Elementary Chemistry

Combustion
Lime Salts
Water
Metals

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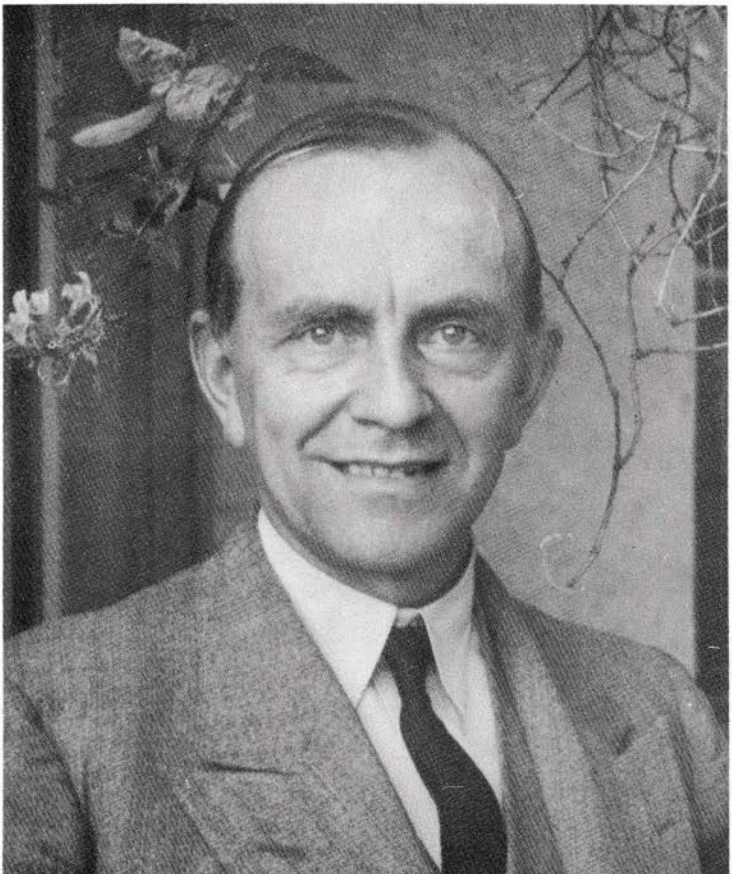

EUGEN KOLISKO

21st March, 1893 — 29th November, 1939

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Preface

The following observations stem from experiences gained as a teacher at the Fre *ie* Waldorfschule in Stuttgart. The lessons concerned with here are those given in the seventh class.

During the first three years of school life the child has been led from an atmosphere of a fairy-tale world through a description of nature, highly rich in fantasy, to Man. From the fourth to the sixth school years a suitable grounding in the knowledge of human nature is given — 'Menschenkunde' — as well as an insight into the Animal, Plant and Mineral kingdoms.

Having been led this far, in a natural way, the child, now in the sixth class, is taught the basic principles of Physics; followed in the seventh class by Chemistry. Thus the child has been taken in a gradual and regulated manner from a hitherto world of the spiritual, of abstract and living matter, to the events of the material world.

So it is at this stage that the child is introduced to the basic concepts of the chemical processes in nature. The teaching should be so organized that the ideas and impressions gained can grow and mature with the child, as suggested by Dr. Rudolf Steiner. The child then takes this knowledge with him throughout the entirety of his school life, a knowledge which will be steadily widened and supplemented from the confirmation of new experiences. Even as early as Goethe's teachings of natural science such a basis was employed. It is with these thoughts in mind that the teacher must educate the child's soul, for it is not merely his task to impart a knowledge of facts, but also to germinate, as it were, the child's soul so that all knowledge gained can continue to work and grow throughout his earthly life.

The usual text books on Chemistry lend little help in this direction, as they frequently deal with more advanced material taught in the higher classes. For an elementary grounding in the subject a way must be found that will appeal more to the soul nature of the child, and it is hoped that these essays will give a guidance to this 'way'. Only thus will the child be able to reach a proper understanding of the chemical processes in nature. The real scientific facts will always be there whatever, and it is only through a very simple beginning coupled with the right foundations that a true understanding of the subject will be able to grow and expand.

These are the two main points to keep in mind: —

1. All matters should be approached in relation to Man — in this way the knowledge of nature comes alive for the child.

2. At all times a connection should be made with every-day events and realities.

It is therefore with these two ideas in mind that every lesson should be conducted. The recognition of the connection between Man and Nature brings a spiritualness into the lessons of natural science, indeed into all subjects! Thus these first elementary chemistry lessons are made a part of the whole teaching curriculum. Each teacher will of course conduct his lessons in his or her own individual way, and the following expositions serve only as one such example and it is hoped that they may give inspiration to the reader.

E. Kolisko — *Stuttgart 1932*

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January 1978.

ELEMENTARY CHEMISTRY FOR CHILDREN

by

EUGEN KOLISKO, M.D.

I.—Combustion

HOW SHOULD CHEMISTRY be introduced to children ? The child is at first much more at home with the concepts of physics, for the action of light and sound in nature is much more obvious. The simplest way of showing the essential elements of chemical action is through the phenomenon of combustion. In it lies hidden the entire chemical process. It is the best point of departure.

The combustion of quite a series of substances should be demonstrated. Let us suppose it is an autumn day. From a walk in the woods the children bring back all manner of combustible substances; dry leaves, twigs, bark, dry moss, dead grass, pine cones, and so on. To these are added various kinds of wood, green vegetable matter, straw, cottonwool, paper, wax, olive oil and petroleum. We show how each of these parts of the plant and other substances burn. When ignited varying appearances of the flame result. It is often possible to recognise exactly the nature of the plant from the form of the flame. Thus, grasses burn with a pointed flame; pine needles flare and sputter; cones burn intensely and with a noisy crackling, each type of leaf differently. A complete " Botany of Flame " results. The children notice that the whole inner nature of the plant flares up once again in the flame. The other substances produce quite a different sort of flame.

Attention may now be drawn to this. On the one side light and heat are always produced. They appear as flame. On the other side the ash remains. The ash is mineral, dead. The children should be taught the phenomenon of this opposition of light and heat against ash and assimilate it thoroughly. Children with a touch of the melancholy in their temperament are attentive to the fact that of this beauty only ash remains. Choleric children are particularly affected by the flame. For all children the flame represents something essentially living.

It is necessary to be cognisant not only with what goes on in the child mind during the day, but also with what it experiences in the night. What the child has observed recurs next day at the commencement of the lesson as an unconscious query as to the true nature of the matter.

There should be little difficulty in eliciting these and similar thoughts from the children through judicious questions, or they may even volunteer them of their own accord. One might ask: whence does light come ? It is nothing other than the sunlight which the plants have absorbed. The sun shines down upon the earth, the plant shoots up and in its turn grows towards the sun. All living things can be burned. When you ignite a fire the light returns to the sun.

What happens in combustion can now be felt by the children. What had been completely materialised as wood or coal, becomes invisible and disappears. The light is released.

The children thus grasp a very important opposition. That of light and weight. They are already accustomed to regarding things in terms of opposites of this kind.

One can now speak of the living plant. Just look at their flowers! Often they seem like flames with their gay red or yellow blossoms. Think for instance of the red poppy! And does much ash remain when these are burned ? No. But if you were to burn the roots there would be a lot of ash. Roots do not shine so bravely. Why ? Flowers are in themselves a form of burning, not in their roots, but in the fact of blossoming. They are akin to heaven, their beauty reveals it. But the roots belong to the earth. That is why they leave so much dead mineral matter, so much ash. What are plants really ? They are living flames! From their green heart the flower escapes heavenward like a flame. But the ash sinks downwards into the root.

Once the children have mastered these elements one can summarise the whole thing in a coloured diagram on the blackboard. Such a picture remains significant throughout life. In this way one may avoid the temptation to regard the phenomenon of combustion as a purely material chemical process. One relates it with the whole world. The burning process later to be completed with the dead parts of the plant can be seen going forward while it still lives. What plants do in the process of growing, blossoming and striking root, is simply continued in a more violent and destructive way when they are burned. That which takes place in a modified way within the rhythm of life, in the flower and the root, is torn asunder when they burn, into shining flame and ash.

This can now be linked up with man. Does burning take place in man ? The children can easily see how warmth has its part in the blood, in the digestive process and in the activity of the limbs. They can feel how warmth acts from within themselves and know that the internal organs are the warmer. But what part of man contains the greatest quantity of ash ? The bone. A sort of flame burns in man, but it is the reverse of the process found in plants.

An approach of this kind can be further developed. The class is reminded of what fire—as used in the funeral pyre—for instance—has meant to man, even in the remotest ages. Just as in burning, the light escapes from matter, so does the soul from the living body of man, leaving behind the corpse. This gives an opportunity of introducing historical and religious ideas. The soul dwells in the living body as light dwells in inflammable matter. Thus by the intimate association of the scientific with the artistic, the sphere of religion and the spirit can be approached. The significance of fire in sacrifice can here be called to mind as well as the connection with heaven which man seeks to build through the sacrificial flame.

Such a point of view can be summarised in simple sentences and dictated to the children. With great interest they have painted the various flames in their experiments and have also had depicted to them the action of fire in plant and man.

" Everything living is inflammable. Thus if we set fire to the dried parts of plants, flames break forth. Light and heat fly upward into the wide world. But the ash is left behind. The light is bright and without weight. The ash is heavy and must fall to earth. Thus every burning is a separation of light from the heaviness of earth. In burning a light that has been bewitched into the plant, makes its escape. It is the power of the sunlight which it has taken into itself. It is just the same when we burn anything from the body of an animal; for the hidden light enters into the animal body, as also into the human, through the plants that are consumed as food. The plant is a living flame. It burns upwards to the blossom. In man and in animals there are living flames, but they burn in a different direction. When we look at fire we feel how it consumes everything and bears it back once more to heaven from whence all things come down to the earth.

" ' And what the might of fire doth seize,
No longer monstrous, cumbering earth;
Is whirled away and vanishing,
Hastes up to where it had its birth.' "

Flame requires air that it may live. A current of air makes it stronger, it gets weaker when there is less air. The rate of burning and the intensity of the heat depend on the amount of air which reaches the flame. A lighted candle will soon go out if you place it under an inverted glass jar. At this stage a well-known experiment can be carried out, in which a bell jar is inverted over a lighted candle floating on a cork on the surface of a dish of water. After a while the candle goes out and the surface of the water on which the candle floats rises within the jar by about one-fifth of its height. The child sees that the flame has consumed some of the air. At this stage there is no need to speak of oxygen. The realisation that the air excites the flame and in its turn is partly consumed, will suffice. A series of flames in which air is introduced in increasing quantities is now shown. One might show a candle flame, then blow into it with a blow pipe and follow with a demonstration of the Bunsen-burner and finally demonstrate forge and bellows. This intensification shows the children the action of air on flame and also how increasing effort is needed to supply the flame with air, until finally in the forge the bellows must be worked with the foot. At the same time the children are being familiarised with a number of contrivances they will later find in general use. Attention is drawn to the fact that without added air the flame is a clear yellow and not too intense; comparatively cool, but the introduction of air changes it to a blue hot flame. A candle flame is shown. Why is it blue nearest the wick ? Because there is gas inflammable until it reaches the periphery. The children's interest is roused when they first observe that the intense blue space of the forge becomes invisible when viewed against a light background—as for instance when the sun shines on the wall behind it.

Before proceeding to more abstract chemistry, the child must first have the experience of the Fire Element. In this way the nature of flame is linked up with the whole universe and with man. One may now proceed to the practical use of flame, for instance in lighting and in heating.

One starts with the phenomenon of the luminous flame which deposits soot on a cold surface. Carbon therefore has its origin in the flame. This carbon shines, but only when there is not too much air. When this happens it is burnt and gives out heat. This can be illustrated by the bright flame of acetylene which deposits a heavy soot, and the hot blue non-luminous gas flame. With the one you may illuminate, with the other heat—for example a gas oven. Flame always plays to and fro between light and air. It is warmth which forms the link between the two opposites of light and air. A question might then be put: Would it not be possible to illuminate with a hot flame ? The children will readily perceive that carbon cannot be used for this purpose as it would soon be burnt up. Something must be chosen which can shine without burning away. Only some ashy mineral substance will serve. And this realisation makes clear to the children the purpose and use of the incandescent gas mantle, for in this a non-luminous gas flame causes the earthy substance to glow white hot. The opposite of this is found in the carbon filament bulb, in which the carbon is caused to glow by an electric current, but cannot burn because all the air has been pumped out of the bulb. Thus in the case of the bulb, something inflammable glows but cannot burn, while in the case of the mantle the non-luminous gas flame causes something non-inflammable to shine.

The most various technical uses of flame may be simply explained to the children in this way.

. . . .

Inflammable substances, such as sulphur and phosphorus which are of inorganic origin, and natural coal should be compared with them.

Sulphur is yellow; there is fire in it. When ignited it burns with a peculiar dark blue or light blue flame. This flame looks just like the blue part of a candle flame if it could be seen by itself. Sulphur comes out of the interior of the earth. For the most part it forces its way out through volcanoes. It is petrified fire which has burst out from the earth. By speaking of sulphur in this way, the children are brought to realise that the piece on the table before them is just a tiny portion of the fire process in the earth's interior. Sulphur acts similarly both in plant and man. The colour of a field of rape might be mentioned and the fact that these plants yield a sulphurous oil. Both the hot-tasting radish and mustard contain sulphur. In man it has the effect of hastening metabolism. Sulphur baths have a healing action in cases of indurations, rheumatism and the like. But the sulphur often has the effect of making diseases which have long been slumbering in the patient, break out again. Skin eruptions may also result and old wounds break open. Thus in man, too, sulphur acts on the bodily functions in an inflammatory, volcanic way.

Phosphorus is quite different. Its flame shines brightly, almost like the sun. It shines even in the dark.

The children are thrilled when first they see that you can write on the blackboard in the dark with a piece of phosphorus and that the shining letters remain. They say: " This is not matter at all, it is light." And there is no heat either. The antithesis between the dull, blue flame of the sulphur and the white flame of phosphorus, is remarkable. It is as if the upper shining part of the candle flame were burning independently. Phosphorus is found in the brain of man. It has such light-giving power and works in the head! What is it doing there ? When we think, there is light in our brains and phosphorus is needed for this. Phosphorus has a peculiar smell, the same we notice after a thunderstorm. It alters the air in the same way as lightning. In a thunderstorm the lightnings flash down from heaven as though something were trying to shine into the world from the outer universe. When a volcano erupts something hot surges up from the subterranean, and there is a smell of sulphur. But when the lightnings flash there is a smell like burning phosphorus. And what does one say when an idea strikes one or one has understood something ? One says: " A light dawns on me." It flashes into the mind like lightning! This has to do with the phosphorus which is present in the brain. Yes, phosphorus is heavenly fire on earth; but sulphur is subterranean fire. Sulphur is found in the natural state as a product of volcanic action, but phosphorus has to be made artificially.

Coal stands half-way between these two inflammable substances. We are already aware that coal is dead vegetable matter. It has therefore its origin in life and so is inflammable. But it keeps its light hidden within. It is bewitched, and so it is itself black and dark. It has been formed within the earth. When coal is burned we get the ordinary kind of flame which shines above, and is blue below. In it are united the two kinds of flames found separately in sulphur and in phosphorus. And so it is with all living flames, for they all contain carbon.

Having shown the action of these substances in the universe their connection with man is again explained. Sulphur is active in the lower organs of man. It acts outwards and upward through the digestion, by way of the blood. It is a fire burning in man's inward parts. But the cold light of phosphorus acts in the brain. *We think with it*. And what is the place of carbon ? We burn carbon within ourselves and breathe it out through our lungs. More about this will appear when we study carbonic acid gas. Through the helpful action of sunlight, plants breathe in the carbon. Flames breathe the carbon out again. Such an exposition will awaken a living consciousness that the three most important inflammable substances, i.e. sulphur, phosphorus, and carbon are associated with quite independent activities in man. Sulphur with digestion, carbon with respiration, and phosphorus with the light of thought which originates in the brain.

II.—Lime and the Formation of Salts

In chemistry an understanding of the antitheses is of the greatest importance. The process of combustion was our point of departure. Salt-formation is the antithesis of combustion. This process is best exemplified in lime. We show samples—as many and varied as possible —of the forms in which lime occurs in nature; sea-shells, and the shells of snails, coral, calcareous sponges, ammonites, chalk, as well as a great variety of bones. All these things originate in the animal kingdom. Then follows rocks whose organic origin is evident, as for example: limestone from the upper fresh-water formations, ammonite marble and " Trochitenkalk," and finally, calcareous spar, statactites and various marbles are shown. The more varied these samples are, the better. And now one asks how all these structures originated ? They have all been deposited by water. It has taken long years for the stalactites, for instance, to grow out of the water. In the oceans a continuous fine rain of dead animal life is sinking to the bottom and being deposited as calcareous mud. Chalk originated from innumerable shells of the tiniest creatures. In this way whole mountains have been formed, such as the chalk cliffs on the North Sea and the Baltic. In the same way sea shells are deposited and form shell limestone. All this takes long ages. Slowly the chalk ranges are built. Chalky matter sinks to the bottom of the sea and forms solid earth. Here we are faced with quite a different phenomenon from that of combustion. In the latter case we set alight various plant parts which changed to fire and smoke and disappeared. Now we have before us an almost unlimited variety of shells and rocks. All of them have either solidified out of water or been separated from live creatures. It is a similar process to the one which takes place when salt is deposited by the sea. Heat, light and air are the active principles in fire. Very little solid matter is left. Quite otherwise are the processes of crystalisation and the deposition of chalk and other salts. Chalk indeed has its origin in the living, but it does not act like fire which devours all that lives and takes it back to heaven. Instead it brings all down to solid earth from out of the watery element of life. Gravity becomes dominant.

Water not only allows chalk to sink to the bottom, but also dissolves it again. At a later stage there may again be deposits. The stalactites in caves originate in this way as does tuffaceous limestone and the chalky crust which forms quite soon on objects immersed in certain wells, for instance at Carlsbad. Streams and rivers dissolve much chalk and bear it away with them. Now if there is so much chalk in the rivers, there should be a great deal more in the water of the sea into which all the rivers flow. But sea water contains hardly any chalk. Whither has it gone? Into the bodies of all marine creatures, into the shells of molluscs, into coral, and so on. And when these creatures die they will sink to the bottom again to form chalk hills. There is thus a sort of circulation of lime which includes animal life at one stage. Actually all lime originates in the animals, for marble, stalactites, calcareous spar have all been crystalised out of water in which chalk deposits have been dissolved. And when these in their turn are dissolved they go to make up the shells of marine creatures and to build bone. One cannot consider lime apart from the animal kingdom. In ancient times this was known and found expression in the Latin saying "omnis calx e vermibus" (all chalk comes from worms), for thus they spoke of the lower animals. Chalk is either formed as deposit from living fluids, or crystalised out of water. Water carries chalk all over the globe and then deposits it. The earth can thus be considered as built up from the water. For this and all similar processes of deposit by water, we shall use the term: salt-formation.

Children's reaction to such a demonstration of salt-formation is quite different from their reaction to fire. The latter has an exciting effect particularly on choleric children, but indeed most children become more lively and even somewhat choleric when watching fire. Its effect is on the will, on the metabolic system and the blood. When they consider chalk, it is quite otherwise. The mood becomes more pensive. They are moved to think how this immense variety of rocks has been built up through long ages. Crystalisation takes time. It can only take place at rest. When snow falls and an infinite number of crystals blanket the earth, this too is a kind of salt-formation. True, no salt is formed in the chemical sense, but the phenomenon is similar. Now the question may be suggested: if fire works in man's blood and in the actions of his limbs, in what part of his body does this salt-formation take place? For the most part in the head where there is the most bony substance. We could never think and give anything our calm understanding, if chalk were not being deposited in the head. Moreover, there would be no bony frame. Thus the connection of the salt-forming process in man is established. The burning processes were shown at work in the lower part of man and in his limbs. Salt-formation is at work in the upper part, in the head. We have also seen how dead matter from living organisms is excreted from organisms. Indeed a great part of the earth originated in this way. No one who has thoroughly absorbed this can ever attempt to explain living substance in terms of dead matter. The study of chalk has thus been linked up on the one side with man, on the other with the world.

II.—Lime and the Formation of Lime Salts.

IN A FURTHER LESSON, the study of chalk may be extended in another direction. A piece of chalk or limestone is heated—preferably over a bellow-blown fire. After it is burnt, it is allowed to cool and then water is poured on it, when it is observed to sizzle and get hot. The experiment is repeated with a larger quantity of burnt chalk. It swallows the water thirstily; considerable quantities disappear into the chalk, leaving no trace. Instead, steam rises and heat is produced. We conclude that burnt chalk contains no water; the fire has separated it completely from the water in which it had its origin. That is why it is so thirsty. Long after it was connected with animal life, chalk still retains its animal nature.

If now we add more water, a milky liquid results (milk of Lime). If left to stand for some while, the slaked lime settles to the bottom, but a part still stays in solution as a clear liquid (Lime Water). We now dip a piece of litmus paper into the lime water. It is turned blue. A liquid which turns litmus blue is called an alkali. Like acids, the alkalis have a characteristic taste. Through burning chalk and slaking it with water an alkali is formed. Fire and water have changed the chalk into something else. Perhaps something has gone from the chalk while it was being heated? This is evident when chalk is burned in a lime kiln. Carbonic Acid gas is driven off. A method of catching this gas is explained to the children, and some prepared gas is shown to them. This is the same gas that rises from mineral springs and bubbles up in mineral water. The chalk has evidently breathed out something while it was burning. The quicklime which remains is more solid. This more solid part of lime is also sometimes called a base because it is, so to say, the solid foundation of the lime salt; and as we saw, when it is dissolved in water it becomes alkaline. The carbonic acid gas which was driven off may also be dissolved in water. It gives the water a sour taste, and in it blue litmus turns red. The chalk thus gives rise to the alkaline quicklime, and the acid, carbonic acid gas. In this way the ideas of acid and alkali reach the child. Chalk had its origin in a salt forming process. It is itself a salt, because fire can change it, carbonic acid gas passing off and quicklime remaining. Thus:

Chalk { Carbonic Acid Gas—Air
Quicklime —Solid, Chalk-earth

Fire has produced this division. The addition of water to each of these parts brings out their antithetical nature as acid and alkali.

These distinctions can be even more tellingly demonstrated. Two bottles are shewn, the one containing carbon dioxide in solution (ordinary mineral water), the other containing lime-water. From the first bubbles arise; they are the gas that has gone out from the chalk. The liquid tastes sour, prickly, and sharp, and it turns blue litmus paper red. The lime-water in the other bottle tastes flat and insipid and turns the litmus paper blue. Experiencing these things for themselves is a joy to the children; it seems only natural to them that the sharp and sour turns red, while the dull and insipid turns blue. What they have learnt in their painting lessons as well as their own experience of colour make this entirely comprehensible to them. Carbonic acid gas bubbles up from the carbonated water; the stopper flies out if it is not firmly fastened down, but at the bottom of the lime-water bottle a white deposit has settled. The stopper stays firm and may even ' freeze in ' because solids are deposited around it. In the carbonic acid bottle, gas strives to escape upwards, in the lime-water bottle the solids tend to settle down to the bottom. These two contradictory factors were originally contained in the chalk. Fire was able to drive them apart, and water could bring out the characteristics of each. But now see what happens when some of the mineral water is poured into the lime-water! It becomes cloudy, and presently a white salt settles on the bottom. The opposites are once again united, for this salt is nothing else than chalk.

Now let the children blow through a pipe into a glass of lime-water. Again the water clouds and there is a white deposit. Our breath therefore contains the same substance that chalk gives off when it is burnt—carbon dioxide gas.

Fire changed the chalk into light gaseous carbon dioxide and solid basic quicklime. The water, which was driven off, stands as a link between them. Bring each to the water independently and acid or alkali will result. But bring the two together, and chalk—or as we should more correctly say Calcium Carbonate—is formed. Fire split the chalk into two parts manifesting their different natures. Water brought these contradictions separately into evidence, but it also combined them once more. What fire has divided, the water once again unites.

It is important to notice that we did not start with acid and alkali and obtained the salt from them. Instead we took the opposite and natural way, for chalk is a natural substance which is in process of formation around us at all times. Acid and Alkali can only be produced by artificial means. They are opposites which can only be differentiated by splitting the salt. In teaching a young child to add, we do not start with the numbers to be added and deduce therefrom the total, but we make the child understand that an original whole has been divided up and that the sum of these portions must bring us back to unity—our original whole. We start with the integer and not with the integrant. So here we start with the whole and show forth the parts. Teachers should appreciate how, even at this early stage in the teaching of chemistry, the concept of a ' chemical combination ' may be regarded not merely as the sum of its parts, the chemical sum of its elements. It is something new, often indeed something primary. In this case we start with chalk as our natural substance which is taken up by the organic processes to build shells, bone, etc. Only when this has been made clear, we proceed to separate from it its different factors. Chalk itself is the resultant of organic processes. Fire, in dividing it into acid and alkali, shows that it was the chemical compound 'calcium carbonate.'

The uses of lime in everyday life, and its technical uses, are explained in another lesson. After it has been quarried from the earth, chalk is taken to a limekiln. If possible, the children should be shown over a lime works, where they might make a drawing of the kiln, whose design is explained to them. In this kiln the chalk is heated, when the carbon dioxide escapes and burnt or quicklime remains. This is filled into sacks and despatched to masons for building. At this stage, the commercial working of a lime works and its relationship to other businesses can be explained, since it is a part of the curriculum for children of this age. The hygienic aspect may also be touched upon in explaining the dangers of the slaking process due to the corrosive action of the lime alkali. The violence of the action when large quantities of lime are being slaked will bring this home to the children. Again one asks: whence all this heat? It is due to the great heat that was applied to the chalk in the kiln. This heat dwells in the quicklime and also in the carbonic acid gas. It is this slumbering fire which gives the quicklime its great thirst for water.

The masons mix the slaked lime with sand. The result is mortar. Here again we have an important antithesis; namely that between silica and lime. Sand is silica earth (an acid), lime, on the other hand, is a base. It is unnecessary to go into the process of glass making which brings out the acid nature of sand so strongly: it will suffice to point out the contrast between the hard brittle, shapely and immobile sand, and the greedy quicklime, which becomes so slimy and smooth when slaked.

Then there might be a demonstration of how two bricks may be united with mortar and how this quickly hardens. Something new has resulted from the interaction of the two opposites. In newly built houses this process is hastened by lighting fires in them. These not only drive out the water from the slaked lime, but also give out carbonic acid gas which unites with the lime to form calcium carbonate (chalk).

Carbonic acid (in air) Silica acid (from sand)	Slaked Lime	Hard Mortar Water driven out

The drying out of newly built houses is also hastened when people live in them, for the air they exhale contains carbonic acid gas. Those who do this are called ' drying-out ' tenants, and it may be remarked here that it does no good to their health. Here we have a practical instance of the similarity of our breathing process to burning in nature; the practical use has been shown of the things we recently demonstrated in the laboratory.

On the following day we return to our starting point. Our investigation has taken us back to calcium carbonate, to the chalk from which we started. Originally it lies in the chalk pit, now, in union with the sand it holds our houses together. Why have we gone to all the bother of splitting up the chalk, if in the end we are going to arrive back at the same chalk we set out from ? Because the lime and the carbonic acid gas in the process of reuniting have bound together the stones of our houses. Man has split chalk into its hidden and opposite factors and then utilised the force of their reunion to cement his houses. It is as though the stones of a quarry, which had been scattered all over the world were to draw together again uniting to form the houses of mankind. It is an impressive moment for the student when he first realises how in his technical processes, man forces apart natural powers which are striving to be united and then uses the energy of their rapid effort at reunion to carry out his various tasks. The dammed-up lake for instance gives water-power when its pent waters are released and so, too, here in the field of chemistry.

Our investigations into chalk have also included the vital processes. The pupils have learnt that chalk is the source of the bony framework of their bodies, and how it is associated with animal processes and has its home in the animal kingdom. Throughout all nature and bound up with man, chalk formation proceeds.

The concept of salt formation may now be extended to include the salt of the sea. Salt is an inseparable part of the sea. The technique of salt manufacture from sea water, rock-salt mines and brine springs is explained. The slowness of the evaporating and crystallisation of salt are demonstrated. It is contrasted with chalk. This salt—our ordinary cooking salt—has much less to do with the life processes than has chalk. It is essentially mineral, indeed the only mineral nutriment man requires. Other needful minerals are to be found in the normal diet, only salt must be provided independently. If he could get no salt at all, man would die, for salt preserves; it retards the processes of decay. The salting and pickling of foodstuffs is based on this knowledge. Sea air also has this effect; it makes man more awake. On the other hand an excess of salt in the sea will kill every living thing, as happens in the Dead Sea.

What happens if we treat the salt as we treated the chalk? Heated in the furnace it melts and even passes off in steam, but very great heat is required to drive out from it any gas. Instead of using high temperatures it is more simple to pour sulphuric acid over the rock salt. A white vapour with a strong pungent smell is driven off. When led off into a vessel of water, this vapour becomes Hydrochloric acid, or spirits of salt. But this process will not serve for obtaining the alkaline base. To obtain this by heating as with chalk, requires tremendous heat, and so an alternative method is used. The children will hear more about this electrical method later on.

Caustic soda and spirits of salt are now shown to the children. Here the polarities of acid and alkali are much more obvious, they are tabulated graphically:—

ACID	*ALKALI*
Sharp	Dull
Red colouring	Blue colouring
Awakens	Dulls the tongue's sense of Taste
Gaseous	Solid

The whole thing is now shewn in its relationship to man. Every time the arm is moved, acid is formed in the muscles. When we walk or run or indeed do any sort of work acid is formed in the human body. But we may also sit still in our room and think. No acid now appears, but instead basic or alkaline substances are formed in the brain. When we move, our muscles turn sour, when thoughts move in our heads as we sit resting, our heads become alkaline within. A base is formed. Thus acid and alkali play their part in us too. (I owe this example to Rudolf Steiner who made use of it when instructing a class on the occasion of a visit to the Waldorf School.)

The same contrariety can be shown in the plant world. In the roots there is a preponderance of base, while the leaves, fruits and sprouting parts generally are acid. The sour taste of the wood sorrel will be familiar to all, its roots, however, taste salty and alkaline. There is no need at this stage to speak of the exceptions to this law, because these exceptions will make an important lesson later on.

The matter in this section is summarised in the following dictation:—

" The two opposites may also be extracted from salt. They are Hydrochloric acid gas, and sodium base. The gas has a strong pungent smell and a sharp sour taste. It colours litmus paper red. Its property is to awaken, for it is an active substance. But the caustic soda is insipid and deadens the sense of taste. It gives a blue reaction with litmus paper. Like caustic soda, most bases are solids. Their nature is essentially heavy. Thus the roots of plants tend to be basic while their leaves are acid and have a sour taste like wood sorrel. Acid has affinity to the air, base to the earth. With man the tendency is reversed, the activity of the legs produces acid, while quiet thought awakens an alkaline, basic condition in the head, where, incidentally there is also much chalk. Acid and alkali thus appear as two great opposites whose interaction may be observed throughout all nature."

During a subsequent lesson, the children should be encouraged to represent this antithesis in a picture. They are by now familiar with the contrasting colours that acid and alkali produce with litmus, and they are now asked to depict the battle between the two. To make the reaction more vivid for them, a quantity of concentrated hydrochloric acid should be mixed with strong caustic soda solution. They will observe the extreme violence of the reaction, so much more violent than when lime was slaked. The liquid seethes and splutters and fumes. When the children express this in colour, letting the red mingle with the blue, quite remarkable pictures result. The characteristics of all the different temperaments reveal themselves. This provides an opportunity of experiencing this fundamental chemical antithesis with the artistic side of the nature. An element both scientific and artistic has been awakened in the child. (It would be absurd from the educational point of view, to introduce the concepts of acid and alkali with talk of Hydrogen and Hydrates (Hydroyl), a tendency that is all too common today, even in school books.) The interaction between acid and alkali that proceeds throughout the universe and in man too, has now been surveyed.

The child has been introduced into quite a new department of chemistry. First it learnt about combustion, now it also knows about salt formation. Before proceeding any further with the lessons it is advisable to bring out again very forcibly, the contrast between these two processes.

III.—Some Considerations Touching Water and the Metals

WATER

THE SUN'S HEAT causes the water of the ocean to rise as vapour, while in winter the water freezes, becomes solid and more like the earth in its nature. Whatever state we may find it in, whether as vapour in the heavens or earthbound as ice, it must always return to its liquid state. So we find the rain falling and giving rise to springs. Furthermore the sea never freezes right through to the bottom. This is due to the fact that ice floats on water. The water in the depths too, is warmer than near the surface, for it is heaviest at 4 degrees Celsius. The water in the sea thus never becomes entirely solid, and so too, glaciers can slide down into the valleys because they have water under them. The water vapour in the air moreover must fall back to earth again as rain. As Goethe says " It comes from Heaven, to Heaven it rises, for ever changing." One might ask why the water in the depths of the seas never freezes ? It is because water must always seek to be liquid. It is only on the surface and not in its depths that water solidifies. The water does indeed become solid ice but in doing so it becomes lighter and is pushed upward while other substances as they cool become heavier and sink to the bottom. Glaciers show us that even as ice, water still flows and indeed it never becomes truly solid but is more like a kind of fluid stone. Under pressure ice will melt and so a skater is not really skating on ice at all, but on a film of water produced by the weight of his body pressing on the ice. All this is summarised in the following dictation:—

" Water ever strives to remain liquid. Its home is therefore the ocean which is the bloodstream of the earth. It must always seek its way back to its liquid state, its home. Water also unites with air and with solid matter. Fish could not live in the sea if it did not have air dissolved in its waters. Sea water too, has much salt dissolved in it. When sea water is evaporated this solid salt is left. Water always contains something of earthy origin, i.e. its saltness, and something of the air. Thus water unites earth and air and acts as an intermediary between them."

And has water any other mediating attributes? From what they have already learnt, the children will adduce many examples. Water is a link between the different parts of the earth and a means of communication between peoples. Nations are united by ocean routes, trade flows on them. East and West are united by the sea. And is there not in man too a fluid that unites everything? The blood flows to every part of the body and wherever it flows it is the unifying principle. As the cities of the earth are linked by waterways so are the different parts of the body by the arteries. Through water all things are united.

Having thus indicated to the children something of the true nature of water, its chemical aspects may now be more closely examined. The children will remember how carbonic acid gas had no effect on litmus paper until the latter was moistened, when it turned red and similarly how quick-lime did not turn the litmus blue until a drop of water had been added to it. Acid and alkali do not appear until water is present. When the tongue is perfectly dry we cannot distinguish acid from alkali. Taste is only made possible by the presence of water. A little experiment will drive this point home. Take some crystals of citric acid, the substance which gives lemons their sour taste. Moisten a little with water and the solution will turn litmus red and must therefore be an acid. In contrast take some ordinary baking soda. When moistened this will turn litmus blue, and must therefore be an alkali. Mix the two dry powders together. Nothing happens. But if water is poured over the mixture, it will foam up violently. The reaction is just like the one we had when caustic soda and hydrochloric acid were mixed together. What we have made is the well known effervescing powder. In this way we learn that acid and alkali only react on one another when water is present. Water alone makes the combination possible.

Next day the children should be asked to enumerate all the instances in which water plays a unifying role; as for example in the slaking of lime, the combination of acid and alkali to form salts, its power of dissolving salts and air as also its function in binding nations together etc. We can then add the information that it is only in water that colours appear. The children are familiar with the rainbow. When does it appear? When light and darkness meet; the sun with the dark curtain of rain. But between the two there must be water, in the form of raindrops. Once again water is the unifier, in this case of darkness and light. The Greeks and Romans called the rainbow the " Rainbow of Hermes " (or Mercury), for Mercury was the messenger who bore down everything from Heaven to Earth and also from Earth up to Heaven again.

Goethe's poem " Gesang der Geister über den Wassern " (Song of the spirits on the waters) forms a fitting and lovely conclusion for the dictation in which all this is summarised. Every word of the poem can be prepared in class and so there is no need to comment upon it. It expresses and summarises everything, simply and conclusively. From what was at first mere knowledge —mere information, there spontaneously arises within the child, a something it can cherish in its heart. This will remain with it to form the basis for further studies. It would be superfluous at this stage to speak to the children of Hydrogen and Oxygen. It is better for them to regard water as a unit. Later they will understand more easily that even in water, opposites interact, that in it too contradictions are united. Once it is appreciated that water in itself unites the greatest paradoxes, its ability to unite all things will appear even more wonderful.

THE METALS

Having considered water in this simple way, the children can now turn to the metals. A selection of metals should be displayed and the children should have plenty of opportunity of seeing them and of familiarising themselves with the peculiarities of each. It is best only to take the more easily obtainable and more important metals. Sodium and calcium being in fact only pseudo-metals are best left out of account. The following are recommended: gold, silver, lead, tin, iron, copper and mercury. In what follows we shall see why just these seven are taken as best suited to our purpose. It will help the children to learn the characteristics of the metals, if objects made of them are brought to their notice.

Now why are all these substances, so different from one another, called by the one name of metals? They shine; a kind of inner light of their own seems to shine from them. They are not transparent. From the darkness of the metal a light of its own breaks out. Metals look quite different from stones. They are found in the interior of the earth. The experiences of a miner can be described, when, after working long days in the mine, he suddenly strikes a lode of metal, of silver or gold or perhaps of some metallic ore. It is as though a star were to shine out from the dark earth. An attempt should then be made to evoke a picture of such a lode of silver, as but a very small part of all the silver distributed throughout the whole Earth. The sum of this silver constitutes a sort of silver-body in the Earth. Imagine that you could see the whole of this silver-body on earth. You would see little threads of silver shining everywhere, veining the Earth. With gold and the other metals it is just the same. Everywhere such constellations shine in the interior of the Earth. They form a whole starry Heaven, and it is for these stars that the miners search. Mankind accomplish a great work in bringing out this shining metal from the dark interior of the Earth. It is this which gives to metals their value.

When we show the children gold, they will readily perceive how it glows like the sun. What then is the origin of the metals ? They have come down to Earth from the Heavens. In former ages, when the earth was not yet so solid, the metals, in the form of metallic vapours were dissolved in the earth's atmosphere. They were later deposited on the earth, but before they became solid, they were for a while still quite fluid. In a gaseous world they were dissolved and were themselves gaseous. While they were yet fluid, they flowed into the metal veins. And then all became solidified and the metals were buried in the dark womb of the earth. The rocks had become solid first and enclosed the metals in their veins. Thus did the metals come down from Heaven. They are sons of Heaven enclosed within the Earth which embraces them like a mother. It was not on earth that the metals had their origin. From out the Cosmos they were radiated into our earth; small wonder then, that like the stars, they have their own independent light. That gold shines like the sun and silver like the moon is easy to discover. And so it is with the other metals, only in their case the likenesses are not so easily seen.

The individual metals may now be approached. Let us start with gold. It is found in the veins of the earth and also in the beds of streams. The veins might even be described as subterranean streams. Gold continues almost directly from one vein to the next. From the night of earth it flows out into the light of day. It is the association of gold with the sun that from the earliest times gave to gold its value. Here is an opportunity for bringing in some history. Thus, gold was used by the Indians of Mexico and Peru in their sun-worship. When the Spaniards took away this gold, their use of it led to much evil. It is evident that gold may be used in a great variety of ways. In the hands of unselfish men it may work much good, but when used in selfish ways it can do harm. In the hands of the Templars for example it was of great benefit to mankind. The moral aspects of a natural phenomenon of this kind can thus be brought home to the children. They can then be told how, through the ages, gold has been used as a measure of value for all other objects. In nature too the worth of all things is shown by the light of the sun. This kinship with the sun is the deeper meaning of the true value of gold. And now the material properties of gold can be examined. Gold is a noble metal. It is capable of withstanding the consuming power of fire, as may be demonstrated. Like stone or quick-lime, fire leaves it unchanged. And yet in colour it resembles such a combustible substance as sulphur; it does not look like a stone or an ash. It thus stands midway between inflammable sulphur and the unburnable salts. It is the noblest of all the metals. Here is a substance which is preserved from fire, not because it is cold and dead like a stone or ash but because it has the inner quality not to burn. The significance of this fact should be emphasised. Within the gold there is already a fire, but it is a controlled fire which is not permitted to burst forth. The position of gold, standing as it were in the midst of the chemical processes, is a striking one. It stands between the impressionable world of fire and the calm world of solid matter. If we hold up a piece of leaf gold before a light, it will appear green instead of its usual red colour. It is thus too with our blood which is usually red but shows green when light shines through it. Gold is in fact associated with the heart and is used as a remedy in heart disease. To view gold from such aspects as these engenders a feeling for its true significance. History and religious instruction have already made much of this familiar and by its means the economic significance of gold is also made understandable.

Two further metals, by nature opposites are now examined. Objects made of lead and of silver are shown to the children. The dull, grey lead is altogether unattractive, but its weight is remarkable. It has a marked affinity to the earth. It is found in the depth of mines, always in company with chalk. When exposed to air or water, it becomes coated with a greyish-white layer. It is no noble metal, for it burns readily in the presence of air and becomes ash. Nor can it endure very long in water. Certain everyday expressions aptly describe its character. We say " heavy as lead " and " leaden footed." One of the chief uses of lead is for making the type from which all our books are printed.

The effect of lead on man is remarkable. It is a poison and its action is to cause the bones and arteries to harden. It is as though it were to make a man as old as the hills and indeed of all the metals it stands nearest to the grave. From the cosmos, it has sunk deepest into the earth. Sad, sombre and immensely heavy, it is yet of little value, for it is not noble.

In contrast, silver shines brightly and is an excellent mirror. Most of the mirrors we use today are made of silver, though in the old days mercury was generally used. Lead is dark and blackish grey while silver is white and shining, especially when it has been newly won. When silver ore is being smelted, it gathers in the bottom of the crucible and gives forth a bright light, the " silver-glint," which can be demonstrated. One cannot help feeling how silver is bound up with the power of light. Its light reminds one of the moon and the moon too is a mirror for it reflects the sun's light. Silver has precisely the opposite effect on man to the effect of lead. It is used in feverish conditions and has a powerful effect on inflammations. It does not harden man, nor make him old. It is still quite young and shines as though it had just come down out of the universe. A noble metal quite different from lead.

And now we turn to a second pair of antithetical metals; mercury and tin. Tin is brittle, and when you bend a stick of solder, it grinds and grates. This sound is called the " cry of tin." Tin is not so unsightly as lead, nor is it so heavy. Objects made of tin are very durable, for tin is quite a noble metal. Only great cold will make tinware flake away and crumble to dust.

The most remarkable thing about mercury is that it is liquid. While tin is full of internal angles and corners, which creak and grind, mercury readily divides into round drops which quickly gather together again and are lost. While tin is jagged and angular, mercury is round and mobile, like a round wave.

The fluidity of mercury is a constant source of wonder to children, as is the way in which it escapes in all directions when the hand is plunged into it in an endeavour to grasp it. Here mention can be made of the fact that at one time all the metals were as fluid as mercury. This was the case when the earth as a whole was still fluid, but mercury is the only one which has remained a fluid until the present time. That is why we are so amazed to find that a metal can be like water. But in some ways it is markedly different from water. If two tubes are filled—one with water and one with mercury, it is found that the former has a concave surface and the latter a convex surface. Compared with the weight of an equal volume of water, the mercury is surprisingly heavy. When you spill it, water makes everything it touches wet, while mercury breaks up into little drops which presently coalesce leaving everything dry. Mercury and water are almost the only natural fluids on earth.

Mercury is the fluid of an earlier age. Unlike our water of today, this " water " of an older age is still preserved in fine drops in the interior of the earth. It can also be won from ores. The fine drops are called " Virgin quick-silver." The children are now told that mercury is capable of dissolving silver and gold and indeed nearly every metal except iron. When this so-called amalgam is heated, the mercury passes off as vapour, it becomes air and is presently deposited all around as a fine rain of tiny drops of mercury, while the gold or the silver is left behind in the crucible. Again we see the likeness to water. Just as salts can be dissolved in water, so can most metals be dissolved in mercury, returning in this way to their liquid state. Like water, mercury is mobile and reconciles the greatest contradictions. The alchemists, or chemists of medieval days, called it " servus fugitivus " the volatile servant, because it may be driven off again after gold has been dissolved in it. The gold or silver may be recovered, just as salt or anything else dissolved in water may be recovered by evaporation. Thus we make both water and mercury into our servants, who we may dismiss at will. In former times the qualities one associates with mobile drops were known as " Mercurial " qualities.

In like manner, copper and iron may now be contrasted. The red colour and malleable nature of copper are first pointed out. A thread of copper can be drawn out to extreme fineness. When blended with tin, copper gives us bronze. It thus becomes harder and suitable for a great variety of uses. Before men had learnt how to use iron, they made weapons of bronze. It is the bronze in bells which gives them their beautiful tone. Copper turns black in fire. When exposed to the air for some time it turns green—the well known " patina." Dissolved in acid, it turns blue. It can thus assume a variety of colours. There is something mild, soft and colourful about copper. Its beauty, softness and flexibility are remarkable.

Iron is grey, almost black, but it has nevertheless a metallic shimmer. It rusts when exposed to air, especially in the presence of water. The colours of iron ores and salts tend toward red. Iron is present in our blood and without it we could not breathe. Weapons and railways and the whole world of machinery are made from iron. The terrific heat of the blast furnace, alone makes it possible to win iron. Steel is made from iron. There is about it something hard, powerful, and downright warlike. It permeates the whole earth, which contains more of it than of any other metal. In many respects it is the opposite of copper. Copper is red and turns black in the fire. Iron is black and becomes red in the air. Iron ores are usually reddish while copper ores are blue-green.

The picture we draw of the metals at this stage is thus quite a simple one, but we shall later be able to build on these beginnings.

In our comparison of water with mercury, we have already seen in what relation they stand to each other. Water is the upper sphere of the fluid on earth. Water is always associated with the atmosphere and so with the whole universe. All life moreover has its origin in the water and it is active in every living thing. Mercury on the other hand has retained the fluid state of an earlier world. It is the modern representative of a world of fluid metals cut off from the cosmos. The metals which we dig out of the veins of the earth, belong to the lower sphere. The contrast between these two spheres is strongly impressed on the children when they see what great heat is needed to make mercury disappear and then appear again like rain as it cools, while water evaporates quite easily into the atmosphere. The distillation of mercury requires the might of fire.

These demonstrations with metals have shewn activities which stand midway between combustion and salt-formation. In water, as in metals, the characteristics are, drop-formation, fluidity and the tendency to evaporate and again condense. Water and the metals may be regarded as representatives of the middle or circulatory processes on earth. Having thus given the children a brief cross-section of chemistry in its three main stages, we can conclude by contrasting the three processes. Firstly, we demonstrate combustion by burning some sulphur, and thus show the tremendous contradiction such burning involves, calling up as it does all the powers of the will. Secondly, we obtain crystals from a salt solution, a cold tranquil process which can be calmly observed. And finally we distil water or mercury—contrasts and reconciliation, the water ever moving and ever again returning to rest and also the unique mercury; they swing between the airy and the fluid. The foundations have now been laid of those fundamental chemical concepts which have a bearing alike on the processes of external nature and of the human organism.