The Metamorphosis of Clover acid and Formic acid

Suggestions for dealing with a curriculum statement by Rudolf Steiner on chemistry lessons in the 12th grade

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The first sentence that Rudolf Steiner said about the chemistry main lesson block in the 12th grade is, in a way, already a summary: "Let us look at chemistry in the most intimate connection with the human being". This is then explained and clarified in various ways. The chemistry in the human organism is to be dealt with, which is quite different from that in the inorganic nature surrounding it, but also different from that in plants or animals. "It must be shown that all substances and processes are completely transformed in humans." "One would have to have an inorganic, an organic, an animal and a human chemistry" (Steiner, GA 300c, Conference of 30.4.1924). In other words, three distinctions would have to be made: between an inorganic and an organic chemistry, between a plant and an animal chemistry and finally between an animal and a human chemistry. A few examples for the lessons follow in brief, the last one being the one that will be dealt with in the following: "Metamorphosis process formic acid – oxalic acid".

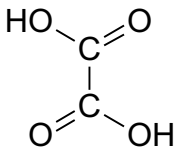
Rudolf Steiner has commented on oxalic and formic acid in many talks and on many different occasions. For example, the keyword formic acid can be found in at least ten volumes in over 40 remarks in the complete edition. The topic was dealt with primarily in the medical context and in lectures for the workers at the Goetheanum, but also in lectures for members and on other occasions. It must therefore have been of more central importance to Steiner. Eugen Kolisko was present at several of these lectures. As school doctor and first Waldorf chemistry teacher he built up and developed the chemistry lessons at the first Waldorf school. So, Steiner was able to presuppose a thorough understanding of this when he gave him the above-mentioned hints for teaching chemistry in the teacher conferences.

Among these prerequisites, Steiner's remarks in the cycle "Mystery Shapes" and in the doctors' course at Christmas 1924 deserve special mention. In the context in question here, it should first be looked upon the important distinction between reactions in living organisms and those in lifeless reaction vessels: "Now the human being is not a retort. The retort shows in a dead way what is present in a human being in a living and sentient way". And it is not the substances oxalic acid and formic acid themselves that are important in the human being, but "the work, the activity within, which consists in the oxalic acid process taking place, the formic acid process taking place" (Steiner, GA 232, 13th lecture). The process of the formation of oxalic acid, which mainly takes place in the digestive organs, is – according to Steiner – a necessary basis for the fact that man can live at all (i.e. for his etheric body); its transformation into formic acid – more localized in the upper human being – forms the basis for the soul (i.e. for his astral body). One year later, Steiner explained to the doctors that in the case of formic acid, it would be necessary to come to the insight that

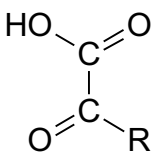
it has the task, both in man and in nature, to enable further life and development in the face of the processes of aging, dying and decay (Steiner, GA 316, 1st lecture).

After the almost revolutionary advances in biochemical research since then, it can be assumed today that there should be hardly any significant transformation process in the human organism that could have escaped discovery. Strangely enough, however, on the basis of this very detailed knowledge, it must be said that neither the formation of oxalic acid nor its conversion into formic acid is of any significance worth mentioning. If oxalic acid is formed in significant quantities in the human organism at all, then this is pathological and especially alarming because the human metabolism cannot deal with oxalic acid in an appropriate way and cannot, for example, convert it into formic acid. On the other hand, some formic acid is probably always formed, but not from oxalic acid, but in completely different ways. And this formation of formic acid is only of very minor importance in the whole context of metabolism. In no case, therefore, could the conversion of oxalic acid into formic acid be an essential physiological process that is decisive for life and death. Now Steiner, in his remarks on the oxalic acid and formic acid processes, explicitly said that "today's physiology" must also find these processes (Steiner, GA 232, 13th lecture). And only scientific facts can, of course, be the subject of the lessons in school; so, all of Steiner's curriculum information is, of course, only meant as recommendations. Based on this, a new approach to understanding this curriculum specification for chemistry lessons in the 12th grade will be presented below.

A general characteristic of biochemical processes is that the substances involved do not exist freely and react with each other as in the retort, but only occur in various ways in ligated forms. For example, there is a ligated form of formic acid, which is called "activated formic acid" and plays an important role in e.g. the formation of nucleic acids (purine synthesis). Only in such an activated form can the substances participate in the biochemical conversion processes at all. What we have in the retort as a substance, what we can examine in its properties and let react externally with other substances, exists *as such* only as long as it has fallen out of the living process, i.e. is dead. This is what the biochemical facts teach us. If we now look for *ligated* forms of oxalic acid and formic acid, we will quickly come across the process we are looking for, the conversion of oxalic acid into formic acid + carbon dioxide (CO_2). One group of organic acids that occur in metabolism, the α-ketocarboxylic acids, can be considered as bound oxalic acid; through decomposition, oxalic acid can be released from them. This is also clearly reflected in the formulas (the R denotes the "moiety" to which the oxalic acid is bound):

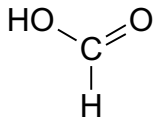


Oxalic acid

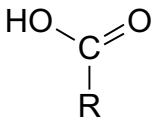


ligated Oxalic acid

These acids can now be converted into other acids with the release of CO_2, which we can in turn regard as ligated formic acid:



Formic acid



ligated Formic acid

In such a ligated form, a considerable amount of oxalic acid is continuously converted into formic acid during metabolism. In a way, it is the same process as in the retort, but completely on an organic level.

These conversions are essential partial steps of cellular respiration. When organic matter – starch, sugar, fats or proteins – is broken down in the organism, the first thing that happens is that it is converted into organic acids. This is basically a fermentation process, much like the souring of milk. This fermentation goes all the way to the acids that we have called ligated oxalic acid. In a next step, CO_2 is released from these acids and they are transformed into ligated formic acid. During this transition from ligated oxalic acid to ligated formic acid, as well as during the preparatory reaction, practically all the CO_2 we breathe out is produced. And since the vast majority of the substances that we ingest during our lifetime and do not excrete in any other form ultimately enter into this process, it is, on the other hand, quite true when Steiner says that everywhere in our bodies the substances ultimately enter into formic acid formation.

However, the ligated formic acid resulting from the process does not remain as such, but is usually immediately converted into other forms. This again is a characteristic difference to the retort experiment. To put it very simply, one could say that the ligated formic acid is reintroduced into the process from which the ligated oxalic acid is derived. This is a cyclic process, the so-called *citric acid cycle* (or, according to its discoverer, the *Krebs cycle*). This cycle, as it is usually presented, appears to be quite complicated and the individual steps require careful analysis in order to understand exactly what is presented here. But in fact, nothing else takes place than the conversion of ligated oxalic acid into ligated formic acid + CO_2 and the further transformation of the resulting formic acid into another form of ligated oxalic acid.

It is now possible to bring the observation closer to the human organism in a differentiated way and thus take up the close inner relationship with the 10th grade human biology main lesson block. Substance transformations without the involvement of oxygen are found everywhere in the organism, in every single cell, but they are undoubtedly concentrated in the intestine and liver. The intestinal contents are not supplied with oxygen at all, and of all the organs, the liver is the one with the strongest venous blood supply, i.e. the one with

blood low in oxygen. While the intestine is mainly concerned with the decomposition of food substances, the liver is the place where the greatest variety of biochemical transformations take place. And, as its name suggests, it is also the most living organ, the centre of the body's living construction processes. Contrary to the widespread assumption that venous blood is the 'used' blood, it is precisely in the venous environment that the build-up processes take place. This also applies to the most comprehensive developmental process of all, the embryonic development, which takes place in its early stages with a remarkable lack of oxygen. The various forms of ligated oxalic acid play an essential role in all these building and rebuilding processes, which are then concentrated in the liver after birth: they are the starting point for the formation of new protein components, the amino acids, as well as that of sugar and starch. These substances can only be built up if ligated oxalic acid is provided by the oxalic acid process.

The centre of the oxygen-dependent processes, on the other hand, is in the brain. When there is a lack of oxygen, it is the first organ to be permanently damaged. And this is now related to the fact that the brain serves the unfolding of consciousness. Consciousness, a soul life of its own, is only possible on the basis of oxygen-dependent decomposition processes and thus on the basis of the conversion of oxalic acid into formic acid + CO_2. We have life in common with the animals and the plants, but an own, conscious soul life only with the animals. This is in accordance with the fact that only animals are dependent on oxygen in the same way as we are. The oxalic acid formation process generally serves to organise life (the etheric body), while the formic acid formation process forms the basis for the unfolding of the soul (the astral body). It is thus also understandable that death occurs in humans as soon as the formation of formic acid can no longer take place: Then the soul-spiritual no longer has any basis for action in the body.

In plants and insects, the oxalic acid and formic acid processes are more distinct from each other than in humans, where they belong to the lower and the upper human, respectively, and are thus united in one organism. This is apparently related to the fact that one of the two processes is modified in such a way that oxalic acid and formic acid are produced in larger quantities in their pure form. Here, formic acid is not restricted to the relatives of ants, bees etc.; it also occurs in beetles and caterpillars. And although oxalic acid takes its name from its occurrence in Wood Sorrel (Oxalis), it is widespread in the plant kingdom. However, most plants contain only small amounts of this pure acid; only in certain species, e.g. Wood Sorrel and Common Sorrel, does it occur abundantly. Among the numerous organic acids found in plants, oxalic acid occupies a special position because it is even poisonous in corresponding quantities. Many plants provide food for animals and humans and are not toxic as such. Plants become poisonous when they undergo degradation processes that go beyond what is 'normal' for plants. Oxalic acid must be regarded as an end product of plant metabolism, which is usually no longer or hardly ever involved in the active metabolic process. It differs in this respect from other plant acids which, although they can also be deposited in masses, this often only happens temporarily, e.g. only at certain times

of the day. Of all the plant acids, it is the one that has fallen furthest out of processes, and it is also the one that has become the most mineral. In it, the acidity, which occurs in organic matter during decomposition processes, is most concentrated. This makes it by far the strongest organic acid in nature and in this respect, it is already comparable with stronger inorganic acids.

The oxalic acid process characterised at the beginning is a slight, only initial degradation towards acidity, which can also change into a build-up again. If this process is exaggerated without, however, changing into the (essentially animal) formic acid process, the oxalic acid is formed as the material end product. If, on the other hand, the formic acid process meets it, as is the case with animals and humans, the acidic substance is exhaled in latent form as carbon dioxide, which forms carbonic acid with water. If the carbon dioxide is reattached to organic matter in living metabolism, organic acids are formed again. So if the insect world were connected to the plant world in the same way as the upper human being is connected to the lower, then oxalic acid would not be produced in the plants.

The vegetative growth of the plant comes to an end in the flower. It dies there. Only from the seed can a new plant germinate again when it gets into the ground. Here too, the flower shows its closeness to the animal, which develops its consciousness on the basis of bodily decomposition processes. The root is completely different, it grows further and further and can branch out at any point by lateral roots breaking out from within. And only where it grows can it function as a receptive organ. While the flower could rightly be seen as a 'parasite' on the actual plant, the root is entirely part of the vegetative life of the plant. Whereas we have otherwise always found the formic acid process in connection with the soul, with the development of consciousness, the root area seems to be an exception. However, the soil is by no means just a dead substrate. And just as the plant enters into an intimate relationship with the insects above, so in the root area with the fungi. Research into mycorrhizae, the symbiosis of plant roots and fungi, has led to the initially surprising result that most plants in a forest or meadow are functionally cross-linked with each other by the mycorrhizal fungi and thus actually form a uniform, coherent organism much more strongly than one would immediately suspect. And this fungal life now turns out to be that which outside in the organism of the landscape and of the whole earth in general corresponds to what is the brain activity in our own organism. Only out there the decomposition processes do not form, the formic acid process does not form the basis for a separated self-awareness as in animals and humans, but for an extensive nature-sanity, a nature-spirituality.

As emphasised at the beginning, chemistry in the 12th grade should be treated "in the most intimate connection with the human being". It can be seen that the metamorphosis process oxalic acid – formic acid proposed by Rudolf Steiner as a subject for teaching can be successful, and that a close interrelation between man and nature can even be focused upon as a central theme. This metamorphosis process should therefore be part of the curriculum in every Waldorf school. The essay presented here would like to stimulate this as well as a

more comprehensive examination of this topic. It should also be read as a contribution to the ongoing discussion about how Rudolf Steiner's statements and the results of biochemical research fit together and how the latter can be treated in the classroom in a Goetheanistically expanded way.

This text is a shortened version by Dirk Rohde (d.rohde@waldorfschulemarburg.de), FWS Marburg/Germany, of the article by Klaus Frisch (chronos@onlinehome.de) "Oxalic acid and Formic acid", published in the journal Erziehungskunst 7/8 1992, pp. 577-599; available online in the Erziehungskunst archive:
https://www.erziehungskunst.de/fileadmin/archiv_alt/1992/p008EZ-06_07-1992.pdf
The text was translated by Dirk Rohde.