SELLING CHEMISTRTY WITH A SAMPLE CASE - - CHEMISTS SEE MOLECULES DANCE

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"A while ago, I sang the blues complaining that no one is interested in chemistry anymore. The media ignore us. I have studied a science that is dying out … and so on. A friend pitied me and explained thoroughly that 'all things are chemistry - their names just do not show it.' We made a tentative list of alternative names for chemistry, and my favourite euphemism was 'material design'. Be honest: which tools can you use to design a material, if not chemistry, you see? Anyhow ... I now announce that I am not a chemist any more, but ‚a molecular designer, the profession formerly known as chemist' ..." [1]. Blogs can be interesting sources of information for chemists! Has chemistry got a bad reputation? Or just no reputation at all? If Europe wants to become, as the Lisbon Declaration puts it *"the most competitive and dynamic knowledge-based economy by 2010"*, the number of young people studying chemistry is must increase [2]. Why do many of them refrain from doing so? *"It is most astonishingly the high 'technology content'' of everyday life that decreases interest in technical studies: everybody can operate a mobile phone or an MP3 - but few have an idea how it works. Technology becomes self-understood, and at the same time a black box."* [3].

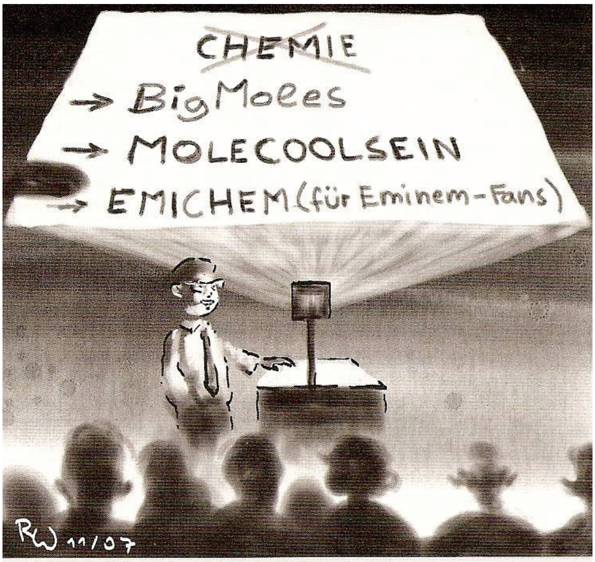


Figure 1. This is how teachers are expected to “sell” chemistry

A group of partners identified chemistry teachers, especially those in secondary schools, as - probably - the most important target group for a COMENIUS project intending to help increase the number of chemistry students. Chemistry and Industry for Teachers of European Secondary Schools, CITIES [4], is a project which aims at:

- giving teachers the tools to tell pupils why and how chemistry is indispensable in a modern society,
- inspiring them to tell others how chemistry makes a difference to their lives,
- helping teachers to make the chemistry they are required to teach more exciting, vibrant and relevant to its real life context,
- interesting teachers and pupils alike in the European context in which all this happens.

Within the scope of CITIES, the partners decided to design a "sample case" with a set of relatively simple materials for experiments that can be performed while visiting schools and fairs. Along with this sample case, a draft of a Power Point presentation was prepared which would accompany the experiments, giving historical and/or theoretical background information. It was first presented during the "Why Chemistry ?!" meeting (Krakow 2007).

More experiments and Power Point slides are currently being prepared to offer choices for "tailor made" presentations.

Can we "sell" chemistry without being spectacular? Do we have to, and does that nourish imagination? Or can we, in a time that is dominated by the media, foster imagination with more subtle, everyday examples? Why is imagination so important for chemistry? Because chemists are different from other people in one decisive respect: chemists see molecules bounce, run, collide, and dance where and when other people see everyday life – or nothing ...

Let us accompany a chemist through his or her day and see some daily "events" with a chemist’s eyes!

7 a.m.: The **alarm clock** rings while the **digital display** switches from 6:59 to 7:00. Shouldn’t everybody want to know what happens in the display at that point? While stretching and yawning, the chemist sees rod-shaped molecules which are ordered like the steps of a winding staircase. He watches a polarized beam of light trying to dance with the molecules which indulge in this game and thus guide the polarized light to change its orientation by 90 °. This allows them to pass a filter and show us a bright area at the other end. When the alarm starts, the molecules obey the strong command of an electric field that aligns them, like logs of wood being rafted, in the field direction. No more guidance for the light beam – it hits the filter, and the area in the display becomes dark. Experiment: we observe a liquid crystal melting to become a turbid liquid, and at higher temperature a clear liquid. We listen to the history of the discovery and technology, starting with Reinitzer and Lehmann 1888/89 [5], and ending with the technical break-through and patent 1970 [6]. We follow the path of a polarised light beam through an TN-cell and see how structure is used for function.

7.10 a.m.: The chemist takes off his/her pyjamas/ night dress. While doing so the **rubber band** of the trousers is stretched and then goes back to its original shape. We bring down our own size to the size of the molecules in the rubber and watch them while the rubber is stretched. We see rotation motions of C-C-bonds and the untangling of coiled, entangled network-like molecular structures. We meet Hermann Staudinger and listen to the story [7] of a man who fought for his idea of the existence of large molecules, "macromolecules", while his academic adversaries kept up the old theories and even laughed at him in some cases. We learn how he convinced the scientific community with a simple, conclusive experiment (the hydrogenation of polystyrene). We get an idea of how his tenacity and the hard work of hundreds of polymer chemists and physicists led to new and better materials, and we smile about a by-product of the technical development which became a toy: "Silly Putty" [8].

7.55 a.m.: We accompany the chemist having breakfast. He or she starts with an **apple** - because "an apple a day keeps the doctor away". It had been cut and sliced for the chemist and **turned brown at the surface**. We share an observation that the Hungarian Nobel Prize winner Szent-György made in 1925. It struck his mind that patients suffering from Addison’s disease, a severe renal dysfunction, suffered from brown pigmentation of the skin [9]. He remembered that the apple will not become brown when the surface is soaked with lemon juice. He expected to find a substance in the lemon juice that would interfere in the browning of fruit and help to heal the disease. It later turned out that this idea was just too "simplistic" - but he discovered Vitamin C [10]. We see the structure of Vitamin C and learn that it inhibits an enzyme which takes part in the fruit browning process. We listen to his message: "Discovery consists of seeing what everybody has seen, and thinking what nobody has thought."

1:00 p.m.: Lunch time. We have chicken soup with "our" chemist and commemorate a colleague of the XIXth century who lived in a boarding house at little cost. It did not escape his always sharp attention that the cook served chicken soup every Saturday - and roast chicken every Thursday. What if ... . The thought took his breath! The week after, he brought a white powder, sprinkled it over the almost fleshless bones of his chicken half and waited for the Saturday to come. When the soup was served, he took a magnesia stick out of his pocket, soaked it with the soup and held into the flame of a Bunsen burner. The flame was intensively red! The lithium contained in the white powder had become a forensic chemist’s tool to convict the cook of having used the bones he and his poor fellow guests had gnawed clean on the Thursday before for making a chicken broth. We learn that the red light in a fireworks display is of the same origin. We again shrink our size to see the lithium atoms with a chemist’s eyes: they are "excited", the chemist’s wording for the uptake of energy in the flame, and then lose the energy again in the form of photons of (in the case of lithium) red light. Bunsen [11] and Kirchhoff published their groundbreaking discovery in Fresenius' Journal of Analytical Chemistry [12] in 1862. We see how chemists use absorption and emission of radiation to detect minute quantities of atoms or molecules in complex mixtures.

4:00 p.m.: The chemist drinks a **lemonade**, a home-made one. He/she mixes mineral water and lemon juice - and observes **effervescence**. Would anyone who is not a chemist or does not know the shorthand which chemists call "formulae" be aware that the chemical reaction causing the frothing is identical with the one that makes sherbet froth and with the one that makes cakes become fluffy when baking powder is added to the dough? Chemists would probably add that stalagmites and stalactites, and that scale found in hot water tubes and boilers are phenomena caused by the carbon dioxide - hydrogen carbonate - carbonate equilibria and describe them with similar and similarly simple equations. They classify reactions and thus have a systematic approach of a wide variety of daily observations - classifying is simplifying by using abstractions. We share this approach and see relevant experiments and their "shorthand description".

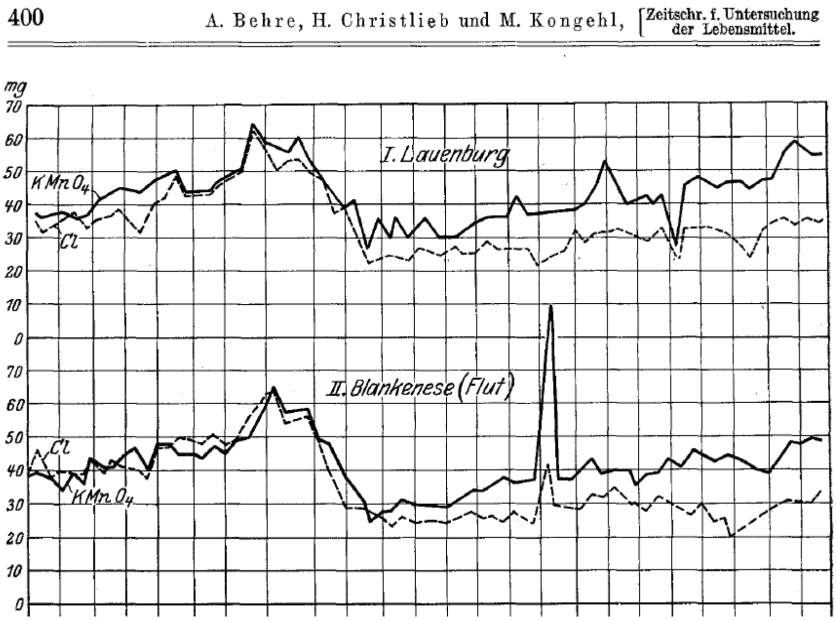


Figure 2. Evidence for water pollution obtained using the permanganate test [13]

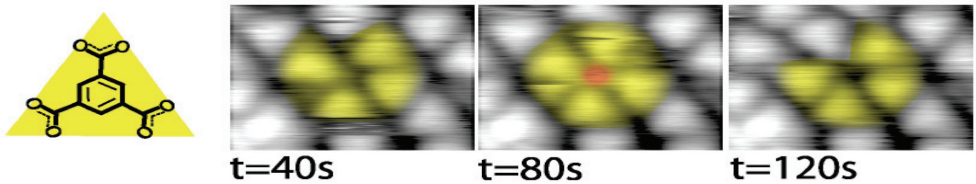
7:00 p.m.: The chemist has supper and eats, among others, healthy **garlic**. Healthy? This time we do not shrink, but move - we fly in time and space to a traditional Munich market where a salesman loudly praises his healthy product - garlic juice. How does the salesman illustrate his claim? He shows the curious audience he attracted verbally a violet liquid and says this is poison. He pours it into the garlic juice, and the colour is immediately gone. The garlic eats the poison! A chemist would see nothing spectacular in this observation - per-manganate is re-duced to Manga-nese(II) ions in acidic solution when, at the same time, it oxidises a wide variety of organic substances, such as some main constituents in garlic, alliin and allicin. A wine lover (like the author) would replace the garlic juice by a white wine and see the same effect, because many constituents of wine are equally oxidisable. The interested pupils who watch the presentation described here now learn that this reaction is used to quantify all matter present in e.g. drinking water that can be oxidised by Permanganate. Chemists call this a "global (or: composite) parameter". Another flight backwards in time brings us to an old publication which shows that the milligrams of permanganate that were discoloured by Elbe water back in the 1930s give an indication of environmental pollution in this river, and that allowed our colleagues of the time to detect a major pollution in the running river (revealed by the "peak" in the permanganate test result).

While "googling" the literature for this contribution, the author came across the following statement: *"Here we show that human RBCs convert garlic-derived organic polysulfides into hydrogen sulfide (H_2S), an endogenous cardioprotective vascular cell signalling molecule … . The vasoactivity of garlic compounds is synchronous with H_2S production, and their potency to mediate relaxation increases with H_2S yield, strongly supporting our hypothesis that H_2S mediates the vasoactivity of garlic."* [14] The biomedical chemistry aspects of the pharmacology of garlic are still investigated and still lead to new, unexpected findings. It is still worth while to study chemistry - the subject is very, very far from being exhausted!

8:30 p.m.: The chemist takes a **bath**. When she or he has finished and lets the water run down the drain, a **whitish-grey solid** remains on the wall of the bath tub which needs to be wiped off. While everyone else just wipes it off, the chemist sees its constituent molecules: two detergent molecules having a negative charge are captured by one calcium(II) ion having two positive charges. Together they form what chemists call a complex, and - here - an insoluble complex which is precipitated. We watch a model experiment using a soap solution and a calcium chloride solution and admire the thick, whitish flakes that emerge from the solution immediately.

9.00 p.m.: The chemist's baby cries. The **diapers** need to be changed. Diapers? They soak in the urine of the baby and thus keep its "bottom" clean and dry. How? What we need for this purpose is a solid which avidly takes up water like a

sponge. In contrast to a sponge, this material must not liberate the water when the baby turns around and lies on the diaper. A chemist designing such a material makes use of the high “affinity” for water of salt like, ionic large molecules that are crosslinked in such a way that they become huge, insoluble “macro-ions”. They bind water so strongly that even under mechanical pressure they will not liberate it again. We learn that one gram of such a material can bind up to 1000 grams or one litre of water.
The chemist’s day ends, and our presentation from a sample case, too. Many other experiments could be made in the same way, and some are currently being developed. What they all have in common is that a chemist has a particular view of our world. He or she sees atoms, ions and molecules dance. “Dance? What did I mean when I coined this term” said the author of this contribution to himself. He “googled” again and came across the following microscopic image and picture:



Tma-molecules bond in a flat adsorption geometry at a copper surface are resolved as equilateral triangle in STM. The sequence of STM images reveals how the thermal motion of molecules at the surface proceeds. Following rational motions and displacements, a single Cu atom is captured whereupon a cloverleaf-shaped $Cu(tma)_4$ coordination compound evolves (second image for t=80 s)

Figure 3. Dancing molecules in the www [15]

The author’s imagination had not carried him too far – there is a molecular correlation to what, in the macroscopic world, would be called dancing! The tma-molecules bounce and leap and capture a copper atom from a copper surface, and 40 seconds later let it go again!
What is everybody to benefit from this particular view of our world? We can discover, make and measure substances and produce new materials with better properties. We can make drugs, we can design more sustainable processes and produce energy in a way which saves cost and energy.

All this is and will be done by humans who were “infected” by the “chemistry virus”. We need to find them!

This is why CITIES will support teachers. And these are the teacher training modules which the project will deliver by October 2009:

Module 1: European context of chemical education, training and development

1. General Basic Information on EU policies, with special respect to the context of chemistry and chemical industry
2. International educational programs, sources of funding etc.
3. Different approaches to vocational and tertiary chemical education in Europe (not only: also secondary – EURYDICE), with a sub-section on student work experience and student mobility
4. Employability of the graduates in a global economy

Module 2: Commerce and innovation – our future

Scope and impact of the European Chemical Industry, its workers and employees and of chemistry based products on the European economy, on citizens' everyday life, on the environment and on the labour market

Module 3: Chemistry changes everything

Current and future development trends in the field of commercial application of chemical innovation, with particular regard to the European area (covering fields such as nano-technology, bio-technology, bio-analysis, sustainability of material and energy use, Green Chemistry, chemical engineering design etc.)

Module 4: Chemistry – bringing it alive

Modern, practically oriented, appealing methodologies of teaching chemistry to a broad spectrum of pupils from different abilities and interests, including those who are heading for a career in chemistry and those who will just be "users" of applications of chemistry and voters in elections (societal aspects)

- Forensic chemistry brought alive
- Chemistry of a tin of Ravioli
- Everyday chemistry experiments

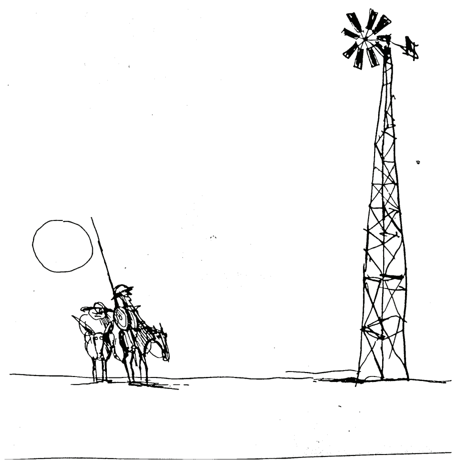


Figure 4. Don Quijote and Sancho Pansa contemplating the windmill

Imagination is as important as solid facts: Chemists need to have a bit of both Sancho and Don Quixote in their minds and hearts!

And wise chemistry teachers will follow the path described by Antoine de Saint-Exupéry:

"If I communicate to my men
the love of walking on the sea,
then you will see them soon diversifying
according to their thousand particular qualities:
that one will weave the fabrics,
the other in the forest will lay down the tree,
the other still will forge nails
and it will be some share which will observe the
stars to learn how to control,
and all however will be only one.
To create the ship,
it is not to weave the fabrics,
to forge the nails,
to read the stars,
but to instead give a taste for the sea." [16]

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