

A model free introduction of chemical formulas

Manfred von Mackensen, 'Prozesschemie', 2001

1. The transition class 10 – class 11

Reflection on class 10. In the 10th class we give a survey of the manifold and structured expressions of the salts and their symmetries. We got to know transforming forces of the acids, the absorbing action of alkalis and the mineralising action of bases. Within the plant world alkaline processes are characterised by weight and over-ripeness, acidic processes by freshness and growth. The internal processes of the animal, not directly accessible from outside of the body, are alkaline in character; those processes however, which are accessible without resorting to incisions, are acidic in character, i.e. gastric juices and feeding juice of the bees. When teaching about salts, alkaline and acidic phenomena are reviewed in minerals, natural water and juices of living organisms. Different directions in processes may be discerned, which are represented in the most varied way through different substances – even within the crystal form.

Preview class 11. At times it will happen that one or another chemical formula for a salt, an acid or a base, will be used in class 10, declared in anticipation of what's to come; possibly even encouraged to remember it for next year. However, how the innumerable substances of the world can be reduced to a small number of chemical elements, in what densification, concentration and finally decay of the change- and emerging-impulses of the material abundance are present in nature, this process of identifying, of narrowing down and individualising to the extreme, to an element, that belongs to class 11. In class 11 this is didactically appropriate, as it requires an overview of chemical possibilities, presented in class 10, to notice the focussing and one-sidedness.

2. Laws and atoms

Actions of elements? Only in compounds. Firstly, irrespective of whether one starts the main lesson with calcium, nitrogen, sodium or sulphur, we have to establish the fact that such an element, seen as the concentration of that specific substance impulse, has the smallest weight of all its derivatives. All compounds of the element weigh more than the portion of the element used to make them. Every time something was added. The element stands as the concentration in the centre of its derivatives (compounds). Only through the compound does the element act in a process of nature and leaves its mark because it is bound differently or in a different manner. Isolated, as pure elements, mostly prepared in the laboratory, they have little influence in nature's processes. An element doesn't realise its impulse, its driving force on its own but only in conjunction with other elements. Only in that manner can our world exist: aiming for innumerable new qualities, with unlimited flowing forces. These don't emerge monotonously from the elements as building blocks of the substances. Every compound exhibits new, *particular, own* qualities. The elements only indicate these. They themselves are poorer.

No material world-building blocks! We should not speak trivially of elements in a material constitutional manner, as mystical invisible beings, before we have demonstrated their impoverishment. Even if conventional school chemistry admires them as much as it wants as building blocks of the universe, as root causes or simply as the only reality: we have no reason to introduce the elements before class 11.

Proportions. The so called law of constant proportions is an early, unspoken experience of children from the first melting icicle running away. From nothing comes nothing, from little little, mostly something is in surplus. But a lot of acid given to a base forms the same salt as a little acid, only one or the other remains unchanged. Substances have their own property identity, just as they have their fixed proportions when reacting initially; there is no way changing that. In class, therefore, we don't have to discuss the laws of

constant proportions and of conservation of mass too much.

Conservation of mass of the element. It is just as obvious, that the substances or elements reappear when destroying the substance, in the same quantity, as long as nothing is lost. Otherwise one of the initial substances would be changed into the other when repeatedly producing and destroying a compound. However, they are something different! The so called law of the conservation of (elemental) mass can be put to the pupils, without much introduction or proof.

Consequences, not definitions characterise laws. What we need in education is not an extensive *measuring*, but an experience and a judgement how laws present themselves, what aspect of experience *points to them*. For example, that is the point of the experiment producing iron-sulphide. We base the use of formulas on that or similar experiments – not on laws, much less on atoms. Even the explanatory satisfaction derived from using 'atoms' arises from an even deeper layer of half-conscious pre-existing wish to have elements as building blocks; this leads even more strongly away from the personally strengthened meeting with the world and one's own judgement. We must protect ourselves from both. We all have the intuitive feeling, even the particular thoughts, to consider everything in the world to be caused by matter.

Experiencing the boundaries of particles. Mainstream laboratory and industrial chemistry is based on the conservation of mass, on number ratios, constant and graded proportions, conservation of the elementary mass, and finally: the conservation of particles, those particles which are eternal and make everything! One feels life on earth as a cage, wherein the particles actively and bring forth the world – and simultaneously restrict it. Reaching to the particles is felt as the great empowerment in the cage, the formula becomes its image and all the qualities of the phenomena of the world become uniform: It is as if we are engaging with and manipulating eternal reality. Here we do not need qualitative observation, no empathy with living nature and the substances it produces, and in particular: one need not form self-generated, self-evaluated thoughts in conjunction with this empathy and phenomenon. One has one's ready concepts (the molecules, electrons and ions), which are strongly founded in physics: on the eternal, static world, to which everything in the

opening questions is ultimately reduced.

Basic attitudes. The present approach is not to be seen as a philosophical programme, but more as an accessible presentation; also in the soul of the pupils. We can summarise this as follows: chemical knowledge based on atomic conceptions and a few experimental signals, combined with 'make-ability' and power-instinct results in a non-verbalised credo: "Greetings atoms! We thank you for everything, the structure of nature, our bodies, our brain processes: we in you and you in us!".

Didactic switches. Initially we'll let the atoms be. Just as they are unchangeable, so too are the basic attitudes and preconceptions with which we experience them; in this instance we cannot develop anything spiritual for the students. We can mention, 'praise' and lightly cover the atoms, and demonstrate that we know how to use the system, that we admire the system's overwhelming intelligence and power opportunities and consider it scientific, but do not expect wisdom or salvation from it. Because these we only acquire from experience, not from conception.

No final judgement. The previous remarks regarding the problem of atomism are intended to enlighten our daily consciousness with a view to making it receptive for the obvious, for what is appropriate for life so it can find its way. A historical, philosophical, scientific theoretical, or let alone a specialist appreciation will not be achieved. To present the fundamental problem inherent to the materialistic, causal-analytic cognition of nature, let us mention a few short essays from 1882 and 1890 by R. Steiner ('The only possible criticism of the atomic concepts' and 'Atomism and its refutation')¹.

1 Steiner, R (1882....) Einzig mögliche Kritik de atomistischen Begriffe; Die Atomistik und ihre Widerlegung. In 'Beiträge zur R. Steiner Gesamtaufgabe ' Nr. 63, Michaeli 1978, R. Steiner Nachlassverwaltung CH 4143 Dornach (Contributions to Steiner's complete works)

3. Manner of perception

Steps to arrive at chemical formulas. Chemical formulas have to be introduced en passant; developed from observation yes, but not by spending time on special experiments. In the end Hofmann's apparatus may be the only demonstration experiment used. The formation of iron sulphide would be a key experiment. It can demonstrate in a wonderful manner what it means to have a surplus of sulphur or iron. Burning of steel wool in air or the reduction of copper oxide with ammonia – experiments that could all be demonstrated – are suitable to demonstrate the proportions, the changes and the residues of the substances one started with.

The choice of the molar-mass. After the proportions the problem of abbreviations raises its head. We define a unit of mass specific to each element, in the case of hydrogen this is 1 gram. Thus the basic definition for the whole system is

$$1 \text{ g Hydrogen} = 1 \text{ H}$$

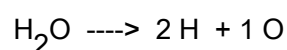
The element specific mass, in the above example 1 g, is also known as the molar-mass. Under normal conditions (i.e. standard pressure of 100 kPa (=1 atm) and standard temperature of 0°C, or STP) 1 mole of hydrogen has a mass of 2 g, because of its bimolecular nature, therefore it is written as H₂ and the molar-mass is 2. In contrast here a mole of atomic hydrogen is meant. A mole of hydrogen is therefore a proportion of this species with a mass of 1 g (that does not contradict the atomistic definition of the mole; distant digits after the comma don't have any meaning in the introduction of the mole). The mass of 1 g was chosen because hydrogen is the 'lightest substance', i.e. under standard circumstances (STP) it has the smallest density; and because all compounds that can be made with it have less hydrogen mass than of the reaction partners. Hydrogen is physically and chemically the lightest element.

In principle we could choose the molar mass of other elements, which will also be represented by one letter,

by any number, at least in the simplest cases. However, the use of formulas only has an advantage if you take the mass proportions into account with which compounds are formed, so that we don't end up with complicated fractions of molar masses and of the representative letters. Thus we allocated the number of grams of chlorine that reacts with 1 gram of hydrogen, which is (rounded) 35, as its molar mass. We can then write:



The formula for water from the mole volumes. Interestingly Gay-Lussac found in 1808 that equal volumes of hydrogen and chlorine react to form hydrogen chloride, thus indicating that molar masses relate to a unitary volume. This volume is set to roughly 24 l at room temperature. It is the same for all (gaseous) elements. We can thus ascribe the mole volume to one letter of each element. The number of letters for the elements are in proportion to the number of mole volumes participating in forming the compound, at least in simple cases. For example when we electrolyse water we find that for every mole volume (~24 l) of oxygen we get 2 mole volumes (~ 48 l) of hydrogen gas. Thus the formula for water is H₂O and it follows – with a mass ratio of 1 to 8 – that the molar mass of oxygen is 16 g.



First advantage. What have we gained by such formulas?

- Firstly, in an abbreviated form, they represent quantities of used or produced substances during reactions, so that we don't need to weigh but only need to write letters, which, at the most, will be accompanied by small whole numbers. Formula writing is thus initially an adequate protocol for quantities, for example production.
- If we boldly state that we could retrieve, in a roundabout way, the elements which disappeared in a substance we can predict reaction possibilities and exclude others. We get an overview of the whole.

4. The great discovery

A universal system “falls from heaven”. The last advantage mentioned follows from a circumstance, which is difficult to grasp. In all compounds of an element with the *most different* other elements, it always “uses” the same molar mass and all other elements use the same molar mass amongst themselves as with the first. That goes beyond constant and graded proportions of a single combination of elements. The molar mass calculated from a dual combination of elements, if necessary supplemented with small whole numbers, suddenly shows itself applicable over a large range in chemistry for all combinations of elements.

We could call this a law of *universal proportions*. An example:

- Sulphur dioxide uses once 32 g and twice 16 g (sulphur respectively oxygen);
- Water uses once 16 g and twice 1 g (oxygen respectively hydrogen);
- Hydrogen sulphide uses once 32 g and twice 1 g (sulphur respectively hydrogen).

The same molar masses apply generally. All proportions in the net of countless combinations fit into this rule. That is the implication of Richter's law (Jeremias Benjamin Richter, 1791). Imagine one compound: its composition is governed by a universal proportion of molar masses of innumerable other combinations of elements; as if only particular mass intervals — i.e. just those of the molar masses — were possible in the universe. We only wanted to produce a shorthand for the mass proportions, however, as if by magic, the element specific 'mass-parcels', initially simply chosen on practical grounds, turn out to be universally applicable for all imaginable pure compounds! Conventionally this is called the law of equivalent proportions². It would be more correctly to speak of the “universality of proportions”, a concept based on a concept; not a fact.

² Hollemann, Wiberg: Lehrbuch der anorganischen Chemie, (1985), p 22; (Diederich Ruarus: see also Partington, General and Inorganic Chemistry, (1946), p 4 ff; and Parkes, G (ed) Mellor's modern inorganic Chemistry (1967), p 63 ff)

Mysterious properties of the volume of the mole. How did universal wisdom become embedded in our system, initially started spontaneously? Because we calculate theoretically the molar masses for all elements from the same *volume*. As only a few of the elements are gaseous, the others would need to be brought into the gaseous state before being weighed, and then recalculated, using the gas laws, to standard conditions³. It would be necessary to heat nearly all elements and bring them in a state of low pressure. That means to bring them out of the current densified earth condition. They have to be thought of as being at a maximum state of rarefaction and at the highest temperature, i.e. in a more cosmic, perhaps an ancient state⁴. By basing ourselves on a single mole volume (or molar-volume) we are as it were connecting with the cosmic origin of substances. Out of that the wisdom-filled universal ratio streams into our system, unthinkingly begun, and makes it successful, because it is universal. Formulas get their natural lawfulness out of a world of warmth and light, as if out of another world, the universe⁵.

3 The so called 2 atomic gasses, such as H₂, O₂, N₂ etc, would also need to be brought, through temperature increase, to give up this earthly heaviness and consolidation softly introducing densification, as exemplified by 2H ---> H₂. They have to be made '1-atomic' to have the molar volume as indicated by the underlying mole masses.

4 It is possible to circumvent the difficult to achieve gaseous states, particularly through the use of Richter's law and through other measurements of collative properties; people did this with the known system and encircled what couldn't very well be measured. (Collative properties = rising of boiling point, lowering of freezing point, osmotic pressure, vapour pressure and the like).

5 As the discussion ends with the initially nebulous concept "cosmos", which is neither based on a substance nor on an instruction for measurement, yes, even shouldn't, the willing reader is invited to take something, initially considered a flaw, as a reason for further research. Because the 'open' concept 'cosmos' and 'cosmic past', which leads away from only ordering what is tactile, can generate interest and reverence which make it possible to touch something larger, whole that unites with the origin of humanity and the earth – the only source of effective understanding. In contrast the cool ordering of the world leads, as is well known, only to exploitation of that which is produced rationally. The concept 'cosmos', which cannot be adequately discussed here, is therefore not a flaw, but a gem which it is worth writing this article. Rudolf Steiner describes the source of the above complex, the 'chemical ether' (ether in the sense of the field of formative forces), as a boundary to the endless physical occurrence of changes of substances. It seems that Steiner saw the law of the conservation of elemental masses as the reason for the universal proportions.

Steiner indicates the generation of the chemical ether from the life ether, which manifests itself in permanent differentiated element activity, in Akasha chronic (GA/CW 11, p 113 ff, 1904 – 8/1973); in the Agricultural course the action on earth of the life- and chemical-etheric from the region of the universe of the 'outer' planets, about the reflection by silica (GA/CW 327, lecture II p 30 ff, 1924/1984); in the 2nd medical course the conservation of the element mass (mole-mass in this article; Diederik Ruarus) through the continued existence of etheric substances in the chemical ether, in contrast to the varying chemical turnover (GA/CW 313 lecture II, p 29, 1921/1963).

Atoms as thought models

If one rejects the origin of heat and dilution and insists on having something that doesn't depend upon its surrounding but rather relates centrally to itself (based on simple matter), then one imagines atoms (Dalton). One goes therefore to the opposite position and leaves the world of objects (e.g. that of classic physics). One delves with one's thoughts into "causal" material structures. Daniel Bernoulli's kinetic gas theory from 1738 starts with something of this kind, fully in modern materialistic consciousness in such an ingenious way, drawing on Mariott's empirical gas theory, that one forgets the original fundamental decision.

Keeping the interest of the pupil. It is advantageous not to follow Bernoulli⁶, but to introduce the formulas without reverting to a model. Because everything that rests on invisible, but clearly conceptualised but reductionistic entities, turns the initially thinking student off. That is demonstrated by the ongoing powerless bemoaning about the loss of student interest (powerless, as the complaint is reductionistic) at senior High school level, lately described by Hörner and Greiwe: Chemistry – No thank you?⁷

The cult of phenomena. Pupils are only attracted by a thinking based on phenomena: to wit - that engages the pupils to judge for themselves. If we do not swim, as many excellent authors, who are looking for a phenomenological approach, also with our thinking outside the reductionistic frame, then we cannot keep the interest of the pupils over time. For example the following two authors:

Mins Minssen describes the "essential difference between possible goals of a phenomenology of nature and of science: science tries, *in the long run, to banish mysteries from the world, by reducing them to relations between numbers, structural units and their chains of development....*

6 Bernoulli, D. (1700 – 1782) 1738 beginnings of a kinetic theory of gasses

7 Hörner & Greiwe (2000) *chimica didactica* 26(1) p 25 & 26 (2000)

A phenomenology of nature tries, without adding mystification, to describe an appearance in nature knowing that, in principal, the phenomenon remains more complex than the description, which goes beyond the descriptive powers of the observer.” Wender writes about describing a substance: “I let pupils hear how it can mummer and bang, observe how the wonderful colours and forms appear, let them smell how awful or heavenly substances can present themselves, feel how warm and smooth something is, let them taste how acidic and bitter they are. I devote all my attention to making sure that they can really observe and that this becomes a real experience. I notice that their emotional life is engaged through the senses and that in this way they can participate in the beauty of life, that their morality also develops”.⁸

Boundaries to observation only. It should be in the nature of adolescents, that after the richest observation *some form of thinking* occurs. We encounter the deficit of phenomenological aspiring modern chemical didactics. We must - in complete opposition to using models - find the spiritual transition from the nice, separate experience to the whole of living nature and the human.- Where else can moral freedom come from? Only a personal idea can give force to thinking, because we can nurture it in our inner life, even subscribe to it. In contrast concepts, embedded in a thinking, which as a reductionistic consequence declares molecular processes as epiphenomena of our nervous system and just considers itself to be an impartial registrar of a world inventory independent from itself — a registrar, in which any thrust to cognition is levelled — cannot be worthy of the interest of the adolescent in the long run.

Previous goetheanists. We should add that Frits Julius also extensively discusses and recognises the phenomenal, i.e. the real phenomena underlying the fixture of molar masses in gas volumes⁹. Julius describes the net of universal proportions or, as we say, the universality of the proportions

8 Both quoted from *chimica didactica* 26(2/3), p 91 resp 92 (2000)

9 Julius, F. (1965) *Grundlagen einer phänomenologischen Chemie*, Verlag Freies Geistesleben; English: *Fundamentals of a phenomenological study of Chemistry*, AWSNA USA (2000)

as follows: "When some substances form compounds with each other, the involved mass ratios draw a fragment of this net into our view".

5. Teaching practice

A table of rounded mole-masses of elements (previously so called 'atomic weights', nowadays 'relative atomic weights in gram') enables pupils to manage the following exercise; the relevant formulas of the compounds, which may be calculated at any time from the weight proportions of the elements involved, are given.

— How large is the molar mass of carbon dioxide, formula CO_2 ? (44 g)

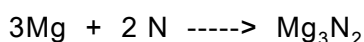
— How much carbon is used to produce 88 g of carbon dioxide? (24 g)

— How much carbon is used to produce 88 g of carbon monoxide? (37.7 g)

If such stoichiometric calculus becomes too complicated and practised too long, one only achieves a separation in emotionally interested pupils, who now drop out, and intellectually capable, who learn to view a passing skill as the essence of chemistry.

After writing correct formulas for compounds (CO , CO_2 , H_2O) we can now proceed with another result from our discussion of formulas, the possibility to practice precise reaction equations.

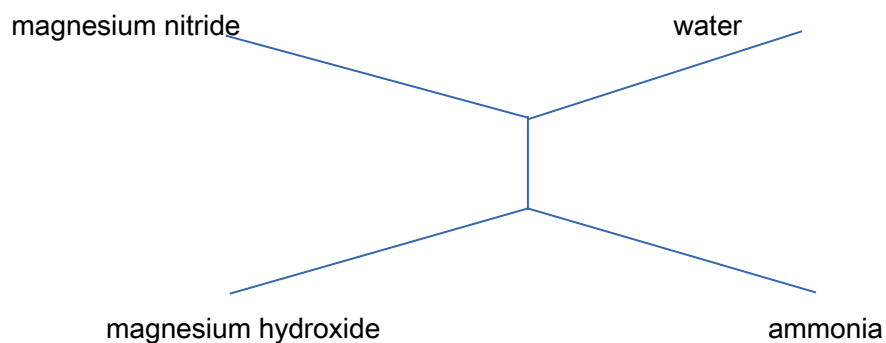
Having made magnesium nitride and given the formula Mg_3N_2 , we can now write



Initially we say 'three mole-masses of magnesium', not 'three magnesium' or 'three Mg'. Mg is thus not a general abbreviation for magnesium. Because Mg doesn't mean 'substance of the sort magnesium', but '24 g magnesium'. The same applies for example to carbon dioxide, which I in

general abbreviate with 'Kd' and not by CO₂, copper with 'Ku'¹⁰ etc. Universal abbreviations seem to automate cognition: however they also repress cognition by subjugating the concrete – therefore the use of Kd and Ku which are not theory laden.

What happens when we let the nitride react with water? We start by writing a reaction scheme. From the nature of the substances we have deduced that the gaseous reaction product is most likely to be a nitrogen compound, the mineral solid residue is a metal compound. The combustibility of magnesium, which in the case of the nitride has only partially been spent (mild glowing instead of a bright burning as with oxygen), transforms into the gaseous compound, i.e. a hydrogen compound, which further experiments show to be combustible. We therefore restrict substance to:

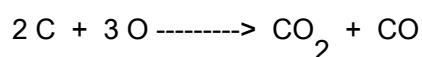


After the formulas NH₃ and Mg(OH)₂ have been given, the students can write



¹⁰ In German carbon dioxide is Kohlendioxid or Kd, a non existing chemical abbreviation; Copper in German is Kupfer, which abbreviates to Ku.

The principle followed here is: 'that we don't miss out on even one', because of the element masses being constant, all the letters on the left must equal those on the right. This principle allows us to write unknown reaction equations just by using the formulas; for example 24 g of carbon have consumed 48 g of oxygen, what kind of gas will come about? Using what we have learnt and knowing of the possibility of carbon monoxide, we can write:



Indeed, (poisonous) carbon monoxide is also formed, which we have 'discovered' by writing our reaction equation — a triumph of using formulas.

Before we continue with looking at the way the reaction proceeds (the so called reaction equations) as depicted in formulas, what we can predict or after the event can understand, we look once more at the advantages and dangers the single formula can have for cognition (as started above on page 4). Take CO_2 for example. We have a heavy gas, catch 44 g in a container and call this proportion CO_2 . What do we know from that?

1. The proportion is given with the formula CO_2 : for every 12 g of carbon 32 g of oxygen are used. These amounts, even if in a roundabout way, have been used; and just by these substances and none others!
2. When carbon dioxide loses carbon or oxygen, i.e. when it disappears, only carbon and oxygen are produced (often caught in new compounds) in the original amounts, and nothing else.

The formula thus presents an unambiguous past and a certain future. What does it tell us about the present?

3. The formula of the substances forces you to think that to be an addition; as if carbon dioxide were active and stimulating (exiting, rousing), water explosive and rust weldable. The depicted

elements are either only past or only future, not the present! That there is something new now makes life and change on earth possible. The formula negates this. Cognition blocks itself right there, nicely said: a disadvantage of the formula.

4. However, something of the element combination remains a reality in the present: and that is the mass. Its conservation suggests a continuation of the components; with respect to change mass has nothing to say. It is only conserved.
5. There is something else of the elements which remains in the present: the propensity for qualities. The qualities are gone, but some return changed, more for a qualitative thinking than as measurable data. Solely as tendencies, inclinations, only accessible to a phenomenological overview. But these inclinations do order nature.

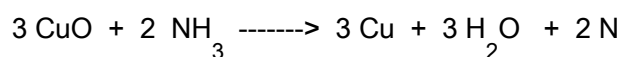
We thus have four advantages and only one, but a very seductive disadvantage (above #3). If one succumbs to this disadvantage, i.e. the assumption of a physical continuing existence of the elements in the compound — and it is nowadays difficult to disregard this —, we then subsequently need to ask: How do the dispersing elements hold together? And if the elements are simply there why don't we see them in the compound? This last question leads to the 'most fine dispersion' as atomic granulation, this leads initially to a theory of bonding, to the electrons. The decisive searches for models in modern chemistry have their origins in the problems related to the formulas; which is only one variant of the problems associated with materialism.

We could interject: "Let's keep materialism, if it does us such a lot of good and has built the whole impressive edifice of modern chemistry". However, we don't reach the pupils! And what's happening with nature, the environment; with the health of our children which is declining continuously? - These comments are from the field, from practice and as such are unscientific.

However, initial understanding and education start from basic experiences. Based on an original understanding of the phenomena, they seek to demonstrate comprehensive relationships, without postulating from the start such a comprehensive relationship, which is embedded in particles. It is possible, based on life and related to humans to find such relationships, if we are prepared to extend observation beyond the external maintenance of substance. Of course we cannot immediately dismiss the 200 years since Dalton. But it is sufficient if we in the first instance focus on the advantages 1, 2 and 5 above, leave the rest (the whole model work) behind; at any rate for class 11. — Let us turn our attention to an old problem, to that of valency. How does one solve this without electrons?

6. Oxidative and reductive valency

A first suspicion of valency. When formulating the reaction (setting up the reaction equation) — as mentioned above — the number of letters (symbols) is the same on the left and right, i.e.



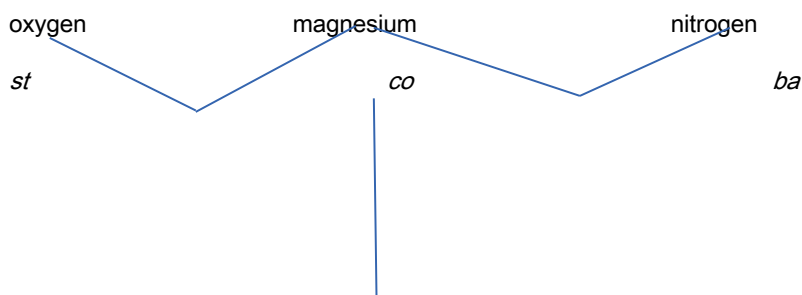
In teaching one can initially use a table, such as the following, for complicated reaction equations:

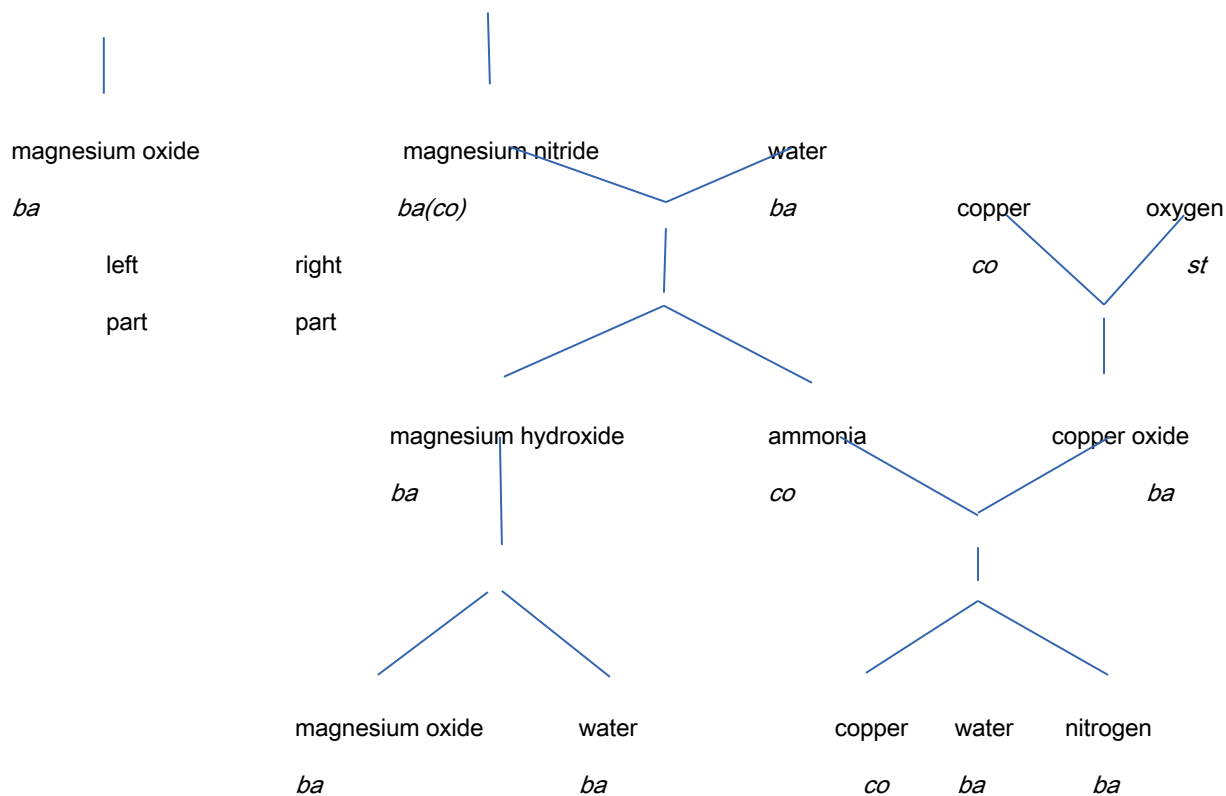
symbol	numbers	
	left	right
Cu	3	3
O	3	3
H	6	6
N	2	2

Even if the students use this sort of table, it remains unsatisfactory for them that they must be given the formulas. You can point out that these can always be derived from precise weightings (measurements of weight). However the students notice that the teacher not only knows the results of previous weightings, but also that he derives the small whole numbers from an element specific stock of numbers, which he, because he is an expert, knows about. The stock contains 'valencies'.

Stepped proportions, stepped properties. The valency describes the steps by which elements participate in the stream of transformation of the others. An element is not only determined by numbers or quantities but also shows qualitative grades, for example bivalent iron; one finds a unique, typical complex of tendencies to certain properties (see above point 5). If one changes the valency, then a new related complex arises, a new force effective in nature. Therefore the valencies have to be drawn from pathways of qualitative change of matter in nature rather than from imagined numbers of electrons, that are only based on systems of physical measurements and the reification of quantities.

The Polarity of forces of transformation. Firstly one has to explain qualitatively, drawing on the natural impulses of the reactions, that there are two transformational directions, oxidation and reduction. These are forces of open nature, of the emerging and decaying of living organisms and their materials. We observe a tableau of schemas of the linked reactions (that were demonstrated over several days):





combustible = *co*

stimulate (fuel, inflame, foment) = *st*

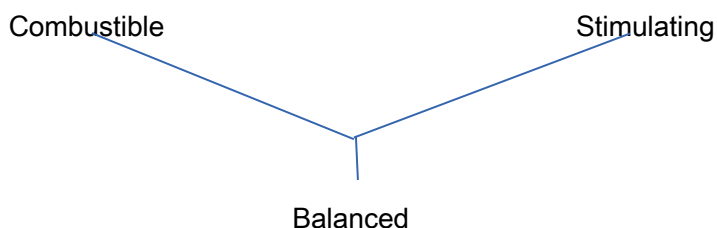
balanced = *ba*

Students recognise amongst other things that the result of magnesium's transformation in the left part is the same as in the right part, as all other substances on the right appear as they were used (water in 2 parts).

Which forces are involved in the reactions? We need to state firstly that producing magnesium is an act of violence: magnesium oxide and carbon have to be heated to 1800°C and then the magnesium vaporises.

Imponderables as driving forces. The imponderables of carbon, i.e. the all moving force, which in the end derives from the universe, is impressed forcibly on magnesia (magnesium oxide), while carbon is being converted to its highest state of oxidation through the intense heat. The imponderables, or more precisely, the disposition of a substance to bring actions of imponderables to the fore is the driving force for all changes on earth from the universe (sun, planetary system); it continuously brings forth life and chemistry. In the end, the idea of imponderables suggests ways of understanding how the universe works.

Combustible and stimulating. In school the descriptive part of the idea of imponderables has its place. We can divide substances as: *combustible*, *stimulating* and *balanced*:



These qualities have been inserted in the previous scheme in *italics*. We see that nitrogen is forced into the role of stimulator: through the extraordinary combustibility of magnesium. It therefore is not adequately balanced, because nitrogen doesn't have any balancing qualities. The uncompensated combustibility emerges in a repressed form in ammonia, it maintains itself even in copper (last reaction), because that is fairly oxidisable. We learn that it depends on the conditions and the partner in the reaction, if a combustible or stimulating property is used, i.e. in which direction a substance, in this case nitrogen, is pushed. Everything is interchangeable with everything else, nothing stands on its own. (In reductionistic chemistry that is expressed in the table of redox potentials).

Oxidation and reduction. We don't need to show how students now train in the use of the conventional statements "no oxidation without reduction" (= no disappearance of combustibility without disappearance of stimulation) and "the oxidiser is reduced and the reducer is oxidised" etc. from many examples. The expression 'redox reaction' will then become familiar and obvious. Examples of such substances are:

Combustible substances

Wood, straw, hay

Resin, wax, oil

Carbon (coal), peat, tar

Stimulating substances

Air, oxygen

Nitrate, chromate, permanganate

Oxides of: lead(II), lead (IV),

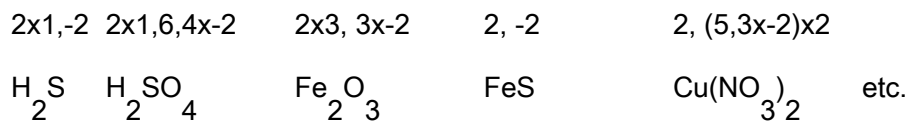
	manganese; sodium peroxide
Oil, asphalt, natural gas	Chlorine, Bromine, nitric acid
Alcohols, sugar,	under certain conditions sulphate,
aromatic liquids	carbonate

A concept, related to the large number of substances, to the totality of nature, even in regard to the openness of the earth to the universe, such as combustibility and giving off imponderables replaces a concept of losing electrons — a goethean turn, which can free us from an underlying pressure and ultimately from naïve realistic mental images.

Twofold valencies. Once we've developed a qualitative notion of redox forces we can quickly order the valencies. The reductive valency of hydrogen is set to +1. In hydrochloric acid hydrogen (here and always) has the reductive valency of 1 (it acts as a reductor), chlorine of course the oxidative valency of also 1, but negative; in shorthand:

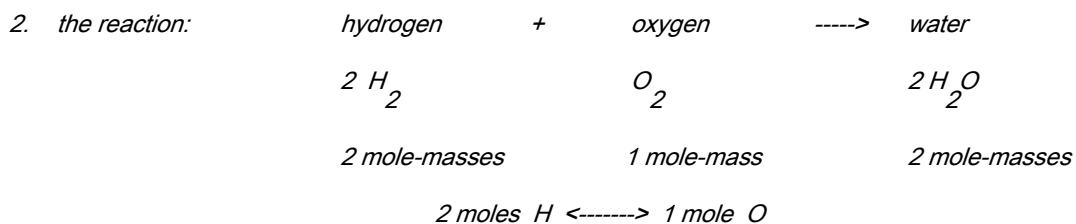


It is now possible to determine the valency as oxidation (+) or reduction (-) number (read x= times):



[Diederik Ruarus: I find the above not very obvious, and you do need to know the oxidation numbers; these can be deduced much easier using the mole concept.

- Oxidation can be defined as a reaction of an element with oxygen (or in von Mackensens terminology with stimulating agencies);*



and by consensus hydrogen has the valency +1 (or the oxidative valency) and oxygen has the valency -2 (or the reductive valency -2)]

Every change of valency (elements have valency 0) is a redox reaction. Writing redox-reactions will probably start in class 12 with exercises to train the students to become competent. Initially the following statement may be helpful: Hydrogen and hydrogen representatives have the valency +1, their partners, when they react with 1 mole, have the valency -1; oxygen and its representatives have valency -2. It is incumbent on the chemist and to some degree on the students too, to memorise the most occurring valencies of the elements.

What expresses itself in the valency? A derivation of the valencies from physical data (spectroscopy) from quantum values is initially beyond the scope of a general introductory chemistry curriculum to attain the necessary level of knowledge to judge. However, the origin of the valencies can be shown as follows phenomenologically. Hydrogen, as the element with the smallest specific gravity and the lowest temperature of condensation signifies, for all practical purposes, a permanent gas and the transition between the earth atmosphere and outer space, where it is found as a gas fleeing the earth. As such it is furthest removed from terrestrial qualities like solidification and weight. Amongst other things that is expressed in its very small mole-mass. Significantly it has the smallest valency. With the other elements substantiality increases, the mole-masses increase. Then the influence of the earth acts; ever more valency states come about. In particular with respect to oxygen, the element which doesn't flee the earth, rather a binding, mineralising element, it even has valency eight when reacting with the heaviest elements (osmiumtetraoxide). In that light the sequence of elements in a period with their increasing oxidative valency is a pathway of increasing compound forming, a submerging of one substance into another (and an increasing openness of a substance for another).

Whereto with the periodic system? From a phenomenological point of view the periodic system can only be introduced as a system of diversification and valency. We only need to remind ourselves that the much highlighted similarity of properties between elements of a group already with the showcases at the outer wings of the system (Na/K and Cl/Br), are absent in life processes. However tempting a periodic ordering

of the elements on the principle of mole-masses may seem, so difficult is the interpretation based on the physical manner of measuring, taking the level of knowledge of the students into account; not to mention the overloading with all the presented elements. It is better to forget the periodic table (system) or just to mention it in passing.

7. What is achievable?

Conclusion. The students know: the initials of an element represent a mass, which has been determined skilfully for each element. In the case of gaseous elements the mole-masses have the same volume. However that is already taken into account when setting the mole-masses, the students only need to think of masses when they write formulas. Initially all formula intricacies can be restricted to this. — Do they have to?

Goetheanism as a professional advantage. Everything calls for formal education, scientific reductionism, abstraction: “Internet in the Kindergarten” — because of assumed advantages for later work life. However, these sorts of jobs are not available for many, 80% must do something else. Phenomenological chemistry qualifies people to take leading roles in agriculture, natural medicine and pharmaceutical industry, nutrition and health, environment and natural history, in industries such as the textile industry, the production of cleaning materials, dyes, building materials and many others. That will be the future task for part of the workforce, there, where mainstream sciences fail.