad missed.

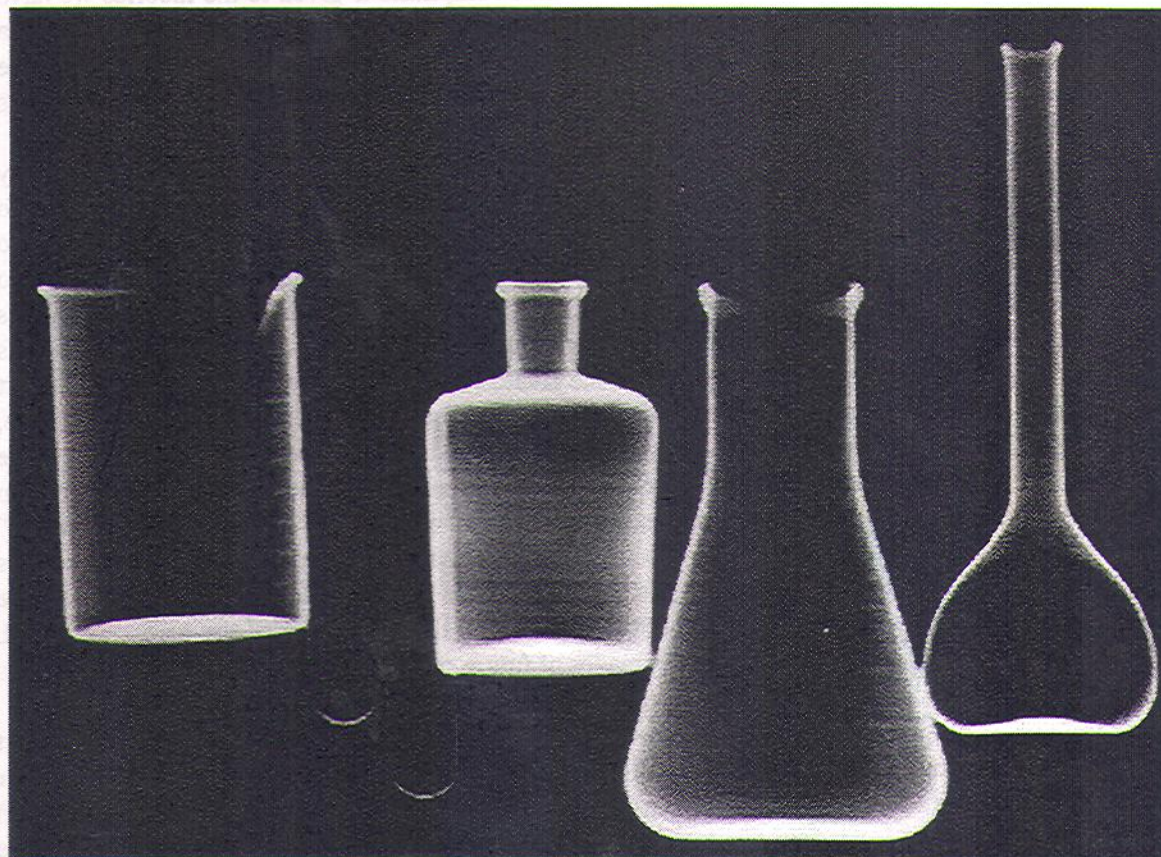
## About the Author

Reinhard Schoppmann, with a Diploma in chemistry and a Doctorate in Natural Science, was born in 1930. He graduated from the Rudolf Steiner Schule in Wuppertal, studied chemistry in Karlsruhe and Innsbruck. After working for a pharmaceutical industry for seventeen years, he was a high school teacher at the Pforzheim Waldorf School for eleven years. Since 1987 he has been a researcher and member of the Pedagogical Research Institute of the Union of Waldorf schools in Kassel, and an instructor at the Waldorf training seminar there, teaching Waldorf pedagogy and chemistry to Waldorf teachers.

## Endnotes:

- 1 Wolfgang Schad: About Chemistry Lessons at Waldorf Schools. In: *Erziehungskunst* 1998. volume 62: 3, p. 264 ff.
- 2 Rudolf Steiner: Lecture on Contemporary Spiritual Life and Education, August 17, 1923, GA 307 Dornach 1986.
- 3 See "Discussions" with Stockli and Hiller in: *Erziehungskunst* 1998: 7/8. p. 808.

- 4 Similar things happen when we attribute speed to a body after observing that it has changed position within a particular time frame. The possibility to perceive separate sounds and experience them as "music" is another example of human abilities to "complete a picture mentally."
- 5 Johann Wolfgang Goethe: "First Draft for a General Introduction to Comparative Anatomy," Jena 1795. Hamburg edition, book 13, p. 170.
- 6 For example, in: Towards a Phenomenology of the Etheric World," Edited by Jochen Bockemühl, Stuttgart 1977, transl. Anthroposophic Press 1985, p. 11ff and p. 131 ff.
- 7 Here, we primarily consider a) the "Steigbilder" method which Lili Kolisko first described in 1923, b) the sensitive crystallization method worked out by Ehrenfried Pfeiffer since 1930, and c) the drop-picture method which Theodor Schwenk introduced to research during the 1950s. Since then, these methods have been used, adopted and critically analyzed by numerous researchers in many areas of quality studies. Most of these works have been published during the past couple of years in the periodical, *Elemente der Naturwissenschaft*, Verlag Cooperative Durnau.
- 8 Upon the request of *Erziehungskunst*, a chemistry teacher is working currently on an [article/report] about these methods and experiences with their application in chemistry lessons.
- 9 E.A. Karl Stockmeyer: "Rudolf Steiner's Instructions for Teaching at Waldorf Schools" manuscript print, Stuttgart 1988. p. 235.
- 10 *Faculty Meetings with Rudolf Steiner*, GA 300a, Sept. 25, 1919, p. 29f.
- 11 See endnote # 8.



# *Experimentation as an Art*

by

*Frits H. Julius*

With a renewal of the instructional methodology in the subject of chemistry, it is natural that the style and method of experimentation may not remain unconsidered or unaltered. Conventional science rests in large measure on a foundation of experimental research, and one can only develop the greatest admiration for the methods which are utilized. However, if one organizes the teaching too much according to these usual methods – which are appropriate in research – we won't do the students justice. In the school there belongs, firstly, a fully developed demonstration experiment. This is something valid on its own, which must be implemented according to its own viewpoint.

In a scientific experiment, we are usually trying to detect the presence of some substance, or to prove or disprove a theory, or explain some phenomenon. So, typically we are working in realms which are new fields of inquiry or which we want to develop further.

However, in school we are dealing above all with areas which people already know and comprehend. That which is already general knowledge to a degree must be presented in the best possible way and as impressively as possible. But above all, we ought to base all demonstrations on allowing nature herself to speak as impressively as possible.

With many usual demonstration experiments, too much emphasis is given to the theories we have developed, i.e., to human thought or technology. For example, we are often dealing with phenomena which are noticeable through strong color development; nevertheless, we tend to pay less attention to the color as such and to what it might express, but rather take it only as an indicator: this color appears, so this material is present or that process has occurred.

If we wish to show the same experiment as a demonstration-experiment, not only should we pay attention to the color itself, but also—through every sort of technique—we should allow the color to develop to a brilliant expression. There is an "art of experimentation" where in we can allow ourselves to be led entirely by nature to some degree, and place our faculties at her disposal, thereby allowing her to show herself as unhindered and directly as possible. To this end, we must learn to see how something lies in the phenomena which could be called a delicate intention or design. If we take such impressions seriously and seek to realize these "intentions," then the greatest surprises follow. We should always start from the conviction that in nature something is concealed which can be revealed and, in a certain sense, wants to be manifest. In the preparation of an experiment, we shouldn't rest until we have the same feeling towards it as towards a plant: there, out of a jumble of green leaves, the splendor of the blossom develops. With such a style of experimentation, something like a "will towards the redemption of nature" must play a part. We will then notice that the processes become so matured and intensified [see Goethe's method] that an entire world-picture expands. In many cases, the images reflect a particular part of the macrocosm; in other cases, it appears as though a fragment of the prehistory of the earth is revived. Perhaps it is even possible, also, to make visible images of future stages of the world. However, with this we have reached a realm which goes beyond the domain of what we do in school.

In summary, perhaps we can say the following: nowadays, in doing an experiment, we usually start out from some intellectual, scientific or technical point of view. The alchemical experiments of earlier times had a strong religious background. What must be developed is the experiment as a kind of "art in practice." However, with this we naturally have to do with art in the sense of Goethe, which is at the same time a unity with science and religion.

## Guidelines for Experimentation

Now, we can turn to a discussion of concrete methodology. Some guiding principles can be given, which, if we follow them, will elevate the quality of the experiments to a splendid level.

The first of these principles concerns the size of the vessel—air or water container—in which we allow it to occur. To every experiment belongs a definite format, through which it is best appreciated. Usually we let the experiment occur in a flask which is too small. Nevertheless, almost always we obtain surprising activity when we increase the scale. We should have available beakers and Erlenmeyer flasks of the 2-3 liter size and in special situations even larger ones! Glass cylinders about 50 cm tall are especially useful (often called “hydrometer cylinders”); naturally, we also use flasks of the usual size. In certain cases, smaller beakers and cylinders (12 ml) may be recommended. A variety of reagent glassware is very desirable.

Furthermore, we should set up an apparatus in which a fire can be ignited, which is clearly observable, and from which dangerous vapors can be pulled away. A glass case ventilation when placed on the demonstration table is especially effective. (We will return to this in more detail below.) Doubtless, a good exhaust duct mounted over the flames or fuming liquid will have the needed effect.

The second principle has to do with the temporal sequence of the experiment. One part of this involves each individual's tempo of manipulation and another part deals with the rounding-off, ripening, which occurs in many experiments if one lets them stand quietly for a while.

Generally, we should not work too quickly, and also should not intentionally break off the experiment too soon. For example, if we get a precipitate to form while pouring one liquid into another, it is usually best to begin with a small quantity and introduce it bit by bit. Thereby, we give the precipitate an opportunity to develop impressively. Usually a characteristic play of colors or forms will develop in this way. If we allow the whole thing to stand overnight, usually something surprising will occur, as if nature grasped the proffered opportunity in order to develop a glorious play of color and form.

The third principle is connected to illumination. Even with the most mighty phenomena, something of the activity is lost through weak or poorly directed lighting, or an error in darkening. Therefore, we should have a strong light source available, and a way of making real darkness (thick room shades). For lighting a space, filament lamps of at least 150 watts are best; with fluorescent tubes false colors too easily arise.

The clearest experimental image is obtained if we darken the room and only illuminate the experiment itself, or just place it by a light source. Thereby we have the advantage of concentrating the attention of the students, and they also receive strong impressions at even moderate distances. In this way, we can demonstrate in front of even 150 people.

It is very advantageous, if we have special apparatus (light box), to illuminate the experiment. In doing this, experiments must be differentiated; those that require a dark background and are side-lit and those illuminated from above or below, as distinct from those which require no lighting, or simply a bright background.

With dark or only slightly transparent crystalline precipitates (e.g., Berlin blue), a bright background works best. With transparent crystalline materials, well-directed side-lighting calls forth the best results. Partially transparent hydro-gels are best appreciated in front of a dark background and illuminated from below; this provides a brilliant “dark field” illumination. A difficulty with this is that the precipitate often covers the light source; top-lighting can also be tried, but this is often less pleasing and more difficult to set up. Side-lighting often gives rise to disturbing reflections with round glassware. In certain situations, this can be avoided with rectangular flasks.

## Apparatus

### A Demonstration Cabinet with Ventilation

It is especially useful if we set up a demonstration table with an opening through which a strong airstream can be sucked away. (Note: this is not very common, and your architects will have

to be convinced of the real value of this.) There are many different ways for using such a device. If we want to do experiments on a reasonably large scale, where unpleasant or poisonous vapors are produced, a rectangular box or case with a zinc top and no bottom can be useful (75 cm wide, 60 cm deep, 70 cm high). The bottom half of the rear side is a sliding glass door which can be fixed open, closed or partway open. Because usually vapors rise and the warm air accumulates at the top, it is important to have a chimney vent (about 12 cm diameter) connected to a ventilation opening on the roof, that reaches about 5-10 cm down from the roof.

An important point is keeping the glass walls really clean; old newsprint can be used for this, or spirits can be used. If there are heavy, greasy gasses sinking down to the bottom of the box, we can pretty much close up the sliding door, and the gasses will spiral up and be sucked away. In that case, it would be best to have the air vented from the bottom and fresh air enter at the top. Therefore, a moveable door opening higher up is not convenient, because the rising vapors can escape too easily.

As background dark or illuminated, plywood can be used, with one side covered with white paper and the other with black. This can be stood vertically near the rear, using two long wood pieces to form a groove. We could also use frames covered with paper or frosted glass that can be illuminated from behind.

### **Bottom Lighting**

For this we recommend a common filament light bulb, suitably strong (100-150 watts). The bulb should not form a beam but should be as diffuse as possible. For example, we could set a beaker or cylinder on a tripod, without the wire gauze, and set the lamp underneath. A paper cylinder should surround the bulb and extend up almost to the tripod circle; the inside of the cylinder should be black to prevent the light from reflecting out sideways. White paper primarily prevents too strong a heating, and it additionally concentrates the light more. On the one hand, we must provide good ventilation for cooling, and on the other hand take care that as little light escapes sideways.

Water-filled flasks will appear very impressive with such lighting in a dark room. They will seem nearly invisible to the eye, except for the surface of the liquid and the edges of the glass vessel glowing strongly. The slightest imperfections in the glass walls, such as air bubbles or fingerprints will show immediately. The glassware should be totally clean. Under these conditions, most of the light is kept inside the vessel by total reflection and is directed up through the water. It is really necessary to protect the light bulb from accidental drops of water with a glass sheet; it is tricky to prevent the glass sheet from cracking if it gets too hot, however.

Of course it is easy to make a better light box. A cardboard cylinder, lined with aluminum foil and painted black near the top is mounted on a plywood base; on top, we attach another plywood sheet with a opening corresponding to the cylinder; we cover it with a glass window, maybe hexagonal with the edges protected by thick tape. Ventilation holes are punched in the cylinder at the top and bottom, but must be small enough not to let light out. The glass beaker stands on nested wooden rings, stacked to make the opening larger or smaller.

### **Examples of Experiments**

1. Set an empty glass cylinder on the light box; pour a thin stream of water into it. The air bubbles caught up with the water form a wonderful silvery sheen.

2. A 3-liter beaker is filled with tap water and set up on the light box. Slowly add saturated copper sulfate solution, a spoonful at a time. Initially, the water will have a light blue color, but eventually a weak blue turbidity (opalescence) will be visible with strong lighting (hydrolysis of the salt). Now, add a spoonful of hydrochloric acid; the turbidity is consumed and a clear solution remains. We can help this by gently making little vortices with a glass stirring rod; then we see amazing forms emerging in the turbidity, which remind us of cirrus clouds. Now, add some sodium hydroxide solution; wonderfully luminous, delicate flakes of copper hydroxide emerge. By adding hydrochloric acid again, these can be dissolved again. Then, carefully add ammonia (ammonium

hydroxide) dropwise to the solution. Deep, blue colored vortices are formed surrounded by a pale blue precipitate. The vortices rise to the upper part of the beaker, forming a deep blue but transparent layer there. Again, we can add sodium hydroxide; copper hydroxide is formed, even more beautiful than before. Now, carefully add some concentrated sulfuric acid. This sinks immediately to the bottom, causing some sloshing motion, and dissolves part of the precipitate, while the rest remains floating above. We can produce an enchanting image in this way, consisting of various layers. If we allow it to stand for a while, there will be slow changes which will often go through exceptionally beautiful stages.

This experiment shows clearly how we must carefully account for the various densities, but how we also can use them to achieve specific results.

3. Place a 3-liter Erlenmeyer flask on the light box and fill with a slightly acidified solution of copper sulfate. Suspend a yellow crystal of potassium ferrocyanide ( $K_4FeCN_6$ ) at the top (stick it on a wire loop with lip-balm or beeswax); a red-brown precipitate forms and sinks as luminous flakes to the bottom of the flask.

If we use iron sulfate instead of copper sulfate, the result is dark blue flaky precipitate in a red-brown solution. This phenomenon is most clearly seen against a bright background, while the former copper sulfate version is best shown bottom-lit with the light box.

In general, we often get surprising images in our experiments if we do not mix two substances which react by using solutions, but instead introduce one as a solid into a solution of the other.

Other examples: copper sulfate crystal in a solution of sodium hydroxide lye; a piece of soda lye in a solution of hydrochloric acid.

4. The light box: With the illuminating apparatus, one can greatly enhance the visibility of smoke or haze (mist). As a beautiful example, one can show the formation of ammonium chloride by bringing together hydrochloric acid gas and ammonia gas (ammonium hydroxide reagent solution). We place a large Erlenmeyer flask or wide glass cylinder on the light box. Pour some ammonia in the flask and place a filter paper over the opening. On this, we pour a few drops of hydrochloric acid (concentrated reagent). A brilliant white smoke results that sinks to the bottom in twisting threads or streamers. If we do the experiment in the reverse order, with hydrochloric acid at the bottom and ammonia at the top, then it develops much more slowly.

As with every other chapter of this book, this chapter assumes that the teacher has mastered the usual scientific knowledge and laboratory skills to a certain degree before taking up teaching. So, again, we will not strive here for a complete explanation of all details.

Of course, we will also use the usual methods in teaching. There are excellent books in this area. I wanted primarily to enrich the possibilities for doing demonstrations and experiments and further to find new ways to allow certain aspects of matter which often remain hidden to reveal themselves in the experimental scene. When one has used this image to school oneself, then the eye will, as it were, penetrate deeper into the phenomena, meet the phenomena; by developing the experimental skill adequately, the hidden is drawn out (unlocked), and the phenomena come forth to meet the perceptive eye.



## Dmitri Mendeleev

Born in Tobolsk, Siberia, on February 7, 1834, Mendeleev came from a large family of seventeen children of which he was the youngest. He received his first lessons in science from political prisoners who had been exiled to Siberia by the Russian government.

Just as he was finishing high school his father died. His mother brought him to the university in St. Petersburg and then she died. He finished college at the top of his class and then travelled to Europe for graduate studies.

In 1869 he worked out the periodic table of the elements after recognizing that the properties of chemical elements recur in regular patterns when the elements are arranged according to their atomic weight. His table had blank places for unknown elements which were discovered later. He also discovered the phenomenon of critical temperature, the temperature at which a gas or vapor may be liquefied by pressure.

He died in St. Petersburg on February 2, 1907.

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\* Taken from *The Wonder of Chemistry—7, 8, and 9*, by David Mitchell, available in Spring 2000 from AWSNA Publications.



## Joseph Priestly

Priestley was born in Fieldhead, England, on March 13, 1733. He was raised by a pious and strict aunt – his mother had died when he was seven years old. His health was fragile and his aunt would not allow him to go to school so he retreated to the attic where he taught himself French, Latin, algebra and geometry.

He attended the university and became a preacher. He was fond of dressing in fancy clothes and had delicate almost feminine features.

While attending a lecture by Benjamin Franklin on electricity, he was encouraged by Franklin to write. His writing led to his own experiments, and he discovered that carbon was a conductor of electricity.

Living next door to Jakes & Nell alehouse he observed the constant smell of beer fermenting. Experimenting with it, he found that the fermenting grain produced a gas which turned out to be carbon dioxide. He injected this gas into sweet water and created the first soda pop.

His greatest discovery occurred in 1774 while he was experimenting with gases; he heated mercuric oxide and discovered a gas which was to be later named “oxygen.” He noted that this gas encouraged materials to burn much more intensely.

Politically he was sympathetic with the American Colonies and the French people’s struggle against their monarchy. This led a mob with opposite views to burn down his house in 1791, and he fled to America. He spent his last decade teaching chemistry in the United States where he died on February 6, 1804.



## Marie Curie

Marie Curie was born in Warsaw, Poland, in 1867. Her father was a professor of physics and mathematics; as a young girl she lost her mother to tuberculosis. In 1895, she married Pierre Curie, a famous scientist. Along with her husband, she spent her entire life working in France and helped usher in the nuclear age by discovering the radioactive element radium. She was awarded two Nobel prizes—one for physics and one for chemistry. She is the only scientist to have won two Nobel prizes.

Curie faced profound difficulties as a woman scientist in turn-of-the-century France, and she also has personal tragedies—the untimely death of her husband who died in a Paris street in 1906 after his skull was crushed by the wheel of a heavily loaded horse-drawn wagon.

Marie worked in great difficulties. She spent most of her money to buy laboratory equipment. She lived in poor quarters and used an old shed as her laboratory. It kept out neither wind or rain. She studied x-rays, radiation, and the mysterious pitchblende, a highly radioactive rock in which uranium is found. Curie and other scientists handled the uranium with their bare hands, having no fear of the substances that were burning the tips of their fingers. Her cavalier attitudes fit into the craze over radiation that was gripping the world at the time.

Marie Curie founded the Radium Institute in Paris. She died in 1934, poisoned by the very radiation she labored to understand, from leukemia, which is caused by long exposure to radium. She is remembered today for discovering radium and polonium, two highly useful elements that can treat cancers, and tumors.

# DESTRUCTIVE DISTILLATIONS: THE EFFECTS OF HEATING A FERN LEAF AND WOOD SPLINTS

by

John Hoffman

Destructive distillation is appropriate for Grade 7 (burning, acids and bases), Grade 9 (organic chemistry) and Grade 10 (acids and bases). When teaching in the high school, I assign it as the second lab experiment in Grade 9. The first experiment I assign is glass working so that the students become familiar with the bunsen burner and learn how to break, polish, bend and draw glass tubing (5mm. flint glass). The students work individually or in teams of two or three, depending on the size of the class. Destructive distillation is an excellent hands-on experiment for introducing students to chemical apparatus and procedures. Although they may recall having seen the experiment demonstrated in Grade 7, carrying it out themselves is a very different experience. I have never had a student complain about carrying out an experiment he or she saw demonstrated in the lower school. Destructive distillation is also excellent for sharpening the students' observational skills, and it gives them an opportunity to reflect back to the burning and acid/base experiments in Grade 7. For the Grade 7 teacher it is a good experiment to tie the burning and acid/base work together.

The destructive distillation experiment is conducted in two parts. In part-1, a 5 to 8 cm fern leaf is placed in the bottom of a 25mm x 150mm test tube. Any green leaf will work, but I recommend a fern with a serrated leaf such as the cinnamon,



Fig. 1 Hay-scented fern

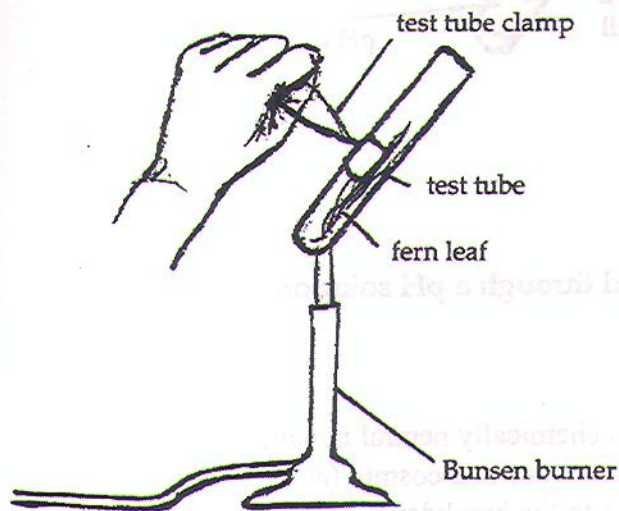


Fig. 2 Heating a fern leaf in a test tube

wood or hay-scented fern (Fig. 1). The delicate leaf structure gives impressive results. Also, leaves can be frozen in a sealed plastic bag for winter use. The 25mm x 150mm test tube has a fairly wide mouth which is important for good air circulation at the burning stage. The leaf should lie flat on the side of the test tube. The leaf is then heated uniformly in a Bunsen burner flame (Fig. 2). The first observation is that moisture is driven off and condenses in tiny drops around the mouth of the test tube. This is subtle and often missed by the students. The leaf continues to break down releasing a wispy, pleasant-smelling smoke. The leaf

retains its structure, slowly turning to black charcoal. Upon further heating, the charcoal burns with a glow. Sometimes it is possible to have a single glow burn slowly through the whole leaf structure. This burning produces almost no smoke. At completion, the structure of the leaf is still present as a silver-grey ash; but when the test tube is tapped, the ash falls to the bottom.

After the test tube has cooled, purple cabbage juice pH indicator solution is added to the ash. The solution turns green, indicating the presence of a base. The students are able to observe that the earthy residue (ash) of a leaf produces a basic or alkaline solution.

Next, two or three fresh fern leaves are placed in a 25mm x 150mm test tube. The test tube is stoppered with a one-hole #4 rubber stopper, and a bent glass tube (5mm) is inserted in the stopper hole. A second test tube is half filled with purple cabbage juice pH indicator solution. The open end of the bent glass tube is submerged in the indicator solution (Fig. 3). The fern leaves are then heated uniformly in a Bunsen burner flame. Once again the students should observe the breakdown of the leaves and release of volatiles. As the volatiles are bubbled through the indicator solution, the solution turns red, indicating the presence of an acid. (It is important to remove the glass tube from the indicator solution before removing the test tube with the fern leaves from the Bunsen burner flame! Failure to do this could result in indicator solution being drawn through the glass tube into the hot test tube.) The students are able to observe that the more cosmic volatiles (gas and smoke) from the destruction of a leaf produce an acid solution. The volatiles also mix with condensate in the test tube to produce a brown liquid which has a strong smell and stains the glass.

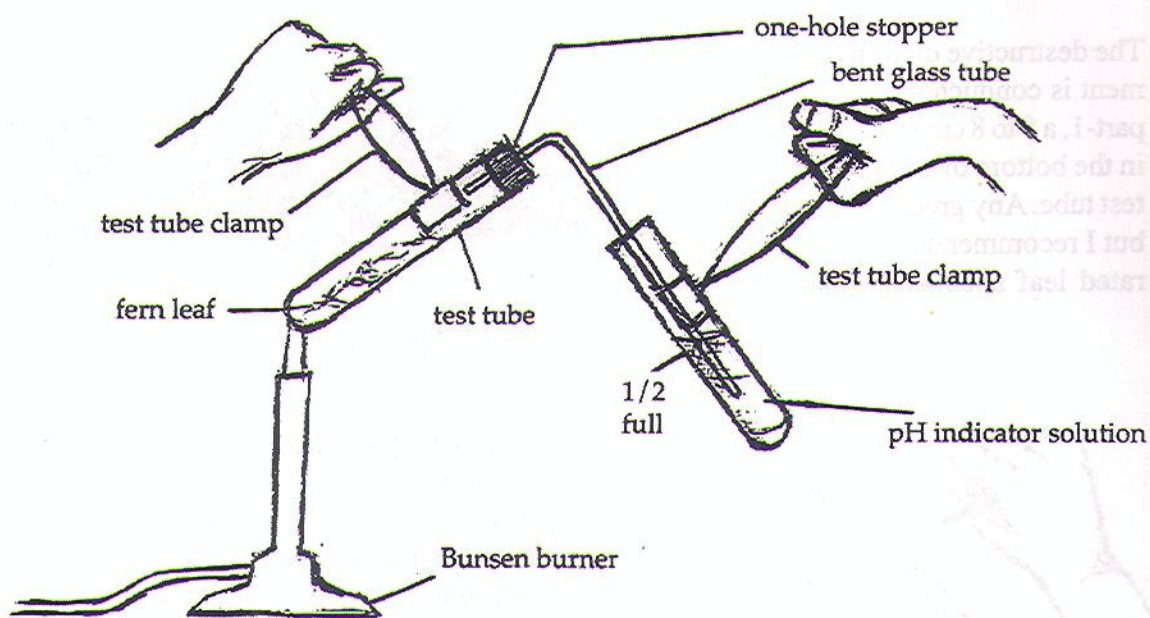


Fig. 3 Fern leaf volatiles bubbled through a pH solution

The students should experience that the green leaf is chemically neutral in nature and that heating it separates it into its more earthy (base anhydride) and cosmic (acid anhydride) components. The high school students can relate this to the breakdown of a salt. I recommend a review of the chemistry of the lime (calcium carbonate) cycle in Grade 10.

Part 2 of the destructive distillation experiments involves the breakdown of wood. A few 4-8cm wood splints (a broken-up popsicle stick works well) are placed in the bottom of a 25mm x 150mm test tube. The test tube is fitted with a one-hole #4 rubber stopper and a bent glass tube (5mm—the tip could be drawn to make a jet) inserted in the stopper hole (Fig. 4). The wood splints are heated with a Bunsen burner. The students are told to make careful observations as the splints break down. First, moisture is released, then smoke and a brown liquid (oils and a water solution of acetic acid, methanol, and acetone). The sides of the test tube become stained by the liquid. Gases exiting the jet tube have a foul smell and when lit burn with a yellow flame. The wood sticks gradually turn black (charcoal) but do not burn (why?) and retain their shape.

Once the volatiles have been driven off and the test tube cooled, the stopper is removed. The students are usually amazed that a few pieces of clean popsicle stick can produce such a foul-smelling mess. The black pieces of charcoal are taken out and burned. The students observe that the charcoal burns very clearly. The by-products have been left in the

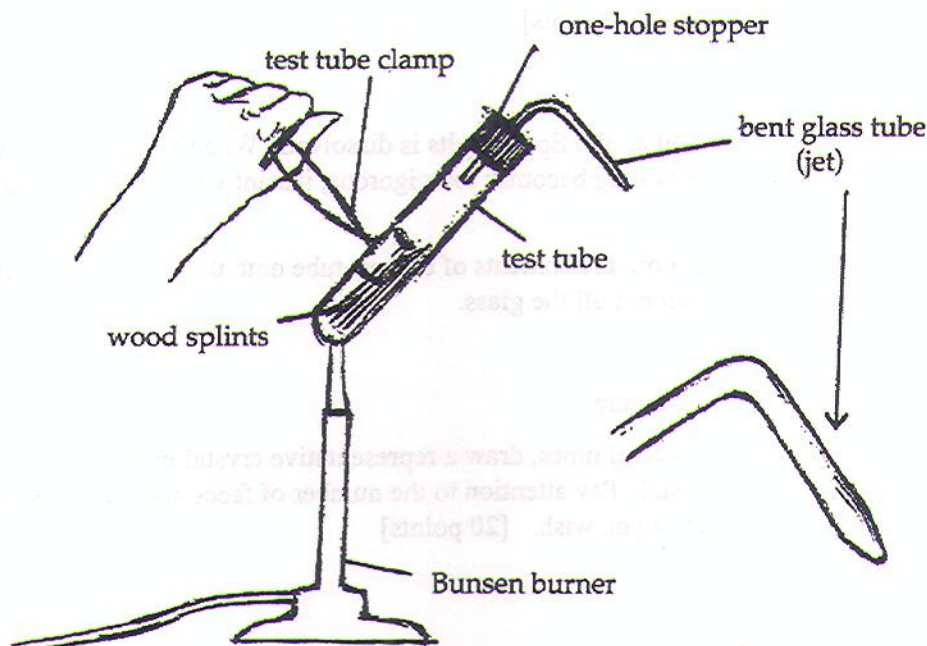


Fig. 4 Heating wood splints

air and the test tube.

This brings up the opportunity to discuss industrial pollution. In order for people to have clean burning charcoal, someone somewhere has to suffer the pollution left behind. Prior to the 1920s, the destructive distillation plants in the Catskill Mountains rendered local stream water undrinkable. Children were warned against swimming in the water. Men working in the plants suffered chronic lung and skin problems. In reaction to these harsh conditions, they sometimes drank poisonous wood or methyl alcohol which resulted in blindness or death. Today modern technology has helped to reduce the pollution, but unfiltered smokestacks are still a worldwide problem.

A last observation for the experiment is the difficulty in cleaning the test tubes, especially the one with the wood splints. I recommend the latter be thrown away.

# EXPERIMENT 1

Chemistry 11

Name: \_\_\_\_\_

## Crystallization of Epsom Salts

WEAR GOGGLES AT ALL TIMES DURING THIS LAB

### PROCEDURE:

- A. Wash a 8 1/2" x 11" pane of glass with detergent and carefully dry with a paper towel. The glass sheet must be completely dry.
- B. Support the glass sheet with a pencil under one end so that the glass sheet forms a slightly inclined plane.
- C. Using a funnel, carefully transfer two level teaspoons of Epsom salts (magnesium sulfate) to a small test tube.
- D. Add exactly 3.5ml of water.

What is the chemical formula for Epsom salts? [5 points]

- E. Using a Bunsen burner, heat the test tube until all the Epsom salts is dissolved. When all the salt is dissolved, the solution will go completely clear. If the boiling becomes too vigorous, instantly remove the test tube from the heat.
- F. Remove the solution from the heat and then pour the contents of the test tube onto the glass pane, starting at the higher end, so that the solution runs down but not off the glass.
- G. Observe the crystals that form.
- H. Wash the glass plate again and repeat the procedure.
- I. After examining the growth of the crystals several times, draw a representative crystal in the space below. Draw an idealized version of the perfect crystal. Pay attention to the number of faces and the angles between them. You may draw more than one crystal, if you wish. [20 points]

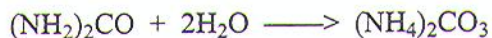
Note for instructors: the glass plate may also be placed on an overhead projector so that the whole class can watch the growth of the crystals.

# EXPERIMENT 2

## Investigating the Enzyme Urease

### BACKGROUND:

The chief sources of the enzyme urease are jack and soy beans. Urease converts urea to the basic salt ammonium carbonate through the addition of water according to the following reaction:



Urease was the first enzyme to be isolated in pure crystalline form by James Sumner at Cornell University in 1926.

### MATERIALS:

Dried soybeans (obtainable at a health food store), mortar and pestle, graduated cylinder, urea, phenolphthalein indicator, distilled or deionized water.

### PROCEDURE:

- Grind up a tablespoon of soybeans with a mortar and pestle into a fine meal. (Husks may be removed by gentle blowing.)
- Add 40 to 50ml of water and grind for a few minutes more. Let this mixture stand in order to form a crude urease solution.
- Fill a small test tube 2/3 full with distilled water.
- Add 1/2 teaspoon of urea and shake to dissolve.
- Add a few drops of phenolphthalein indicator and shake to mix thoroughly.
- Add a few ml of your crude urease extract and closely observe the test tube for several minutes. How do you account for what happens?

### EXPLANATION:

The solution slowly turns pink. The urease from the soybeans catalyzes the conversion of urea into ammonium carbonate. Ammonium carbonate, a basic salt, hydrolyzes to form a basic solution, causing the indicator to change color.

# EXPERIMENT 3

Lab Report – Chemistry 9

Name: \_\_\_\_\_

Experiment # \_\_\_\_\_

## Bunsen Burner

1. Examine the construction of the Bunsen burner. Note below the location of the air inlet.
2. Using a flint, light your burner.
3. Close the air inlet and note below the effect on the flame.
4. How do you think that it is possible for the gas to burn with the air inlet completely closed?
5. Hold a spoon or a cold porcelain dish above the luminous gas flame and examine the solid deposit. Describe it.
6. Push a pin crosswise through a match, just below the head of the match. Turn the burner off and hang the match exactly in the center of the burner barrel, with the head pointing up. Now turn on the gas, and ignite it at a point 8-10cm above the burner. Write down your observations.
7. Check your results of #6 above with the lab team next to you to see if their results correspond with yours. If they do so, give an explanation of why you think what happened did happen. If their results are not the same as yours, check to see if someone else in the class has the same results as you. If not, see me.

8. As accurately as possible draw a picture of your Bunsen burner showing all the working parts. Check with my sketch and label the parts. For this sketch use another piece of paper and make the burner barrel 5 inches high so that your drawing will be detailed.

## THE BUNSEN BURNER

