FRITS H. JULIUS

THE WORLD OF MATTER AND THE EDUCATION OF MAN

CHEMISTRY PRESENTED BY SIMPLE PHENOMENA

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FOREWORD

The author of his book, Frits H. Julius, has taught for more than a generation in Dutch schools, mainly at the Vrije school in the Hague. As most of his books are in Dutch, they are little known in England. They deserve a much wider circulation. This translation of the first part of "The World of Matter and the Education of Man" - Chemistry presented by simple phenomena - is meant to contribute to this.

Here the investigator and teacher shows how the study of man that we owe to Rudolf Steiner passes over into practice in education and lessons. Through this, an instruction in Chemistry, founded upon the points of view represented in this book, may become an essential element in education, and thereby serve the great task of schoolteaching at the present time and in the near future. The research section of the Association of Free Waldorf Schools welcomes this work, which it believes will stimulate not only the more limited circle of schoolteachers, but also everyone interested in the furtherance of education. The doctor, the farmer, and the lover of nature in the widest sense, as well as all parents, will profit from this book.

Dr. Wolfgang Rudolf.

INTRODUCTION

The educator is faced with the task of so presenting natural phenomena to young people, and stimulating insight into the connections in Nature that an echo of the spiritual is called up, and strong impulses for development are given. It is particularly in the teaching of chemistry that the danger lies of bringing about the opposite: either the pupil is cramped in a certain way which leads to antipathy towards the teaching matter, or else he is numbed by abstract ideas. The former danger arises more with the girls; the latter with the boys. These dangers really have nothing to do with the actual subject matter itself. They only appear, because in his thinking consciousness man has separated and isolated himself from the life pulsating through Nature. However, in those depths of his organism which are inaccessible to his ordinary consciousness, he is still absolutely bound up with the surrounding world because otherwise he would not be able to take nourishment, breathe, or even perceive anything. This indicates that the teacher must call into consciousness the unconscious connection with life and with the wisdom in Nature, so that he finds the way to a method of teaching, rich in meaning and really according to the facts. Only then will his teaching be able to do justice to the demands made on him, not only by the pupils thought-life which is being awakened by the teaching-matter, but also by those deeper parts of the being of the adolescent which remain more hidden.

Lastly, the teacher has the task of developing a form of science which satisfies the deepest demands of the human being. Only through thoroughly coming to grips with this task is the teacher able to cultivate that enthusiasm so essential to his profession.

Rudolf Steiner on the other hand regarded as one of his chief tasks, the indication of paths by which a comprehensive picture of the world can be acquired.

Here we reach a point which must be brought to our attention with the utmost seriousness: whoever wishes to penetrate with understanding the life of Nature, or that side of matter which is of particular importance for the processes of the human body, will find that a purely intellectual training will not suffice. The usual study course is confined to a development of thinking in as far as this is head work. When only the head is engaged in thinking, it works as a kind of filter. It allows only certain things to come into consciousness and wards others off, so that only a onesided picture of the world arises. On the other hand Rudolf Steiner considered it to be one of his chief tasks to show ways of acquiring an all-round picture of the world. He inaugurated a method of training whereby the knowing consciousness is extended to other regions of the human being, in spite of the fact that the exactitude of scientific thinking is retained. It is possible to achieve this through learning to use not only the thinking but also the feeling and willing in such a way that all three unfold into faculties serving the process of knowing. Particulars of such a training are to be found in the following

Anthroposophical literature:-

Knowledge of higher worlds and its attainment;
Road to self-knowledge in eight meditations;
The Threshold of the Spiritual World;
Occult Science, etc.

When one follows this path one becomes aware of the reality of the life forces which build one's own organism. As these are also closely connected with the structure and the interplay of processes in the whole of nature, we acquire in this manner a quite different, much more direct, a deeper and richer conscious connection with the world. One also experiences very soon along this path, that the usual intellectual consciousness is not admitted to these realms, because it arises at the cost of life forces. It is not based on building-up processes, but on those that destroy and which during waking life are active chiefly in the brain. Particularly characteristic of modern natural science was the effort to blot man out completely, as a sensitive, feeling being, during experiments. People acted in this way, in their striving after objectivity, because they believed they should deeply mistrust the subjective character of sense impressions and the feeling bound to them.

Steiner, on the other hand, places the human being in every respect in the centre. He shows again and again that it is impossible to practise a science without making the being that carries out this science, namely man himself, the measuring rod. The necessity therefore arises to focus attention right at the beginning, on human faculties in order to test their possibilities of development, and find ways of training them towards greater exactitude. The realms into which one can then knowingly penetrate expand unbelievably with the use of these cultivated faculties.

Steiner himself followed such paths, and was consequently able not only to sketch a complete picture of the cosmos and the evolution of the world, but also to show in numerous specialised fields, the way to new knowledge and new methods of working.

The criterion in this, is that the human being stands in the centre, not only in the method of investigation, but also in its results. Man is no longer a chance by-product of the cosmic evolution, but is the centre of the whole creation. Everything in it has its objective in him. Only through investigating him can the veils concealing the meaning of creation be raised.

When this general rule is applied to Chemistry, the result is as follows: the phenomena which arise through the interaction of substances and the laws which they obey, are only comprehensible in their deepest sense, when related to man's life-processes. (Steiner: The origin of Natural Science in world history. Lecture 9). (Der Entstehungsmoment der Naturwissenschaft in der Weltgeschichte - Dornach, Dec. 1922).

This point of view is not only of the greatest importance for Chemistry as a scientific field, but also for the teacher of Chemistry. He can only expect real interest from his pupils, when the subject is regarded in its connection with the human being. Furthermore, he can group the extensive teaching matter, which is usually given in a form lacking any clear survey, into a clearly constructed unity around a central point. In this way he can develop a teaching method which is well grounded, and simultaneously uses the pupils time and energy economically. This will be shown in the following pages.

It may be appropriate to mention here, that this new method amounts to a quite exact reversal of the materialistic point of view so widely accepted today. While, during the last centuries, many people enthusiastically strove to understand man as a sum of complicated material processes, we must hope that in this century insight into the human being as the key to the mysteries of the world of matter, will kindle just as great an enthusiasm. How shall we otherwise achieve the mighty work expected of us?

Now we can ask, "Are there not in the development of natural science, at least the faint beginnings of a striving in the direction indicated?" Such seeds certainly exist. They appear most clearly of all in the many-sided natural scientific works of Goethe. In studying natural scientific material in accordance with what is dealt with here, we could do no better than follow his example. He has, it is true, not written an important work in the domain of Chemistry, but if one makes the method one's own, which he used for example in his colour theory, and his metamorphosis of plants, then one will also be able to discover the way in chemistry to a deepened knowledge, and a systematic treatment of the single facts.

Goethe paid such great attention to the being of man, and its central position in the world's happenings, that all his works, the artistic as well as the scientific, are centred around it. When one follows his method, all the single entities one works upon, slowly unite to form a picture of the world so proportionately constructed that the whole becomes a true reflection of the human being. And the human being himself becomes a richly varied and differentiated whole, in which the world likewise is reflected. Man becomes the world; the world becomes Man. This is precisely in the direction indicated by Steiner.

It would have been extremely difficult to work in this way, in the spirit of Goethe, if Steiner had not characterised his method in detail, and also given it the foundation of a theory of knowledge. That which in Goethe, arose half instinctively from fortunate talents, is brought into the clear light of the philosophical consciousness by Steiner, and thereby made available to everyone. (Rudolf Steiner: Theory of Knowledge Implicit in Goethe's World-Conception; Goethe's Conception of the World; Goethe as Scientist).

In the organic world, Goethe demands the phenomenalogical method. If one is confronted by a new domain, then first of all one should, so to say, disentangle the phenomena and then describe them according to their natural order, so that the essential part clearly appears. Goethe did not rest until he had in this manner, sifted out what he called the original phenomena, from the chaotic mass of the world of appearances.

These are phenomena which are simple and easy to survey, and from which the more complicated phenomena develop. In his efforts to discover explanations, he never goes further than the original phenomena. He never theorises, but wishes to arrange the phenomena so that they are able to express their own real being. He does not project his thoughts into Nature, in the way Huygens did when forming his Ether-chemistry, but lends his thoughts to Nature. He allows nature, so to say, to think in him. Goethe believed that if we let the original phenomena become thoughts in us, Nature speaks to us.

In his whole approach, the inner attitude to the sense-world is at least as important as the more external system of his method. This inner attitude, which is completely directed towards allowing the sense appearances to speak for themselves, is quite ideal for the person following Steiner's path of training. In a certain sense natural scientific study in Goethe's manner, is the best preparation for this schooling.

As the contents of this book are chiefly concerned with what must or can be taken with the pupils, we shall limit ourselves mainly to the phenomena accessible to our senses, as well as to thoughts arising on the basis of a purely Goetheanistic method. This need not really be a limitation, because a correct arrangement of the external phenomena always lays a healthy foundation for a later understanding of the more obscure aspects of the substances.

One can also maintain the opposite view. Experience teaches that the study of a particular field of knowledge, in the Goetheanistic method usually leads to a clear and complete survey of the phenomena, only when one knows through Anthroposophy, the more concealed background of the subject. It is not without a certain hesitation that I express this here. It could arouse objections. Actually one need not worry about working in this way, with a predetermined standpoint. Much patience and great restraint belong to a true Goetheanism. Should one have both of these at his disposal, then things will appear in their true light under all circumstances. Should one possess neither, then with or without Anthroposophy, distorted ideas will always arise. If the appropriate reserve is practiced, then through knowledge of Anthroposophy simple obvious phenomena, and their inter-relationships will be noticed, which are an essential requirement, but which would normally have been overlooked.

One sees again and again, how Goetheanism and Anthroposophy go hand in hand; how you are led by the one to the other, and how the latter cannot exist without the former.

Each teacher faced with such questions will have to decide for himself how much stress he wishes to lay on the various points of view; to what extent he wishes to comply with the numerous demands made on him. In general one will have to make room adequately for the commonly accepted teaching matter, even if one considers this to lead to a certain onesidedness concerning the whole of Nature.

Moreover, the method of treatment will need to be such that a suitable transition is found to more abstract thinking, to permit the understanding of the Atomic Theory, and the solving of calculations. Attention will be given to these in the second part of this book.

BASIC PRINCIPLES IN THE TEACHING OF CHEMISTRY

Two guiding principles of greatest importance for fruitful teaching, which cannot be treated anew in every example, will now be indicated.

Simultaneously it will be shown what the adult may achieve for himself through such a procedure in teaching.

One who is not a teacher but who wishes to deepen his natural-scientific view of the world, be he chemist, doctor, biologist, geologist or interested beginner, should not disdainfully look down upon such a "Science for children" as will be described here. If he is striving for a spiritually orientated education he will notice that what is offered will strengthen spiritual activity in a particular way. He will experience on his own body that all healthy human development depends upon "Speaking to the child". be it concerned with the being who is still a child or the child which lives concealed in every adult.

In the first place it must be pointed out that Chemistry is not an isolated subject either for the teacher or the pupil. It is taught along with many other subjects – scientific, cultural, artistic and practical. The pupil is continually approached from various sides and he responds with different sides of his nature. Apart from this the teacher should link his subject as much as possible with all other subjects. Only when these conditions are attained can a subject become part of a comprehensive harmonious picture of the world. Without them it leads an isolated and uncontrolled existence at the cost of the harmonious development of the pupil.

Accordingly, the true natural scientist working along his own lines, should constantly relate his work to nature as a whole and to civilization in general. In this he may follow the example of Goethe who developed a branch of physics – the Colour Theory – to such a high degree that it has become a contribution to civilization. Neither may he neglect to cultivate the arts. We may think, here, of Eurythmy, Painting and Sculpture. Such an artistic training – practised in the right manner – is a means of forming the will and feeling, so that the view relating to the world, previously mentioned, is made possible. Should this training in the artistic realm be neglected by the scientist it is quite certain that he will have great difficulty in approaching certain aspects of Nature and of Man.

The second educational point the importance of which we wish also to show for older people is the following: healthy teaching should not only take into account the taking of new material into the consciousness, but also its submergence into the unconscious. In truth the whole of human life is based upon the lighting-up and darkening of consciousness. With most people this comes about with great regularity through the changes of waking and sleeping. Each night the contents of consciousness sink to unfathomable depths in sleep only to emerge again on the following day. Really good teaching takes into account this going through the depths; it is not only during the day, in lessons, but also during the night, in sleep, that the contents of the soul are worked upon. The sinking down in the night, of the material presented, should be allowed for in preparation and its re-emergence, on awakening, should be guided.

It is particularly during the period of this blotting-out of consciousness that all content is involuntarily brought into connection with the more concealed regions of man's being and confirmed, as it were, by the wisdom operating there. As a teacher, one influences these regions whether one wishes to or not and one is always faced with the results. Here one works continually for good or bad. By the arrangement of main lesson periods the teacher is given the opportunity not only of benefitting the instruction through knowledge of such matters, but also of so handling them that they have a certain hygienic effect. We shall see later how strongly this sinking down and bringing again into consciousness must be reckoned with especially in experiments.

Again, a mature man can purposefully handle these things for himself. He should always live with trust in the hidden wisdom of his organism which reaches far beyond his everyday powers of understanding.

In that, above all, this wisdom is also active in the functioning and building up of the body, it must have a deep connection with the being of matter. Behind the veil of sleep lies hidden for us, therefore, a vast knowledge of the world of matter. Now, one can so occupy oneself with the experiences made through perceiving the phenomena that they become questions addressed to this hidden wisdom. One must prepare for this, beginning by entering completely into the processes as these present themselves to the senses, at the same time denying oneself all inclination to give theoretical explanations. What is then experienced may later be formed in moments of inner contemplation, into thought pictures, which are then able to become messengers into the realm of sleep bringing into activity a fountain of inspired knowledge. In this way one can achieve a relationship to his own unconscious wisdom, similar to the relation of the pupil to his teacher. One asks, and one receives an answer. Experience teaches that in this way one kindles light which not only shines into the deepest regions of matter but which gives a surprisingly new view of many everyday phenomena. Also, in experimenting, one will discover all manner of devices which assist the demonstration of the phenomena. Without this light many of the most important manifestations escape our notice.

When one tests current ideas on Chemistry from the view point represented here, an intrinsic fact becomes evident. These ideas, specially in so far as they point in the direction of atomism, influence thought-life in a way which isolates it from Nature; and besides they obstruct the possibility of a union of Science with the Humanities. These ideas are completely unsuited to a healthy and enriching interplay between the states of sleeping and waking. Might this not be one the causes of sleeplessness and of the steady decrease in the refreshing effect of sleep which present so many problems to doctors?

In spite of their negative qualities the atomistic ideas have had a very positive meaning for mankind. Certain of the more instinctive connections with the surrounding world, which existed earlier, have been destroyed by them and just through this, the capacity of the individual to judge and to be independent has been assisted and developed. For a long time the effect of this aroused such enthusiasm that it was not noticed how, simultaneously, the possibility of gaining a deeper insight of man and the world was lost.

The actual importance of atomistic ideas, therefore, is to be found in a quite different province from the one generally thought. It is also a mistake to believe that they are deduced from nature itself for it was only towards the end of the 19th Century that the phenomena in which the tiniest of particles are perceptible were recognised. Viz., Radio-activity, whereas, long before this, people had begun to think atomistically. Although one may be absolutely convinced that, through atomistic ideas, one gains a sure starting point for the approach to many-sided nature from one particular aspect, one should also learn to see that with these ideas one is concerned with a phenomenon of the present age. All who do Chemistry in the orthodox way direct their attention chiefly to this aspect at the expense of other aspects of Nature which are equally important.

The whole practical teaching method that is worked out here is based on the assumption that the time is past when man must be separated from the world in order to achieve independence. It is a social necessity that a renewed connection with the deeper strata of reality be discovered. The results of forms of thought cultivated up to the present time show themselves very clearly in destructive processes in cultural and technical spheres. Therefore, we have purposely not used the atomic approach at all, as a basis of explanation. Of course modern young people must become acquanted with the atomic theory and its chief effects; but they must be protected from "believing" in it, and, in consequence of that belief, from observing all phenomena from this one aspect only.

We now wish to summarise those points of view which are essential in the development of a Chemistry syllabus.

(a) The teaching material for each age range must be treated so that it corresponds with what is taking place in the child. Only when this is carried out will it be possible for a subject such as Chemistry to make a significant contribution to the education of the young. It will then help each child to find a healthy connection with the world as a whole, as well as with his particular environment. One can provide material for his thinking so that correct thought structures and a content true to reality penetrate it. It is even possible in this subject to make important contributions to his self-knowledge as Man. The better the teaching material is attuned to the respective class the deeper will be the effects achieved.

(b) Following a particular system, building stones must be brought together to form a comprehensive all embracing world-outlook. This must apply to the natural as well as to the cultural surrounding world with which young people will have to deal.

(c) The pupil should clearly understand a certain amount of the matter taught and be able to remember it.

It is possible to have confidence in the fact that there is such a thing as an ideal syllabus which coincides with the laws of development of the child. Various adjustments and compromises which will appear in the actual syllabus will have a disturbing effect while in the ideal syllabus the themes and styles of treatment would easily allow of adaption to every age-range.

Perhaps one might dare to compare it with themes in a symphony. In the way that all of these have their own form, their own beginning and end, even their own character and tempo and yet altogether build the greater whole, so should the whole of the Chemistry instruction be divided into periods which vary greatly in character. In this respect I hope to be able to show that it is good to distinguish one year from the other.

The matter for one class should be touched upon as little as possible in the preceding class or in the one following. Only then, will justice be done to the particular qualities of the pupil which one attempts to cultivate at a certain age. It is not only the amount of material covered, that is important, but equally the lapse in time between each step in building up the whole Chemistry syllabus, i.e. the distribution of the material through the years. The more one reckons with this kind of rhythm and structure the more lively will the teaching become and the more powerfully will it be absorbed into the whole development of the pupil.

If one takes into account, in this way, the given and characteristic stages of development in the life of the child one will notice that exactly through this, a really practical progression of lessons, guaranteeing a complete survey, is made possible by the whole syllabus. Consequently the teaching can be economical as well as thorough.

WORK IN THE 7TH CLASS

1. Fire

While teaching in the Free Waldorf School in Stuttgart, Dr. Eugen Kolisko wrote an essay on teaching Chemistry in the 7th class, as developed by him. This bore the title "On the first lessons in Chemistry". This is a good starting point as it gives a living picture of the fundamental thoughts of the lessons, is beautifully and concisely built up, and very carefully demonstrates the various phenomena in their manifold connections with the world and with man.

As this essay has been out of print for a long time, part of it will be incorporated here in broad outlines. I shall add some points of view from my own experience. The whole scheme will, in order to include this, naturally have to be altered somewhat in its style and construction, whereby it will lose something of its intimate character and individual style, which is so inspiring in the original work.

From indications given by Rudolf Steiner we begin with combustion, a process the children know well, and which fills them with enthusiasm. *

We let the children bring all kinds of combustible things, including as many natural products as possible, and set fire to them. During this we draw attention to the marked difference between combustible and non-combustible substances. Furthermore, we indicate how each substance has its own particular manner of burning.

We also show the characteristic differences between the burning of various plants e.g. between grass and pine needles, or the various parts of a plant, like the root, leaves or flowers.

In order to create a kind of climax to the work on the first morning, we finally pile up wood-wool. When this is kindled, we have a particularly beautiful and lively fire. We draw attention to all kinds of peculiarities; to the colour and form of the flames; to the transition from flame into smoke; to the flashing sparks; to the carbonisation of the light wood; to the glowing places which devour the charcoal. Especially important is the change into the dull, formless ash.

When this has been demonstrated, we summarise briefly all that we have seen. This is really most important because the observation of a fire causes much excitement; and apart from this, merely through gazing so intently, the child comes to be to a certain extent, outside himself. If all that has been seen is now called to mind it has a calming effect, bringing people to their senses again. Interspersing this with all sorts of view and explanations, however, should be avoided. The picture as such should remain with the children as clear and undistorted as possible, so that it can later be taken into sleep.

On the following morning as we pick up the threads again we encounter a great eagerness to retell all that had been seen on the pre-

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* List of references. (See German copy).
Kolisko – Elementary Chemistry for Children – "The Present Age". Vol. III, No. 5,6,7/8.

vious day. However, we must ensure a really vivid re-emergence of the pictures, laying particular value on intimate observations.

Only now has the moment arrived to enter more deeply into the phenomena, and attach other considerations to them. If this were done on the day of the experiments, barriers would be raised to a certain degree between the child and the phenomena and the impressions also would be prevented from being carried over into the realm of sleep. Through postponing such considerations until the second day, questions are touched upon which arise simultaneously with memory from the depths. One throws a kind of light on, and brings a certain order into, the jumble of half-conscious things that the child brings with him. Besides this, all that one says carries more weight, because it is continually being strangely re-echoed from the depths of the child's being. This relationship of the first two days to each other is valid, with the required modifications, for all the following days where the matter being taught is accompanied by experiments. We shall therefore not refer to this essential aspect again.

On the second day we draw the children's attention to the wonderful phenomena that the flame gives out light and warmth in a very cheerful way, always striving upwards, while on the other hand lustreless remains of carbon or more particularly, formless ash fall downwards. The question then arises, of how it is possible for the wood to emit light and warmth on the one hand, and leave dull ash on the other.

It is then not difficult to get the children to see that each of these looks towards its origin, returning to the source from which it sprang. The wood of the living plant can only be built up, in that the roots absorb water and salt from the earth, and the leaves catch the sun's light, which they then condense into plant substances.

Now it might happen that someone says, "With the burning of wood, the formation of carbon dioxide and water should not be overlooked." To be sure, some people will consider the formation of these substances to be more important than the effects of light and warmth. Under given circumstances they can be handled too, but over against this I should like to say the following:– The substances as such are not so important for children of this age. Our chief concern here is the picture Nature offers us. We must work at this and investigate it. The work must be grounded upon that which the children perceive. In this picture, warmth and light on the one side, and ash on the other make themselves quite apparent. The gaseous substances are not evident in the same manner. It is important not only for the children, but also for the teacher to restrict himself at first to the picture. The more Nature occupies him, the more he learns to enter with the greatest seriousness into the way she directly presents herself; that is, into that which she herself emphasises. Without doubt, a particular reality is expressed in the fact that the one occurrence is quite obvious, while the other remains for the senses behind the scenes. If one should, however, deal with these practically imperceptible substances, one will need to do it so that the picture described here is called to mind very vividly and undisturbed. I am of the opinion all the same, that it is incorrect to call the carbon dioxide also "Ash", as is occasionally done. From the didactical point of view it may be simpler to give such an explanation for the appearance of this gas, but one is then not taking the picture into account. Ash belongs to the earth, not to the airy element. The escaping warmth is also not called ash. We can discuss oxygen better with the candle experiments, and CO_2 with lime.

In any case it is good to view the processes in the realm of matter, right from the very beginning against the background of the whole world. But let it then really be the whole! We must guard against adopting the onesided preference of the modern natural scientist, who wants to regard everything from the point of view of weight.

When we place fire into the order of the Universe, the child learns to survey the world involuntarily as in a mirror. The world above, especially the sun, is related to that which blazes out from the flame. The world beneath us, similar to the ash from the fire, is fallen from out of the great world flame.

We now look all around for phenomena that reveal the same things to us as those living in fire; thus fire becomes the key to many occurrences in the world.

In flowers we see that plant substance becomes transparently fine and shines in radiant colours from amongst the duller green of the leaves. In contrast to this, the roots with their denser substance resemble the ash to a greater extent. As with the ash something very drab and unattractive arises, so also is the outer appearance of the roots, dull and inconspicuous, as compared with that of leaf and blossom. Similar to the fire, the radiant clear element strives upwards, and the dull, heavy one downwards.

In ourselves the warmth process is to be found above all in the lower parts of our bodies and the limbs. The process comparable to the formation of the ash, however, is to be found in our heads. With regard to the plant, one can speak of a living flame. In man, however, the fire not only possesses life but soul and spirit. Because of this controlled fire in us, we are able to develop the will. The strange thing about all this is that this flame is inverted. When this is demonstrated to the children, they recognise something which has been dealt with earlier: that man may be compared to an up-side-down plant.

We can then begin with experiments showing the importance of ventilation.

A bell jar is placed over a candle, and the children allowed to observe how the flame very soon becomes weaker, and finally goes out. Then this is repeated with a larger jar, or even a glass bowl. We compare the time taken in each case to extinguish the flame. Through pouring water into the jars we can ascertain their volumes, and see that these coincide respectively, with the duration of the candle flame. If we place a jar under which a candle has gone out, over another candle, this is immediately extinguished. The air therefore is markedly changed, even though nothing of this is seen. It would be good to clearly emphasise this change by drastically describing how cramped we should be in this air and unable to live. Such a description is an example given by Rudolf Steiner to bring the children to an experience of the vacuum.

Having done this, we pour a little water on to the table around the candle and invert the bell jar over it. At first we see air escaping, but then much more air streaming in. For ourselves we know that the gas oxygen is not only used up out of the air, but that a gas carbon dioxide is also formed. On being produced this occupies a little less space than the oxygen and is also absorbed to a great extent by the water. Water vapour is also formed, but condenses into water. For the children, it is quite sufficient to see that something disappears.

In a small dish of water, we can let the stump of a candle float on a cork and then invert a bell jar over this into the water. After the extinguishing of the candle we shall see that the water has risen considerably.

Should one wish to carry out the experiment more precisely, a piece of phosphorous must be burnt instead of the candle. It can then be proved, that approximately 1/5 of the air disappears, through being used up by the fire. Under the circumstances one allows the matter to rest here, and says that fire not only requires air, but also uses it up. However, something can also be added about oxygen and nitrogen. With children of this age one will tend to call oxygen the 'fire gas' or 'breath gas', Nitrogen has in German a most characteristic name — 'suffocating gas'.

Once this has been discussed, all manner of things can be dealt with connected with the use of fire, e.g. the phenomena appearing in a big fire; something about the technique of extinguishing with sand, with a cloth, with water, or foam; the construction of a simple oven, gas-stove, paraffin stove, lamps.

In the course of these discussions attention will also be drawn to the fact that man's relationship to fire in earlier times was quite different from that of today. Fire was then a gift to him from heaven, and therefore played a central role in the Temple sacrifices. Even today there are customs directly connected with this. Thus candles burn upon the altar, while clouds of incense rise up around them. And when the mood on Christmas Eve is as it should be, the candles on the tree also become flames of sacrifice.

When preparing for St. Nicholas Day, Dutch people have a rather strange custom. The children sing songs to the Saint in the evening; they sit around close to the great tiled stove, and later on place their shoes under it. This reminds us of the time when people let an open fire burn on the floor with the smoke ascending through a hole in the roof. The fire was not only used for heating and cooking, but also must have been the centre of a certain form of sacred worship. The opening in the roof too played an important role. Right up through it a connection was sought for with the Gods, with the stars. The smoke ascended to the gods; the gifts of the gods descended through the opening. We are reminded of this by the children's beliefs that St. Nicholas rides over the roofs, dropping presents down the chimneys into their shoes (which really are filled with presents next morning).

In certain demoniacal practices, this outlet for the smoke is also of major importance. So the witch on the broomstick rode through the opening over the fire on the hearth.

It can be quite illuminating to us to think of how this opening gradually became a chimney, then a fireplace, and later the bricked-in open range, how then the portable heaters and the oven (right up to the paraffin heating) originated. The history of the stove evolves so to say from above downwards. It is typical that the fire thereby became more and more enclosed and controlled. This is connected with the fact that man has isolated himself more and more from his gods and Nature, until he finally experiences himself as an independent self-reliant ego.

Central heating, that is communal heating from a single furnace under the earth is very characteristic of the inner soul state of the present day.

Man's attitude towards, and handling of fire, is a symptom of the way, he with his ego, faces the world.

To what degree such things can be handled in lessons, must be left entirely to the discrimination of the teacher. In any case, it is good to know something of such things for oneself, and have it in the background.

Naturally, heat as the source of power in steam engines and motors, can also be indicated.

After these more general considerations above fire, we examine rather more carefully, certain substances with particular combustible characteristics: sulphur, phosphorus, coal.

We know other substances also, which with the help of oxygen show combustible qualities; among these are a few, which I am of the opinion, should not be taken initially, in this connection. I refer to such metals as Magnesium, Zinc and Iron. Rusting is actually characteristic of these metals, as well as others, and it would side-track us far too much if we should discuss them here, only later drawing attention to their rusting. (The contrast between rusting and burning is taken in connection with the work in the 10th class.)

We first set fire to some powdered sulphur, which either lies on a stone, or is held in an iron spoon. We see a strange pale blue flame, that stays close to the yellow powder like a blue edging. It gives off a penetrating smell, which very soon causes irritation when inhaled, so that much coughing results if the gas spreads through the classroom. The work therefore must either be done under a bell jar or some outlet.

Then we set fire to a piece of charcoal. It rarely bursts into flame, but just glows. If the room is darkened, and the glowing piece is moved quickly to and fro, long flashing streaks of fire can be drawn in the air. Although this is a kind of optical illusion due to the slowness of the eye, I still consider it to be an important phenomenon, connected with the burning of carbon. A similar phenomenon appears when the sparks from a wood fire swirl upwards. This is an essential in the picture of the St. John's fire.

We can then light a whole heap of pieces of charcoal. It will glow only from the inside, leaving the outside black. This must be regarded as a most characteristic phenomenon also.

Finally, a piece of yellow phosphorous is taken out of the water in which it is kept. As soon as it has been dried carefully with a piece of filter paper or a cloth, one sees that it constantly emits a fine white smoke. If the room is darkened, it is seen to glow. This phenomenon can be made more impressive by drawing with the phosphorus carefully on paper or wood. The traces are seen to glow; but do refrain from sketching the skull and cross-bones, as is so often done. Senseless, sensational things like this only distract the children from attentively perceiving the phenomena.

Whereas sulphur burns with much warmth and very little light, with the glowing phosphorus, light effects predominate, and scarcely any warmth is noticeable. One needs to be extremely careful with yellow phosphorus. On account of its very poisonous nature, the children must really never touch it. Phosphorus is always stored in water. It ignites so easily, it has to be cut under water as well. Should you wish to write with it, it is best to hold it with a wet cloth. Tongs are too precarious, because if the piece should jump out, or suddenly slip, it could well ignite. Picking it up with one's fingers, must be avoided absolutely.

Then we light the phosphorus with a gas flame or a hot wire. Preferably red phosphorus is used for this. It doesn't require such terribly careful handling as it neither ignites itself, nor is poisonous. We get a hot, bright, yellowish-white flame which develops into thick white smoke. We proceed to observe the phenomena in connection with the particular tasks of these three substances in Nature and in Man.

The places where sulphur is found are mostly connected with volcanic activity. Although it is a phenomenon of the earth's crust, it absolutely contradicts it. The chief characteristic of the earth's crust is that it is that part of nature which has come to rest and grown hard. When a volcano erupts it is just this formed and ordered part of creation that is broken and brought into movement by wild, chaotic warmth processes rising from the depths. Deep-seated transformations are thereby taking place. A piece of crystallised sulphur, taken from the earth shows a similar contradiction: at first glance it resembles a beautiful stone, a usual piece of the earth's surface. However, the difference is noticed, the moment it is heated. It is immediately made mobile and dispersed in that it comparatively easily melts and evaporates. It will then also catch fire, developing strong heat effects. From this it is understandable that sulphur used to be called Solferos or Sun bearer. Powers belonging actually to the sun, like the raying out of warmth and the ability to disperse things through movement were rediscovered in the earth. Sulphur is always connected with forces which are actually at home in the heights, but which in a sometimes really chaotic, and chaos creating manner, work upwards out of the depths.

A piece of yellow phosphorus, not only has the quality of sending out light, but it also slowly diminishes, if left lying unprotected. It is something, which is continually changing into cool light. This is again a quality not inherent in the earth. If the children are asked whence this quality originates, they will probably hit on the idea that it is to be found in the stars. And when only one of them expresses this, the others will generally agree immediately. With us adults such knowledge would be less likely to arise, because it contradicts the kind of thinking we have learned. We must train ourselves first, so that we may recognise the language nature uses even in her simplest phenomena as the very consequential and serious expression of comprehensive universal connections. There are still clearer phenomena, however, which would be a help to us ourselves, but would lead too far in the class. In the phosphorus experiments, phenomena often appear reminding us of the picture of a starlit sky, or of moonlight at night. It is a spiritually scientific truth, that phosphorus is a representative of and bearer of star forces upon the earth. Sulphur and phosphorus therefore are polar opposites; the one a bearer of chaotic forces from the depths, and the other of strictly regulated star-forces. Carbon is their mediator; its actual province is the surface of the earth. It can be obtained from all living substance by allowing this to carbonize.

Let us now consider these substances with regard to the human being. We find them active in realms agreeing with those in Nature. Sulphureous forces are found chiefly in the digestive system, which is centred in the abdomen. In connection with this it is understandable that sulphur baths or nourishment containing sulphur, activates the digestion or even speeds it up. (See Class 11 "Sulphur"). These digestive forces are directed chiefly upwards in us, just like the volcanic activity in Nature. In us also the danger of chaos and loss of control threatens. The typical phenomena of sulphur can be summarised in two words: "wallowing warmth" (wühlende Wärme).

The activity of phosphorus is found mainly in the brain. While the action of sulphur whips up, and disperses, that of phosphorus contracts and hardens. It is directed from the circumference, inwards and downwards. The character of phosphorus can be expressed in the words: "glowing rigidity" (leuchtende Erstarrung).

Carbon has its strange relationship to nourishment and breathing. It will be difficult to work this out in more detail, restricted to the material we can handle at this stage of a 7th class. In both the following classes, everything related to carbon, will be all the more thoroughly discussed.

Now in connection with these three substances there is something else that could be taken in the 7th class also, or perhaps under certain circumstances be left until class 8, and this is the importance of these substances in the whole technical use of fire. In one way or another nearly everywhere, heating is connected with carbon. In matches, all three substances are even used together. Let us sketch their history briefly.

In earlier times fire was kindled by rubbing together pieces of wood, or striking sparks with pyrites or iron on flint.

As soon as man became acquainted with phosphorus, he began using it also. Sulphur sticks were made, i.e. wooden sticks, the ends of which were dipped into melted sulphur to form a sulphur head. This was surrounded by a quantity of yellow phosphorus, sand and glue. These matches could be struck on any fairly rough surface. That was very convenient, but naturally involved all kinds of dangers. On account of their being extremely poisonous, these matches were later forbidden. In the meantime the "Swedish" or safety matches had been discovered, which are still used today. These have a head of a combustible substance containing sulphur e.g. antimony sulphide, and a salt which assists the burning by expelling oxygen e.g. potassium chlorate. In order to strike them a special surface is necessary containing red phosphorus, powdered glass and some sulphureous substance.

Still later the wood was specially impregnated with certain salts. Before this the charred wood continued to glow until only some ash remained. Thereby the still glowing head fell off and could cause damage. Now the match flares up and becomes black, but thanks to the salts the carbon ceases to glow.

To ensure good burning the matches are dipped in paraffin. You can see it like a drop, running in front of the flame.

In connection with matches, all kinds of technical things can be discussed, and an understanding of these simultaneously awakened; e.g. one can speak about the construction of a match box. It is just as simple as it is practical. Without having to ponder over it much, nearly every child knows it well. Therefore we allow the children to think about its various constituents, how many they are, why each detail is as it is, etc.

The children are usually very surprised, when faced with the question as to what the next great discovery was after matches, to find that it was the cigarette lighter, nothing more than an improved way of striking fire.

With regard to the very interesting mythological aspect of kindling fire, we recommend the chapter on phosphorus in the second volume (Class 11).

2. Salt

We now turn aside from everything to do with fire, and direct our attention to the formation of salts. We begin with a salt, which confronts us most obviously: with lime.

Firstly we let the children observe typical examples of the numerous forms of lime in Nature: mussels, birds eggs, bits of skeletons, stones. Then we discuss the circulation of lime in Nature; perhaps at first the small one by which the stone is continually worn away by water and deposited again as stalactite. I consider it important to pay attention to the finer processes, to the extremely thin layer washed away by water, to the silent flow of water down the stalactite's cone, to the formation of the drop from which the tiniest speck of lime is added each time to the cone, and to the falling of the drop, its splashing up, and building of stalagmites. If carbon dioxide has already been dealt with, one can point to the fact that lime dissolves in water containing carbon dioxide and that the lime is deposited again when the carbon dioxide escapes.

One begins to awaken an idea of the endless array of forms which appear. As is so often the case, here also Nature uses the opportunity to create a marvellous display out of very simple circumstances.

Then we discuss the somewhat larger circulation of lime, by which stream beds are levelled as a result of lime being deposited, the movement of waterfalls is caught in petrified forms, and branches are surrounded by a rough crust.

Finally the largest circulation is considered. One part of the lime flows dissolved down to the ocean. Everywhere there are animals and plants which build shells and armour with the help of the absorbed lime. These shells it is true partly dissolve again when the animal dies but still layers of lime are deposited in certain places. In our limestone mountains we recognise such layers, which were deposited in olden times and raised above sea level through movements in the earth's surface.

A constantly fluctuating dissolving and depositing is what concerns us here. However slowly these processes may take place, the impression of a restless, circulating movement should be awakened.

Calcium deposits in our skeleton can also be given attention here. There again it is dissolved as well as deposited, although with an ever greater tendency towards deposit, the older one gets. During the growth of the skeleton e.g. on a tubular bone, it can be seen particularly well, that a continuous renewal of the solid part of the body also takes place. The thigh bone of a newly born child is so small, that it fits approximately into the hollow space of an adult's thigh bone. Growth is therefore only possible through the substance being taken away at one place and deposited again at another. Lime in the human organism is also constantly on the move.

Once these things have been dealt with, we move on to the burning of lime. With the aid of a bunsen burner and a few shells this is more or less quite easily done. It is better still if a blow-pipe or oxyhydrogen burner (if necessary with coal gas instead of hydrogen) is used and a piece of marble. One of my colleagues chose the following experiment. A small enclosure was built with bricks, a piece of marble placed in the centre, and the whole thing filled with coke. It was then covered with a brick, leaving a small opening in the front into which some pieces of charcoal were pushed. After these had been lit with a gas flame, oxygen was blown in. In this manner a particularly good fire is achieved, so that after a time the marble glows through and through, and is consequently thoroughly burnt.

One now shows that the burnt marble has acquired very strange characteristics. Above all it has become unattractive and crumbly. It reacts particularly powerfully with water, even after cooling. If only a small quantity of marble has been burnt, bought quick-lime can be used instead. A piece is placed e.g. in a beaker, and water added. Perhaps only after a few seconds, it will then begin to hiss and steam furiously, swelling up and disintegrating in a strange, apparently almost living manner. The dissolving of lime can be shown in this way.

It is not quite so easy to observe that a gas, carbonic acid gas, escapes when lime is burnt. The possibility of obtaining this gas from lime may be demonstrated in another manner, e.g. through dropping a piece of marble into a flask containing dilute hydrochloric acid. One sees it dissolve while a stream of sparkling gas bubbles arise. If the glass has not been filled, but covered with a glass plate, after a while a burning match can be extinguished by the collected gas. An important characteristic of carbon dioxide has now been shown: it is a kind of air by which fire is extinguished.

When a number of shells are dropped into the hydrochloric acid instead of marble, a very viscous foamy mass arises which creeps up over the edge like a snail, and glides down. This phenomenon is rather significant as the connection with the animal is recognised in it.

Of course it would be well to deal with the lime-kiln in connection with all this.

Through testing with litmus we come nearer to the chemical characteristics of the substances arising from the burning of chalk. Litmus is a plant dye, obtained from a lichen grown in warmer regions. Certain flower dyes, which react in exactly the same manner, could just as well be used. In an emergency, red cabbage can serve the same purpose.

When a little dissolved lime is added to red litmus solution, the colour turns blue. If one has enough carbon dioxide to lead into a blue litmus solution, this changes to red.

Litmus paper can naturally replace the solution. However, it appears to me more effective to experiment on a somewhat larger scale than that brought about by the use of litmus paper.

When carbon dioxide is blown on to the tongue a faint pricking sour taste is felt.

Dissolved lime gives water a queer insipid taste, similar to soap or soda.

These experiments can be summarised by indicating that marble and lime, on burning, break up into two parts which not only go in opposite directions, the gas upwards and burnt lime downwards, but in many respects also have opposite chemical properties.

We can then explain that this is just a typical example for many other substances. A substance like lime, which can crystallise so beautifully, and also disintegrate into two characteristic substances, is called a salt. The burnt lime which represents the solidity of salt, is called the base (actually basis). The evaporating substance is called an acid after its taste.

Some slaked lime is now shown, and how it becomes hard after a while. One might even go so far as to skilfully build a small wall.

A little slaked lime is then mixed with water, giving a cloudy white liquid, milk of lime. This is filtered through filter paper to become a clearer liquid, limewater. Limewater has strange qualities. It turns red litmus paper blue. When allowed to stand a thin skin forms which is brittle, rather like an ice crust. It shuts itself off, therefore, from its surroundings.

In order to explain this phenomenon we either lead carbonic acid gas through the water, or shake it up with this gas that we have blown into the vessel. The limewater becomes cloudy. From this it is apparent that the slaked lime and to a still greater degree, the quicklime, are very covetous substances that absorb carbonic acid gas or water respectively with great force. Finally it all results in the forming of chalk again, or limestone.

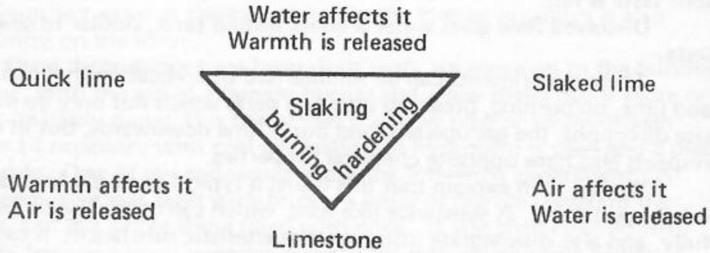
It is very easy to demonstrate with limewater that we exhale carbon dioxide; but it is preferable perhaps to show this in a higher class.

If the children follow well, they might also be shown how the cloudy limewater becomes clear again with excess carbon dioxide. Limestone is dissolved in water containing carbon dioxide. When this solution is heated, at first much gas is given off, leaving behind the cloudy state once more. This last phenomenon is connected with the formation of stalactites, and the scales or fur inside a kettle.

One could eventually deal with the "digestive" qualities of quick-lime, by referring to their use in compost heaps; the burial of diseased bodies, etc. It is well known that on chalky earth, which consists of limestone – that is, of a salt – which acts more or less as a base, very little humus or black earth is made. Here also decomposition is promoted.

The use of lime for building houses will also naturally be dealt with here. The limestone has been extracted from Nature, and made mobile through the burning. When the lime hardens again due to the absorption of carbon dioxide, an artificial rock arises in the form we desire, and for which purpose we originally brought it into the plastic state.

The following diagram may be useful in understanding the use of lime. The way lime is related to the four elements is recognisable.



We then move on to cooking salt. Fine, crystallised salt sprinkled on to black paper makes a peculiar, typical impression. If possible larger crystals are also shown. The cubic crystals are then noticeable. In general we find the absolute purity of substance in rock salt most impressive.

Then we point to the fact that in Nature, cooking salt usually appears in a dissolved state. Therefore the first thing that we should do with it, is to dissolve it in water. It is best with such an experiment to simply reckon with the fact that at this age even the simplest phenomena arouse the greatest enthusiasm. One shows for example how the salt dissolves at first very easily, then less readily, until at last the moment comes when a residue remains at the bottom. With bought salt an opaque solution may easily result. In this case, it only needs filtering. With this clear solution all sorts of experiments are possible. A little can be just poured out, or smeared on to a dark background. Soon a glittering white crystal crust appears. A small bowl containing some of the solution could be left standing for some time. Then larger crystals are formed. A very delicate, but particularly beautiful type of crystallisation, like snow falling, is achieved when concentrated hydrochloric acid is poured on to a saturated salt solution in a glass. When in a half-darkened room, light only falls on the glass from one side a quite magical sparkling is seen, and this often in places where the crystals are so minute, that they are scarcely recognisable. This seems to me to be an unusually important experiment, because this phenomenon tells so much about the nature of crystallisation.

Then part of the solution will be heated and the salt regained through quick evaporation. Here something can be said about the extraction of salt. It seems to me also not unimportant to describe the old primitive methods used in extracting salt from the ocean.

Extracting salt in:

Cold regions: Sea-water is allowed to freeze in ponds; the concentrated solution remaining after the ice (pure fresh water) has been removed, is evaporated through heating.

Temperate regions: The wind is allowed to blow through walls of brushwood down which sea-water is trickling (cooler). The concentrated solution is then heated.

Warm regions: Sea-water in shallow basins is allowed to evaporate in the sun.

Furthermore it is worth telling something about the German salt mines. Compared with modern methods, those used there were really rather incredible. Finally the extraction of salt today can be mentioned. After this the great importance of salt in our diet is dealt with. In the human organism the salt-like substances are constantly needed as a foundation: so lime supplies the foundation for the hardest part of our bodies, the skeleton, while salt is a chief constituent of the salt in the blood, which appears as a very strictly regulated concentration.

It is interesting to note the herbivorous animals' greediness for salt. In the past also, the peoples engaged in agriculture set great value on acquiring salt. There were even mighty wars fought over sources of salt.

As soon as the salt content of water becomes too high, it begins to exclude all life, as for example in salt deserts and in the Dead Sea. This principle is then utilised in conserving meat and other foods. Decomposition can therefore be counteracted with salt.

This quality of salt is connected with the fact that it may help towards a clearer consciousness. Through repelling life correctly in the right place, the consciousness is better able to unfold.

On the basis of these facts one can well believe that salt was of a quite special ceremonial and cultic value in earlier times. In its square, crystalline form, its transparency, and pure whiteness, it presents something like an ideal condition of the earth. When we take it into ourselves, it helps us in a healthy harmonious way, to feel ourselves as citizens of the earth.

One will then speak about how an acid and base i.e. hydrochloric acid and sodium hydroxide, can be prepared from this salt. As this is not achieved through heating, it is difficult to demonstrate. The easiest way, of showing how hydrochloric acid is made, is to pour concentrated sulphuric acid on to salt. The mass begins to effervesce while a penetrating, sour vapour escapes which turns blue litmus paper quickly red. When this vapour is collected in water, hydrochloric acid is obtained.

Then caustic soda, the base produced from salt, is shown. It is a lustreless white substance which becomes readily moist and slippery. One shows its extraordinary solubility. On dissolving, the water even becomes hot. If the water is already hot, then the addition of small pieces of caustic soda, will cause it to boil furiously. This alkali possesses even stronger 'digestive' properties than quicklime. All sorts of substances like coagulated egg-white, or leather are either dissolved or at the very least softened, when cooked in it.

Three bowls are now placed side by side, a, b and c; a – containing dilute caustic soda, b – dilute hydrochloric acid, and c – tap water. The children are then allowed to file past these dipping their fingers into each bowl in turn and rubbing them against each other. In a, the fingers feel slippery – soapy (the beginning of digestion), in b, rough, and c, serves merely to rinse the fingers.

Into a beaker containing litmus solution we pour alternately sodium hydroxide and hydrochloric acid, whereby the colour changes are particularly clearly visible.

Having acquainted ourselves with these phenomena, we can now characterise the nature of Base and Acid far better than with the slaked lime and carbon dioxide.

	Base	Acid
State of matter	solid matter	vapoury matter
Colour of litmus	blue	red
Taste	insipid	pricking, sour

Now we show these things again in connection with man. The stomach juice contains some hydrochloric acid; the intestinal juice alkali. The stomach not only has the function of dissolving food, but also of warding off, above all things, substances that the body is unable to assimilate. Among other things the acid serves this function. The actual digestion and assimilation of the food into the blood occurs where the alkali is active.

We then point out how acid arises in the muscles as soon as one moves an arm, or other part of the body. When one sits, collected and pondering, a base arises in the brain. The various examples therefore show that outward activity is always connected with the appearance of an acid, and the inward activity with that of a base. (These last examples of the formation of acid and base in the body were indicated by Rudolf Steiner during a lesson given by Dr. Kolisko.) *

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* Eugen Kolisko:– "Vom Werden und Gestatten des Naturkunde-Unterrichtes an der Waldorfschule" in the Journal "Zur Pädagogik Rudolf Steiners" III Jg. 1929. Heft 3/4.

The way substances appear in our own organisation is always one of the most important keys to the investigation of their natures and functions. When we try to view that which has been said about Base and Acid connected with our body, we arrive at the following completion of the picture. The typical Base is always somewhat contracting and to a certain extent directed inwards, while the acid possesses a radiance, something whereby it expands into space. The base has a more passive attitude; the acid a more aggressive one.

Letting caustic soda and hydrochloric acid interact, of course mustn't be left out. The most natural way is to let hydrochloric acid gas pass over sticks of caustic soda. However, this is not easily performed, nor is it very pictorial. We therefore dip a stick of caustic soda into concentrated hydrochloric acid in a beaker. The moment it meets the surface we hear a sharp sizzling, while the fine, white glittering salt rushes in all directions, and falls like snow. When this experiment is done in a test-tube the liquid boils over vehemently, and a test-tube in a wooden holder begins to hop about.

3. Water

When writing his essay on elementary chemistry for children, Dr. Kolisko based its structure on the 'Tria Principia' of the alchemists. This proves to be a particularly appropriate foundation for lessons, which have to be brief and yet give a comprehensive picture of the ground covered. On this basis it is even possible to make a valuable contribution to the child's whole view of the world.

We shall refer to these tria principia again in a particular chapter in Part 2. We must here be satisfied with but a few indications.

For the true alchemists these three principles, Sal, Mercurius and Sulfur – salt, mercury, and sulphur – formed the basis for an all-round view of the world, indicating both the human organism and Nature. Although the words appear to point to certain substances, actually far more comprehensive principles are being named, which condition order in Nature.

Wherever solidification appears, above all where the liquid condition passes over into the solid, the alchemist spoke of **salt**. The earth's crust therefore originated as a result of a great salt process.

With **mercury**, the alchemist indicated chiefly the mighty role played by water in the whole of Nature. This is often connected with the interplay between air and water.

With **sulphur** he points to processes in which fire and warmth play a part. In nature this principle is pre-eminently connected with the sun's influences in the atmosphere, and the warmth processes proceeding from the sun.

In man, the salty element is found mainly in the head, the mercurial in the interaction of blood and breath, and the sulphureous in the warmth processes of the blood.

Our first discussions were about fire, the sulphur principle. Then a few salts followed. Let us now seek the transition to water.

A complete picture of water, as that which is truly mercurial, is only attained through considering its role of connecting everything.

First of all, therefore, we must notice the unceasing oscillation between salt and sulphur. One thing above all, must stand in the foreground; that water is a primary element, and must be treated as a unity. Naturally the children in the higher classes are shown how Hydrogen and Oxygen can be obtained from water through analysis, but even then it should not have the consequence that water is thought of chemically as a duality. In general one must avoid as far as possible, arousing through the knowledge of the analysis of a compound, the idea that one is concerned with something fitted together. Exactly this is what is so wonderful about chemical phenomena, that two combining substances actually do form a unity. Besides this water should not be looked upon as the first typical chemical compound. More than most of the others, it is the bearer of a world Principle.

Let us now characterise this aspect of water. Immediately an inner contradiction meets one with water. Considering all the streams, rivers and waterfalls, one sees how water is continually flowing together into one great unity surrounding the earth. However, it shows equally the inclination to disperse into myriad, tiny particles, as observed in the spraying out of falling water masses. In both cases though something similar is found: The formation of a mobile rounded unity, whereby each part is linked with every other, and that the form itself is a reflection of the greatest whole: the Universe.

In his lecture entitled "Christmas Imagination", * Rudolf Steiner compares the whole earth, in so far as this is covered with water, to a drop of quicksilver. When one observes a drop of mercury, one sees in the pictures reflected, that this too mirrors the surroundings in miniature. With regard to its form, the earth as well as the drop of mercury is an image of the universe. Correspondingly this applies to every drop of water.

Particularly delightful phenomena are found in dew. Dew-drops not only mostly build very exact spheres, but also, like the quicksilver drops, although in a different manner, show pictures of the surroundings. One should sometime observe closely one of these miniature lenses. Then one sees that the dark colour of the upper side is nothing more than a picture of the earth, and that the sky is recognisable again in the pale underneath side.

Dew arises through the condensation of the fine water vapour in the air. This usually happens during the night, when the air is cool and sparkled through by starlight. This condensation can continue with increasing coldness so that the drops once formed, are frozen, and the edges of leaves and various things are decorated with the delicate crystal shapes we call hoar frost. Later as the sun comes up filling the atmosphere with light and warmth, all these decorations begin to glitter in their full splendour, but as soon as the warmth becomes effective it is

* The Four Seasons and the Archangels. 5 Lectures. Dornach, 1923.

as though the air develops a gentle desire to absorb all this beauty into its own invisible spheres.

When the phenomena are carefully described in this manner, the "tria principia" are easily recognised. The dew-drop, itself water in the mercurial state, swings to and fro, between the freezing effect of the cold, and evaporation through the warmth; between the crystal forces of the salt principal and the devouring activity of the sulphur principle.

The manner in which the "tria principia", are named here, is naturally only meant for the adult. If he brings these concepts to life in himself he will discover quite a new approach to Nature. And this again will enable him to develop a consciously directed didactic (teaching method?) for the children.

The same oscillation of water between hardening and evaporating is also seen on a large scale, spreading spatially over the earth. In cold regions there is much ice-formation; in the warm much water absorbed from the ocean by the atmosphere.

A similar hardening and evaporating takes place seasonally in our regions, between winter and summer.

Although water is continually liable to be drawn out of its liquid state, it also returns to it ever again. Occasionally it is only half-released by the air, so that mist and clouds arise. Sometimes it is absolutely freed, but in a very gentle manner. Then dew forms, or drops from branches. With rain, the air lets the water finally fall. This process based on condensation and becoming heavy, can occur so powerfully in a thunderstorm that hail stones result. Water has then shot from one extreme to the other ignoring the liquid state. When it is cold, the liquid state is always skipped. The water vapour in the air then freezes into the most wonderful snow crystals.

In that the great snow and ice masses from mountains and even most of the inland ice from cold regions glides continuously downwards and later melts, or is carried by water into warmer regions, in that the tremendous ice fields of polar regions are also constantly moving, nearly all ice some time or other returns to the liquid state.

With freezing, phenomena even appear which show a remarkable resistance to the abandonment of the liquid state.

When the origin and movement of the glacier is closely followed, it becomes evident that its ice although hard and splintery, still yields like a liquid. This is due to the fact that ice below freezing point turns into water under heavy pressure. When the pressure is released, the water freezes again. Each obstacle meeting the pushing masses of ice, temporarily causes the ice to flow. We owe the possibility of ice-skating to this principle, for we glide thereby on a thin sheet of water which is continually forming, only to disappear again once the pressure is released.

This resistance to freezing expresses itself again in the way ice floats on water. Although this plays a mighty role in Nature's household it actually deviates from the general rule. Usually substances contract through cooling. They do so with a leap when changing from the vapour into liquid, and from the liquid into the solid form, but contract regularly in the in-between stages. Consequently e.g. solid stearin sinks in melted stearin. However, ice floats thanks to the fact that all waters lock themselves up in winter with an ice covering with which in a sense they defend their fluidity. It is well worth describing how the ocean depths as well as deep lakes in regions subject to severe winters would slowly cool and freeze if water were suddenly to behave otherwise. Such a thorough freezing to the ground would be fatal to all life in these waters.

The circulation of water from every point of view is both horizontal and vertical. It is partly concerned with the movement of water as a liquid, and partly with water going through the vapour and ice stages.

Those forms of circulation caused by the cooling and heating of water in the fluid state, are again the result of contraction and expansion. The change in the state of the water, however, is much less obvious than with freezing and evaporating.

When water containing any kind of fine particles which will make the water currents visible, is heated in a beaker with a gas flame on one side, the particles are seen to rise in the warm place and sink in others. This phenomenon is made use of in central heating. In principle this consists of a circular system of pipes in a vertical plane. In practice this form is altered through extension at certain places, branching off, and adapting the pipes to the demands of the space to be warmed. Downstairs the boiler is switched on; at the highest point there is a reservoir; and in the descending section are to be found the radiators, which act as a warming apparatus outwardly, but for the circulation play a cooling role. In the boiler, the water becomes lighter through expansion, and in the radiators heavier through contraction. The heavier water sinks down, pushing the lighter up. The circulation can be described as a continuous attempt of the flowing water to balance out the temperature or to distribute the warmth evenly. We continually disturb this balance, in that we heat the water.

In dealing with these processes one can go as far as it appears either necessary or possible. One thing however which should never be omitted is the characterisation of expansion as a becoming lighter, and contraction as a becoming heavier; the one as an inclination to loose oneself from the earth; the other, as a tendency to become more bound to it. Only then will insight into the phenomena be achieved.

It might appear humdrum relating such a list of everyday facts, as given in this chapter. The chief consideration, however, is not so much the facts themselves, as their presentation on the background of a comprehensive world picture and their respective structural relationships. In this connection great care is required with explanations with regard to a line of thought. It is quite correct, and yet in a certain sense false, to say that ice floats on water 'because' water expands when frozen. Working in this manner, one involuntarily agrees with the possibility that it could be different. The fact that ice floats is so completely bound up with Nature's whole order that anything else is inconceivable. An inseparable connection certainly exists between the facts that water covers itself with an ice-sheet, and that it expands when frozen. This link can be admirably shown, without directly introducing ideas of cause and effect. This should even be avoided because the idea of "cause" in Nature always points to something preceded by an effect. The relationship as such, however, is here an expression of Nature's order. This can be regarded as cause, on a higher plane of the whole connection. One could almost call it a kind of facial expression of Nature's order.

Seen from another aspect it isn't exactly correct to select central heating in this chapter, before something about the circulation of water in oceans has been dealt with. Our technical achievements are initially always a kind of unintentional imitation of Nature. In the oceans too the cooled water which has become heavy sinks down in the cold regions, rises up in warm regions and vanishes along the surface of the warmed water. Naturally this whole procedure is far less easily surveyed than in the central heating.

With this circulation also an immense equalizing of warmth, or conveyance of warmth is effected. A good illustration of the import of this conveyance of warmth, is the fact that palm trees can grow outside throughout the year on the southern coast of England, and even at certain spots in Scotland.

In our blood circulation, the circulation of liquids and the spreading of warmth are at their highest niveau. That which is typical of water – circulation and exchange of warmth, gases and other dissolved substances – are found here exactly as in Nature. Everything that occurs is, however, strictly regulated by the demands of our whole constitution.

It can be very valuable to show that a similarity to Nature certainly exists in such things, but that here it is not the outer warming and cooling that starts things rolling. In man everything is moved by an impulse from inside. And when even here a certain equalising of warmth takes place – the chief thing is still a sort of given form of his own warmth which is totally decided from within. External influences of warmth must of course be taken into account, although these are not deciding factors but in a sense are counteracted.

There are still many more things that might be discussed.

Water not only transports warmth but also dissolved gases, products of thunderstorms in the mountains, etc.

Ships make full use of the strange distribution of water over the earth. In trading therefore all sorts of water characteristics are reflected; the all-connecting, the balancing out, the transport of materials.

All of this we accompany again with numerous experiments. A few of these have already been indicated. Furthermore we can try to so arrange the evaporation of water and its condensation again, that it demonstrates weather phenomena in miniature. e.g. we take a large conical flask containing a little water and heat it until it begins to boil. At first a mist is seen, but as soon as the water simmers properly, the water vapour becomes quite invisible when the opening is loosely covered with a piece of paper. If a test-tube is now hung in the neck of the flask dense mist gathers around it. The test tube then becomes coated with water which runs down and starts to drip.

It is especially fruitful ever again, to strive towards so arranging the phenomena that a deeper insight is gained, e.g. one can first dissolve a crystal of salt in water and then extinguish a flame with water. This shows how water not only oscillates constantly between these two extremes, but tries to conquer and balance them out.

A very fine example of the combining effect of water is the following experiment:- Two solid substances, which in solution strongly react, are mixed in a dry state. As a rule then nothing happens. When water is added, the mass reacts powerfully. If this experiment is done with citric acid and soda, with the addition of water, carbon dioxide is forcibly given off.

4. The Metals

Eugen Kolisko discusses the seven chief metals also in connection with lessons in class 7. As the material already dealt with is fairly extensive it will be better to postpone taking these until the 8th class. This might even be considered more desirable for other reasons.

I shall let the matter rest here with a brief characterisation of these metals, whereby a rather different direction is taken from that in Kolisko's essay. If material is lacking, the chapter in Part II connected with the work in classes 11 and 12, deals with the metals in more detail. Wilhelm Pelikan's work "Sieben Metalle" also offers an excellent source of information. [1]

We can begin with a presentation of those metals which from olden times have always been regarded as the chief ones:- lead, tin, iron, gold, copper, mercury and silver. These are also the metals which stand for the material representatives of the planets. Although an old document spoke of this connection between the metals and the planets, it was difficult to substantiate. Since experiments were made by Mrs. L. Kolisko and others, this connection may be regarded as a scientifically grounded fact.[2] One will notice in practical work in the realm of teaching that particular possibilities arise out of knowledge of the planetary system and the link between planet and metal. It is of course not absolutely necessary to explain to the children the background of the whole presentation.

The character of the metals emerges specially clearly when we observe their technical uses and the methods of working them. We therefore wish to treat the metals here from this point of view, because Pelikan's book is such an excellent source for the consideration of other aspects.

We ask ourselves first of all, which was the first metal to be worked. Some are surprised to hear that it was gold. This is, however, understandable considering that gold is found as a pure metal. Besides it is workable with a hammer, without fire being necessary. To a certain extent, the same applies to the making of stone implements. This was also done by hammering and without using fire. People in certain regions therefore, had

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1. Wilhelm Pelikan, Sieben Metalle. Bd. II d. Schriftenreihe "Beiträge zur Substanz-Forschung," Neuauflage Dornach 1959.
2. Lily Kolisko, Das Silber und der Mond. Schriftenreihe der Natura III Stuttgart 1929. Sternenwirkungen in Erdenstoffen. Saturn und Blei. Copyright. 1952. L. Kolisko. Edge near Stroud.

many gold objects already during the stone age. From the point of view of the use of metals, the 'stone age' could also be called the 'gold age'.

The children are always delighted to hear how a stone chisel for example was made. At that time there was quite a trade in pieces of flint. When the edge of one of these flints was struck in just the right way, a piece broke off similar to a mussel-shaped piece of broken glass. Naturally this was much larger than a mere splinter. It had thus acquired the same sharp edges that we know from glass. If the sharp edge had split off irregularly, then it could be struck carefully again. Smaller splinters sprang off, leaving a new sharp edge. Finally, therefore, the chisel originated.

During the Bronze age, men understood the art of working upon the materials more intensively. With the help of charcoal fires copper and tin were smelted from their ores. Very hard bronze was obtained by smelting these two together.

In order to obtain iron, more skill in dealing with fire was necessary. Larger furnaces had to be built.

It is important to deal not only with the fact that the winning of metals has evolved, gradually adopting quite different forms, but also to discuss the change in the attitude of humanity towards these things. Thus gold e.g. was of no trading value originally in Peru. It was used chiefly for cultic purposes, into which category its use for ceremonial dresses also comes. It serves therefore, to maintain a connection with the spirit. We are told, that the Inca had a room lined with gold, in which a golden throne stood with a golden disc, a picture of the sun, attached to it above. His wife is supposed to have had a silver room, with a silver moon over her throne.

Last vestiges of this attitude to gold are still evident in certain customs today, e.g. the wedding ring, and the coronation of royalty.

Bronze was immediately used for earthly purposes. Swords and implements were fashioned as well as personal ornaments and clasps used to hold clothes together. There is another use of this metal though, still practised now. That is its casting of church bells or sculpture.

When eventually the use of iron was learnt, this was a sign of man's final dominion over the earth forces. The use of iron for cultic purposes is unthinkable.

A striking fact about the chief metals is that each is used for technical purposes in a quite characteristic manner. One can therefore even speak of a copper, a tin, or a lead technique. When one enters fully into this, one learns to view each metal as the bearer of a certain 'motif', which appears in all kinds of variations. The connection with the planets may also be recognised in this theme. In the same way as there is a contrast between Mars and Venus, a corresponding contrast exists between iron and copper motifs. If one wishes to speak about the connection between metal and planet, for some reason or other, it is not difficult to do so with the help of these metal-motifs, and myths about the planetary gods. One can actually speak openly of "Metal characters".

Indications of these motifs will now be given. With *iron* we are concerned with *strength* in many variations. We could even speak of crude strength. Magnetism as a radiating force should not be forgotten here.

With *copper*, *beauty*, *flexibility*, and *tenacity* are essential qualities. Under various circumstances, this metal produces the most and the loveliest colours. It is relatively easily worked. It can be hammered and rolled out without heating. Also the high conductivity of heat and electricity can be considered in connection with the flexibility. All sorts of artistic objects are made by the copper-smith. Red copper is found in the best taps, because an hermetically sealed joint is ensured when copper presses on copper. It is used for large coppers, heating pipes in boilers, and conducting wires.

The contrast between copper and iron is clearly shown in the colours of their compounds. Through combining their contrasting qualities, an extraordinarily adaptable source of power is acquired in the electro-magnet.

Characteristic of *lead* is *inertia* and *weight* (although silver as well as mercury and gold are heavier). A typical relationship to the earth is thereby shown. Its appearance also – outwardly it very quickly becomes dull – points in this direction. Most typical however is the fact that it is constantly used as a secluding, protective layer. All possible processes work actively on the outer surface of the lead, but exhaust themselves after a while and come to a standstill. Lead does not ward off; it merely paralyses the influences working upon it. The whole method of working, including casting, is founded on the movement which has come to rest. Lead plays a central role in printing, where use is made of its relative softness and low melting point.

Similarly as lead is orientated to weight, so is *silver* to *light*. It is not difficult to make a pure silver mirror. The characteristic of silver in this state is that it conceals itself behind the pictures it reflects. On looking in the mirror you only see yourself and not the silver. In photography silver compounds are always used. Here there are likewise pictures, and again the silver hides in the pictures. We use silver therefore in order to be able to reproduce pictures.

The fact that it is the best conductor of heat and electricity is also very characteristic. Therefore it should not be said that silver is related to the light. No, it is influenced by gravity and gives access to electricity just like the other metals, if not much more so. It is related to nature forces, opposed to the light. In a sense, it carries a dark world in itself, inaccessible to our consciousness, from which it carefully wards off the light. In that it opposes the light, it is also very intimately attuned to the light.

The chief characteristic of *Quicksilver*, is particularly obvious. It is entirely *mobility*, and in a certain sense *formlessness*. It is the great trespasser. Its use in thermometers and the original barometer is very typical. It is also needed to dissolve other metals and bring them into a mobile state. An example of this is the use of a quantity of tin, silver and mercury in dentistry. This is then called an amalgam.

Tin shows characteristics from which it is evident that it is *a bearer of radiant form forces*. Outwardly it is tough and smooth, almost lead-like, but a delicate shimmering crystal structure traverses it inwardly. Its hardening powers are used in bronze, and amalgams for filling teeth; its tough surface is used in coating sheets of iron. In preserving or transporting food it is particularly useful. (Compare this also with the tin-coating of water pipes). Tin is especially serviceable at places where a boundary must be set to moisture.

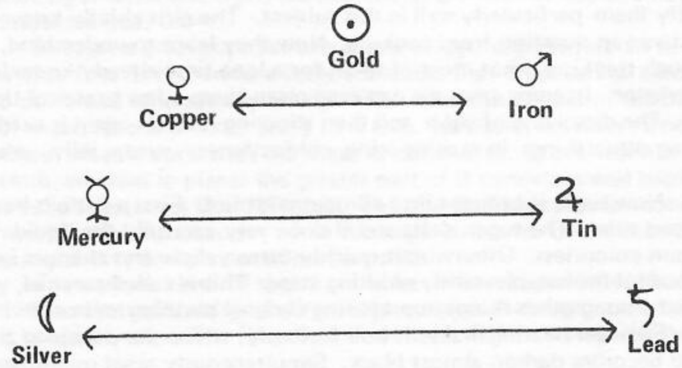
As *gold* is the heaviest of the seven metals, its relationship to the earth is therefore also the strongest. On the other hand it can be drawn into such fine threads, and rolled so thin, that scarcely anything but a sunny, glittering surface remains. Through this it is drawn out of the heaviness, to surrender itself completely to this play with light. Gold must be regarded as the grand reconciler of the most primitive contrast in Nature; that of light and weight. When it was pressed into bars to be used as precious goods for barter, or came to be the acknowledged basic value for the exchange of goods, the power of gold was constantly threatened with misuse. It then became the tool by which a man placed others in his service. However, when all manner of objects are coated with the rolled-out gold, exactly the opposite is achieved; then it is used to stamp less noble surfaces with its own noble quality.

With careful, skilful beating artistic and useful objects can be produced, exhibiting both material and work of a high quality.

It would lead too far in this short summary to introduce the physiological effects, the poisonous and curative effects, of the metals. It can, however, be said that these are closely related, broadly speaking to the motifs indicated.

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

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



WORK IN THE 8th CLASS

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

In the syllabus for the 8th class attention is particularly directed to the carbohydrates, fats and albumen as foodstuffs. Elementary organic chemistry is spoken about in the 9th Class. This is a very broad subject to which the carbohydrates, fats and albumen also belong. During the work one notices that all manner of things can be done and handled for which no time remains in the 9th Class. If the starting point is well chosen, the work in Class 9 can even be supported and well grounded through that preceding it. Above all care must be taken not to deal too early with isolated separate parts of the teaching matter and definitions. Usually this kind of "being very learned" is the result of a certain awkwardness for want of guidance, or through not being master of the subject. In a way, it is the greatest art, to make something out of simple things. And exactly through this, one succeeds in fostering and protecting the children's fiery enthusiasm and faculty of deeply immersing themselves in the phenomenon right on into the higher classes.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

We now allow fat to melt and reset.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE LESSONS IN THE NINTH CLASS

What is the reason for dealing with the first principles of Organic Chemistry in this class, and how do we have to present them to do justice to it?

Before answering this question, we must first remind ourselves that Rudolf Steiner declined to make the distinction between organic and inorganic Chemistry. One can only approach Chemistry in its entirety in a healthy way, if one maintains the closest contact with life at all times. (See "Konferenzen" 17.6.1921 and 21.6.1922).

If we now speak about 'organic' Chemistry, it is only to imply that substances will be studied in such a way that they can be directly associated with living things.

Perhaps it would be best to outline a plan for a possible structure of this period, in order to use it later in discussing the points of view which form its basis. If, in this way, a clear picture of the whole has been formed, we can present a number of separate themes more fully and so incorporate a certain scheme to include everything with which one might deal.

It appears necessary for me still to mention that I have been able to test the suitability of this outlined plan over a period of about twenty years and was able to follow this on from the work done in teaching by Dr. Eugen Kolisko and Dr. Ernst Lehrs, as it was developed at the start of the Wardorf School in Stuttgart.

The natural starting point in this period is the carbon dioxide assimilation, as this is also the beginning for the formation of those substances with which living organisms build up their body. Following on from this, the most important carbohydrates: sugar, starch and cellulose, are studied. In connection with sugar and starch, fermentation is discussed. The study of alcohol further provides various starting points, about which more will be said later. After cellulose one can talk about wood and the various technical products and chemicals which can be produced from it.

What has been indicated so far, starting with sugar, takes us already in two different directions. Firstly, in the sense of a steadily increasing condensing process, in the formation of starch, cellulose and wood, and secondly in the process of rarefaction as in the production of alcohol in fermentation. We shall now proceed in the direction of condensation and thus reach a realm already beyond that of the plant, i.e. peat, lignite and, above all, coal.

After carbohydrates we consider plant and animal fats and oils, and finally the mineral oils.

To every one of these substances belongs a whole realm of uses, manufacture and physiological processes. Furthermore, a number of other substances can develop or be produced by us from them. We shall consider a few of these.

In connection with alcohol, various alcoholic drinks are referred to, also ether and vinegar, after which one will, if possible, treat the sequence of alcohols, followed by aldehydes (with alcohol radicals), fatty acids and ester formation.

A number of organic acids, such as oxalic and citric acid, can be touched on in relation to sugar.

To starch belong the dextrins and the production of beer, methylated spirit and spirituous liquors.

Cellulose provides a study of rayon and the manufature of cellophane, also collodion and celluloid. Linen, cotton and other plant fibres, as well as wood pulp and paper, belong to this group. The importance of wood as principal substance for making paper and rayon is stressed, also the products of its destructive distillation, i.e. woodtar, acetic acid, acetone and methyl alcohol.

In relation to coal, one studies the production of gas, coal and tar, and mentions a series of important coal tar products. Other synthetic products may also be discussed here.

There are other important substances which I believe should not be gone into, such as some nitrogen compounds, among them the alkaloids. Later, in Class XII, it is right to make a more thorough review of such compounds which often are deeply rooted in our organism.

It is possible to treat soap, candles, nitroglycerin and dynamite, following on from the fats. Mineral oils should mainly be discussed in relation to their extraction, distribution and uses.

As we have considered the structure of a chemistry period in the Ninth Class and the substances to be studied, we can now stress those aspects which will be decisive in our teaching. They can be classed as positive and negative.

An important positive aspect is the following. During the Class IX age, the pupils are in the midst of puberty. Their task is not only to achieve physical maturity but to become 'ripe for the earth' as Rudolf Steiner expressed it. If one is to help them during this stage of development to maintain a wholesome outlook, one must above all, enliven their interests in the world around them in the widest sense, for this is now awakening in them more than ever. If one provides them with material for observation and work, so that their attention is directed outwards, one can divert this from the processes taking place within their organism and prevent the gloomy inward brooding in which they are apt to indulge.

The substances which we have already mentioned give us an excellent opportunity to develop and widen the pupils' interest for every-day things and thus make it possible to discuss and illustrate current matters of interest. This provides a starting point for experiencing the acute problems with which every human being comes into contact and with which he may have to live, such as the problems connected with alcohol or the rearmament industry combined with a striving to maintain peace in connection with the life of e.g. Alfred Nobel and others. It is, however, not intended to force on them certain opinions but to show them as objectively as possible where the problems lie, and to provide them with the facilities for forming their own well founded judgment.

There is a more negative method of dealing with the subject at this age. What is commonly called organic Chemistry has become very much a subject of molecular and structural formulae. With the help of these, one then tries to produce all kinds of substances synthetically, which frequently have very little to do with life. In this way one builds up a system from substances (hydrocarbons) with the most distinct properties, the products of mineral oils and certain tar products. One takes one's point of departure from the most dead materials, which have been rejected by living organisms. It belongs to the tragedy of our time that one likes to win concepts about the workings of living things from the realm of the dead.

It is obvious that one also pursues this direction of thought in the sphere of technology. A whole world of new substances and substitutes has been developed which more and more replaces natural materials, and through this one loses not only the understanding, but, what is more serious, the feeling that there are realms where one must not lose the connection with life. One would hardly object to a motor car made from artificial materials but one is on doubtful ground if one dispenses artificial vitamins when the natural ones have been destroyed by present methods of conservation, or if one produces synthetic footstuffs. It is not easy to raise real objections to such matters if a true education has not developed understanding for organic substances which have their origin in living processes. An unerring sensitivity must be cultivated for the fundamental difference between natural substance taken from living matter and an apparently identical one, synthetized chemically in a factory.

We are not dealing here with trivial matters, for it is this character of organic chemistry which so strongly works on our whole organism and brings to it the influences of technology. In an ever increasing measure we have to assimilate substances to which our body is not conditioned.

We shall start with the study of **carbon dioxide assimilation** and straight away follow on with a series of processes where the initially formed substance is changed more and more to become, in this manner, the basis for life in plant, animal and man. Everyone acquainted with these facts will recognise that this sequence in teaching is the most natural one and corresponds most closely to nature. It is necessary to proceed in teaching as much as possible according to the principles observed in life. The previously mentioned points of view can thus without difficulty assert themselves, and the most inveterate materialist can hardly find fault with this.

In applying this method, one takes a direction which has its origin in the influence of the sun on happenings on the earth, and so starts from the cosmos and leads deep into the earth. This means that our method is sufficiently sound to meet the even greater demands of a study of matter according to the principles of spiritual science, one of whose most fundamental realisations regarding the nature of substance is the following. Matter has a cosmic spiritual origin, has condensed out of the cosmos, and finally undergone a kind of fall into the depths.

If we describe the formation of organic substances in teaching in the way indicated, it becomes a real picture of the forming of matter, and the pupils are led in such a way in developing these forms and habits of thinking that they do not have to reject more profound realizations because of a forced one-sided training of their thinking.

It is just in the 9th class, that pupils are turned most towards concrete outward objects and show relatively little interest in what transcends the realm of matter. If one does not want to sever the connection with deeper reaching realities, one must draw the pupils' attention with great enthusiasm to material things in such a manner that, without this being mentioned, the presentation is illumined by the light of supersensible and pre-material events. Thus a foundation is laid for a later awareness of the real nature of matter as a medium in which spiritual processes are reflected. One need only prepare the ground for subsequent individual discernment in the pupils.

There is another direction in which future ground may be prepared by starting with carbon dioxide assimilation. In discussing the period in class II, we shall see that the principal chemical elements take part in a whole system of cycles, in which a very strict and harmonious order prevails. Rudolf Steiner considers in 'Occult Science' a period in the development of the earth, where all the relationships and movements of the celestial bodies were arranged by the intervening creative powers which were sending forth balancing and healing impulses into the created world.

Because on the earth the material processes, which will be worked out more exactly later, must always be reflections of cosmic relationships, one is brought to the conclusion that this new order in the cosmos must be bound up with a corresponding one, working closely into matter.

We now find in the assimilation of carbon dioxide, which provided the first major example of a cycle in matter, that this is very clearly in tune with the cosmos. Further, the balancing and heating properties are here most clearly shown.

It is very good to take one's starting point in the same way as

Ingenhousz presented his discovery of carbon dioxide assimilation, because he brings out the essential points in a very pertinent manner. His treatise was published in 1779, under the title "Experiments upon vegetables, discovering their great power of purifying the common air in the sunshine, and of injuring it in the shade and at night."

He writes on pages 33-38 (translated from the Dutch):

"I observed that plants not only cleanse the air in which they grow after six to ten days, as Priestley discovered, but that they carry out this important task already after a few hours, and that the cause lies not in the growth of the plants, as Priestley maintained, but, on the contrary, in the effect of the sun's rays. I found at the same time that plants possess an astonishing ability to change the air present in them and constantly absorbed from the atmosphere, into genuine dephlogisticated air (i.e., rich in oxygen). Purified air constantly emanates from plants and makes the atmosphere more suitable for maintaining animal life, as this air spreads out everywhere. The brighter the day and the more the plant is subjected to the effect of the sun, so this process proceeds more easily and more readily. On the other hand, plants which are found in deepest shade are not able to take part in this activity and on the contrary give off air which is harmful for animals and which spoils the atmosphere .... Not every part of the plant is suited for this activity (purifying the air), only the leaves and green stems. Even poisonous plants, and those with a strong and unpleasant smell, are just as able to take part in this process as the most wholesome and beneficial ones. The most strongly dephlogisticated air (richest in oxygen) emanates from the underside of the leaves. At night all plants pollute the air immediately around them and those in the shade also do so by day. All blossoms are unfavourable for cleansing the air, both by day and by night, as well as the roots one has taken from the ground."

One will try to show with experiments how carbon dioxide assimilation and breathing indicate an exchange of substances and how, for instance, the gases involved behave.

It is good to show the presence of carbon dioxide in exhaled air by letting it make limewater cloudy. It is sufficient if one has a flask partly filled with limewater to displace the air in it with one's breath. After shaking, the limewater quickly becomes milky.

Conversely, it is easiest to show how oxygen is given off in sunlight, with pond-weed (e.g. Elodea Canadensis) kept under a funnel closed above with rubber tubing and a clamp.

We can now make several experiments with pure carbon dioxide and show that it is heavier than air, that it will put out a flame, etc.

After this we experiment with oxygen. We show how it makes a fire burn more brightly and how a glowing spill is rekindled in it.

One must, of course, not omit to develop once more a picture of the plant, how it unfolds between earth and heaven, surrounded by the air. We see how from below, water with a certain salt content is taken up. Fundamentally this flows through the plant and again evaporates from the leaves. On the other hand, there is the taking up of carbon dioxide under the influence of light. At the same time we can see the formation of starch and sugar in the leaves.

It will now be necessary to treat these happendings with great clarity, and just for this reason I recommend the use of simple chemical equations. This further has the advantage that one can prepare very carefully the later use of formulae.

Carbon dioxide assimilation can be represented in this way:

Carbon dioxide + water ⟶ sugar and oxygen.

In order to determine quite exactly what changes here take place, we can use a flask of limewater. We light a piece of charcoal and hold this in the flask without putting it in the liquid. We now shake carefully and observe that the liquid becomes cloudy. Invisible carbon dioxide has been formed from burning carbon. Again we can write our equation:

Carbon + oxygen ⟶ carbon dioxide.

We can now elaborate that the opposite process is at work in the plant:

Carbon dioxide – oxygen ⟶ carbon.

In the first process, light and warmth are given off; in the second, light and warmth are taken up. In the plant, however, we do not find black carbon but starch grains or dissolved sugar; a very useful and active substance in place of a rigid one which is not suited to life. Investigations have shown that from carbon and water, sugar has been formed. One might call it carbon which has been made alive and active through water. The word 'carbohydrate' could be translated as 'water coal'.

Carbon + water ⟶ carbohydrate.

All carbon which appears from any part of the plant after vigorous heating, has initially been taken from the air. Air, in a sense, is the coal-mine for the plant.

It is, of course, right to mention the combustion of sugar which takes place inside our body. At first it may perhaps suffice to show that this is a process opposite to carbon assimilation. We take up sugar and oxygen and exhale water vapour and carbon dioxide.

Sugar + oxygen ⟶ carbon dioxide + water.

The warmth produced in this reaction contributes to that of our body and is the basis for activities engendered by our will.

There can be no doubt that it is helpful in teaching to stress strong characteristics of substances, i.e.,

Sugar is living carbon, made active by water.

Carbon dioxide is dead air.

Oxygen is living air.

Sugar and starch have already been characterised to some extent in class 8. Now we can treat them in greater detail and more scientifically. Following on from carbon dioxide assimilation we can speak for example about different kinds of sugars and their occurrence, and touch on the significance of the most important types. We indicate the difference between monosaccherides, disaccheride, and polysaccherides. Above all, we must not omit to let the pupils taste the various sugars.

This section can easily be presented in a general collective and schematic way. An economical method is to treat certain aspects clearly and thoroughly and to intersperse those with greater numbers of relevant facts and figures. If one does not proceed in this manner, it is hardly possible to present such a vast subject as that of substances from the living realm, in a lucid and condensed form. Furthermore, this method is especially satisfying to a class 9, as the pupils display a marked wish to be given a great deal of subject matter with plenty of facts.

In connection with beet sugar, it is naturally relevant to discuss the manufacture of this sugar and to illustrate this with diagrams. Visits to factories are always very popular.

At this stage it is right to talk about the symptomatic historical changes in the sources of man's sugar supply. Before cane sugar and beet sugar were known, fruit juices, and above all honey, were used. At that time there was, on the whole, less demand for sweet nourishment. Later, cane sugar was introduced from the east and it appears that one became acquainted with it through the Arabs, to whom we are indebted for sugar in crystalline form. Finally, at the beginning of the 19th century, one began to obtain sugar from beet when the continent was cut off owing to the conflicts between Napoleon and the English.

In this way, sugar was first obtained from the region of the blossom, then the stem and finally from the root. Initially fragrant sugar in liquid form, later a crystalline sugar, still more or less mixed with syrup and lastly a purified, bleached and wholly mineralized sugar.

All this goes hand in hand with a change in the direction in which the interests of mankind proceed. More and more, humanity turned away from the supersensible-divine to develop at last a predominant interest in the sub-earthly, such as mineral oil and coal. Meanwhile, self-consciousness developed in an ever-increasing measure and was helped to become more pronounced by concerning itself with clearly defined thought in mathematics and natural science. A kind of crystallisation has been brought about also inwardly.

We now move on to **alcohol** and start by describing wine-growing and the preparation of wine. The vine is such a prolific creeper that it can cover a large tree top with its tendrils. It is a plant which has a great water content in its roots. If one cuts off the stem it is possible to produce a water column up to 30 feet from the stump. On the other hand, the plant needs a great deal of warmth from the sun, and grapes ripen only very slowly and are just ripe at the warmest time of the year. The result of this meeting of fire and water, and its mighty interplay, is the grape. The influence of water is visible in the large, closely clustered, juicy grapes, the effect of fire is noticeable in the sweet taste. The more southerly the region where it has grown, the sweeter will be the taste.

A comparison between the vine and the cereals is very impressive. In the latter, everything is simple and restrained. The whole structure is evidence of its supreme ability to remain upright without support. One can call this a plant with a dry fruit. The cereals show above all a connection with the earth element and the air. The earth's force is overcome to the greatest possible degree and the plant sways gently in the breeze. The two plants are in every sense opposites and when the gospels refer to bread and wine, this has, as always, a very exact background.

If grape-juice is left to ferment, one can see that carbon dioxide is given off and the sweet taste has given way to a fiery one. The calm and nourishing properties are replaced by strong stimulating qualities. The process which has taken place is summarized thus:

Sugar ⟶ alcohol + carbon dioxide.

It has already been mentioned that sugar is related to fire and water and this in intimately bound up with the fact that sugar can be directly taken up by the blood. Alcohol has a still more direct access to the blood, for not even the liver can act as barrier here. Unlike the case of sugar, there is also no governing of the percentage content which the blood is allowed to take up. If we drink alcoholic beverages, alcohol diffuses immediately and without restraint throughout the whole body.

It is possible to characterize the effect of alcohol in the following way; that which we really owe to sugar, alcohol provides in a merely illusory way. Whereas sugar provides a basis for the will and the control of our body, alcohol only too quickly makes us feel that we have the ability and license to do whatever we want, although our capacities in this direction have really in no wise been increased. Instead of a gradual development of warmth, a state of overheating is engendered; in place of calculated efforts there is an urge to attempt superhuman feats and to bluff. Sugar enables our personality, the ego, to engage in healthy activity, alcohol produces a kind of double of our ego and behaves like an irresponsible sugar.

During the time when these things are discussed, we naturally let the pupils see and smell concentrated alcohol. We demonstrate the volatility of alcohol, its low boiling point, its unlimited solubility in water and its inflammability.

After this, we can mix strong alcohol with concentrated sulphuric acid and heat the mixture. If we now condense the escaping vapour, we obtain a strong smelling and very volatile liquid. It is ether. This has come about through a kind of condensing process, coupled with the taking away of water. Its reaction on man can be regarded as an increased alcohol effect. In an anaesthetic, our ego is driven out entirely. In ether, the solubility in water has decreased, while the inflammability is increased.

It is fascinating to test the nature of such liquids in their reactions with an inflammable substance such as fat. If a piece of solid fat is put in water, it will remain there in a state of total isolation. In ether, fat dissolves rapidly while it will only become soluble in alcohol after heating and separates out on cooling, turning the former solution turbid. If this is done slowly and carefully, it is even possible to obtain crystals of fat.

These phenomena can be understood if one considers that the solubility of a substance in a liquid depends on their mutual affinity. In this case, it is the degree of inflammability of the solvents which determine the solubility of an inflammable solid.

It will naturally be necessary, when dealing with **starch**, to take into account what has already been dealt with in class 8, and what was then discussed and carried out will undoubtedly be useful for the lessons in class 9.

Perhaps in class 9 one can study the cereals more closely as the original foodstuff of mankind. It can be indicated, for example, that rice, with its relatively only slight earthly nature, its easily digested grains and delicate panicles, is the typical staple food in the east. Maize, with its distended, massive stems, luxuriant leaves and hard and heavy head, comes from the west. All these manifestations indicate a very earthly nature. Wheat has a modest but strong structure; the ears are firm but not heavy. It has come from the Middle East, originally the pivotal region of the earth. The inclination of western man towards the earth, or the turning away from the earth, which is the nature of eastern man, and the attempts to achieve a state of equilibrium between these two by men in the middle region of the earth, is reflected in men's nourishment.[1]

If the potato is now considered, it is good to look at its history. Potatoes, which originated in America, were introduced in the 18th century with the intention of producing a bigger harvest than would have been possible with cereals, in order to drive away the spectre of famine. However, quite unintentionally quite different effects were also obtained.

A grain of corn is something between seed and fruit. Because the cereals do not develop a real blossom in the ordinary sense, their seed is formed in a place which belongs more or less to the green middle region of the plant. The potato tuber, on the other hand, has been formed from a stem and therefore should definitely belong to the middle part of the plant. During its growth, however, it moved downward into the sphere of the root.

The pupils will need to have learnt enough about plants in order to be sufficiently aware that here one is confronted with an unusual historical symptom. It was just at the time when mankind was convinced that all questions could be answered solely with the head, through observation and logical combination of observations, that they began a one-sided feeding of the head. There must be a connection between eating potatoes and the development of abstract thinking which has led to the excessive development of technology.

The pupils should be able to understand this if they can realize that there is a relationship between the roots of a plant and our nervous-sensory system which provides the basis for thinking; between the stem-leaf region and our rhythmic system, as basis for feeling; and between the blossom and our metabolic system, as basis for our will. At the

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1. See Dr. A. Usteri, Die Schöpfungszentren der Pflanzer. 3rd vol. of 'Gäa Sophia', Annual of the Natural Science Section of the Goetheanum. Dornach 1929, page 138.

time when potatoes were introduced, one was engaged in entirely eliminating every trace of feeling from scientific thinking. This same indication can be found in the movement of the potato tuber from the region of the stem to that of the root. In nourishment obtained from cereals, the emphasis is on the middle sphere.

We can now study starch metabolism in our body, and the transforming of starch by the plant more closely. To do this, we carry out an experiment which will cause much sensation. We collect some saliva from a few children after we have let them imagine the most delicious confectionery. We mix this saliva with some thin starch paste in a test tube. First we show that a drop of iodine solution colours this mixture dark purple. We then keep the test tube at a temperature of 99°F. in warm water or give it to one of the pupils, to keep it at this temperature on their body. After a few minutes the contents no longer show a colour reaction with iodine but react with Fehling's solution (see class 8). The starch has disappeared and sugar has been formed. We have demonstrated a life process outside an organism.

It is also possible to transform starch with the help of a little dilute hydrochloric acid, but the liquid has to be boiled and this also takes somewhat longer. One can then show intermediate stages when different colours are obtained with iodine. On comparing these two experiments, we can see quite clearly the difference between a living process and an inorganic process. Living things always have a 'key' available for opening doors with the least amount of energy, whereas by technical processes they can only be forced out.

In connection with the digestive action of saliva, we then talk about the subsequent starch digestion caused by the juices of the pancreas and the intestines. It is always a strange thought that the bread or porridge which one eats is changed completely into liquid.

We next concern ourselves with the taking up of sugar into the blood which flows around the lining of the intestine, and describe how this is conveyed through the portal vein into the liver. The sugar content of the blood is strictly controlled by the liver and any excess sugar is deposited as glycogen, a kind of starch, which can be changed back into sugar whenever it is required. In connection with this, one can also discuss diabetes.

Starch, after it has first been converted into sugar, can also be used for making alcoholic drinks. The simplest method, which has indeed been employed by primitive peoples, is a continuation of our saliva experiment. One adds saliva to a starch paste and leaves this liquid, which now contains sugar, to ferment.

A life process is also used when beer is made, and this is the transition from starch into sugar. We can now, with the help of diagrams, discuss beer brewing.

For making pure alcohol one uses the processes discussed in the case of malt, only the cheaper potato flour is used as principal raw material. In connection with alcohol manufacture one should naturally discuss its distillation which can be demonstrated in a very vivid manner. Some alcohol is set alight in a small porcelain dish.

One then adds some water till the mixture ceases to burn. The liquid is now distilled and different samples are collected separately while the pupils note the temperatures at which these have been given off. The first samples are seen to be highly inflammable and so have a high alcohol content, while the later ones are progressively harder to light. The preparation of distilled liquids can be linked to the preparation of alcohol.

It will be useful at this stage to list the most common alcoholic drinks with their relevant alcohol contents.

In drawing the pupils' attention to the world around them, and this is very important to cultivate at this age, they must become awake to the great problems which arise in society. It is possible, for example, to deal with the alcohol problem in the form of a discussion between, if necessary, imaginary supporters and opponents of alcohol consumption, during which the symptoms and effects of dipsomania are also gone into, as well as the conditions regarding this in different countries. One can show that the solution to this problem is so difficult because alcohol, especially in the form of wine, really had a great mission at one time. It is literally true what the wine merchants say, that wine has been present at the beginning of all the great cultures. It is further possible to indicate what contribution alcohol made in freeing man from old ties and earlier states of consciousness when he was not free. It will then become obvious that this use of wine has in our present time become superfluous.

In this connection one can discuss the control of alcohol consumption by laws and the high duty which has to be paid on it. Above all, however, one will bring about the necessary resistance by improving social conditions, and by kindling enthusiasm for a higher culture through the right education.

It is most interesting here to see the appearance of the Salvation Army, who take the gospels as their stand against being led into temptation through alcohol. This is doubtless based on a deep reality. In the gospels it is clearly stated that our blood should become Christ's blood, so that Christ might become active in our blood. This is surely also an aspect of the words: "I am the true vine." At the last supper Christ said about the wine, which he shared out: "This is my blood."

In class 8 we talked about making bread with flour. We saw that the true recipe is based on the most fundamental laws which work in the human body. Now, in class 9, the connection between blood and wine becomes apparent. One can gain the impression that bread and wine, as a holy theme, form a background to these periods. It is just in this rather outwardly directed period that the deepest inner truths constantly re-echo.

It is useful for the teacher to recognise that sugar, in its physical make up, shows an ideal state of balance. The formative and hardening forces of carbon have combined with those of hydrogen, which dissolve all form and bring everything into movement. Carbon tried to form hard and rigid structures on the earth, while hydrogen disperses matter and tries to draw it away from the earth. Oxygen maintains a balancing effect through which both elements can be placed into the service of life. (Chapter on Carbon, Hydrogen and Oxygen in Part II).

A recognition of the above can contribute directly to the structure of this period. Life processes can transform sugar in two opposite directions — in the one of alcohol and in the other of starch and cellulose. In the fermentation ot carbohydrates, carbon dioxide is given off. This means that part of the carbon is removed and something of the healthy connection with the earth is lost when this gas escapes. One can therefore relate this process to escaping from the earth. In the formation of starch and cellulose, there is a condensing and solidifying, while water separates off. This causes a loss of both mobility and the readiness to undergo chemical changes.

A relationship as between the formation of stem and blossom is found in these two directions of sugar transformation, although alcohol is never found free in a living plant, unless it is in juicy fermenting fruit. Alcohol is found however in the form of esters, which are mentioned next, where it is in a sense overcome and restrained.

These volatile and sweet smelling substances contribute much to the scent of flowers and fruit. Alcohol, in this form, adds to these imponderable and subtly differentiated qualities which are so characteristic for this sphere of the plant.

Following on from alcohol, whole series of compounds can be treated in a summary manner. Firstly the alcohol series, in which wood alcohol (used e.g. in denatured alcohol) should be mentioned especially. The aldehydes comes next. The first members of this series can be produced quite easily. A little wood alcohol (methyl alcohol) is poured into a flask and a plug of heated platinized asbestos is inserted, so that it almost touches the liquid. When the mixture of air and alcohol vapour has reached the right proportion, the platinum begins to glow and a sharp smell is noticed. A partial oxidation has taken place and a substance is formed which is called formaldehyde. A 40% solution of this gas in water is formalin, used as disinfectant and for preserving and hardening anatomical specimens. Here we have also seen a very good example of catalysis. We can do the same experiment with spirits of wine (ethyl alcohol). From the alcohol series we obtain another series which can be produced by a certain degree of oxidation. If ethyl alcohol is treated with a strong oxidizing agent, e.g. potassium bichromate in concentrated sulphuric acid (it is not necessary to 'explain' the effect of these substances to pupils at this age; for them it is just a mixture which can give off oxygen to other substances) one can notice an acid smell. Acetic acid has been produced. Once again, a series of substances, the fatty acids, can be prepared by oxidizing alcohols or aldehydes. Some of these substances in this series must be considered in greater detail. This applies in the first instance to acetic acid, to a lesser degree to formic acid and lastly to butyric acid. It should not be omitted to mention that butyric acid is not only found in rancid butter and stale cheese but is also very noticeable in the smell of human and animal perspiration.

These three series of substances show a certain similarity in so far as the first members show most clearly a specific individual character, while the more complex ones become gradually less soluble in water, more oily and even paraffin like and in this way also less differentiated from each other.

It is obvious that the names of these series should be written in columns, side by side, and that one may possibly put the names of salts next to the corresponding acids. If the pupils are thoroughly familiar with the names, it will make things much easier later on.

In the transition of alcohol to aldehyde and butyric acid, one of the best examples of the activating effect of oxygen is apparent. As the oxygen content increases, the substances become chemically more active. This point can be discussed more fully later on.

Following on from what has been discussed up to now, it is also possible to deal with the **acids found in plants,** e.g. oxalic acid, citric acid, tartaric acid and malic acid. Plants also breathe in a similar way to man and animal and these acids can be regarded as sugar which has partly undergone a combustion process. This is especially clearly indicated in the succulent plants, which do not give off carbon dioxide but which at night have a much more sour taste owing to this partial combustion. One can let the pupils taste a little of these acids. They contribute greatly to the taste of fruits and e.g. sorrel and are inflammable and soluble in water.

A very important subject is reached in the study of **cellulose.** It is best to use cotton wool, which is especially pure cellulose. We also draw attention to the fact that seed fibres (e.g. cotton), linen filter-paper and also paper to some extent consist of pure cellulose. These substances, of course, give us only a very one-sided picture about the appearance of cellulose, for in this form it is already to a large extent a product which the plant has rejected. In the ordinary way, cellulose is found as an exceedingly fine structure, built into the whole plant. It could be termed a 'noble' substance, just as cold is termed a noble metal. Linen, for instance, is remarkably clean, resistant and strong. It is good to go into the processing of flax, if this has not been done already. The flax plant is especially delicate and slender. The fact that the fibres are freed by a process of decomposition can make a deep impression on us, for here we can see a typical alchemical process of ennobling.

An experiment will reveal that cellulose can be boiled in water or even dilute acid without a definite change taking place. If some cotton wool, however, is put into a test tube and covered with concentrated sulphuric acid, it will be seen when the contents have been poured into cold water, that the cotton wool has been dissolved completely. It can be proved with Fehling's solution that sugar has been produced. In this way we have shown that cellulose, like starch, was formed from sugar. We now cover a piece of filter paper with concentrated sulphuric acid in a small dish. If the dish is rinsed out after a short time, a parchment like substance will be found. If the filter paper is left in the acid for a longer time, it will be completely soluble in water. We can cover good quality paper with concentrated sulphuric acid and also ordinary newspaper, which is made of almost unchanged wood. The newspaper immediately turns black, the real cellulose paper stays almost white.

If it is possible, one can now study the manufacture of paper more fully at this point.

The manufacture of gun-cotton has an unusual significance. In dealing with it we come into the realm of explosives and meet problems relating to war. This would again appear to be a typical problem for a ninth class if one later on discusses Nobel and his invention of dynamite. These things bring the pupils in touch with the greatest technical achievements of our time and also with the serious problems connected with them. In this way, without being directly conscious of it, the pupils begin to realize that they have a responsibility towards the events which happen around them.

Gun-cotton can be made very easily in class. In an experiment one shows the difference between burning ordinary cotton wool and gun-cotton. It is characteristic for the latter that the flame bursts forth vigorously in all directions while in the case of ordinary cotton-wool, the flame gives the impression of having to wait for the air to reach it. Instructions about these experiments and the necessary safety precautions can be found in suitable books on practical chemistry.

If some acetone is poured on to gun-cotton, it will become gelatinous and eventually dissolve completely. On evaporation, a viscous greasy substance remains which can be made into a smokeless powder. A substance which explodes less violently has been produced and this can be used in ammunition. A solution of cellulose nitrate in acetone is also used in the manufacturing process for rayon. One can show this very simply by pouring the solution into water when fine threads and films of cellulose nitrate are obtained.

In connection with rayon, one can talk about the history and production of man-made fibres. Starting with silk, one goes on to rayon after which materials much used currently, such as nylon and orlon, are discussed. One can also still show one or two experiments where cellulose is dissolved and then precipitated, either with Schweitzer's reagent (cuprammonium process) or one which illustrates the process used in making viscose rayon.

When silk is studied, one can point out the extraordinary properties of this material. Silk is destined by nature to provide the ideal covering, as cocoon, which can also be penetrated by air. Clothes made from silk are therefore warm and strong, porous and light. Silk is comparable to spun sunlight.

Rayon lacks these fine qualities and is therefore an inferior substitute. Nevertheless, less valuable materials and even waste substances can be used for making rayon and in this respect, this industry deserves admiration. This is still more true for other man-made fibres.

It is worthwhile to mention the fierce rivalry which came about through these new materials. The effects on conditions in a silk producing country, such as Japan, are as problematical as they are instructive.

We next consider wood from a chemical aspect. A wooden spill is put into some concentrated sulphuric acid where at first it turns brown and eventually is changed completely to black carbon. If a wooden spill, however, is boiled in dilute sulphuric acid, it does not turn into carbon but is converted to sugar.

The reactions which take place in burning are demonstrated once more and explained, so that we can link them to what happens in a destructive distillation. An intermediate stage can be shown, where for instance wood is strongly heated in an open test tube, so that it chars, while thick fumes arise which can be ignited at the top of the test tube.

In a destructive distillation the apparatus is set up in such a way that the fumes which arise are passed through a cooled container. A liquid then condenses which shows two layers, while gases are given off which can again be ignited. The liquid consists of brown wood tar covered by an aqueous layer. The latter contains some especially important substances such as methyl alcohol, acetic acid and acetone. We come across acetone frequently as a solvent of e.g. lacquers and synthetic adhesives. It is also an abnormal by-product in the metabolism of diabetics.

If the experiment is arranged in the way which has here been indicated, it can be seen that wood is analysed in the sense of a fourfold substance containing the four elements. A plant is formed from forces and substances which have been drawn together from all sides and it is therefore not surprising that it splits up again in such a well ordered manner.

Wood should be mentioned as raw material for poor quality paper as well as for the production of cellulose, rayon and celluloid.

When **fats** and **oils** are studied, we must again consider carefully what has been done in class 8. If the chemistry main lesson was a little meagre, it will be good to carry out the experiments described for that class in class 9, but these may also be repeated, varied and done more fully. The main thing here, is the relationship between fat and water and fat and fire. The best method would be to do these experiments in a simpler and briefer manner in class 8, and to emphasise these phenomena as much as possible in class 9.

In studying the production of fat, we enter a field where great problems are once more encountered. A definite shortage of fats is noticeable in our geographical latitude. We mention plant and animal fats produced here and characterize them briefly. Butter and linseed-oil are perhaps studied a little more thoroughly.

We then describe how these existing fat supplies must be supplemented from tropical and polar regions. It is a fact that after the war the problem of obtaining enough fat appeared insoluble, owing to the fact that Indonesia, one of the world's chief sources of fat supply, was then in a state of chaos. It is explained why cold regions supply animal fats and the tropics provide mainly plant fats, while in Europe both plant and animal fats are produced. Plants in the tropics are subjected to the powerful forces of the sun and this enables some of them to store warmth in their seeds. In the polar regions, the warm-blooded animals have to protect themselves actively against the cold. One of their ways of achieving this, is to produce thick layers of fat below the skin.

The uses of fats are now studied in greater detail and their value as foodstuffs is again given prominence. In this connection the manufacture of margarine from oils is of special importance; the solidifying and treatment of this fat so that its unpleasant taste has disappeared and a consistency of butter is obtained.

Finally the use of fat in the treatment and care of leather may be mentioned. It is also possible to deal with the manufacture of soap, candles, glycerine and dynamite.

If the process for making soap has not been demonstrated in class 8, it can be shown now. It can be done in such a way that a lather is produced as quickly as possible. On the other hand one can try to obtain a usable end-product in which case the experiment in only fully appreciated later on.

The quickest results are obtained when a few pieces of caustic soda are put in a large flask of boiling distilled water. In order that this solution boils less violently, some grains of sand are put in. Lastly a few drops of oil are added to the boiling liquid. Generally, a great deal of froth appears instantly, but if this is not the case, a little concentrated alcohol or methylated spirit is added. If sufficient fat has been used, the liquid will set in varying degrees after cooling.

Soap is dissolved in distilled water and this clear solution is poured into some tap water. Immediately this will turn cloudy and the degree to which this happens depends on the hardness of water, principally on its calcium concentration. In this way insoluble calcium stearate has been obtained.

The pupils are always very astonished if a piece of soap is heated in a deflagrating spoon until all the water has evaporated, whereupon the remaining part burns brightly. If a little acid is added to a soap solution, a precipitate is formed.

If one wants to explain these phenomena it must be realized that fat, as an ester, can be split up into glycerin, which resembles the alcohols, and into a fatty acid.

Fat → glycerin
Fat → fatty acid

The most important fatty acids and their related salts and fats are given:

Butyric acid	butyrate
Palmitic acid	palmitate
Stearic acid	stearate
Oleic acid	oleate

In a specific example the reaction would be represented thus:

Glycerin palmitate → glycerin
Glycerin palmitate → palmitic acid

The production of soap can now be seen as a reaction where salt is formed and glycerin is displaced.

Glycerin palmitate + sodium hydroxide → glycerin + sodium palmitate

The pupils are now asked to taste glycerin and they are given a drop each to rub into their hands. They are shown that glycerin dissolves equally well in water and in alcohol. Finally, glycerin is heated in a deflagrating spoon until it starts burning, when a blue flame is observed. Its behaviour in every way is akin to that of a somewhat passive alcohol. Glycerin is used as an anti-freeze in radiators of motor-car engines and in preparations for the care of the skin.

In connection with glycerin, it would be good to talk about the life and discoveries of Alfred Nobel. One can stress his greatness and versatility; his noble character and the far-reaching problems connected with his aims. One may have a strong impression that in his case there was a schism between heart and head. It is as if Nobel had been under a kind of spell which made him pursue always the most difficult and dangerous of his many inventions, for example work with explosives and finally even the manufacture of armaments. His heart rebelled against these things and so he proposed the fatal solution: 'Peace through re-armament'. It is of course quite true that dynamite has opened up many new possibilities in mining certain raw materials, and in constructing tunnels and roads. It has contributed much to technology and the mutual relations of different peoples, and Nobel naturally gave much thought to these things. Nevertheless, his greatest endeavours have been in making inventions in connection with firearms. He thought wars could be prevented through instantaneous and far reaching methods of destruction. When he bought a munitions factory in Sweden, at the end of his life, so that he would be on an equal footing with Krupp, he started at the same time to make propaganda for peace. The fact that Nobel decided to donate his enormous fortune to the well-known prizes which are all to serve the preservation of peace and the development of culture, sounds like mocking laughter of the evil spirit of our time when one considers that a great part of this money had been amassed from war-industries.

One can speak about the history of candles next and tell the class that one used to have wax candles, which served their purpose well, tallow candles which stank a lot and used to melt away. All candles produced smoke and had to be snuffed repeatedly, which presented quite a problem in theatre performances and on festive occasions. The solution was very simple and found over a hundred years ago. One has a plaited wick, where one of the three strands is shorter and serves to twist the burning end so that the tip comes outside the zone of the flame, and can burn away. Finally candles which did not smell were made of parafiin wax and stearic acid. There is a book 'The Chemical History of a Candle' by Michael Faraday* which is a course given to young people. Its purpose is to

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* 'The Chemical History of a Candle', published by 'The Scientific Book Guild', Beaverbrook Newspapers Ltd., London

develop an extensive natural-scientific picture of the world, starting from a candle-flame. It is literally true that a burning candle is an extraordinarily complex phenomenon. This is only realized when it is seen in relation to the four elements. The candle itself is the *earth*. It melts and forms the element of *water*, which in turn evaporates and changes into the form of *air*. Towards the outer edge, the flame has a darker zone of *warmth* which can be made visible by introducing a little common salt or copper chloride. It is interesting for the teacher that it is even possible to see to a certain extent a reflection of the four ethers. Below the warmth zone, the flame is luminous and in a still lower zone, chemical forces are at work. The material burnt originates from living organisms.

If it should happen that this period is given near Christmas-time, one can touch on something of great importance. One can make it clear that the Christmas-tree is not only a symbol but also an example. Among those trees which have ceased growing, there is an accumulating and condensing of substance during the summer months which goes hand in hand with a tremendous intake and assimilation of energy from the sun. In the case of conifers this can be clearly observed. Their characteristic way of growing indicates that the emphasis lies on a condensing process. Their needle-like leaves show the inability to divide and to spread out. Pine wood, as it is permeated by resin, burns especially well. This process of materializing the power of fire in dense matter must be seen as direct representation, even as an imprint, of the descending movement of the sun during summer and autumn. Light and warmth radiating from celestial bodies unite during this time with the earth. Because of this, the pine tree is the most fitting symbol for the cosmic constellation in the winter – the sun tied to the earth. If the pine-tree is now decorated with candles and these radiate light while their substance is used up, this is the finest picture of the winter solstice – the sun freeing itself again from the earth. But the Christmas-tree is also a wonderful example of the sort of way in which we should treat matter. For a long time now, we have been occupied with something akin to a technical solstice, which is becoming increasingly pronounced. Substances like coal and petroleum which became condensed in primeval times and took with them the powerful energy of the sun, are taken up and burnt. This process, naturally takes place entirely in the sphere of egoism and for developing power, and this invariably produces serious repercussions. One can even consider atom splitting from this aspect. Energies are also liberated here which were knotted together in primeval times, but their origins go back much further, and therefore they are far more powerful and the consequences more far-reaching.

In this way one can learn to cultivate a new attitude towards the custom of lighting the Christmas tree in honour of the Jesus child. A religious attitude should accompany not only the yearly winter solstice but also the solstice of technical science, for in raising up matter which has sunk down into the earth, and in liberating energy, man works after all with what has been achieved by processes active in the creation of the world. He reverses these processes and brings about a kind of liberation of matter. If man were to become permeated by the feeling that in this way he is taking a share in the divine processes of the development of the world, quite different relationships would come about within mankind, and also between men and nature. Working with matter would no longer lead away from the divine but would become an act of consecration in the service of the new connection with the divine.

In concluding the condensation of carbohydrates to cellulose and wood, one can study the change of plant substance to peat and the subsequent carbonizing to lignite and coal. It is obvious that coal deserves special mention and in this connection also the manufacture of glass.

The destructive distillation of coal can be demonstrated, showing how methane, ammonia solution and tar separate out from the gas given off. It is of course a great asset if gas works can be visited.

One can then show the pupils tar, and if possible distil this, whereby benzene, naphthalene and related compounds can be seen and smelt. Special attention should be given to the flame of these substances, which produces a great deal of smoke.

Lastly, dyes and similar coal-tar products are shown. A whole world of synthetic products, dye stuffs, aromatic compounds, drugs and all kinds of man-made materials are made from coal-tar. It can become quite obvious to us that this realm may be related to what alcohol conjures up. The taking of alcohol produces a world of *illusions*. In coal-tar products we have made something which we might call *illusory substances*. They may resemble plant substances as far as smell and taste are concerned, but they are useless to our organism. A person who tastes and smells them really carefully will only make use of them with aversion.

Following on from fats and oils, the mineral oils may be studied. Firstly, crude mineral oil is shown and afterwards a series of the products obtained from it. It can be demonstrated that they float on water and are very insoluble. They mix very much less easily with water than do plant oils. Soap does not help here.

The following experiment is instructive. Benzene or petroleum is poured on some paraffin. If some coloured water is now allowed to run over this, large separate drops will be formed on the surface.

Several of these substances are now ignited. It is shown that burning benzene cannot be put out with water. The higher compounds in this series can be made quite mobile and also volatile if they are warmed sufficiently.

A fractional distillation of crude oil, or of a mixture of products obtainable from this, can now be made. The extraction of crude oil, its refining, transportation and distribution is discussed. Special emphasis is placed on its relation to aviation fuel, its application as engine fuel, lubricating oil and asphalt.

As background to all these substances, we now go into their chemical composition. We are here dealing with hydrocarbons, i.e. substances which can be made by combining hydrogen and carbon, as is indeed being done in technological processes. Both substances are very inflammable but otherwise have very different properties. Carbon is the element which is most difficult to melt; hydrogen is the element which has the greatest rate of diffusion. The one substance has the tendency to withdraw into earthly rigidity and even to exist within the earth itself, while the other always escapes in the direction away from the earth. Hydrocarbons are naturally also very inflammable, and in their constitution they form a kind of bridge between hydrogen and carbon. The lightest of them, such as methane, are more like hydrogen, and the densest, such as paraffin and bitumen, behave more like carbon. Like hydrogen and carbon they tend to be inert, hence the name 'paraffin'.* These compounds have very little chemical affinity to other substances and can even be used to protect substances against reacting chemically, (oil, to prevent rust, paper treated with paraffin, etc.).

The character of hydrocarbons is best understood if they are compared with the inner nature of sugar, as has previously been described. Here both the balance and chemical affinity are lacking, which come about through the presence of oxygen. (More details about this can be found in Part 2, in the chapter called 'Carbon – Hydrogen – Oxygen').

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* lit. 'having little affinity'.