Eugen Kolisko

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

FIRST LESSONS IN CHEMISTRY

Preface

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

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

Special importance is attached to two considerations:

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

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

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

1. About Combustion

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

---

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

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

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

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

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

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

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

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

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

[8] See note 7.

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

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

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

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

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

2. About Calcium and Salt Formation

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

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

---

[9] See note 7.

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

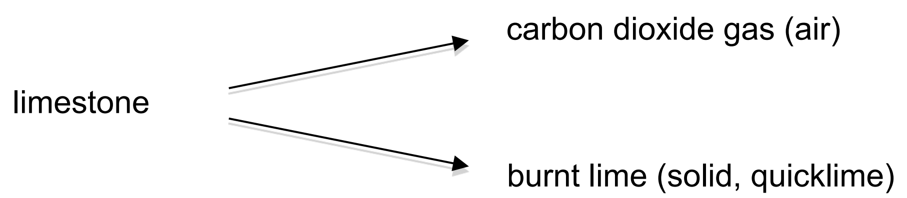
Water not only allows lime to be deposited but also dissolves it again, and it can then be deposited again later – for example, as stalactites and stalagmites in caves, as calcareous tufa, or as the crusts of lime that develop relatively quickly around objects placed in calcareous springs such as the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

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

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

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

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



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

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

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

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

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

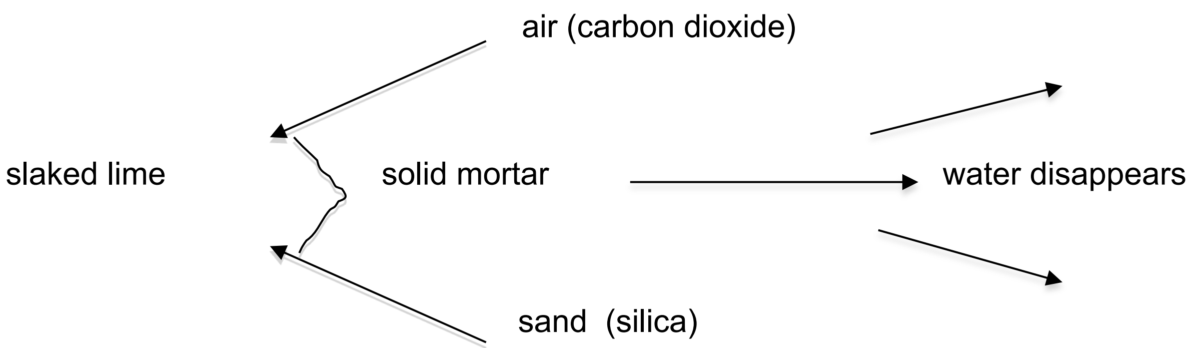
It is very important to avoid the usual approach of beginning with the acid and the base and deriving the salt from them. Instead, we must take the opposite approach, which is the natural way, because lime already exists everywhere in nature whereas the acid and the base are only produced later and by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

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

This block can again be summarized in a dictation:

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

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

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

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

3. About Water and Metals

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

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

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

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

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

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

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

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

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

Metals

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

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

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

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

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

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

---

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

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

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

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

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

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

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

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

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

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

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

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

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

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