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Contributions on any matter of interest to second-level chemistry teachers are welcome. Normally the results of research (chemical or educational) are **not** published, except in a general form or as a review. Articles should be submitted electronically (email or disc) to peter.childs@ul.ie together with a printed copy to Dr. Peter E. Childs, Hon. Editor, *Chemistry in Action!*, University of Limerick, Limerick, Ireland.

For subscription details etc. see inside back cover.

Cover photo: Chemistry in art – one of series of paintings by David Cordes, Pacific University, Oregon, USA on the History of Organic Chemistry. This one features Louis Pasteur and Jacob van t'Hoff. Among his many accomplishments, Louis Pasteur also did some groundbreaking work in Organic chemistry, helping to work out some of the details of the three-dimensional structures of organic compounds. Later, Jacob van't Hoff would develop these ideas further, winning the Nobel Prize for his work. You can access a slide show of his paintings at:
http://newton.ns.pacificu.edu/~cordes/Cordes_Organic_Chemistry_Art_Show.pdf

Editorial

The century looms

This issue is #98 of *Chemistry in Action!*, which was first published in May 1980. This means that the Summer 2013 issue will be #100! We marked the previous milestone of 30 years of publication with issue #90 in 2010. However, it still seems appropriate to mark the publication of the 100th issue. If you have anything to contribute, any reminiscences, ideas to mark the occasion or just an article on an interesting topic, please send them in to me. I would like to make #100 a special issue and ideas and contributions from our readers are welcome.

Merger mania

I don't know about you, but I find it hard to keep up with the current merger proposals in higher education. There have been several different and conflicting proposals for mergers, acquisitions, regional groupings etc. and it is hard to see which, if any, of these will succeed and which are recommendations or merely suggestions. There have been strong recommendations for merging teacher education courses, and also for regional mergers or groupings of higher education institutions, as well as those proposed locally. The ultimate aim seems to be rationalisation and removal of duplication, sharing of resources, and presumably, saving money on both staff and facilities in the long-term. For such a small country Ireland does have a large number of higher education institutions, virtually all state-funded, and there is considerable duplication of courses. Each institution is competing against the others for students (witness the number of radio, TV, cinema and billboard advertisements before the CAO deadline.) There is apparently no strategic planning as to how many places to offer in an area in relation to the demand for the graduates. For example, the University of Limerick (originally through Thomond College) used to be the only place producing PE teachers and intake was linked to the number of jobs. Now there are several PE teaching courses and an over-supply of PE teachers. The same situation applies to science teacher education courses.

On the one hand the state has been investing in development and expansion of many higher education institutions, even in the last few years,

and on the other the state is calling for merger, and presumably closure, of some facilities. To put it mildly, it does not make much sense. It will be interesting to see how the 'merger mania' turns out and whether anything actually happens and whether it saves any money or improves things.

'Good, but could do better'

This was Minister of Education's, Ruari Quinn, comment on the results of the TIMSS 2011 and PIRLS 2011 surveys (see p.5) in the *Irish Times* 19/12/12. He said: "*Irish students scored significantly above the international average in both maths and science in the Trends in International Mathematics and Science Study (TIMSS 2011). Ireland was placed 17th in maths and 22nd in science out of the 50 participating countries.*" The Minister went on to comment on the time spent on various subjects in the primary school. "*TIMSS also challenges us to think about the importance we attach to different aspects of the curriculum. The performance of students in science is somewhat disappointing, although Irish students are above the international average. One underlying reason may be the lack of science skills among primary-school teachers, but the TIMSS study shows that Irish pupils spend considerably less time on science than pupils in other countries.*" Even though Northern Ireland (described as the new Finland in the *Irish Times* 15/1/13) did better in reading and maths, the performance in science was almost identical to the ROI score. This is an unexpected finding because primary science has been established for longer in N. Ireland schools (from 1990 compared to 2003) and has probably been better resourced. Given the good performance in maths and reading by N. Ireland, one might have expected better performance in science as well.

Assistant Editors

I am pleased to announce the following people have agreed to act as Assistant Editors of *Chemistry in Action!*: Marie Walsh, Limerick Institute of Technology and Sarah Hayes, Mary Immaculate College.

Peter E. Childs

Hon. Editor

Education News and Views

RSC | Advancing the
Chemical Sciences



The RSC is the leading organisation in Europe for advancing the chemical sciences. Supported by a network of 45,000 members worldwide, RSC activities span education and training, conferences and science policy as well as the promotion of the chemical sciences to the public. They have recently appointed a number Regional Coordinators to work locally on RSC educational aims, my name is Angela McKeown and I will be working as the RSC coordinator for Ireland.

The RSC education team aim to support Chemistry teachers and enable them to inspire their students into pursuing a future in the chemical sciences. Following their global strategy of electronic access, the RSC have put together a comprehensive platform called **Learn Chemistry** that enables Science and Chemistry teachers all over the world to access fantastic free resources. Find it at www.rsc.org/learn-chemistry.

Too many resources? Teachers can find out which ones other educators are finding useful by asking on the new Chemistry teacher forum (**Talk Chemistry**) on myRSC which is free to join. Go to <http://my.rsc.org/talkchemistry>.

The RSC have amassed their local members as **Chemistry ambassadors** within their communities, and these members will go out to schools to give talks to students about careers in Chemistry. I have ambassadors in Dublin, Cork and Galway ready to go out to your school - just fill in the online form at: <http://www.rsc.org/Education/Teachers/ChemNet/VisitRequestForm.asp>

The RSC will be offering some **free Teacher CPD** throughout Ireland this year, look out for "Learn Chemistry CPD" sessions on "the mole" and "redox chemistry" in Galway and Dublin so far this year.

For students the RSC have **ChemNet**, online support for 14-18 year olds studying chemistry. There are online magazines, online tutorials, an "ask Dr ChemNet" advice forum for help with homework and practical projects as well as competitions. Students will also be able attend ChemNet events throughout Ireland such as the Interactive Careers Sessions in Trinity College Dublin and Limerick IT coming up during science week 2012. Students can join for free at <http://my.rsc.org/chemnet>.

Don't forget that the regional coordinator will also act as a platform to get your voice heard, ensuring that the RSC continues to develop resources useful to your teaching community. So if you have any questions or ideas or want to hear more about events mentioned, get in touch with me at <http://www.rsc.org/Education/RegionalCoordinators/ireland.asp>.

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RDS Primary Science Fair

Primary school students representing 120 schools from across the island of Ireland displayed their class projects at the RDS Primary Science Fair from January 10-12, 2013.

The RDS Primary Science Fair takes place alongside the BT Young Scientist and Technology Exhibition and provides an opportunity for approximately 3,000 primary school students to showcase their class STEM (*Science, Technology, Engineering and Mathematics*) projects, receive feedback from experts in the field and learn from viewing other projects at a major exhibition.

The 120 participating schools represented 24 counties in the north and south of Ireland and come from as far afield as Fermanagh, Donegal, Clare and Cork. 4th, 5th and 6th class students aged between 9 and 12 years of age displayed their class projects in a specially designated RDS Primary Science Fair Zone of the Exhibition.

The RDS Primary Science Fair is not a competition, and the emphasis is on encouraging child-led investigation and for students to learn how to work scientifically and develop practical inquiry based skills. Students work as a class under the supervision of their teacher on a project

which should seek to pose and answer a question related to the primary science curriculum. Questions under investigation by primary schools at the 2013 Fair include:

- What would happen if earthworms didn't exist?
- What type of hurling ball will travel furthest and why?
- Can you use a broken ruler to measure accurately?

The RDS Primary Science Fair took place from Thursday, January 10 to Saturday, January 12, 2013 at the RDS with 40 different schools showcasing their class project on each day of the Fair. For further information on the RDS Primary Science Fair and a full list of participating schools and their projects, please visit:

www.rds.ie/primarysciencefair.

Since 1731, the RDS has continued to further the broad economic and cultural development of Ireland. The RDS Primary Science Fair is part of the RDS Foundation Science and Technology programme which aims to encourage the development of science and mathematical skills in primary school aged children by fostering education innovation.

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Videos of the Leaving Certificate Mandatory Experiments

As a result of requests from many Chemistry teachers, videos are now available of the mandatory experiments: [Preparation of Ethanal](#), [Preparation of Ethanoic Acid](#) and [Investigating Le Chatelier's Principle using Cobalt\(II\) Chloride](#).

Teachers will find these videos particularly useful as these experiments involve the use of chemicals, which are no longer recommended as being suitable for use in schools by the Department of Education and Skills. The videos may be viewed online at <http://chemistrylive.folensonline.ie>

As Folens have sponsored the videos, the site is password protected and passwords may be obtained from Folens.

In addition to the above experiments, the website also contains videos of all of the other Leaving Certificate chemistry mandatory experiments. The experiments were filmed in the science education laboratories of the [Eureka Centre in UCC](#), which are used for training science teachers. The videos show the experiments being performed by Dr Declan Kennedy and three of his recently graduated student science teachers - David O'Connell, Jamie Semple and Alan O'Donoghue.



The purpose of the videos is to help students revise the mandatory experiments for their Leaving Certificate chemistry examination. Students must still carry out the experiments themselves, collect their own data (where relevant) and write up each experiment as per the guidelines from the Department of Education and Skills. Hence, data have not been provided in the videos for each individual experiment. It is also hoped that the videos will be of help to students when preparing to carry out the experiments themselves, as all apparatus is clearly shown and the relevant practical skills required to carry out each experiment is also included.

Please note that these videos are only available to teachers adopting Declan Kennedy's LC Chemistry textbook from Folens. See p.15 for alternative videos.

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Results from PIRLS 2011 and TIMSS 2011 studies

<http://www.education.ie/en/Publications/Education-Reports/PIRLS-TIMSS-2011-Reading-Mathematics-and-Science-Outcomes-for-Ireland-Main-Report-.pdf>

"In 2011, Ireland participated in two major international studies assessing the skills of Fourth class pupils. PIRLS (Progress in International Reading Literacy Study) examined pupils' reading achievement, while TIMSS (Trends in International Mathematics and Science Study) examined mathematics and science achievement" The results of the studies on maths, reading and science attainment in primary schools were released in Dec. 2012. Ireland was 10th in reading (N. Ireland was 5th); 17th in maths (N. Ireland was 6th); 22nd in science (N. Ireland was 21st). This is a summary of the science results, the first time Ireland took part in TIMSS since 1995.

"With a score of 516, Irish pupils performed significantly above the scale centre-point of 500 on the TIMSS science assessment. Ireland's mean score was significantly higher than that of 22 other countries, and similar to the scores achieved in 10 countries, including Northern Ireland and Australia. Seventeen countries – including Singapore, Finland, the US, England, and Germany – had significantly higher mean scores on the science assessment than Ireland."

In Ireland, boys and girls obtained identical mean scores (516), mirroring the lack of any notable gender differences on the overall international average science scores – girls averaged 487 and boys averaged 485. Roughly half of participating countries had no significant gender differences on the science assessment. In countries where differences were found, those where girls outperformed boys were broadly counterbalanced by those where boys outperformed girls."

Irish pupils performed at a similar level across the three science content domains of Life science, Earth science and Physical science. The mean of 520 for Earth science was the highest score, but was not significantly higher than the means for Life and Physical science. However, on the cognitive subscales for science, Irish pupils showed a relative weakness on Reasoning, with a mean score of 509, compared to their score of 516 on the overall science scale."

As with mathematics, Ireland has not participated in a comparative international study of science achievement at primary level since TIMSS 1995. Comparing science achievement across that timeframe, the difference between the mean score of 515 in 1995 and the 2011 score of 516 is negligible. Achievement by Irish pupils in science now is therefore broadly similar to performance in 1995. However, as with mathematics, it is worth noting that Ireland is significantly above the TIMSS science study centrepiece in TIMSS 1995 and 2011, in contrast to the performance on IAEP II in 1991, but similar to performance on successive cycles of PISA at post-primary level. The lack of any significant gender differences in science achievement among Fourth class pupils in 2011 also mirrors the findings of TIMSS 1995 and successive cycles of PISA from 2000 to 2009."

This report contains much interesting information and the success of N. Ireland in maths and reading, where they are near the top of the table and well ahead of the Republic, bears some further analysis. (See *Irish Times* 15/1/13 <http://www.irishtimes.com/newspaper/education/2013/0115/1224328845766.html>)



The Learning Curve Report

This important report, reviewing research on educational performance in a number of countries, including Ireland, was published at the end of 2012 and is available online at:

<http://thelearningcurve.pearson.com/>

The report has five lessons for education policy-makers:

1. **There are no magic bullets:** The small number of correlations found in the study shows the poverty of simplistic solutions. Throwing money at education by itself rarely produces results, and individual changes to education systems, however sensible, rarely do much on their own. Education requires long-term, coherent and focused system-wide attention to achieve improvement.

2. **Respect teachers:** Good teachers are essential to high-quality education. Finding and retaining them is not necessarily a question of high pay. Instead, teachers need to be treated as the valuable

Aerosols – relevant for climate and medicine

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The volcanic eruption of Eyjafjallajökull, Sahara sand over Europe, condensation trails of airplanes, clouds, green zones and particulate pollution: all these points can be united under the term of aerosols. Some examples denote sources of aerosols, while others are consequences. Especially in connection with the concept of fine dust it is common to think of a man-made phenomenon. But in fact, natural aerosols (fog, smoke, volcanic ash) show that man is not always the source of aerosols. Large parts of the aerosols emitted daily are of natural origin and have been with us since long before industrialization.

Scientific background

Basically, there are two sorts of aerosols: primary and secondary aerosols. Primary aerosol

emissions derive from both natural and anthropogenic sources, while secondary particles are formed in the atmosphere from trace gases such as NO_x, NH₃, SO₂, H₂S, or gaseous organic compounds (volatile organic compounds, VOCs) [1]. The reactions that form these secondary particles in the atmosphere are called gas-to-particle conversion (GPC).

Aerosols can further be divided into biogenic (microorganisms such as fungi and bacteria, pollen and spores, but also isoprene and terpenes from forests, see Table 1), inorganic abiotic (sea salt, mineral dust, carbon black or volcanic ash) and organic abiotic aerosols, like anthropogenic aromatic compounds and solvents.

Table 1: Classification of Aerosols.

	Primary	Secondary
Natural	sea salt, mineral dust, volcanic ash, fungi, bacteria, pollen, spores	biogenic VOC-Emissions (BVOC), mainly terpenes and dimethyl sulfide
Anthropogenic	black carbon	NO _x , NH ₃ , SO ₂ , H ₂ S aromatic compounds, solvents

Sources of aerosols

The sea salt of the world's oceans, with an amount of about 1,000 million tons per year, is the largest share of the primary aerosols. They result mainly from bursting of air bubbles at the sea surface. The other main source is mineral dust, which is stirred up mainly during spring storms and is distributed by convection of particle streams in the troposphere over very long distances. Places of origin are particularly large dry areas like the Sahara, the Arabian Desert and the Gobi Desert. Depending on the origin of the mineral dusts, aerosols are made of silicates, aluminosilicates,

calcite and kaolinite. Calcite, a form of calcium carbonate, is an important reactant for acidic trace gases such as H₂SO₄ or HNO₃ [2].

But overall, the natural secondary organic aerosols dominate. They are formed by oxidation of unsaturated hydrocarbons (e.g. isoprene, mono- and sesquiterpenes, see Figure 1), which are released by trees. The secondary aerosols play an important role for cloud formation. Often in the morning, one can observe this phenomenon over a forest [2] (see Figure 2).

Figure 1: Examples of monoterpenes (except Isoprene and β -Bisabolen) from trees.

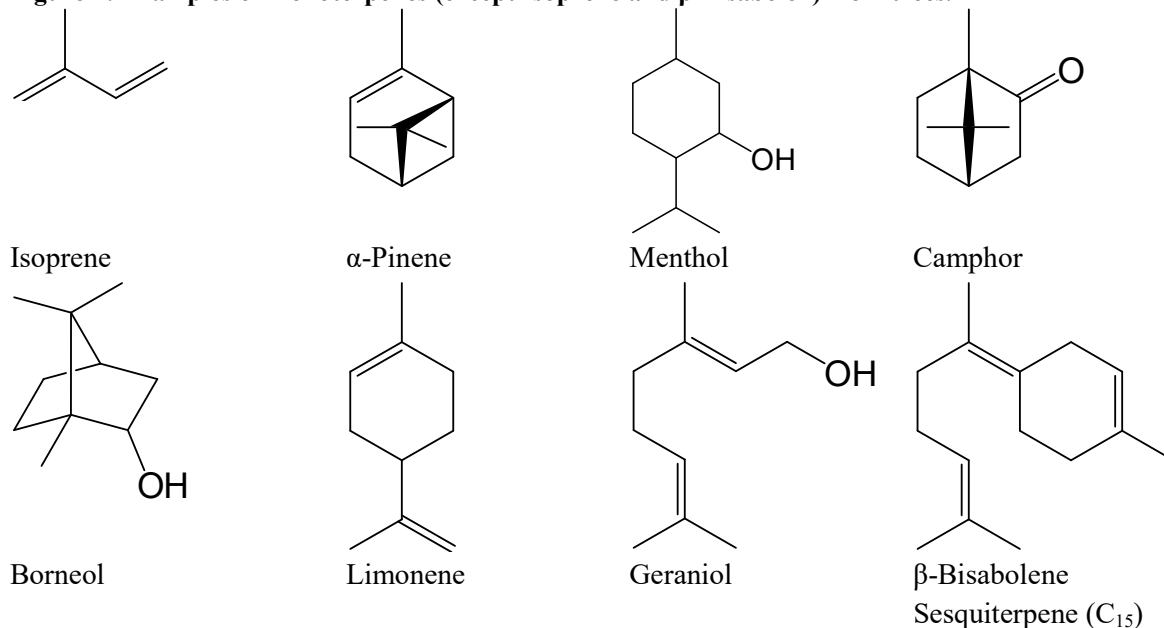


Figure 2: Cloud formation over a forest induced by secondary aerosols released from the trees.

Sources of anthropogenic emissions are mainly the transportation system, incineration for energy (power and heating plants) and other combustion plants based on wood, coal, oil and gas (e.g. in residential buildings), industrial processes (metal-generation, sintering plants) and repackaging of bulk material. The main sources of emissions in Germany are the burning of fossil fuels and the associated release of black carbon [1].

Black carbon – a very interesting aerosol

While fossil fuels based on hydrocarbons (neglecting impurities) react under ideal conditions to form CO_2 and H_2O , under inadequate oxygen supply this reaction leads to the formation of black carbon. Large quantities of black carbon are released into the atmosphere by industry, transportation and heating processes. So

aerosols based on black carbon are in the focus of the debate about the greenhouse effect.

Unlike other aerosols, black carbon takes is particularly important due to its light-absorbing properties. In particular, the air convection carries these aerosols to a very sensitive layer of the atmosphere, where they impact heavily on the radiation balance and the greenhouse effect. Studies have shown that the adsorption of water vapour by black carbon at a height of 5,000 m and higher is an important process for its lifetime and for the formation of clouds and condensation trails of jet aircrafts [2].

Size classification of aerosol particles

Generally, aerosols can be subdivided according to their diameter. A commonly accepted distinction is as follows [1]:

Ultrafine particles (UFP):	< 100 nm
Fine particles:	< 2.5 μm
Coarse particles:	2.5 μm - 10 μm

Medically relevant are particles smaller than 10 μm , which are inhalable and particles smaller than 2.5 μm , which can penetrate the alveoli. The air quality directive of the European Union commits the member states to keep the pollution of particles of this size as low as possible ("regulation of fine dust").

Distribution and lifetime

The lifetime of aerosol particles in the air shows a clear dependence on the particle size (corresponding index, see Table 2). Typically, about 10^{-2} to 10^{-6} particles were found in the lower atmosphere with a total mass concentration of about 5-100 $\mu\text{g}/\text{m}^3$. Due to the high mobility of aerosols, local observations are difficult to evaluate, and in many cases no direct connection between the occurring aerosols to a cause or possible source can be found. Some days, the daily mean values correspond to the expectation that large industrial areas are more polluted than the countryside. Other days, the situation is completely different and previously uncontaminated areas are largely affected by particulate matter.

Table 2: Life times of aerosols.

Particle size	Life time in the atmosphere
approx. 10 nm	a few hours; conversion with other particles
0.1 - 1 μm	lower troposphere (0-5 km): some days upper troposphere (5-18 km): up to four weeks stratosphere (18 km and higher): up to three years
more than 10 μm	a few hours, due to sedimentation rate

Formation of secondary aerosols

During the gas-to-particle conversion, the precursor gases emitted by oxidation processes, form low-volatile products. Using the example of sulphur compounds, which may as well be of natural origin, we can illustrate this fact.

In several reaction steps gaseous emissions such as SO_2 , H_2S or Me_2S are oxidized to sulphuric acid, which on the one hand may condense with pre-existing aerosol particles. On the other hand, the molecules can begin to form new particles by a process called nucleation. The absorption of water by sulphuric acid is a key step, because the absorption of water-soluble compounds is possible in this newly formed solvent. This allows further chemical reactions inside the water drops. Various sulphur compounds such as SO_2 are converted by oxidants such as H_2O_2 or ozone to sulphur in the oxidation state +VI, for example. This provides a plausible explanation for high sulphate concentrations. Often, the ammonium cation is found as a counter-ion for sulphate. This occurs in the acidic particles from ammonia that are released through agricultural processes.

Aircraft condensation trails as a climate factor

Condensation trails of jet aircrafts were suspected of acting on regulating the temperature at the earth surface, but there was no scientific proof. But with the attack on the World Trade Centre on 11 September 2001, the complete air traffic over the United States of America was banned for three days. During this period it was possible to compare the temperature differences between day and night without condensation trails, with the usual situation. Travis *et al.* [3][4] compared for the first time the surface temperature, meteorological satellite images and further weather information from a 30-year period prior to the flight ban (1971-2000) with the information collected during the flight ban (11-14 September, 2001).

To make the differences in temperature comparable, the temperature difference between daily maximum and nightly minimum was determined for each day, because this difference is relatively constant during the season. In comparison with the reference period, averaged over the measurement period of three days, the value increased significantly by more than 1 $^{\circ}\text{C}$.

This observation can be attributed to two properties. For one, the condensation trails, which are stable for several hours, have a particularly good reflection property of infrared radiation from the earth. On the other hand, they shield the earth's surface from incoming radiation from space. The lack of reflection of infrared radiation results in a significant decrease in temperature at night time. This insulating effect of clouds is known especially in the cold season, when the temperature at night drops strongly due to a clear, starry sky. In daytime, the lack of shielding from radiation from space results in a significant increase of the temperature on the earth's surface. Thus, the significant spread between daily highs and nightly minimum is explainable [3][4].

Radiation budget of the earth and global dimming

The incident solar radiation on the earth is partially reflected from the earth and the ratio of backscattered to incident solar radiation is called the albedo. If the albedo is 0.40, for example, only 40 % of the incoming radiation is reflected. The energy balance of uptake and release of extraterrestrial radiation, taking into account all the interactions, is also known as the earth's radiation budget and depends on many factors, which are closely connected with our atmosphere. We distinguish direct, indirect and other aerosol effects on radiation balance. Direct effects are the influences which are caused directly by interaction of aerosols with incident radiation. These include the scattering, absorption and reemission. For example, inorganic salt and sulphate aerosols cool the ground through reflection of incoming radiation. Especially black carbon cools the ground as well, but at the same time the upper atmosphere is heated by the radiation absorbed by the carbon particles. These indirect effects of aerosols play an important role for the climate balance of the Earth. One example is the clouding process that takes place even at low water vapour super-saturation in the troposphere. The aerosol particles act as condensation nuclei for the droplet formation. Research has shown that a particularly high number of condensation nuclei from aerosol particles, for example via shipping routes, lead to an increase of clouds with a long lifetime and low precipitation efficiency, since the size of water drops is not sufficient to produce rain [2][5].

Worldwide long-term studies have shown a significant decrease of solar radiation on the

Earth's surface. As a main reason, anthropogenic emitted aerosols mainly from fossil fuels are suspected. In contrast to the greenhouse effect, the aerosols cause cooling to the Earth's surface by direct and indirect effects. The indirect effects include the formation of clouds with very little chance of rain. The interplay of a reduced incident solar radiation with a corresponding reduction in water evaporation and low precipitation of the resulting clouds is called global dimming [6].

Natural aerosols and their impact on the climate and economics

Taking a closer look, a variety of control circuits in nature can be found where aerosols play an important role. Two examples should illustrate this phenomenon. Charlson *et al.* [7] found a species of marine algae that release dimethyl sulphide (DMS) after death and degradation by zooplankton. DMS is converted by chemical processes into sulphate and methane, which form secondary aerosol particles. The warming caused by greenhouse gases leads to an increase of the DMS-releasing seaweed. This consequently leads to an increase in aerosol particles over the sea, which is associated with a decrease in surface temperature. In other words, the seaweed helps in keeping the climate in a stable condition.

Another, better known phenomenon is the impact of volcanic eruptions on the climate. One very important example is the eruption of the Tambora in 1815. Nearly 160 km³ of particles with a mass of about 140 billion tonnes were released to the atmosphere. The year 1816 is also known as the "Year without a Summer" because of the low temperatures caused by the volcanic ash in the atmosphere. The average annual temperature decreased by about 0.4–0.7 °C. The effect was dramatic: in Europe, several nations suffered from crop failure and economic crisis and a period of emigration from Europe started.

Aerosols in medicine

The gas exchange between the body and the environment is one of the fundamentals of life. This gas exchange occurs in our body mainly in the lungs. Together with the nose, the throat, the larynx and the trachea it forms the respiratory system of our body. If any foreign substance except air enters the lung, a strong cough is immediately triggered as a defence mechanism, ensuring the expulsion of the foreign particle. In addition, the so-called *cilia epithel*, which consists of millions of cilia, carry the foreign particles and

mucus to the throat. This ingenious system works only up to a minimum size of pollutant particles. If this threshold is breached, harmful particles like fine particles ($\text{PM}_{2.5}$) can accumulate in the lungs. They can penetrate into the alveoli (air sacs), deposit and lead to permanent pathological changes of lung tissue, like the coal workers' pneumoconiosis [8].

Modern medicine has taken advantage of this otherwise undesirable phenomenon of respirable particles, to administer drugs directly into the lungs with fewer complications. On the one hand, these can then be absorbed very quickly; on the other hand, lung diseases can easily be treated locally. For example, a person suffering from bronchial asthma has an obstructed respiratory track. It is therefore useful to apply the anticonvulsant drug directly into the lungs either with powder inhalers, nebulizers or inhalation aerosols [9]. The aim of all of these variants is to produce active ingredient-containing particles of a given target size, which can enter the respiratory tract with the air flow. Particles larger than $5\text{ }\mu\text{m}$ do not penetrate deep enough into the respiratory tract because they are too slow and can deposit in the throat. Particles smaller than $1\text{ }\mu\text{m}$ are subject to Brownian motion of the surrounding gas molecules and follow the exhaled air. Only particles with a size between 1 and $5\text{ }\mu\text{m}$ can penetrate deep enough into the lungs and remain there, in order to exert their effect [10].

Aerosols as a possible part of chemistry education

Aerosols offer multiple ways to integrate environmental and multidisciplinary aspects in teaching chemistry. In the following section some of these possibilities are presented. As a curriculum base, the core curriculum for lower secondary schools (class 5-10) in Lower Saxony, Germany [11] was used.

Class 5/6

In the lower grades pupils already learn about the classification of substances and mixtures, in which the aerosols (namely black carbon) can be introduced as example of heterogeneous mixtures. Furthermore it can be discussed that aerosols have both natural and anthropogenic sources. In mathematics, where sizes close to everyday life are discussed, the size of the aerosols could be

mentioned and compared with the normal everyday sizes, to point out their small size. The description and explanation of basic weather elements and weather phenomena are part of geography classes. Thus the formation of clouds could be seen from a chemical point of view, since the aerosols are necessary condensation nuclei for water vapour.

Class 7/8

During geography class, students deal with environmental impacts of transport. This topic can be deepened by working on the impact of aerosols caused by transportation. Because of a high amount of particle emission, smaller water droplets are formed in the clouds, leading to a longer life of the clouds, and thus to the global dimming effect. The elongated lifetime of clouds causes a lack of rainfall in certain regions of Africa, which has a direct impact on the livelihood of the local population. The influence of aerosols on the heat balance of the earth and its cooling effect, which can be shown well by different experiments (see next section), has a direct relation to teaching physics (thermal radiation). In chemistry class these experiments could be part of the topic of oxygen. In addition to oxygen, it is advisable to treat the formation, the properties and importance of ozone and to demonstrate the formation of secondary aerosols.

Class 9/10

In the context of organic chemistry, important organic substance groups are presented. Since a basic understanding of the influence of the climate can be regarded as quite socially relevant, the terpenes could be integrated into chemistry classes. It is a very heterogeneous class of compound, making a reduction e.g. to alkanes and alkenes of the terpenes necessary. Terpenes are found to a high degree in lemon or pine needle oil, so the properties of the terpenes can be experimentally developed by using these substances. A reference to geography topics can be made to discuss the natural and anthropogenic causes of climate change and its consequences. Since aerosols are formed both naturally and anthropogenically, this could be a new aspect of the climate discussion. Looking at the natural temperature regulation of the earth by volcanic eruptions, biogenic terpene or other emissions, aerosols are integrated into the classroom.

Table 3: Some internet resources about aerosols.

Source	Link
Brookhaven National Laboratory News	http://www.bnl.gov/bnlweb/pubaf/pr/pr_display.asp?prid=06-09
Pacific Northwest National Laboratory	http://www.pnl.gov/atmospheric/research/aci/aci_aerosol_indeffects.stm
Meteorological Research Institute	http://www.mri-jma.go.jp/Project/1-21/1-21-1/aerosol-en.htm
Alfred-Wegener-Institute	http://www.awi.de/en/research/research_divisions/climate_science/atmospheric_circulations/research_themes/aerosol/aerosol_forcing_due_to_arctic_haze/
Earth Observatory NASA	http://earthobservatory.nasa.gov/Features/Aerosols/
MPI for Chemistry	http://www.nasa.gov/centers/langley/news/factsheets/Aerosols.html http://www.atmosphere.mpg.de/enid/5dadafb8c54cc1b463f636f695c7481e,0/Climate_in_brief/-_Clouds_Aerosol_2t8.html
Esa Kids	http://www.esa.int/esaKIDSen/SEMP4LXJD1E_Earth_0.html
Kids.Net.Au	http://encyclopedia.kids.net.au/page/ae/Aerosol
BBC Documentation	Part 1: http://www.youtube.com/watch?v=bLfBXRPOHRC
Global Dimming	Part 2: http://www.youtube.com/watch?v=2e_XBwPHqz8 Part 3: www.youtube.com/watch?v=ueaib127Ebk Part 4: http://www.youtube.com/watch?v=ayd5R2NkVcA Part 5: http://www.youtube.com/watch?v=yA74df19bWs

Model experiments with pine needle oil

The following school experiments presented here have been revised on the basis of a previous publication [12].

Preparation of Ozone

Equipment:

Hoffmann decomposition apparatus, DC power source, silicone tubing, gas syringes with tap (100 cm³), stand, clamps, couplings

Chemicals: sulphuric acid, c(H₂SO₄) = 5 mol/L

Procedure:

The Hoffmann's electrolysis unit is filled completely with 5M sulphuric acid and the valves are closed. The syringe is connected via a silicone tube to the gas valve at the positive pole. The platinum electrodes are connected to the DC power source and it is electrolysed with max. 15 V and 0.6-0.8 A. At the positive pole an oxygen-ozone gas mixture is formed, with a proportion of about 0.1-0.2 % ozone. Hydrogen gas is formed at the negative pole. Then, 100 cm³ of the ozone-oxygen gas mixture is transferred into the gas syringe and the hydrogen gas is released into the fume hood.

General remarks:

Per experiment, 100 cm³ of the oxygen-ozone mixture are needed. The electrolysis time takes about 45 min. It is therefore advisable to prepare the required amount in the gas syringe shortly before class. The gas mixture should be prepared at the same day and not at the day before, because ozone decomposes rapidly. Gas syringes are not greased, otherwise the flask may shatter.

Experiment 1: Formation of Aerosol

This experiment serves as basis for all following experiments.

Equipment:

Round-bottomed flask (1000 cm³), rubber stopper (double pierced), glass tube with a 90° angle, silicone hose, stand, clamps, couplings, measuring cylinder

Chemicals: 100 cm³ of oxygen-ozone gas mixture, pine needle oil

Remarks:

For the formation of aerosols, different substances were tested. The pine needle oil gives the most impressive aerosol. It can be purchased,

like lemon oil, from a pharmacy and can be used multiple times. Less impressive aerosols arise from turpentine (15 g) or finely chopped pine needles or organic lemon peel (15 g).

Procedure:

The round-bottomed flask is filled with 15 cm³ of pine oil, tightly capped with a rubber stopper and thoroughly shaken, so that the liquid distributes well. After 5 min sufficient steam saturation should be established. For further procedure the flask is fixed to a stand and the rubber stopper is exchanged with a prepared pierced stopper with the glass tube. Once placed on the flask, it is advisable that the opening of the glass tube is just above the level of the pine oil and absolutely necessary to leave the second opening for pressure compensation. The gas syringe is connected to the glass tube with a silicone hose and fixed to a stand as well. Then all of the gas mixture is quickly and evenly transferred to the round bottom flask. The pierced stopper is replaced immediately by a normal stopper to prevent the aerosol from escaping.

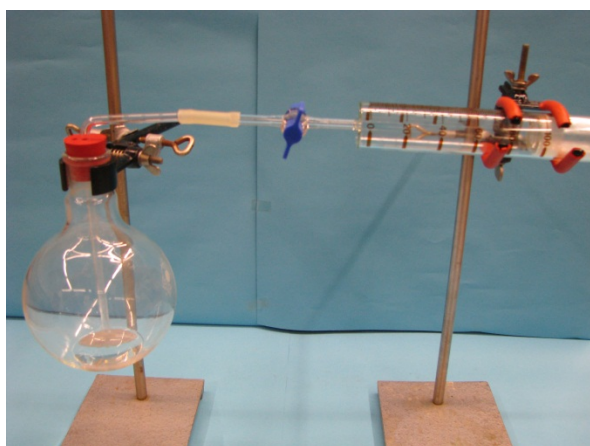


Figure 3: Experimental set up for the formation of the aerosol

Results:

The initiation of the oxygen-ozone gas mixture immediately creates a dense aerosol.

Disposal:

The aerosol is released into the air. The pine oil can be either reused or disposed as organic, halogen-free waste.

Experiment 2: Change in illumination

Equipment in addition to Experiment 1: lamp with bulb (75 W minimum), light meter
Chemicals: 100 cm³ of oxygen-ozone gas mixture, pine needle oil

Procedure:

The light meter is placed 2-3 cm behind the round flask. The light is placed opposite, so that the flask is between the lamp and the light meter. Everything should be placed at the same height at the widest point of the flask (see Figure 4). The round bottom flask was charged with 15 cm³ of pine oil. After it has been saturated with vapour, the light is switched on and the zero value of the light intensity is measured. Then the oxygen/ozone gas mixture is transformed into the flask. The light intensity is recorded every 10 s.



Figure 4: Experimental set up of experiment 2

Results:

In our experiment, the zero value was 38,000 lux. Once the aerosol has completely formed, the light intensity decreased by 12,000 to 26,000 lux. Due to decomposition of the formed aerosol, the light intensity increased and after approx. 19 min. reached its initial value.

Disposal:

The aerosol is released into the air. The pine oil can be either reused or disposed as organic, halogen-free waste.

Experiment 3: Temperature Change

Equipment:

In addition to experiment 1: lamp with bulb (75 W minimum), temperature sensor, black cardboard

Chemicals: 100 cm³ of oxygen-ozone gas mixture, pine needle oil

Procedure:

The temperature sensor is mounted on the black cardboard box, with as much contact as possible. It is attached to the stand about 2-3 cm behind the flask. The light is placed opposite, so that the

flask is located between light and temperature sensor. The light and the temperature sensor should be adjusted at the same height and the widest point of the flask (see Figure 5). The round bottom flask is charged with 15 cm³ of pine oil and after, as described above, the flask is saturated with steam, the light is switched on. The flask heats up until a constant temperature is reached (note starting temperature). This takes about 15 min. Then the oxygen/ozone gas mixture is transferred into the flask. The temperature is recorded every 30 s.



Figure 5: Experimental set up for experiment 3

Results:

In our experiment, the zero value was 30.9 °C. Once the aerosol has completely formed, the temperature decreases by 1 °C (from 30.9 °C to 29.9 °C). With decomposition of the aerosol the temperature rises again. However, after 15 minutes it has not yet reached its initial value. Re-addition of ozone can demonstrate this phenomenon again. It was observed that the temperature, even after multiple introductions of ozone, always decreased by 1 °C.

Disposal:

The aerosol is released into the air. The pine oil can be either reused or disposed as organic, halogen-free waste.

Experiment 4: Formation of a cloud

Equipment:

In addition to Experiment 1: Erlenmeyer flask (250 cm³), Bunsen burner, tripod with wire mesh, rubber stopper (one time pierced) with a short glass tube, hose

Chemicals: oxygen-ozone gas mixture (100 cm³), pine needle oil (15 cm³), water (100 cm³)

Procedure:

The Erlenmeyer flask is fitted on the wire mesh over the Bunsen burner, filled with 100 cm³ of water and the water is boiled. In the meantime, the round bottom flask is equipped with 15 cm³ of pine oil and after, as described above, the flask is saturated with gas, the ozone gas mixture is transferred into the flask. After a rich aerosol is formed and the water boils, the water vapour is lead into the flask. For the success of the experiment it is important that a strong water vapour stream comes out of the hose.

Results:

The result is a cloud in the flask. After a few minutes, fine water droplets start to deposit on the inner glass wall: the cloud condenses.

Disposal:

The aerosol is released into the air. The pine oil can be either reused or disposed as organic, halogen-free waste.



Figure 6: Experimental set up for experiment 4

Experiment 5: The Influence of the Cloud on the Illumination

This experiment connects experiment 2 and 4. The effect of the cloud on the illuminance is measured with the light meter. The light intensity decreases further and faster than during the aerosol experiment. The light intensity is reduced by 15 200 lux (from 39,000 lux to 23,800 lux). This represents an additional reduction of 3,200 lux with the cloud, compared to the aerosol. The output value is reached after 5 min when continuous water vapour is passed into the flask. This is probably caused by the nucleation and subsequent wash-out of the aerosol. The measurement of the temperature change through the cloud cannot be measured because of

the hot water vapour, the results are not significant.

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Alternative videos on Organic Chemistry practicals

Compiled by Anne O.Dwyer

There is a range of good Chemistry videos at Franklychemistry. These are available at: <http://www.youtube.com/user/Franklychemistry/videos?view=0>

Oxidation of ethanol

These videos are accompanied by a comprehensive narration:

Preparation of ethanol using sodium dichromate:

<http://www.youtube.com/watch?v=i7Ai5JdPYaY>

Preparation of ethanoic acid using excess sodium dichromate:

<http://www.youtube.com/watch?v=VwEiuNPkm3g>

Le Chatelier's Principle:

These videos are available from CHEMTODDLER.com:

Video of cobalt chloride and concentrated hydrochloric acid:

Effect of concentration:

<http://www.youtube.com/watch?v=GS9klj9n-BU>

Effect of temperature:

<http://www.youtube.com/watch?v=BGfYf8OQzuk>

Video of potassium dichromate, hydrochloric acid and sodium hydroxide:

Effect of concentration:

<http://www.youtube.com/watch?v=zP9qEiaL4kQ>

Video of iron(III) chloride, potassium thiocyanate and hydrochloric acid:

Effect of concentration and temperature:

http://www.youtube.com/watch?v=xT43fdoT_4w

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Introducing Isomers for Leaving Certificate Organic Chemistry

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Introduction

The *Organic Chemistry in Action!* programme is a set of teaching materials designed to improve pupils' interest and understanding in Leaving Certificate Organic Chemistry. Details of this programme have been outlined in a previous article in *Chemistry in Action!* (Issue 95, pages 8-15).

Here, we will take a closer look at one of the difficult topics in leaving Certificate Organic Chemistry: Isomerism. The material presented here is taken from the Teacher's Guide and then the corresponding lessons sheets from the Pupil Handbook are given, in a form that can be copied by teachers.

The Leaving Certificate Chemistry syllabus requires pupils to understand (DES, 1999):

- Systematic names, structural formulae and structural isomers of alkanes C-5
- Systematic names, structural formulae and structural isomers of alkenes C-4
- Improving octane number by isomerisation
- Primary and secondary alcohols

To understand isomerism, pupils need a prior knowledge of straight-chained alkanes and alkenes. Pupils should be familiar with the prefixes used for the number of carbon atoms; meth, eth, prop, but etc. Pupils should be able to name straight-chained alkanes from the molecular and structural formulae.

Through this introduction to isomers, the pupils will extend their understanding of the IUPAC naming system by learning how to name branched alkanes. The rules of IUPAC nomenclature that are introduced and learned provide the fundamental tools for naming all other families of organic compounds in the pupils' study of Organic Chemistry. For this reason, it is important that these rules are introduced through worked

examples and the pupils are given sufficient opportunities to practice and understand this new concept.

Learner misconceptions

Difficulties in recognising isomers of organic compounds are closely related to the difficulties and misconceptions related to the representation of organic compounds. If learners cannot recognise substituents or carbon chains, or understand the three-dimensional nature of organic compounds, it is easy to understand how they have difficulty in identifying isomers of compounds. Without an understanding of the structural representations of organic compounds, learners find it difficult to recognise isomers, and resort to selecting compounds that have the same shape (branched or straight) as isomers (Taagepera and Noori 2000). Learners also often incorrectly restrict isomeric relationships to compounds from the same family (Schmidt 1992). While this illustrates a difficulty with isomerism, it does suggest that the learners have the ability to recognise common functional groups within compounds. However, the recognition of functional groups as a method of classifying organic compounds is also another area of difficulty for learners.

Possible difficulties

Both activities outlined here (using plastic building blocks and molecular models) lend themselves well to inquiry-based learning. Through exploration of a problem, the pupils discover for themselves what an isomer is. However, it is important to watch out for structures, which the pupils may mistake as structural isomers, which may in fact actually be the same structures. E.g. bending butane into an 'n' shape is structurally the same as bending the molecule into a 'u' shape.

It is important to encourage the pupils to rotate and examine the molecular models in their hands. Working in pairs is particularly useful for these

activities, as one pupil may see something different from the next pupil.

It is important that the pupils focus on learning and practising the rules of the IUPAC nomenclature rather than memorising the names of the alkanes. Understanding the rules and how to apply them will enable the pupils to name any alkane.

New vocabulary

- Structural Isomer
- Alkyl group

The word isomer comes from Greek: 'isos' means equal and 'méros' means part i.e. structural isomers have equal parts (same molecular formula, same number of atoms) but different structural formulae.

Alkyl groups have the same prefix names as alkanes according to the number of carbons present. Alkyls are like alkanes but have lost one hydrogen atom, hence ending in 'yl' instead of 'ane'.

E.g.

Methane → methyl,

Ethane → ethyl,

Propane → propyl.

Pupil Activity 1- Plastic building Blocks

The pupils can work in groups of two/three for this activity depending on the availability of plastic building blocks. Working with a partner for this activity may be more effective than working individually, as more possible structures may be discovered. Any coloured building blocks can be used. It is best at this stage to restrict use to just two colours. The colours red and yellow are just used as reference colours in the procedure in the Pupil Worksheet to facilitate the pupils' understanding of the activity. During this activity, ensure that pupils closely examine each of the possible variations they build. In the first step, pupils may have the following three possible combinations (Figure 1).

1	2	3
RED	YELLOW	YELLOW
YELLOW	RED	YELLOW
YELLOW	YELLOW	RED

Figure1. Possible combinations using 3 plastic building blocks (1 Red, 2 Yellow)

For this activity, ignore the uneven print on the top of the building blocks i.e. structure 1 and structure 3 are in fact the same, if they are rotated. There are only 2 possible combinations. In the second step with two red and two yellow building blocks, there are 4 possible different structures:

RED	RED	RED	YELLOW
YELLOW	RED	YELLOW	RED
YELLOW	YELLOW	RED	RED
RED	YELLOW	YELLOW	YELLOW

Figure2. Possible combinations using 4 plastic building blocks (2 Red, 2 Yellow)

This Building Block activity prepares the pupil's mind to introduce the new concept of an isomer. It is very important that this activity is carried out properly and clearly understood. The pupils can learn to realise that there may be more than one possible way to form a structure involving just two different types of atoms. The pupils can discover that the greater number of atoms present will allow for a greater number of possible isomers. In this activity, the pupils compare and analyse the different structures e.g. turn them upside down, back to front etc. to ensure that no two structures are in fact the same. The pupils should practice this same inquiry approach in their analysis of the alkane structures in Activity 2 that follows.

Pupil Activity 2- Molecular Models

Like in Activity 1, carrying out this activity in small groups allows pupils to share ideas with each other when experimenting on how to build the isomers. It is important for the pupils to remember all the time that the carbon atom is the central atom when building hydrocarbons. Pupils should be questioned again about the bond angle of their structures to assess their understanding and revise what has been learned in previous lessons.

Questions listed in the Pupil Worksheet probe their thinking. At the end of this activity, the pupils should realise that both structures of butane are different because the atoms are bonded differently to each other and the structures have different shapes. Both structures of butane have the same molecular formula however, and so contain the same numbers of carbon and hydrogen atoms. Only two different structures are possible. Previous to this, the pupils should have learned how to name straight-chained alkanes. In this activity, the pupils are introduced to branched alkanes.

IUPAC Nomenclature

Pupils should recognise that the new compound is not a straight chain like the alkanes they have seen until now, but is a branched chain; and so needs to have a different name than the straight-chained butane. Having the pupils draw the 2-D structure of 2-methyl propane from the 3-D model they made, will assess their understanding of shape and structure. Through the application of the IUPAC rules the pupils learn about alkyl groups. Given

the definition in the Pupil Worksheet, the pupils should be able to deduce the general formula for alkyl groups: C_nH_{2n+1} . Pupils should note the ending of the alkyl groups. Pupils learn the IUPAC Nomenclature system by applying each rule as listed in Figure 3. The IUPAC Nomenclature system outlined in Figure 3 should be supplied to the pupils and facilitate their naming in Activities 2 and 3 outlined here.

IUPAC Nomenclature system:

1. Choose the correct ending.
2. Identify and name the longest carbon chain.
3. Number the carbons on the longest chain.
Number the carbons so that the substituents (branches) will have the lowest possible number.
4. Substituents:
 - Determine the correct name for each of the substituents.
 - List the substituents alphabetically.
 - Number each of the substituents according to their position.
5. Put the name together using commas & hyphens appropriately:
 - Separate numbers and numbers with commas,
 - Separate numbers and words with hyphens.
 - Leave no space between words.

The IUPAC name should include:

Number – [substituent] [prefix] [ending]
E.g. 2-[methyl][prop][ane].

Figure3. Rules for applying IUPAC Nomenclature

Possible Lesson Extensions

Activity 3- Molecular Models

The Molecular Models activity (Activity 2) described above could be repeated with an increased number of carbon and hydrogen atoms. The pupils could then make and name the different isomers for C_5H_{12} following the same format as outlined in Activity 2. Pupils can compare the structure and IUPAC names of the isomers of C_5H_{12} with other pairs of pupils in the class.

Thinking Questions

- Why were there more possible isomers for C_5H_{12} than there were for C_4H_{10} ?

- Do you think C_6H_{14} would have more or less structural isomers? Explain.
- What structural features are present in isomers of C_4H_8 that are not present in isomers of C_4H_{10} (causing C_4H_8 to have more isomers)?

Isomer Construction Kit

General Chemistry online (Fred Senese, 1998) has an interactive exercise for building isomers. This interactive isomer construction kit is available online at:

<http://antoine.frostburg.edu/cgi-bin/senese/tutorials/isomer/index.cgi>

Properties of Stereoisomers

An experiment illustrating the properties of isomers is available in the book: *Microscale*

Chemistry – Experiments in Miniature (RSC 1997, p.167).

This investigation compares the differences between (R) - (+) limonene and (S) – (-) limonene as extracted from citrus fruits oranges and lemons. Although this is beyond the scope of the Leaving Certificate syllabus, it may be of interest to the pupils.

Future Lessons

Octane Number

Table 1. Octane Numbers of hydrocarbons.

Table of Octane Numbers	
Hydrocarbons	Octane Number
Straight Chain	
Pentane	62
Hexane	25
Heptane	0
Octane	-10
Branched	
2-methylbutane	93
2,2-dimethylpropane	80
2,2-dimethylbutane	93
2,3-dimethylbutane	94
2-methylhexane	46
3-methylhexane	55
2,2,4-trimethylpentane	100
2,2,3-trimethylpentane	110
Cyclic	
Cyclohexane	83
Methylcyclohexane	70
Benzene	106
Methylbenzene	120

Use molecular models to build isomers of compounds with a higher Octane Number.

(Using information given in Table 1): Identify the other branched alkanes given in the table of Octane Numbers

Which are isomers of hexane?

Which are isomers of heptane?

Which are isomers of octane?

Alcohols:

Use molecular models to build isomers of alcohols to introduce primary and secondary alcohols.

References

DES (1999) *Leaving Certificate Chemistry Syllabus*, Dublin: Government Publications.

O' Dwyer, A. and Childs, P. E. (2012) 'Organic Chemistry in Action! An Action Research project to improve the teaching of Organic Chemistry by using findings of Chemistry Education Research (CER)', *Chemistry in Action!*, 95, 8-15.

Schmidt, H.-J. (1992) 'Conceptual difficulties with isomerism', *Journal of Research in Science Teaching*, 29(9), 995-1003.

Taagepera, M. and Noori, S. (2000) 'Mapping students' thinking patterns in learning Organic Chemistry by the use of Knowledge Space Theory', *Journal of Chemical Education*, 77(9), 1224-1229.

With this issue of *Chemistry in Action!* you will also find a poster on 'Isomers of C_6H_{14} ' and this is also given on p.24.

Custom-made Molymod[®] molecular model kits can be ordered through CERG at €25 per set. These sets contain 15 sp^3 carbon atoms, 6 sp^2 carbon atoms, 6 oxygen atoms, 6 halogen atoms, 52 bond links and 12 molecular orbitals.

ACTIVITY 1: Plastic Building Blocks

Materials required (per group of pupils)

- 2 plastic building blocks of same colour (e.g. Red)
- 2 plastic building blocks of another colour (e.g. Yellow)



Note:

Any two colours of blocks can be used.

For simplicity in this procedure below, the colours red and yellow will be referred to. When joining the blocks together for this activity, the blocks can only be joined by directly stacking them on top of each other. The blocks cannot be staggered:



Procedure:

1. Using just 1 RED and 2 YELLOW blocks:

How many different ways can the blocks be combined together?

Note your different combinations here:

Check that each of your combinations are different.

2. Using just 2 RED and 2 YELLOW blocks:

How many different ways can these blocks be combined together?

Note your different combinations here:

Check that each of your combinations are different.

If more blocks were introduced, how would this affect the number of possible structures?

ACTIVITY 2: Molecular Models

Materials required (per group of pupils):

- 8 (4-hole) carbon atoms.
- 20 hydrogen atoms.
- 26 bond linkages.

Procedure:

1. Recall the molecular formula for butane: _____
2. Build a 3-D model of butane.
3. Draw the 2-D structure of your butane in the space provided in the box.
4. Is there any other possible way to build the molecule differently than the one you have just made?
5. Use the remaining atoms available to investigate other possible structures with your partner.

When you have built a second structure, check:

- How many carbon atoms are present? _____
- How many hydrogen atoms are present? _____
- Is it really a different structure? _____

6. Draw the 2-D structure of your second molecule in the box provided.
7. Compare both of your structures:

How are the structures different?

Are the structures the same in any way?

Both of these forms of butane are **structural isomers**: they have the same molecular formula but a different structural formula. They also have slightly different physical properties.

	Melting Point (°C)	Boiling Point (°C)
<i>Butane (1)</i>	-138	-0.5
<i>Butane (2)</i>	-160	-11.7

Structural isomers are compounds with the same molecular formula but different structural formula.

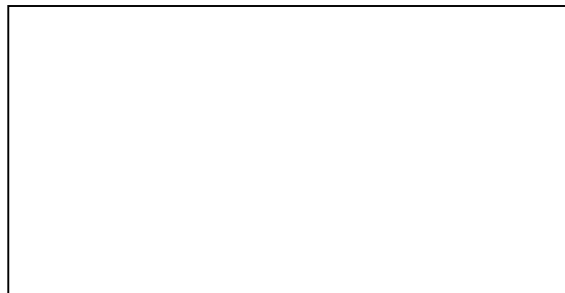
We cannot name these structural isomers as butane (1) and butane (2) as done above. Can the structure be named using the same method to name straight-chained alkanes?



How will you name the isomer?

Draw the 2-D structural formula for the second structure that you made here.

Note: Any part of the structure that is not along the straight chain of the carbon back-bone is referred to as a 'branch'.



1. Circle the branch in this structure.
2. On your structure above, identify and highlight the longest straight chain of carbons.
3. Now number the carbons on the chain.
4. What is the name of this carbon chain (based on the number of carbons)?

5. Which known alkane does the 'branch' most closely represent?

Alkyl Groups are alkanes, which are missing just one hydrogen atom from the end.

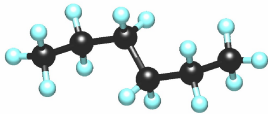

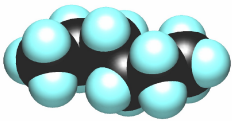
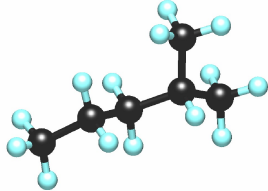
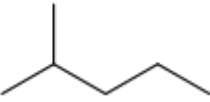
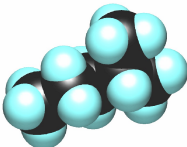
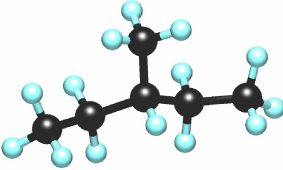
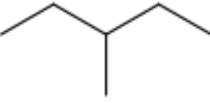
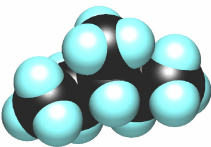
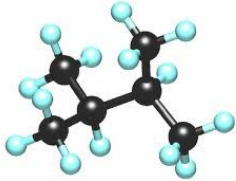
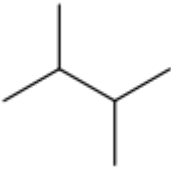
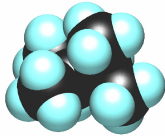
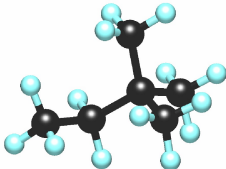
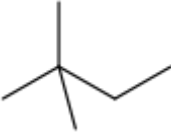
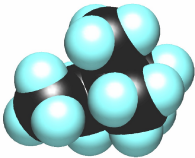
Important

These groups have the same prefix names as alkanes according to the number of carbons present, but have the **ending 'yl' instead of 'ane'**.

Alkane		Alkyl Group	
	Meth ane		Meth yl
	Eth ane		Eth yl

6. Using the IUPAC rules, write a name for the branched isomer that you have made.
E.g. Number – [substituent] [prefix] [ending]

The Isomers of Hexane, C₆H₁₄

Name Formula	Ball and stick model	Line structure	Space-filling model
Hexane <chem>CH3(CH2)4CH3</chem>			
2-methylpentane <chem>(CH3)2CH(CH2)2CH3</chem>			
3-methylpentane <chem>CH3CH2CH(CH3)CH2CH3</chem>			
2,3-dimethylbutane <chem>CH3CH(CH3)CH(CH3)CH3</chem>			
2,2-dimethylbutane <chem>CH3C(CH3)2CH2CH3</chem>			

Different arrangements of isotopes? Different chemistries!

Marten J. ten Hoor

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Atoms of which the nuclei contain the same numbers of protons, but different numbers of neutrons, are supposed to belong to the same element. Because such atoms should be allocated to the same place of the Periodic Table, they are called isotopes. Different isotopes have the same electron configurations, for which reason they are believed to exhibit the same chemical properties. This need not be correct, however, and the purpose of this note is to show this, using the decomposition of ozone as an example.

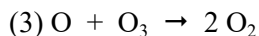
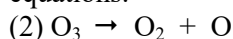
The decomposition of ozone by irradiation

The energy of the OO bond in O₃ is 106.6 kJ mol⁻¹, and the one of the OO bond in O₂ is 498.4 kJ mol⁻¹ (Lide, 2008). If these two bonds are to be broken by irradiation, the frequency of the radiation should be at least 2.67 x 10¹⁴ s⁻¹, and 12.5 x 10¹⁴ s⁻¹, respectively.

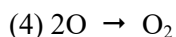
If the frequency, ν , is chosen such that:

(1) $2.67 \times 10^{14} \text{ s}^{-1} < \nu < 12.5 \times 10^{14} \text{ s}^{-1}$
then the OO bond in O₃ can be broken, but not the one in O₂.

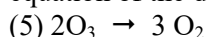
I assume that the frequency of the radiation used to decompose ozone complies with (1). Then, this decomposition can be represented by the equations:



and



Whether the oxygen atoms formed in (2) react as in (3) or (4) has no bearing on the end product, which is O₂ in both cases. As ν has been chosen such that O₂ molecules cannot be split, the overall equation of the decomposition of ozone is

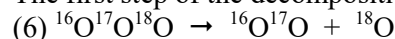


This simple equation describes the decomposition of ozone, if its molecules contain one type of oxygen isotope only. An example of such a molecule is ¹⁶O₃. However, the equation becomes

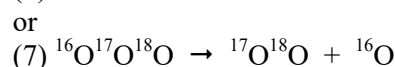
(much) more complicated, if we consider ozone consisting of molecules that contain different oxygen isotopes, for example ¹⁶O¹⁷O¹⁸O.

The decomposition of pure ¹⁶O¹⁷O¹⁸O

The first step of the decomposition is:



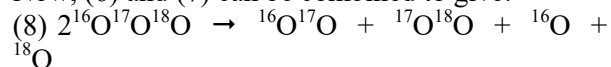
or



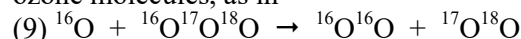
To proceed, I have to make a few assumptions.

Assumption 1. All oxygen isotopes have the same chemical properties.

If this assumption is correct, then (6) and (7) are equally probable, and the amounts of ¹⁶O and ¹⁸O in the reaction mixture are equal to each other. Now, (6) and (7) can be combined to give:



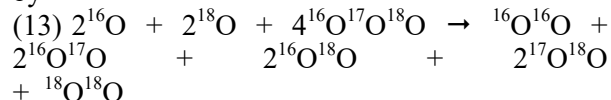
The oxygen atoms formed by (8) can react with ozone molecules, as in



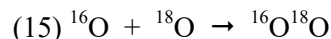
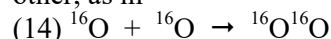
and



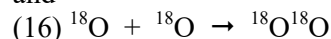
According to *Assumption 1* these four reactions are all equally probable, so they can be replaced by



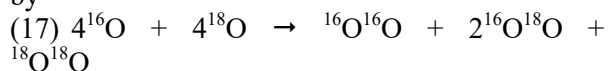
Finally, the oxygen atoms can react with each other, as in



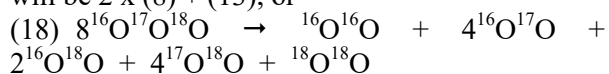
and



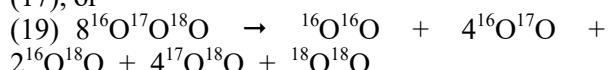
If the reaction mixture contains a sufficiently large number of oxygen atoms, then (on statistical grounds) (15) will occur twice as often as (14) or (16), and so these three equations can be replaced by



At the beginning of the decomposition, there are many ozone molecules present, but only few oxygen atoms. At this stage (13) is much more probable than (17). If I assume that now the oxygen atoms react with ozone molecules *only*, then the overall equation of the decomposition will be $2 \times (8) + (13)$, or



Near the end of the decomposition the reaction mixture contains only little ozone, and now the oxygen atoms have a greater chance to react with each other. If I assume that all oxygen atoms still present react as in (17), then the overall equation for the decomposition near its end is $4 \times (8) + (17)$, or

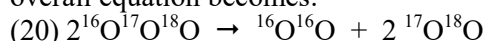


Surprisingly, (19) is identical with (18). Apparently, it makes no difference whether the produced oxygen atoms react with ozone molecules, or with each other. It seems then that (19) can represent the decomposition of pure $^{16}\text{O}^{17}\text{O}^{18}\text{O}$ from beginning to end.

So far, I have assumed that all oxygen isotopes are chemically equivalent, and that the energies of all their bonds are equal. However, the bond between two isotopes is generally stronger, the heavier these isotopes are. Thus, the $^{16}\text{O}^{17}\text{O}$ bond is weaker than the $^{17}\text{O}^{18}\text{O}$ bond. I can imagine that the frequency of the radiation used to decompose $^{16}\text{O}^{17}\text{O}^{18}\text{O}$ is fine-tuned such that the weaker $^{16}\text{O}^{17}\text{O}$ bond can be broken, but not the stronger $^{17}\text{O}^{18}\text{O}$ bond. This leads to the following assumption.

Assumption 2. Only the weakest OO bond is broken.

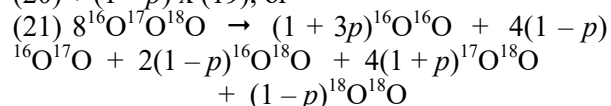
Now, only the reactions (7), (9), and (14) can occur. The products of the decomposition of $^{16}\text{O}^{17}\text{O}^{18}\text{O}$ are $^{16}\text{O}^{16}\text{O}$ and $^{17}\text{O}^{18}\text{O}$ only, and so the overall equation becomes:



Above I have described the decomposition of pure $^{16}\text{O}^{17}\text{O}^{18}\text{O}$ on the basis of two different (black and white) views.. In the black picture, all OO bonds are broken equally easily (*Assumption 1*), and in the white picture only the weakest OO bond is broken (*Assumption 2*). Now it seems more reasonable to me to describe the decomposition in terms of a grey picture, based on the following assumption:

Assumption 3. All OO bonds can be broken, but the weaker ones will be broken more often than the stronger ones.

To find the overall equation for the decomposition which corresponds to the grey picture, I assume that a fraction p of all $^{16}\text{O}^{17}\text{O}^{18}\text{O}$ molecules have reacted according to the white picture of (20), and the fraction $(1 - p)$ according to the black picture of (19). The overall equation then becomes $4p \times (20) + (1 - p) \times (19)$, or



I have been unable to determine the value of p , but it could be found experimentally.

Similar decompositions

The decomposition of pure $^{17}\text{O}^{16}\text{O}^{18}\text{O}$, or of pure $^{16}\text{O}^{18}\text{O}^{17}\text{O}$, can be described in a way similar to that of the decomposition of pure $^{16}\text{O}^{17}\text{O}^{18}\text{O}$. If this is done, it can be seen that isotopically pure oxygen molecules derived from the central oxygen atom of these ozone molecules are *not* formed: the decomposition of $^{16}\text{O}^{17}\text{O}^{18}\text{O}$ yields no $^{17}\text{O}^{17}\text{O}$ (see eq (21)), that of $^{17}\text{O}^{16}\text{O}^{18}\text{O}$ no $^{16}\text{O}^{16}\text{O}$, and that of $^{16}\text{O}^{18}\text{O}^{17}\text{O}$ no $^{18}\text{O}^{18}\text{O}$.

Thus, the decompositions of isotopically different ozone molecules yield different products, hence these types of ozone have different chemical properties.

Different arrangements of isotopes lead to different chemistries.

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Lide, D.R., Ed (2008) CRC Handbook of Chemistry and Physics, 89th ed., 9–68 and 9–74. Boca Raton: CRC Press.

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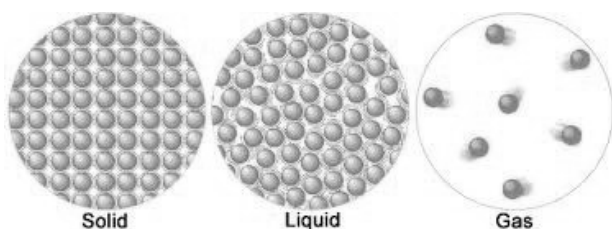
Explaining how Ionic liquids

work: A discussion on chemical bonding featuring RSC teaching resources

Angela McKeown

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Anyone that has ever seen ice and steam can understand that the way a substance looks physically can change any number of times, while it still remains the same substance.



The RSC's interactive periodic table can be a useful tool for teaching this topic as it can be very helpful to make virtual adjustments to a wide temperature range (avoiding the presence of reactive gases!) using the slide on the top and seeing the effects on the phases of the elements. (<http://www.rsc.org/periodic-table>).

Since the physical properties of any substance are transient, the next step in understanding is realising that a substance owes its appearance at room temperature to the relative strength of its component intermolecular forces. Of vital importance to make sense of this topic is the correct visualisation of a bonded molecule. The RSC magazine Education in Chemistry makes its feature articles available in PDF format for free (including back issues) and has an excellent article available on the most correct way to think about the chemical bond and its relation to the forces of intermolecular attraction (<http://www.rsc.org/Education/EiC/issues/2011May/ChemicalBonding.asp>).

A nice worksheet to check on student understanding of the bonding topic is provided by the RSC in their "misconceptions section":

<http://www.rsc.org/Education/Teachers/Resources/Books/Misconceptions.asp>

Once everyone has a good grasp of the basics of intra and inter molecular forces, talking about "how ionic liquids work" can lend itself to an interesting discussion and can allow students to further, as well as check, their understanding in several ways.

Ionic liquids are technically salts that are liquid at temperatures of $<100^{\circ}\text{C}$. So how do they work? Firstly, it is worth discussing what forces hold together the molecules in salts (again the RSC have a good student worksheet, http://www.rsc.org/images/Ionic_bonding_tcm18-189311.pdf). An interesting start could also be sparked by asking about how high the temperature might need to be to melt a salt, or even to boil a salt!

Why do salts generally have such high melting temperatures? The Coulombic forces between the ions lead to most salts having highly ordered infinite ionic lattices and, therefore, high melting points. The dramatic increase in conductivity displayed by simple salts as they melt shows that melting has allowed the ions to move from their lattice positions. This is corroborated by the increase in molar volume upon melting as the structure of the salt breaks up and space is introduced.

However, not all salts have the same melting point. From Table 1 below, it is clear that the strength of the ionic bond varies considerably and the last two entries, which refer to ionic liquids, show significant reductions in melting point compared with the simple salts quoted. These changes occur by making the ionic bond and associated lattice, stronger or weaker.

Salt	Melting Point (°C)
LiCl	605
NaCl	801
KCl	770
CsCl	645
[C ₄ mim]Cl (1-butyl, 3-methyl imidazolium chloride)	65
[C ₈ mim]Cl (1-methyl, 3-octyl imidazolium chloride)	< 0

Table 1 Melting points of some ionic salts

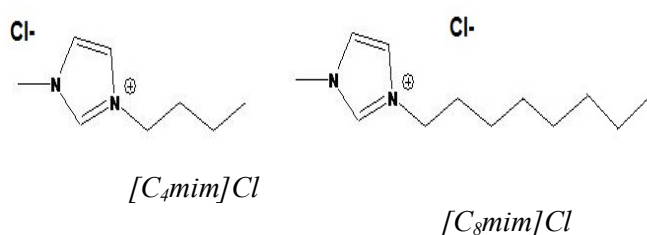


Figure 1: Structure of two ionic liquids

The strength of the Coulombic charge is the same on all the cations in Table 1 above; however, the charge on the organic ions is reduced at a given point on the molecule since the charge becomes “spread” over the ring of the molecule. This property is known as the charge density. Also, the T shape and steric bulk of the organic cation disrupts the availability of the charge and reduces the packing efficiency, preventing a crystalline structure being formed effectively. The increasing effect of this can be seen through the significant difference in the melting points of [C₄mim]Cl and [C₈mim]Cl (structures in Figure 1).

Whilst Coulombic interactions dominate at short alkyl chain lengths, as the chain length increases, the cumulative effects of Van Der Waals forces add up. As Figure 2 below shows, increasing the steric bulk on the N-alkyl cation in this way eventually leads to ionic liquids that melt at higher temperatures.

Figure 2 also shows that above a certain chain length, ionic liquids develop liquid crystalline properties due to the long range “orientational order” of the cations throughout the material. These can be used in liquid crystal displays such as those found in your computer monitor.

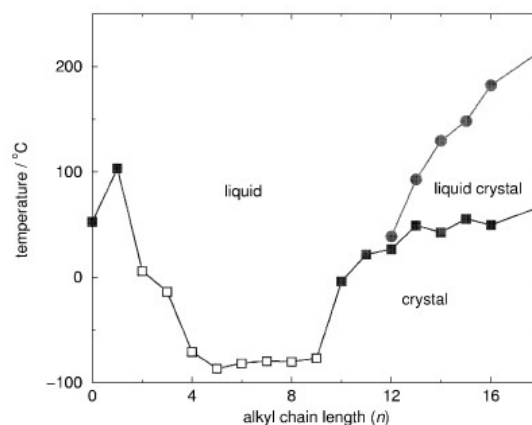


Figure 2: Melting point phase diagram for methylimidazole based ionic liquids as a function of alkyl chain length (*n*) showing the melting transitions from crystalline (closed square) and glassy (open square) materials and the clearing transition (closed circle) of the liquid crystalline termsⁱ

The anion used can also be changed, substituting the chloride anion from the [C₄mim] Cl to a weakly coordinating one, such as the anions below, leads to a very “confused” salt that is a clear syrup-like liquid at room temperature!

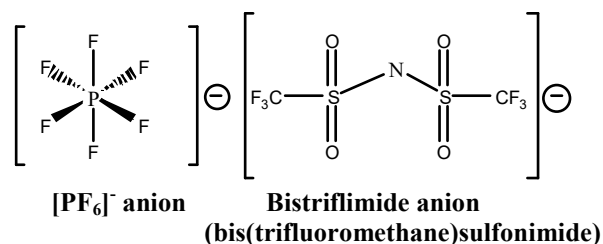


Figure 3: Some complex anions

Using the [PF₆]⁻ or bistriflimide anions shown in Figure 3 above, with the same [C₄mim] cation leads to ionic liquids that are not only liquid at room temperature but that are also stable to air and moisture and can even be used as solvents to carry out chemical reactions.

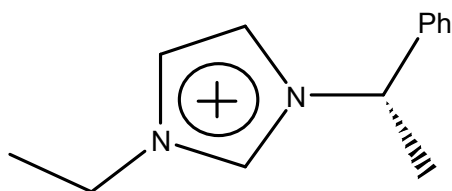
Why use ionic liquids?

Why would you use an ionic liquid as a solvent instead of a traditional organic solvent? For a start they can be effective on materials that otherwise may be insoluble, for example it is well documented that some ionic liquids can dissolve cellulose. After processing, if water is added to the cellulose/ionic liquid solution, the modified cellulose can be separated. The water is evaporated and the ionic liquid can be reused.

Although as described, the forces holding the ions together in an ionic bond are weak when

compared to more traditional salts, they are still quite considerable and this massively reduces the losses from the liquid due to evaporation. The loss of traditional organic solvents to the atmosphere from global chemical manufacture is huge and comes with considerable environmental and health costs since the use of volatile organic compounds has been strongly implicated in the production of photochemical smog. It is for this reason that ionic liquids got a name for being “Green Solvents.”

Thirdly, with traditional solvents the solvent is generally a ‘spectator’ in regards to the chemical reaction taking place, ionic liquids offer a solvent system whereby the solvent can actually will take part in or affect the chemical reaction.



For example using a chiral cation, as shown above, to make the ionic liquid leads to a chiral solvent which can lead to improved chiral discrimination in asymmetric reactions(2). Additionally the alkyl chains could contain a functional group (e.g. a Hunig’s base). There are

hundreds of potential variations on the “scaffold” to make new or even reaction specific “designer” ionic liquids and this is a key area of research for chemists working on these materials.

There are also hundreds of other uses for ionic liquids from batteries to lubricants to dispersion media. Queens University Belfast has a large research cluster known as QUILL, dedicated to working on these materials.

So there you have it, ionic liquids “work” because the forces between the ions are weak compared with those in a salt like NaCl and, therefore, the ions are free to move around, giving the overall substance an incredibly low melting point (for a salt!). But in fact all liquids at room temperature are molten solids; ionic liquids are just salts that have a very low melting point when compared to most salts.

References

1. J. Holbrey.; K. Seddon.; Clean Products and Processes 1 (1999) 223–236
2. W. L. Bao, Z. M. Wang, Y. X. Li. J. Org. Chem, 68, 591, 2003

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Chemicals are good for you — or are they?

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As many know, I supervise student teachers (from UL) when they are let loose on teaching practice in schools. At the end of one class during the last year, the student teacher said to her pupils’ *‘Next day you’ll be in the lab and you’ll be using chemicals, so you’ll have to be extra careful’*. Obviously, like so many journalists, she hadn’t a clue what the word ‘chemicals’ means. When we had a talk after the class was over, I said to her: *‘Did not the children in the class all use chemicals today? What about the soap they (hopefully) had washed with?, what about the salt put on an egg or in a sandwich, or the sugar in the tea, or the medical tablet taken for some reason or other? Look on the ingredients on a tube of toothpaste, ‘you’ll find a dozen chemicals there’*. I think she got the message.

There are of course, ‘bad’ chemicals’ as well as ‘good’ ones, and the Media is largely to blame for the public misconception of ‘chemicals’ by giving the name ‘chemicals’ only to the bad ones; the good chemicals are usually termed something else!

There was a very good article about this issue in a recent ‘Chemistry World’, written by Professor Hal Sosabowski (University of Brighton). (1) He starts by quoting from an article in a recent *Daily Telegraph*: ‘Ozone can now be used to preserve food without the use of chemicals’. He wonders if the paper reporting on the harmful effects of ozone will then call it a ‘chemical’. He mentions the reported benefits of organic food, the benefit

of which appears to be that it is produced without the use of 'chemicals'. What is the manure or compost used if it isn't chemical?

The public's fear is not one of science; it is one of language. To a scientist, a 'chemical' is any substance or material (but of course most everyday substances are mixtures of chemicals) but to many (most?) of the public, it is a substance that has the potential to harm, pollute or destroy, and too often associates the word with all that is unwholesome and unhealthy. This perception is of course completely false, and the public (particularly journalists) needs to be educated as to what chemicals are. Science teachers (not just chemistry teachers) can make the start here (in fact, it might be regarded as their duty), by ensuring that all their pupils understand this word 'chemicals'.



Chemistry is All Around Us Network Project: A Report on the first year of a Comenius project

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Limerick Institute of Technology (LIT) is participating in a €550,000 project with twelve other institutions and universities from eleven different European countries. The project, *The Chemistry Is All Around Us Network Project*, will take three years and is funded under the Comenius LifeLong Learning Programme.

The project will attempt to find ways of bridging the gap between research into different methods of teaching science subjects, particularly chemistry, and what is actually delivered in school curricula. The Project has started to build a Network of different institutions involved in promoting Life Long Learning in scientific issues in order to share experiences, educational materials and methods, and to spread information in order to change the attitude of people towards Chemistry. It also aims to encourage an active-learning approach to chemistry teaching and learning, including the use of ICT. The network is developing collaborations between partners from

When I present '*Fun with Science*', I make a point of using the word 'chemical' for everyday substances like salt (sodium chloride), bread soda (sodium bicarbonate), aspirin (acetylsalicylic acid), washing up liquid (most are alkylbenzenesulfonates), and in one of the experiments that uses Vitamin C tablets, I mention that its chemical name is ascorbic acid. I hope that at least some of those who have been in my audiences, will have an understanding as to what a 'chemical' is.

(1) Hal Sosabowski, 'A chemists' defence', <http://www.rsc.org/chemistryworld/Issues/2011/June/AChemistsDefence.asp>

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Ireland, Italy, Spain, Greece, Bulgaria, Czech Republic, Poland, Portugal, Turkey and Slovakia, and is co-ordinated in Italy.

The *Chemistry is All Around Us* network was launched in Florence, in Italy, in March 2012. Since then the partners in the project have worked with each other and also with partners in schools in each country to develop ways of promoting the value of chemistry in our everyday lives, as well as demonstrating that it is a useful and versatile subject to study in school and beyond.

The first phase involved creating a network of ten teachers and five experts in each country. Some members of the Irish network are shown in the photograph below. The first tasks for the project managers in each country involved selecting five publications on Student Motivation and also a minimum of 20 ICT-based teaching resources and uploading reviews of these on to the project portal at: <http://chemistrynetwork.pixel-online.org/index.php>



Some members of the Irish network

The most difficult part of this task was finding indigenous teaching resources, and most partners resorted to including non-national resources in their selections. Altogether 226 ICT based teaching resources were referenced on the portal. Once this was achieved teachers and experts from each country had to comment on two resources from countries other than their own. In September each manager hosted a workshop for their panel of teachers and experts to discuss the resources they had reviewed and to evaluate the progress to date on the portal. In early October a virtual meeting of all partners, with representatives of their panels was held.

Most participants at the September workshop had chosen at least one Teaching Resource to review. They regularly expressed difficulty with choosing the items. Some had difficulty with translation of the partner reviews, and others were disappointed that, while the review could be translated, the actual resources couldn't all be translated. As each participant took to the floor to show their chosen resources to the other teachers and experts, we were able to gain an impression of the various resources and form opinions about their usability, relevance to the Irish curriculum and general usefulness. As with the papers and publications there was an obvious disparity in quality and relevance. Some of the materials were out-of-date, with one website having a number of links of which about 70% do not work.

It was agreed that if the resources could be mapped to the curriculum their usefulness would become more apparent. It was acknowledged that some of the resources would be more applicable for chemistry/science promotion rather than teaching (especially within an exam-driven curriculum).

The participants were given the list of twenty five resources uploaded by Limerick Institute of Technology to the portal. Most were familiar with some, but not all, of these resources. Many expressed the opinion that they would now use these resources in school as some of them had obvious links to various stages of the Irish curriculum. Others would be relevant to the Irish Transition Year, which is not bound by an exam syllabus.

The proximity of Ireland to the UK means that a lot of material used here originates in the UK. Even the *iChemistry* professional development initiative for Irish chemistry teachers includes many links to UK-sourced materials. All agreed that the quality of national materials is improving, and that mapping to the national curriculum is an advantage. The teachers were most attracted to the visual, interactive content on websites. They also appreciated resources that they could use in class, via interactive whiteboards and other supports, but also direct the students to for additional work at home.

As the items were presented it became evident that some resources had engaged their reviewers more than others. The participants identified the following as being particularly attractive and potentially useful:

- X-Science – paper from University of Genoa – inspiring to link lessons to cinema.
- General Chemistry on Line from University of Dartmouth
- Materials for special uses – from Chemistry is All Around web portal
- Science Kids
- Chemistry of Things
- An Introduction to Chemistry by Mark Bishop
- Chemistry for Life

Disappointment was expressed about the lack of primary school materials.

The second phase of the project is now underway, following a partner meeting in Prague in December 2012. This phase is looking at Teacher Training in science. The final phase of the project will consider successful experiences in the partner countries.



International Meeting Prague, December 2012

common goal of sharing materials relevant to the teaching and learning of Chemistry. Many of the resources which have been collected are useful for motivating students in the classroom and also for directing them to supplementary work outside the formal classroom setting.

One pertinent comment agreed by participants at the evaluation workshop was that the sharing of international experiences was particularly valuable. All Irish participants are awaiting the second phase of the project to observe how it develops. Any feedback you would like to give on the portal would be welcome. If you would like your school to be named an associate school for the project please contact me directly by e-mail to Marie.Walsh@lit.ie

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Conclusion

The first phase of setting up the *Chemistry Is All Around Us Network* portal has been successful in initiating a network of practitioners with a

New European hazard signs – replacing the old ones



The Instrument Makers No. 2: Justus von Liebig (1803-1873)

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Justus von Liebig was the second of ten children and was born in Darnstadt, the capital city of the Grand Duchy of Hesse, near Frankfurt on the 12th of May 1803. His Father, Johann Georg (10/4/1775-28/4/1850) had married Maria Kerline Moserin (1781-1855) and had a business dealing in dried and salted meats and other foodstuffs, as well as operating a drug and painting materials section, for which he had a small laboratory in use. It was here that the young Liebig got the opportunity to dabble with chemicals and to experiment with their properties. In 1811 Liebig was enrolled with his brother Johann in the Ludwig-Georgs-Gymnasium in the town but had little inclination for the subjects taught. Being some two years younger than the rest of the boys in his class might have had some influence in this, as he would have opened himself to being bullied, if he were to have shown a liking for the subjects.

Liebig's siblings were:

Johann Ludwig (1801-1830)

Maria Carolina (1805-1856)

Marie Luise (1807- unknown)

Johann Balthaser (1809-1814)

Johann Georg (1811-1843)

Eleonore Sophie (1813-1817)

Luise Catharine (1814-1849)

Georg Carl (1818-1870)

Katharine Elisabeth (1819-1890)

At the age of thirteen, in 1816, the year of no summer occurred with widespread failure of the crops throughout northern Europe due to a volcanic winter. The unusual weather was due to eruptions between the 5th and 11th of April 1815, when the greatest eruption in history occurred of Tambora (8 degrees 15 minutes South, 118 degrees 0 minutes East) on Sumbawa, east of Java, in which at least 70,000 died on the island and others nearby. It is thought that the effects of that year were the catalysts for Liebig's life-long interest in fertilizers and agriculture.



Bronze medallion of Liebig made by David d'Angers (1788-1856), who prepared over 500 medallions of distinguished living Europeans of his time.

About this time Liebig began to help his father in the preparation of the various mixtures to be sold in the shop. These preparations whetted his interest and he began to experiment with the chemicals that he had to hand. To further his knowledge, he began to borrow books on chemistry from the library and tried to reproduce those experiments detailed there. Most of these books were very dated, but Liebig's efforts were to give him a love of experimentation, which lasted throughout his life. A visiting pedlar introduced him to the explosive fulminates, which he immediately began to produce himself. These were to get him into trouble at home and school, but ultimately were to set him on the path to a successful career.

Liebig was sent to work at an apothecary's shop in 1818 but after 10 months was sent home, apparently because of his father's inability, or refusal, to pay the required apprenticeship fees. Perhaps the young Liebig's experiments with the explosive fulminates, one of which blew out the windows of his attic room, may have hastened his departure.

In 1819 Liebig went to the University of Bonn, where he undertook studies under Professor K.W.G. Kastner (1783-1857). On Kastner's move to the University of Erlangen, Liebig followed. A number of inappropriate sexual liaisons and the fortuitous grant to study in Paris saw Liebig move there for two years, without finishing his course requirements in Erlangen. He was to 'buy' his degree from there in 1824.

Kastner got his Doctorate from Heidelberg in 1805 then lectured in the University of Jena, before being appointed Professor of Chemistry in Halle in 1812. He went on to serve as Professor there from 1812 to 1818, then on to Bonn (1818-1821) and Erlangen (1821-1837). During his time in Halle, Kastner made the acquaintance of Liebig Senior and sourced his chemicals from his shop. Liebig Senior impressed Kastner who printed a paper of his, on the best time of year to spread liquid manure, in his periodical 'The German Tradesman'. Kastner persuaded Liebig Senior to send the young Justus as a student to study under him in Bonn. The young Liebig lodged in Kastner's house and didn't have to pay the usual fees for tuition. Kastner suggested the study of French to Liebig, as he felt that France was becoming the new centre of chemistry instead of Sweden. What we now call Organic Chemistry was then in its infancy and Kastner recognised that Inorganic Analysis, which had been developed mainly in Sweden in the 18th century, was being overtaken by the new Chemistry. Kastner was to guide and support Liebig's career and it was he who organised a grant from the Duchy to enable the young Liebig to travel and study in Paris.

In Paris Liebig continued his work on mercury and silver fulminates and at a meeting, where he gave a talk on these, he was approached by Alexander von Humboldt (1769-1859), who was impressed by him and gave him an introduction to Gay Lussac (1778-1850), in whose laboratory Liebig worked with and met a wide selection of the eminent French scientists of the time.

Having decided that what he really wanted to do was to return to Germany and open a School of Chemistry, Humboldt and Kastner were instrumental in getting him appointed an associate Professor of Chemistry in the University of Geissen in 1824. Liebig was to be appointed a full Professor there in 1826. He also was awarded

a Doctorate by the Medical Faculty in the same year.

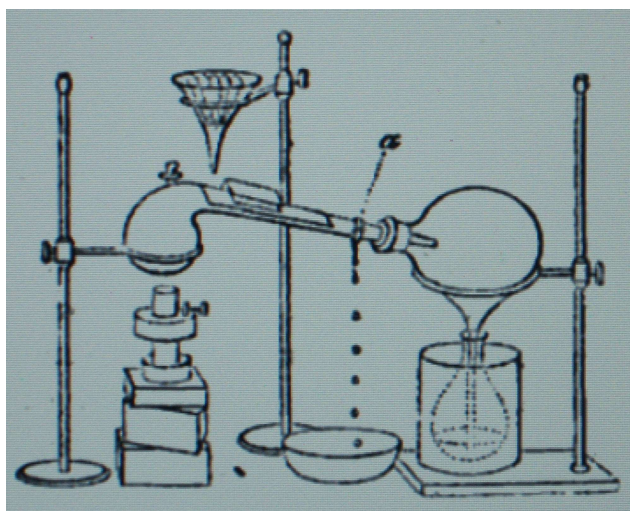
In Geissen Liebig established a laboratory, which was the first in Europe to give systematic training in Chemistry research. While some students were introduced to the methodology by assistants, Liebig began to attract more serious visitors to the laboratory from all over Europe. Here he would meet with them individually each morning, where the visitor would report on experimental data found since the last meeting and would receive Liebig's comments and suggestions on these and work to be undertaken. Two visitors who were to become 'chemical names' in themselves, were August Kékulé and August von Hoffman.

Liebig met Friedrich Wöhler during a visit to Berlin in 1824 and the two were to maintain contact over the following years. In 1832 they discovered the benzoyl radical (C_7H_5O) and this led to Liebig's discovery of the ethyl (C_2H_5) radical shortly afterwards. These two discoveries were important as they showed that radicals in Organic Chemistry behaved somewhat like elements in Inorganic Chemistry. In 1838 the pair published the results of their experiments on uric acid. So influential were the works of Liebig and Wöhler that they can be considered to be the 'fathers' of Organic Chemistry.

In 1831 Liebig discovered chloroform, independently from Eugène Soubeiran from France and Samuel Guthrie from the United States. The name chloroform was given the new compound by Jean Baptiste Dumas in 1834. Liebig was also working on chloral and discovered hippuric acid about this time.

In May 1826 Liebig married Henriette Moldenhauer (1807-1881) and cast aside his homosexual tendencies completely, being a faithful loving husband and father. The couple were to have five children: two boys, Georg (1827-1903) and Hermann (1831-1894) and three girls, Agnes (1828-1862), Johanna (1836-1925) and Marie (1845-1920). The boys were brought up in the Lutheran faith, that being Liebig's nominal religion, while the girls were reared in their mother's Catholic faith.

Distillation was problematic for those undertaking Organic synthesis at the time, with the apparatus being used at the time shown below.



Distillation apparatus in 1827

The above distillation apparatus was illustrated by Michael Faraday in his chemistry text-book '*Chemical Manipulation*' (1827.) Here the vapour is cooled by water being poured into the funnel on top, onto a sheet of cloth or paper placed on top of the retort, with the excess liquid falling into the basin at the table. A spirit burner was used to provide the necessary heat.

Over the years Liebig experimented with improvements to this apparatus and by 1842 had come up with the solution, his apparatus being noted in printed works in this year.

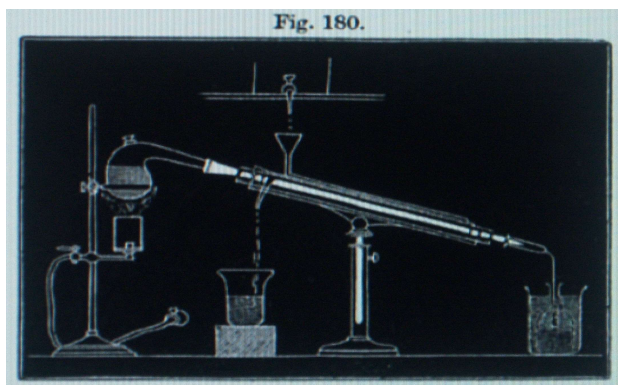


Diagram and description taken from *A handbook of Chemical Manipulation* by C.G. Willims, John van Voord, Paternoster Row, London Publisher 1857.

Liebig seems to have adapted his apparatus from earlier suggestions by various scientists including the German chemist Christian Ehrenfried Weigel in 1771, the French scientist, P.J. Poissonnier in 1779, and the Finnish chemist Johan Gadolin in 1791, and he himself attributed his design as

being based on that of the German pharmacist Johann Friedrcih August Gottling, who had made improvements to the Weigel design in 1794. Irrespective of whose was the original design, Liebig has been credited with its popularization in all chemical textbooks from 1842.

"A tube of tin is closed at each end by a cork through which a glass tube passes: the tin portion is to contain the cold water, which, by means of the funnel enters at the lower end, after becoming heated escapes by the upper aperture."

In order to supplement his income Liebig became the editor of "*Annalen der Pharmacie*" from 1832 to 1839, from which date the publication was issued under the title of "*Annalen der Chemie und Pharmacie*".

1845 Liebig was created a Freiherr (Baron) by the Duke of Hesse-Darmstadt.

In 1835 Liebig developed a method of silvering, which greatly improved the reflection powers of mirrors. (He was to file for a patent with the U.S. Patent Office, Patent No. 33721 for his method on November 18th 1861). Shortly after this, in 1837, his scientific ability was recognised by his election to the prestigious Royal Swedish Academy of Sciences.

Between the years 1837 and 1855 Liebig travelled 6 times to Britain, where he met with the notable scientists and industrialists of the time. His papers and books were to be translated into English and were influential in British scientific circles.

Between 1845 and 1849, Liebig conducted a series of experiments on the actions of the different mineral manures on a 10 acre piece of land, that he bought for the purpose. His results clearly showed that nutrients removed by plants could be replaced in mineral form. His conclusions from the experiments are to be found in his book, '*Agricultural Chemistry . Chemistry in its application to Agriculture and Physiology*', which was printed in English in 1855. His 'Law of the Minimum' is a principle previously proposed by Carl Sprengel in 1828 but now demonstrated clearly by Liebig: it states that growth is controlled ,not by the total amount of the materials available, but by the scarcest of the necessary resources present. He discovered that nitrogen was essential for plant growth and that

this element could be given back to the soil through nitrogen mineral combinations.

Other works by Liebig are on ‘*Animal Chemistry*’ (1842), English edition 1846, ‘*Familiar letters on Chemistry and its relations to Commerce, Physiology and Agriculture*’ (1851), ‘*Chemistry and Physics in Relation to Physiology and Pathology*’ and a paper on the Potato Disease (1866). This last gave ways to improve the crop and reduce infection, but did not solve the potato blight problem.

In 1852 Liebig moved to the University of Munich as Professor and President of the Laboratory there. As a mark of their respect for his work, Liebig was presented with £1,000 by his friends in Europe in 1854. A further mark of the respect shown to Liebig was his election in 1864 as President of the Royal Academy of Science in Munich.



A contemporary advertisement for the Liebig Company's Extract of Meat

Liebig always held that experimental work should lead to profitable use and this idea can be seen in some of his later work. In 1865, he devised a method of producing beef extract from carcasses and with the Belgian engineer, George Christian Giebert, founded the Liebig Extract of Meat Company to produce and market the product as a cheap alternative to meat. In 1899 the product was named Oxo, which is found on every supermarket shelf. The product Marmite is also credited to Liebig's experiments. Liebig is also credited with the popular notion that searing meat seals in the juices. However, the idea is not true. Liebig would not have cared that his notion was to

be found untrue, as he was wont to say “*Show me a man who makes no mistakes and I will show you a man who has done nothing.*”



Liebig's grave in Munich

<http://www.findagrave.com/cgi-bin/fg.cgi?page=gr&GRid=6051>

Liebig died on the 19th of April 1873 and is buried in the Alter Sudfriedhof in Munich.

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Sweet Chemistry: Learning About Natural and Artificial Sweetening Substances and Advertising in Chemistry Lessons

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This article presents a lesson plan dealing with different sorts of sweetening substances. The lesson plan takes up the societal debate about sugar-free and 'light' products and also about the approval of a natural low-calorie sweetener, derived from the Stevia plant. All this is connected to a range of chemistry content learning, which might be graded into different levels of content demand. The article further discusses the use of advertisements as a media and inspiring field for alternative pedagogies in chemistry education.

Introduction

Chewing gums, drops, chocolate, cola, energy-drinks: most people enjoy eating or drinking sweet foodstuffs (British Council, 2002; Mensing, Kleiser & Richter, 2007). This is also the case for most children and teenagers. They like the sweet taste and advertising is doing its very best to support the consumption of sweet products among them. A lot of advertisements are made on purpose for children and teenagers, because they are one of the most important consumer groups for different sorts of sweet foodstuffs (Harrison & Marske, 2005). By using specifically directed advertisements for children and teenagers, combined with e.g. sports sponsorship, food producing companies try to bind the young consumers to their brands for the students' whole life (Dammler, 2011).

This special focus of advertisers on young children and school students, demands that education start developing critical consumership at a very young age. There is need to invest in promoting skills for reacting responsibly to advertising (Brucks, Armstrong & Goldberg, 1988). However, skills for coping with advertising are not typical issues for science or chemistry education. In a *Bildung*-oriented understanding of chemistry education (Sjöström, 2011), chemistry lessons should seek also to contribute to developing general educational skills for

preparing the young generation for a responsible and self-directed life in society (Holbrook & Rannikmäe, 2007). Capabilities of how to react to advertising belong to such skills. Schools should attempt to sensitize students to the effects of advertising within their lives and future. They should encourage them to develop a conscious and critical attitude towards advertising (Brucks *et al.*, 1988), and chemistry education might contribute to this aim.

The societal dimension of science and chemistry education is an often a neglected focus of science and chemistry lessons in many countries (Hofstein, Eilks & Bybee, 2011). Dealing with advertising in chemistry education can create a connection between products based on science and technology and the society in which the students live and operate. It is clear that sweet foodstuff is very prominently advertised on TV, Internet, or in printed media. It is, however, also known that sugar-based sweets can have negative effects both on one's individual health, as well as on society at large. Tooth decay and diseases caused by overweight are two effects which quickly spring to mind, as the result of consuming too many sweet products – if, that is, they are based in sugar. The growing risks of developing diabetes or increasing healthcare costs as a result of obesity, are not simply problems related to individuals. They have consequences for the whole of society, because it is the public health system which has to pay for the costs of treatment.

In many countries in the western world, people eat too much fat and sugar (Harrison & Marske, 2005). Policy has begun to start programs to inform the general public about the risks of eating too much sugar and other high calorie foodstuffs. They try to popularize the benefits of eating with more awareness of the caloric value of food but also force citizens towards changing consumer

behaviour. France, for example, introduced an extra tax on drinks which include too much sugar (Sifferlin, 2012). In Ireland, proposals have also been made to introduce an additional tax on sugary products (Collins, 2011). Such proposals often occur after health insurance companies or institutes of statistics publish results indicating that problems associated with overweight lead to increasingly socio-economical costs (Statistisches Bundesamt, 2011).

This paper suggests taking up these important debates from within society in chemistry teaching (Stuckey *et al.*, in press). A lesson plan will be described dealing with the question of eating sugar-based sweets. It also deals with the question to whether sweets sweetened by other sweeteners than sugar might be a better alternative. Beyond the above mentioned societal discussion, the lesson plan also takes up the societal debate about the natural low-calorie sweetener derived from the Stevia plant. All this can be connected to a whole range of chemistry content, which might be included. The lesson plan is further inspired by starting from authentic everyday life media, i.e. advertisements, as suggested by the concept of a socio-critical and problem-oriented approach to chemistry education (Marks & Eilks, 2009). It also uses the idea of mimicking an authentic societal practice, in our case how to create advertisements, to learn about how society is handling science-related information and to contribute to critical citizenship (Eilks, *et al.*, 2013).

Background

Many sweet products include sugar. Sugar is a natural product which has a high calorific value of about 17 kJ/g. Eating too much sugar over a long time can cause overweight and thus contributes to health risks. To avoid these risks, but as well contributing a changing lifestyle, more and more alternatives to sugar-based products are offered on the market. Sweet products without sugar or with reduced calorific-value are frequently advertised by terms such as 'light', 'sugar-free', or 'without any sugar'. The popularity of calorie-reduced ('light') products is constantly increasing (Sandrou & Avanitoyannis, 2000). Starting from a debate about low-fat and low-carb diets, connecting chemistry education with the debate about the consumption of light products has already proved itself to be a motivating issue for chemistry lessons, with potential to the development of a

broad range of educational skills (Marks, *et al.*, 2008).

Alternatives to sugar-based products can be categorized by the sweetening substance classes: sugar substitutes, artificial and natural sweeteners. An overview on relevant and permitted sweetening substances is given in Table 1. Sugar substitutes are sweet tasting carbohydrates, which do not belong chemically to the group of sugars (e.g. sugar-alcohols such as xylitol). They are used, for example, in toothpastes or sugar-free chewing gum. Their caloric value is about 8 to 10 kJ/g. This is about half of the calorific value of regular sugar. In addition, there is a broad range of artificial sweeteners like aspartame, acesulfame, cyclamate or saccharin. These sweeteners do have practically no calorific value. Artificial sweeteners do not encourage the development of tooth decay. They are used in 'light' products, such as soft drinks, sweets, or chewing gum, too. Due to their low physiological calorific value, sweeteners are also suggested in low-calorie diets and also for persons who suffer from diabetes (Cardello, Da Silva & Damasio, 1999).

Sweetener		Intensity of sweetness compared to sugar	Caloric value in kJ/g
Sugar (glucose)		1,0	17
Sugar substitutes	Sorbitol	0.5	8 to 10
	Mannitol	0.4	
	Isomalt	0.5	
	Lactitol	0.4	
	Xylitol	1	
	Fructose	1.5	
Artificial sweeteners	Aspartame	200	nearly 0
	Acesulfame	130-200	
	Cyclamate	30-50	
	Saccharin	300-500	
Natural sweeteners	Stevia	300	nearly 0

Table 1: Overview on different sweetening substance

Also alternative natural sweeteners do exist. Some of them have a similar sweetening capacity to the artificial sweeteners and also have practically no calories. Examples of natural sweeteners are the steviolosides, which are extracted from the Stevia plant. In recent years Stevia has been the centre of a long controversy in Europe. Although Stevia products have been in use in parts of Asia and in

Latin America for many years now, in the European Union, Stevia products were only allowed to be used as additives in cosmetics, although there were no studies proving any real risk for health potentially caused by Stevia in food. However, even though it was sold for cosmetics, many persons used it to sweeten drinks, tea and food. Finally, in December 2011, Stevia was approved as a legal foodstuff component by the European Union (European Commission, 2011).

Development of a lesson plan on sweetening substances

The lesson plan, described in this article, was developed following the strategy of Participatory Action Research in chemistry education, as described by Eilks and Ralle (2002). The Participatory Action Research project for this lesson plan was conducted by a group of about ten chemistry teachers. The teachers came from different middle, comprehensive and grammar schools from the West of Germany. The teacher group has been working together since 1999 (Eilks & Markic, 2011). The group meets once a month for a whole afternoon. Within the meetings the lesson plans are designed. They are tested stepwise and evaluated in authentic classroom practice. At the end of each cycle, the implemented innovations are reflected on and refined on the base of the gained experience and evidence. In the end, the completely developed lesson plans are tested and data about students' learning and perceptions of the lesson plan are collected. Since 2011, the action research group has been part of the international project PROFILES, founded within the 7th framework programme 'Science and Society' by the European Union (www.profiles-project.eu).

Within this on-going Participatory Action Research project, the teachers in the year 2010 decided to work on a lesson plan for lower secondary chemistry or science education, with a focus on sweets and sweetening substances (Stuckey, *et al.*, in press). The teachers and accompanying science educators jointly agreed to focus on the societal dimension of the socio-scientific issue of consuming too much sugar-based sweets and also to take up the societal debate of approving Stevia for the European market or not (as by that time it was not finally approved). The idea of using advertisements in chemistry education as a new and innovative

pedagogy was suggested by a master's student, who became a member of the group in the academic year 2010/2011. The idea was unanimously agreed by the group as being interesting and innovative. The group decided to focus their work for this specific issue of curriculum development on developing a pedagogy based on advertising, to be used in chemistry and science lessons, and to reflect on its feasibility and potential effects.

As a curriculum design framework the group opted for the socio-critical and problem-oriented approach to chemistry education, as suggested by Marks and Eilks (2009). This curriculum framework includes the idea of learning about the handling of scientific and technology-related information by mimicking an authentic societal practice of information handling and transfer (Eilks *et al.*, 2013). Pedagogies of mimicking such societal practices can be based on role plays, working like a journalist, or becoming a fictive employee of a consumer testing agency (Marks *et al.*, 2008; Marks *et al.*, 2009; Burmeister & Eilks, 2012). The use of science related information in advertising indeed can be such a kind of practice, too. Based on this curriculum framework and the idea of mimicking authentic societal practices, the lesson plan was cyclically developed within the group of teachers over a time span of about 6 months. The lesson plan is connected to the syllabus topic 'matter and its properties'. The complete lesson plan was finally evaluated in two grade-7 learning groups (age 12-13 years) from a comprehensive secondary school in Germany.

Course of the lesson plan

To start the lesson plan by authentic everyday life media, it is introduced by five advertising spots about different sugar-free sweets. The students are asked to make notes about what each spot presents. They are also asked to search for similarities and differences. After the individual work, the teacher gives different statements and the students have to assign themselves between two signs, which are placed in the classroom, "agree" or "don't agree". Both activities intend to open up the field of interest and to show up the different dimensions of the issue. Examples for these statements are:

- I would buy more sugar-free food than ordinary food with sugar in it.
- Sugar-free products are more healthy.

- Sugar is a better option, because sugar is a natural substance.
- I buy many things which are advertised in the TV or Internet.
- ...

From these two activities, questions of the students about the topic are derived. In such a kind of contextual approach, in almost all cases there is a range of questions covering the societal as well as the scientific dimensions of the issue (Eilks, 2002). Following the proposed five-step model of lesson plan structure within the socio-critical and problem-oriented approach to chemistry education (Marks & Eilks, 2009; Figure 1), first the content-related questions are clarified. Different sweeteners are introduced and an overview created. This is done by a fictitious interview about sweetening substances on a worksheet and also by an analysis of different sweet products. The students - working in pairs - each get two similar sweets – one includes sugar, the other one is sugar-free. After its release in 2010, more and more sweets based on Stevia entered the supermarket. Thus, one of the products used might be sweetened by a sweetener based in the Stevia plant (Figure 2). The students investigate the ingredients outlined on the packages and locate the sweetener component by using a second worksheet and the computer.

Objectives	Criteria for selecting issues and approaches	Methods	Structure of the lesson plans
Allgemeinbildung/ education through science	Authenticity	Authentic media	1. Textual approach and problem analysis
(Multidimensional) Scientific Literacy	Relevance	Student oriented chemistry learning and lab-work	2. Clarifying the chemistry background in a lab environment
Promotion of evaluation skills	Evaluation undetermined in a socio-scientific respect	Learner centred instruction and cooperative learning	3. Resuming the socio-scientific dimension
Promotion of communication skills	Allows for open discussion	Methods structuring controversial debating	4. Discussing and evaluating different points of view
Learning science	Deals with questions from science and technology	Methods provoking the explication of individual opinions	5. Meta-reflection

Figure 1: The socio-critical and problem-oriented approach to chemistry teaching



Figure 2: “Sugar free” peppermint drops “sweetened with Stevia”

Further chemistry is learned in a ‘learning-at-stations’ lab work phase (Eilks, 2003). In the ‘learning-at-stations’ approach, students conduct different experiments inquiring into the properties of sugar, sugar substitutes and different sweeteners. Experiments are carried out on the artificial sweeteners aspartame, cyclamate and saccharine, sugar substitutes like isomalt and xylitol, and finally Stevia as a natural sweetener. The students are involved in melting different sugar and sugar-substituted substances. The students are also testing the hygroscopic properties, the solubility and observe the behaviour of these substances by heating. In one experiment the students observe the substances under a microscope (sugar and sugar alcohols produce nice crystals after melting and boiling down again. For the artificial sweetener this is not possible.) The students can also have a taste of some in different solutions (Of course, this experiment is not done in the lab and must be conducted outside the chemistry laboratory and by using disposable kitchen equipment.) On the theoretical stations, the students get more information about the three different classes of sweetening substances. All experiments are easy to handle and do not need a lot of material. Table 2 gives an overview. All inquiries can be reduced or extended in content depth and demand with respect to the prior knowledge and grade level of the students.

Within the five-step model of the socio-critical and problem-oriented approach to chemistry education (Figure 1), the next phase reflects on which questions were answered by the interaction with the chemistry background of the socio-scientific issue. It might have become clear what

the substances are about. However, chemistry alone is not able to answer the questions about which sweetening product to use, how advertisements are influencing our lives, nor whether Stevia is a better alternative compared to synthetic sweeteners.

Investigation	Preparation
Observation of the substance under a microscope or binoculars	Few crystals of the substance are put on a petri dish. Two or three of these crystals have to be drawn.
Deliquescence	A few grams of different sweetener come into different petri dishes. This is weighed exactly. They will be weighed again a week later.
Test for glucose	The substance is dissolved in water and tested with a glucose test stick.
Dissolving behaviour	It must be determined how much water is needed to dissolve each substance. The experiment can be repeated using vegetable oil.
Heating different sweeteners and comparing the smell	The substance is put in a test tube and heated using a Bunsen burner (do not burn the substance, just heat it). Observations must be noted.
Heating and boiling down different sweeteners and observing under a microscope	Different sweeteners must be heated and melted. After melting, it is boiled down and the sweeteners can be observed under a microscope.
Sweetness of different sweetening substances	This experiment cannot be prepared in the lab. Use other (ordinary) classrooms! 1 g of different sweeteners is dissolved in water (10 cm ³) in different plastic cups. The sweetness of the different sweeteners is then compared.
...	...

Table 2: Potential experiments for the learning at stations on sweeteners

To learn about how advertising uses information for its own purposes, the students are asked to create own advertisements for the different sweetening substances, including Stevia products. It is clear that an advert should emphasise the advantages of a product and preferably disregard any disadvantages. If the students are quite young, we developed the lesson plan for 7-graders (age range 12-13), it might be too much to expect for the students to discover the advantages and

disadvantages of the various substances with regard to advertising on themselves. Therefore, in this case each group of students is presented with a list, each containing eight aspects related to the specific advantages and disadvantages of one of the respective sweetening substances. Arguments might encompass the calorific value, whether it is an artificial or natural product, or about the price. The assignment for the students is to develop an advertisement about the product, a task that might be given on a similar base from a food or chemical company or from an advertising agency.

The first assignment for the students to accomplish in the advertisement is to discuss and decide what arguments might be used for or against their respective product. From their list, the students have to differentiate between supportive and negative arguments, since only positive arguments might be used in an advertisement. The students have to sort out the positive arguments, which have potential to be used in the advertisement. However, not every positive argument about a product will appear in every advertisement. The students have to make a selection of the potentially most promising argument(s) they would choose if they were a professional advertising expert. This second selection is no longer a question of the content of an argument, but of an estimate of its potential effect on a target group when being used in advertising.

On the base of their selected arguments, the students prepare their own advertisement for their product. The advertisements are either made on paper, about A5 size, or on the computer (Figure 2). For this last step the students have to consider e.g. questions of briefness, easiness, motivation etc. and have also to reflect about the design, colours and appearance. Parallel groups could work on the different substances, such as xylitol, isomalt, Stevia, sugar and saccharin/cyclamate. Also single substances can be given in parallel to two groups, to let the students experience the huge influence the advertising experts (here the students) have on the selection of arguments, as well as on the appearance of the final advertisement.

In the final phase of meta-reflection (Figure 1), the students have to explain which arguments they selected and those they discarded, and why. This reasoning can be summarised and discussed at the end of the lesson. A discussion could be

encouraged concerning the criteria by which information for advertising is selected and filtered, and how we should treat this information as critical consumers. During the reflection the students will outline the reasons for their decision making, highlighting which arguments should be used. They must justify why they have chosen these arguments, and not the other ones. The students might also discuss the meaning of their choice of an aspect for the advertisement. Also the (quite late) permission to use Stevia by the European Union and the statements of different companies can be discussed in this phase of the lesson plan and the students can express their view on the topic, since this socio-scientific issue is not only authentic and relevant, but also openly debatable and not just one-sided. These are criteria discussed by Eilks *et al.* (2013) to make a specific issue a promising issue for socio-scientific, issues-based science or chemistry education. Table 3 gives an overview of the lesson plan.

Stage of the socio-critical problem-oriented science education	Task
Textual approach and problem analysis	<ul style="list-style-type: none"> - Watching advertising spots about “sugar-free” sweets - Reflecting own positions on different statements - Comparing sugary and sugar-free products by inquiring the declaration of the ingredients on the packages
Clarifying the chemistry background in a lab environment	<ul style="list-style-type: none"> - Learning-at-stations: Making different experiments and investigations on various sweetening substances in small groups
Resuming the socio-scientific dimension	<ul style="list-style-type: none"> - Reflecting which aspects of the topic were answered, and which were not
Discussion and evaluating different points of view	<ul style="list-style-type: none"> - Preparation of own advertisements for different sweetening substances in small groups - Presentation of the different advertisements and explanation why specific arguments were chosen for the

	advertisement and others were not
Meta-reflexion	- Reflecting how advertisings are made and which role scientific information plays in the creation of different advertisings

Table 3: Overview of the lesson plan

Experiences

By analyzing advertisements and reports in the media, we can see that the topic of the lesson plan is authentic and relevant. Often, the discussions are focusing on different sorts of diets and low-calorie food. Such discussions on low-calorie products and diets are highly motivating for students (Marks *et al.*, 2008). This proved to be the case in this example, too. Although this lesson plan was developed for and tested in much younger learning groups, the topic and pedagogy encouraged intense discussions covering a broad range of arguments from the student’s life as well as from chemistry.

The use of advertising as an introduction to teaching proved itself to be very authentic and motivating. The advertisements provoked a deep contention with the topics and provoked many questions. Advertising seems to have potential to better connect the learning of chemistry with the student’s life. As the advertisements did in the beginning of the lesson plan, so also was the pedagogy to develop their own advertisements on different sweetening substances found to be motivating to the students. From the teachers’ observations, it was obvious that the students had a great deal of enjoyment in creating their own advertisement (e.g. Figure 3 below), which subsequently led to very intensive discussions on which the arguments to use.

The students generally liked the teaching unit, which came out in feedback questionnaires. The students reacted positively to statements that the lesson plan was very interesting and motivating in its teaching methods. The students were particularly positive about the modified pedagogy. The cooperative character of the experimental phases, the inquiry nature of the practical work phase, and the creative element while producing the own advertisements, were also found as being very positive. In the students’ opinion, this unit

was not ‘just’ pure chemistry, which is something that they were very positive about.

This case study supports other examples (e.g. Marks *et al.*, 2008; Marks & Eilks, 2010; Burmeister & Eilks, 2012) in the consideration that authenticity and real societal relevance of a topic – as described in Eilks *et al.* (2013) – are essential components in making socio-scientific chemistry education motivating and useful to the students. As described e.g. in Marks *et al.* (2008), Marks *et al.* (2010), or Burmeister and Eilks (2012), the mimicking of an authentic societal practice of handling science-related information in everyday life and society proved to add a motivating element to the pedagogy of chemistry education. Aside from its motivating character, such an approach seems to be of great potential to contribute the students’ learning about society’s handling of science-related information as outlined e.g. in Hofstein *et al.* (2011) or Eilks *et al.* (2013).



Figure 3: Advertising for “Stevia” developed by students (translated from German)

The use of advertisements as a motivational tool in chemistry lessons is still rare. From this case study, one can conclude that it could be used more frequently to provide authentic and modern media and pedagogy in chemistry education. The case of sweetening substances can work as an illustrating example.

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□

Seen in a wet Oxford, June 2011: The Periodic Table Taxi – the only way for a chemist to travel in style! (Photo: P.E. Childs)



2012 LC Results

Peter E. Childs

We have been publishing an analysis of the LC science results and CAO points for science-related courses since 2001. Each year a 3 year overview is given. The examination statistics are available at the Department of Education and Science website at: www.examinations.ie and were published in the Irish newspapers on 15/8/12, the day the LC results were released.

The overall number sitting the examinations is marginally down on last year's number by 3.0%. Of the 55,857 candidates who sat Leaving Certificate examinations this year, 36,762 (65.7%) candidates followed the Established Leaving Certificate Programme, 15,827 (28.4%) the Leaving Certificate Vocational Programme while 3,358 (6.0%) candidates followed the Leaving Certificate Applied Programme. In 2012 52,499 students took the Leaving Certificate (this is the sum of LC (Established) and LCVP), down on 2011 (54,341).

Table 1 Irish birth rates 2006-2011

Year	No. of births	~Date in post-primary
2006	64,237	2018
2007	71,389	2019
2008	75,173	2020
2009	75,554	2021
2010	73,724	2022
2011	74,650	2023

Table 1 shows the number of Irish births from 2006 to 2011 and the ~ date of entry into post-primary school. From birth it takes ~12 years to enter post-primary education and another 5/6 years to the LC exams. So the LC class of 2012 would have been born in ~ 1995 when the birth rate was 48,530. We have had a lot of immigration and more recently some emigration since then, but this figure is in line with this year's LC numbers of 55,815. The birth rate figures jump around 2001, and from 2000 to 2011 increased by 37.6% and indicate an expansion of primary numbers from ~2006 and in post-primary from ~2014, which will continue to increase from

year to year. These data have major implications for schools and third level institutions and more schools, more teachers and more places at third level will be needed in the future.

A recent publication (July 2012) looks at 'Projections of Full Time Enrolment Primary and Second Level, 2012 – 2030 (available at <http://www.education.ie/en/Publications/Statistics/Projections-of-full-time-enrolment-Primary-and-Second-Level-2012-2030.pdf>) and the data are shown in Table 2.

Table 2 Estimated numbers at primary and post-primary levels 2011-2013

Year beginning	Primary Level	Post-primary Level
2011 (prov)	516,460	322,528
2012	524,901	327,105
2013	536,316	335,957
2013	548,939	339,682

We must take account of the changing examination cohort if we are to make sense of an increase or decrease in numbers doing a subject, as the raw numbers are related to the size of the total cohort. (See below to find out what actually happened to the popularity of science subjects in 2012 and which were the winners and losers).

The same is true for the UK A-levels, but there the number of entries rather than number of students is usually published and this makes it impossible to see how popular a subject is compared to the size of the cohort and whether enrolment is going up or not. The raw number of entries alone is not enough as students take different numbers of subjects. Knowing the size of the cohort and the number of candidates (entries) in a particular subject allows us to compare the popularity of different subjects across different school systems.

Comments on the 2012 results

Unless specified otherwise all the statistics are from the SEC or DES websites. Table 3 shows

that all the sciences, except Physics and Physics & Chemistry, gained both numbers and % share and Agricultural Science and Chemistry made the largest % gains. Over the period 2002-2012 all the sciences gained numbers except Physics and Physics & Chemistry, which have shown a steady decline. Biology continues to be the dominant LC science subject (taken by 58.2% of the cohort) and the only science subject in the top 10 subjects (Table 9). The LC cohort decreased slightly this year by -3.0%, and Biology, Chemistry and Ag. Science all gained in market share (see Tables 4 & 10). Figure 1 shows the % taking the main science subjects since 1999 i.e. this is normalised for the change in size of the LC cohort.

Since 2002 Biology, Chemistry and Agricultural Science have all gained significantly, especially Biology and Agricultural Science (see Table 3). Physics and Physics & Chemistry have both decreased over this period. In 2012 Chemistry had the highest % doing the Higher Level course of the science subjects (82.9%), closely followed by Ag. Science, with 81.1% (Table 4). Chemistry

also shows the best gender balance (with a small excess of girls), whereas Biology has many more girls than boys doing it, and Physics many more boys than girls (Table 7). Physics is clearly in decline and this year's figures show that Agricultural Science has overtaken Physics as the third most popular science, as predicted last year. There is clearly a continuing swing towards the life sciences. Physics & Chemistry has been on its last legs for some years and continues to decline - it is definitely a 'dead man walking' of a syllabus, and it is a great pity that the new and innovative replacement, which was drawn up by the NCCA many years ago, has never been implemented. Sadly the new syllabus in Physics & Chemistry is still gathering dust on a shelf in the NCCA - it was a radical and innovative syllabus and it deserved an airing - it could have provided a popular alternative to the full Physics and Chemistry syllabi. If the course is not going to be revised it should be dropped as it must be one of the oldest/longest-lasting science syllabi in the world by now, along with Ag. Science, both over 40 years old!

Table 3: Changes in numbers doing LC Science subjects 2009-2011 (gains in bold)

Subject	Δ 2011-2012	$\Delta\%$ 2011-12	Δ 2010-2011	$\Delta\%$ 2010-11	Δ 2009-2010	$\Delta\%$ 2009-10	Δ 2002-2012 ($\Delta\%$)
Biology	+214	+0.7	+1,100	+3.8	+1,089	+3.9	+8,499 (+38.5)
Chemistry	+409	+5.3%	+129	+1.7	+145	+2.0	+1,589 (+24.45)
Physics	-143	-2.1	-229	-3.4	-178	-2.8	-2,278 (-26.3)
Phys+ Chem.	-65	-13.7	+47	+11.1	-84	-16.2	-468 (-57.4)
Ag. Science	+416	+6.4	+686	+10.2	+515	+9.8	+3,999 (+138.4)

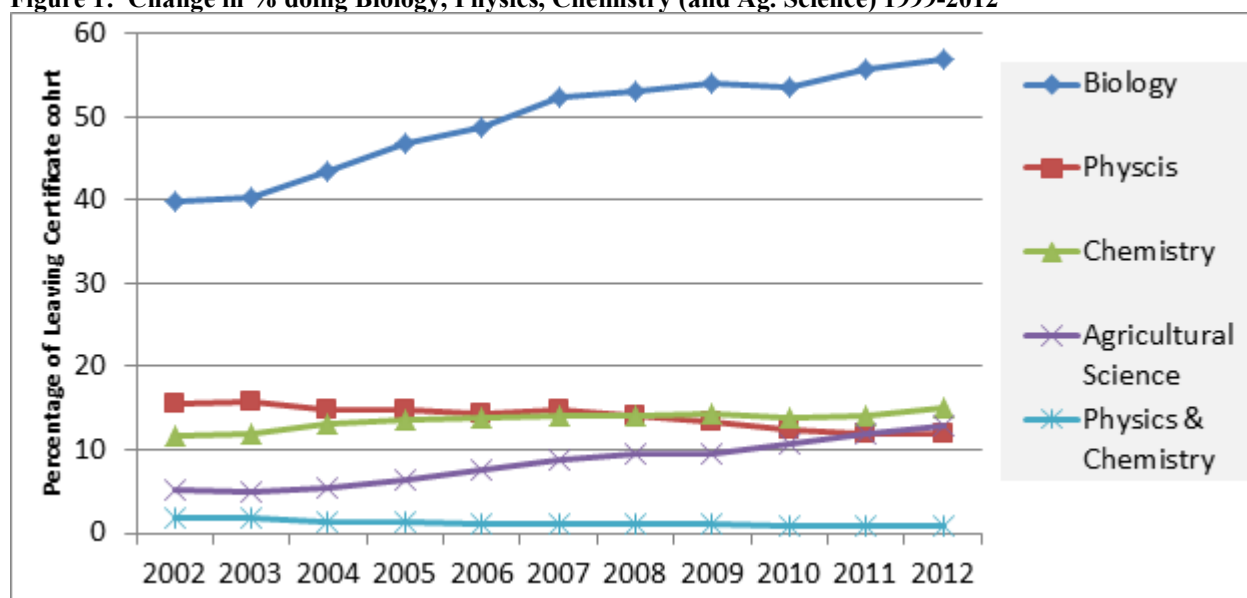
Biology is still far and away the most popular science subject, trailed at a distance by Chemistry and Physics: four times as many students take Biology as take Chemistry and Physics. It is clear that the Physics & Chemistry syllabus is dying on its feet, whereas Agricultural Science is growing steadily (+138.4% since 2002). All the sciences are quite elitist, with Chemistry and Ag. Science heading the poll with 82.9% and 81.1% respectively, doing the HL course (Table 4). Ag. Science is now the third science subject in

popularity, despite the fact that the syllabus is over forty years old! There is a strong case for scrapping the combined Physics and Chemistry course, or introducing a new syllabus, and for a major revision of the Ag. Science syllabus, bringing it into line with modern agricultural practices. The marked disparity in uptake between Biology and the Physical Sciences is more marked in Ireland than it is in most other countries.

Table 4: LC Science - % doing Higher Level and Ordinary Level 2012

	2012	HL 2012 (%)	OL 2012 (%)	%LC cohort 2012	%LC cohort 2011	%LC cohort 2010
Biology	30,536	22,740 (74.5)	7,796 (25.5)	58.2	55.8	53.7
Chemistry	8,086	6,705 (82.9)	1,381 (17.1)	15.4	14.1	13.85
Physics	6,373	4,753 (74.6)	1,620 (25.4)	12.1	12.0	12.4
Phys.+Chem.	405	309 (76.3)	96 (23.7)	0.77	0.87	0.78
Ag. Science	6,889	5,587 (81.1)	1,302 (18.9)	13.1	11.9	10.6

Figure 1: Change in % doing Biology, Physics, Chemistry (and Ag. Science) 1999-2012



In Table 5 you can compare the grades obtained in each subject at Higher and Ordinary level. Four bands are shown: %As, %A+B, %A+B+C and %E+F+NG (fails). At HL Chemistry (19.0%) and Physics (19.8%) students get more As compared to for Biology (16.7%), although this represents over 3 times more students getting As in Biology. This reflects the wider intake into Biology and probably that Chemistry and Physics attract a greater proportion of higher ability students. These results are fairly consistent over 6 years as can be seen above. At OL the differences are more marked – Physics students get 15.2% As at OL, whereas Chemistry students get 7.6% and Biology students 1.3%. The failure rates at HL for all three main sciences are very similar, as they are at OL, but remember that for Biology these represent

greater numbers of students. There is no marked change in the grading over this six year period for any of the three main science subjects.

Chemistry and Physics are more selective subjects i.e. they are done by smaller numbers and a higher % take the Higher Level papers, indicating that these are taken by better students. We would thus expect a higher % of good grades and less % of fails if the student populations doing Chemistry and Physics are more selective. This is what we observe. From 2007-12 the average % getting As in HL papers in Chemistry was 21.5% and 20.4% in Physics, compared to 17.0% in Biology. This does not mean that Biology is harder than Chemistry or Physics: it means that a larger number of students take Biology and have a

greater ability spread, compared to Chemistry and Physics. This is also consistent with the average 7.0% of fails in HL Chemistry of % 2006-12, compared to 7.7% in HL Physics and 8.4% in HL Biology. Again remember that the same % in Biology represents nearly 4 times as many students.

At Ordinary Level we would expect to see smaller % of good grades, as weaker students opt for the ordinary level papers - often at the last minute, and a greater % of fails. We would also expect

more % fails in Biology than Physics or Chemistry, because of the greater numbers and wider ability spread of students choosing Biology. The average % getting As in ordinary level Chemistry was 8.9% from 2006-12, with 15.6% getting As in Physics and 3.0% in Biology. The anomalies here are the high % of As in Physics and the very low % in Biology. When we look at the % fails in the ordinary level papers from 2006-12, 15.7% fail Chemistry, 10.2% fail Biology and 13.7% fail Physics.

Table 5: % of different grade bands 2007-2012

a) Chemistry							Higher level						Ordinary level					
Year	2012	2011	2010	2009	2008	2007	2012	2011	2010	2009	2008	2007	2012	2011	2010	2009	2008	2007
%A	19.9	21.9	20.8	21.6	23.5	21.0	7.6	9.1	7.6	9.2	11.7	8.0	29.7	36.4	29.8	34.6	42.2	31.8
%A+B	48.4	52.4	50.1	52.9	54.6	54.1	29.7	36.4	29.8	34.6	42.2	31.8	59.4	64.7	54.9	63.1	75.0	58.5
%A+B+C	72.5	76.0	75.3	77.5	78.7	79.0	59.4	64.7	54.9	63.1	75.0	58.5	16.6	12.8	18.5	15.3	13.9	16.8
%E,F,NG	9.0	8.6	6.1	7.0	5.8	5.5	16.6	12.8	18.5	15.3	13.9	16.8						

b) Biology							Higher level						Ordinary level					
Year	2012	2011	2010	2009	2008	2007	2012	2011	2010	2009	2008	2007	2012	2011	2010	2009	2008	2007
%A	16.7	15.6	17.4	16.0	16.6	19.5	1.3	2.2	3.1	3.6	4.8	2.7	17.9	22.8	29.6	26.3	29.7	24.5
%A+B	44.4	43.0	44.9	43.0	43.9	46.7	17.9	22.8	29.6	26.3	29.7	24.5	39.2	59.3	62.7	59.1	63.2	57.8
%A+B+C	71.1	69.9	71.6	69.9	71.5	71.7	39.2	59.3	62.7	59.1	63.2	57.8	13.5	13.2	14.1	15.3	11.1	15.0
%E,F,NG	8.4	8.3	9.2	8.8	7.9	7.9	13.5	13.2	14.1	15.3	11.1	15.0						

c) Physics							Higher level						Ordinary level					
Year	2012	2011	2010	2009	2008	2007	2012	2011	2010	2009	2008	2007	2012	2011	2010	2009	2008	2007
%A	19.8	20.2	20.8	20.3	19.9	21.4	15.2	14.8	17.4	17.0	15.5	13.5	46.5	44.3	49.0	49.7	47.3	43.8
%A+B	49.6	46.0	49.6	49.6	46.4	49.7	46.5	44.3	49.0	49.7	47.3	43.8	71.8	72.2	72.8	74.3	73.8	72.9
%A+B+C	74.6	72.9	73.3	72.9	70.8	75.8	71.8	72.2	72.8	74.3	73.8	72.9	9.7	11.2	11.6	10.0	8.7	9.7
%E,F,NG	7.3	8.0	7.0	7.8	8.6	7.5	9.7	11.2	11.6	10.0	8.7	9.7						

We would in fact expect an even higher % of good grades in both Chemistry and Physics given the highly selective populations doing these subjects. An important study by Kellaghan and Millar (2003) compared performance in different LC subjects by comparing a student's performance in pairs of subjects. A preliminary report on the study was given in the *Report of the Task Force on the Physical Sciences* (2002). This found that a student on average got lower grades in Chemistry and Physics compared to other subjects they took, indicating that it is actually more difficult to get high grades in these subjects.

The difference was between half and 1 ½ grades, which is a significant difference. This important study should be repeated at intervals to check on the comparability of marks across different subjects. It agrees with the anecdotal perception of students, parents and teachers that it is harder to get good grades in Chemistry and Physics, notwithstanding the already high % of As and Bs in these subjects. If this effect was allowed for, an even greater % of students would get As in Chemistry and Physics than they do at present and this might make the subjects more attractive to students.

Table 6: Gender breakdown of grades 2012

	%As overall	%As females	% As males
Chemistry	19.9(HL) 7.6(OL)	18.8(HL) 10.4 (OL)	21.2 (HL) 5.2(OL)
Biology	16.7(HL) 1.3(OL)	17.1 (HL) 1.5 (OL)	15.9 (HL) 1.2(OL)
Physics	19.8(HL) 15.2 (OL)	18.5 (HL) 20.2 (OL)	20.3 (HL) 14.1(OL)

Table 6 shows the gender breakdown of the 2012 HL and OL results for A grades. In several cases females outperform males (larger % shown in bold above), although the differences are small and boys get more As in both Chemistry and Physics. The trend for females to outperform males in state examinations has become more apparent year on year. We cannot say from these data whether this difference is due to intrinsic ability or to better study methods and harder work. The better LC results by females mean that

the number of females entering third level exceeds that of males, and more males drop out of fulltime education at all levels.

However, the gender balance in the LC science subjects is still a matter of concern. Table 7 shows the overall gender breakdown of the five science subjects i.e. HL and OL students are combined in these figures and the F:M ratio for each subject from 2010 to 2012.

Table 7: The overall gender balance in the LC Science subjects 2012 (compared to 2011 and 2010)

Subject	No. females (%)	No. males (%)	Ratio F:M 2012	Ratio F:M 2011	Ratio F:M 2010
Biology	18,523 (60.7)	12,013 (39.3)	1.54:1	1.60:1	1.75:1
Chemistry	4,344 (53.7)	3,742 (46.3)	1.16:1	1.23:1	1.29:1
Physics	1,581 (24.8)	4,792 (75.2)	0.33:1	0.33:1	0.33:1
Physics & Chemistry	2,629 (38.5)	4,240 (61.5)	0.62:1	0.74:1	0.61:1
Agricultural Science	161 (39.8)	244 (60.2)	0.66:1	0.59:1	0.55:1

As in the past Biology is heavily dominated by females (1.5:1) and Physics is dominated by males (3:1). Chemistry shows the closest gender balance, with a small excess of females. Ag. Science has a majority of males (1.5:1).

Table 8 shows the top 10 LC subjects from 2008 to 2012. Maths just slips from its first place in 2012 (despite Project Maths) being overtaken by

English. Nearly everyone who stays on a school until age 17/18 does Mathematics and does an examination in it. Biology is in 4th place and the most popular Science subject. Four subjects are taken by >50% of the LC cohort. Interestingly in the UK Biology, Chemistry and Physics are all now in the top 10 A level subjects.

Table 8 Top 10 LC subjects from 2008 to 2012 (HL+OL)

Subject	2008 Total (HL+OL)	2009 Total (HL+OL)	2010 Total (HL+OL)	2011 Total (HL+OL)	2012 Total (HL+OL)	% LC cohort 2012	Rank 2012
Maths (+FL)	50,116	51,902	52,290	51,991	50,442	94.1	2
English	49,382	51,032	51,499	51,455	50,517	94.3	1
Irish (+FL)	44,660	45,636	41,043	44,397	42,965	80.2	3
Biology	26,607	28,160	29,249	30,349	30,506	57.0	4
Geography	24,360	25,061	26,175	27,305	25,734	48.0	6
French	27,698	27,675	27,574	26,766	25,977	48.5	5
Business	18,733	18,425	18,790	18,083	17,248	32.2	7
Home Econs.	12,497	12,936	12,535	12,400	11,898	22.2	8
History	11,850	11,990	11,910	12,106	11,746	21.9	9
Art	10,283	10,693	10,786	10,782	10,279	19.2	10

Table 9 shows the change in the LC cohort (Established + LCVP) from 2002 to 2012, together with the % of the cohort taking Biology, Chemistry, Physics and Agricultural Science (these are shown graphically in Figure 1 above). Biology is clearly in the ascendant and numbers and its % share has climbed steadily since the new syllabus was introduced in 2002 and examined first in 2004. The new Physics and Chemistry syllabi were first examined in 2002 and since then Physics has been on a slow decline and Chemistry

on a slow increase, so that Chemistry overtook Physics in 2009 and the gap continues to widen. More students are doing Chemistry now than at any time in the last 10 years. Agricultural Science numbers continue to increase and it has now overtaken Physics as predicted last year, replacing Physics as the third most popular science subject. The continuing decline in Physics is a matter of concern, although it may have bottomed out.

Table 9 Changes in the LC cohort and science subjects (2002-2012)

	LC Cohort	Biology Total	%	Chemistry Total	%	Physics Total	%	Ag. Science Total	%
2002	58,489	22,064	37.7	6,497	11.1	8,651	14.8	2,890	4.9
2003	56,229	22,669	40.3	6,698	11.9	8,806	15.7	2,972	5.3
2004	55,183	24,027	43.5	7,229	13.1	8,152	14.8	3,237	5.9
2005	54,069	25,362	46.9	7,366	13.6	7,944	14.7	3,625	6.7
2006	50,995	24,885	48.8	7,071	13.9	7,335	14.4	3,912	7.7
2007	50,870	25,792	50.7	6,926	13.6	7,251	14.3	4,267	8.4
2008	52,144	26,607	51.0	7,114	13.6	7,112	13.6	4,738	9.1
2009	54,196	28,160	51.8	7,403	13.7	6,923	12.8	5,272	9.7
2010	54,481	29,249	53.7	7,548	13.85	6,745	12.4	5,787	10.6
2011	54,341	30,349	55.8	7,677	14.1	6,516	12.0	6,473	11.9
2012	52,499	30,563	58.2	8,086	15.4	6,373	12.1	6,889	13.1

***New Biology syllabus examined from 2004 onwards; new Physics and Chemistry syllabi examined from 2002. LC Cohort is LC (Est) + LCVP**

Table 10 shows the change in size and composition of the LC cohort from 2005 to 2012. After a minimum number in 2007, the numbers doing the LC increased above 2005 levels in 2010 and then declined, however, they are due to continue increasing in the foreseeable future due to the increased birth rate working its

way up through the schools system. The drop from 2010 is probably due to emigration and will be corrected in future years.

In Table 11 the grades for all five science subjects are shown for 4 years from 2009 to 2012, at both Higher and Ordinary level.

Table 10 Change in LC numbers 2005-2012

Year	LC (Est)	LCVP	Total LC (Est) + LCVP	LCAP	Total
2005	39,792	14,281	54,073	3,318	57,391
2006	36,932	14,023	50,955	3,155	54,110
2007	36,790	14,080	50,870	3,056	53,926
2008	37,639	14,505	52,144	3,445	55,589
2009	39,112	15,084	54,196	3,259	57,455
2010	38,885	15,596	54,481	3,358	57,839
2011	37,995	16,386	54,341	3,191	57,532
2012	36,762	15,827	52,499	3,358	55,857

**Table 11: 2009-2012 LC Science Results at HL and OL
(Current year in bold)**

Chemistry	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2012	6,705	11.5	8.4	9.9	9.5	9.1	8.2	7.3	8.7	5.3	6.1	7.1	5.9	2.5	0.6
HL 2011	6,272	11.4	10.5	10.5	10.9	9.1	7.9	8.3	7.4	4.8	4.5	6.1	5.6	2.4	0.6
HL 2010	6,298	9.7	11.1	9.7	10.2	9.4	8.5	8.6	8.1	5.4	5.0	6.3	5.3	2.2	0.6
HL 2009	6,037	12.3	9.3	10.4	11.0	9.9	8.5	8.1	8.0	4.5	4.9	6.2	4.7	1.8	0.5
OL 2012	1,381	2.0	5.6	4.9	8.2	9.0	4.0	10.0	9.3	7.9	7.4	8.7	9.9	4.8	1.9
OL 2011	1,405	3.3	5.8	7.5	8.9	10.9	9.3	8.6	10.4	7.8	7.0	7.8	6.8	4.8	1.2
OL 2010	1,250	2.2	5.4	4.9	8.6	8.7	9.1	9.1	8.1	7.9	7.7	9.8	10.1	6.8	1.6
OL 2009	1,366	3.0	6.2	5.9	8.6	10.9	10.8	8.6	9.1	5.3	6.8	9.4	8.7	5.6	1.0
Biology	No.	A1	A2	B1	B2	B3	C 1	C2	C3	D1	D2	D3	E	F	G
HL 2012	22,740	7.6	9.1	8.5	9.1	10.1	8.9	9.1	8.7	7.0	6.6	6.9	6.5	1.7	0.2
HL 2011	22,677	6.3	9.3	7.9	9.4	10.1	9.0	9.3	8.9	7.6	6.6	7.1	6.6	1.6	0.1
HL 2010	20,971	8.9	8.5	8.4	9.1	10.0	8.5	8.9	8.3	6.9	6.3	7.0	6.9	2.0	0.3
HL 2009	20,101	7.7	8.5	8.1	9.0	9.9	8.9	9.1	8.9	7.2	6.7	7.2	7.0	1.6	0.2
OL 2012	7,796	0.4	0.9	2.6	5.3	10.0	5.0	1.0	6.0	7.0	8.5	9.0	9.4	3.5	0.6
OL 2011	7,672	0.6	1.6	3.9	6.6	10.1	11.2	13.1	12.2	10.6	8.3	8.7	9.1	3.7	0.4
OL 2010	8,278	0.7	2.4	5.3	9.3	11.9	11.5	11.5	10.1	8.1	6.7	8.4	8.7	4.5	0.9
OL 2009	7,999	1.0	2.6	5.2	7.5	10.0	11.0	11.3	10.5	9.6	7.8	8.4	9.9	5.0	0.4
Physics	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2012	4,753	9.7	10.1	10.3	9.7	9.8	8.8	8.4	7.8	6.7	5.4	5.9	5.6	1.3	0.4
HL 2011	4,782	8.9	11.3	7.0	9.3	9.5	9.0	8.8	9.1	7.4	5.6	5.9	5.9	1.7	0.4
HL 2010	4,877	8.8	12.0	8.4	10.8	9.6	9.2	9.4	5.1	8.8	6.0	5.0	5.2	1.4	0.4
HL 2009	4,693	10.6	9.7	10.2	10.2	8.9	8.6	8.6	6.1	7.2	5.8	6.3	5.1	2.4	0.3
OL 2012	1,620	5.3	9.9	8.3	5.0	8.0	8.1	8.6	8.6	4.5	6.4	6.4	6.4	3.2	1.0
OL 2011	1,734	6.0	8.8	6.2	10.6	12.7	6.7	10.3	10.9	4.4	6.2	5.9	7.6	3.2	0.4
OL 2010	1,868	8.0	9.4	9.0	9.8	12.8	7.5	7.2	9.1	3.9	4.4	7.3	5.8	4.2	1.6
OL 2009	2,230	5.7	11.3	9.2	10.0	13.5	8.2	8.2	8.2	5.4	4.5	5.8	5.7	3.3	1.0
Phys+Chem	No.	A1	A2	B1	B2	B3	C 1	C2	C3	D1	D2	D3	E	F	G
HL 2012	309	8.7	10.4	10.0	10.7	10.4	5.8	8.4	10.0	3.9	4.2	6.5	7.4	2.3	1.3
HL 2011	379	12.9	9.5	7.9	9.2	10.0	6.9	6.9	8.4	5.5	6.1	5.8	8.2	2.4	0.3
HL 2010	355	8.2	11.3	7.9	12.1	6.2	10.1	4.5	7.0	4.8	6.2	6.2	8.5	3.7	3.4
HL 2009	408	7.8	9.3	7.8	10.3	8.6	7.6	9.1	9.3	6.1	6.4	7.1	5.9	3.7	1.0
OL 2012	96	1.0	5.2	4.2	7.3	9.4	2.1	6.3	7.3	5.0	5.2	4.0	8.3	4.0	9.4
OL 2011	93	2.2	2.2	2.2	4.3	17.2	7.5	4.3	10.8	6.5	4.3	12.9	10.8	11.8	3.2
OL 2010	70	1.4	2.9	2.9	2.9	5.7	2.9	5.7	14.3	7.1	7.1	18.6	12.9	10.0	5.7
OL 2009	111	1.8	3.6	0.0	2.7	9.9	1.8	8.1	16.2	9.0	9.9	10.8	11.7	10.8	3.6
Ag. Science	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2012	5,587	4.3	5.7	7.2	8.5	10.1	10.3	10.0	9.6	9.3	8.3	8.1	7.6	1.1	0.0
HL 2011	5,287	6.3	6.8	7.9	8.3	8.5	8.9	9.7	9.4	9.3	7.8	8.6	7.5	1.1	0.1
HL 2010	4,675	3.8	6.1	7.7	9.2	9.9	10.5	10.8	10.2	9.3	7.5	7.7	6.3	1.1	0.1
HL 2009	4,164	5.7	6.9	8.0	8.7	9.4	9.8	9.3	10.4	9.3	7.0	7.4	6.6	1.4	0.0
OL 2012	1,302	0.0	0.3	1.0	2.8	5.1	9.1	4.0	6.0	8.0	9.0	1.0	4.0	4.2	0.2
OL 2011	1,186	0.0	0.3	0.4	1.9	5.1	7.5	11.6	13.3	12.4	13.6	14.8	13.8	4.6	0.8
OL 2010	1,112	0.1	0.3	1.8	5.2	7.3	11.0	11.9	13.5	12.8	12.0	11.0	9.9	3.2	0.2
OL 2009	1,108	0.0	0.4	1.2	3.0	5.1	7.3	11.9	13.4	14.3	10.6	13.4	13.3	5.8	0.5

(LC Grading at Higher Level: A1 90-100%; A2 85-89%; B1 80-84%; B2 75-79%; B3 70-74%; C1 65-69%; C2 60-64%; C3 55-59%; D1 50-54%; D2 45-49%; D3 40-44%; E 25-39%; F 10-24%; NG 0-9%)

Conclusion

Overall the sciences are holding their own at LC level, with the life sciences showing strong growth. A majority of LC students (>60%) take at least 1 science subject, the greatest number taking Biology, and virtually every LC student takes Mathematics. This is a very good foundation for further study and Irish students have a wide range of courses and careers open to them. Many students in the UK drop the sciences and Mathematics at age 16, and much smaller percentages of those doing A-level do Mathematics or a science subject. There is still room for growth in LC Chemistry, which is still a long way from the 20% take-up of the early 80s. However, something needs to be done to reverse the decline in Physics, even though this year it appears to have bottomed out. All three of the main science subjects – Biology, Chemistry and Physics – are under major revision and the proposals, if implemented, will mean a radical

change in content, teaching approaches and assessment. However, it would perhaps be more urgent, less controversial and cheaper to have new syllabi for Agricultural Science and the combined Physics with Chemistry courses, both over 40 years old. Agricultural Science is showing strong growth but the combined Physics with Chemistry course should either be revised or dropped due to the small take-up. As well as the healthy numbers doing LC science courses, enrolment on science courses at third level have also shown an increase over the last two years.

For the NCCA's Senior Cycle Consultation Report

see http://www.ncca.ie/en/Consultations/Senior_Cycle_Science/Senior_Cycle_Science_Consultation.html

For the draft new Chemistry syllabus see: http://action.ncca.ie/media/942/draft_lc_chemistry.pdf

□

Technical Tips for Teachers #2

Ordering and storing chemicals

Anita Mahon

Technician, Villiers School, Limerick nindi17@eircom.net

Buying chemicals

Using and storing chemicals has implications for the person who purchases them. There are legal requirements regarding the safe handling, transport and storage of chemicals, see:

http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/chemical_products/121276_en.htm

Most of the chemicals used in school laboratories are safe; however, they may not be when mixed with other chemicals.

All chemicals must be kept in their original containers: **never** transfer into other bottles, tubs, jars etc. They must have their original labels with the safety risks and phrases.

If you find chemicals in a lab with no label or an illegible label - consult a chemical disposal company.

Do not dispose of chemicals yourself, unless you have a technical qualification to do so.

Material safety data sheet (MSDS)

The MSDS is a document that describes the chemical, gives its pseudonyms, chemical formula, its risks and storage advice.

It is a legal requirement that you have them available and they must be written in the school safety statement.

All chemicals must have a MSDS: these will be supplied with the chemical when purchased. If you have older chemicals get the appropriate MSDS

from <http://www.scichem.com/msds.aspx?char=1>

Labels

The format on labels on chemical has a layout to inform you of its risks.

This web site will give you all the information needed to assess the risks involved in handling

chemicals:

<http://www.hse.gov.uk/chip/phrases.htm>

Never be tempted to accept an offer from an institution of their unwanted chemicals. Buy them new from a reputable laboratory supplier. It is very expensive to dispose of unwanted chemicals. Only stock what you need.

Storage

Storage label colour code:

	oxidising agent
	corrosive alkali
	poison/health risk
	corrosive acid
	no risk
	Flammable

There are 5 main storage categories



Flammable



Corrosive



Oxidative



Poisonous

General

You can buy rolls of coloured safety labels from laboratory suppliers.




Chemicals may have a number of safety instructions on the labels. The MSDS will give you the information needed.

I would advise that you buy liquid chemicals in 500 cm³ or 1000 cm³ volumes. Some suppliers still supply Winchester bottles of acids and corrosives. These bottles contain 2.5 L and can be very difficult to work with.

Storing chemicals is not simply a case of putting them on shelves in alphabetical order.

- All oxidising chemicals must be stored together separate from all other chemicals.
- All flammable chemicals must be stored in a safety cabinet at ground level
- All corrosive chemicals must be stored a safety cabinet at ground level
- All the rest can be stored in alphabetical order
- All solutions made on site must be stored in bottles (**not** in volumetric flasks or conical flasks!!!), again I suggest 1 L or 500 cm³ bottles be used. Plastic ones are convenient – lighter and unbreakable.

MAGNESIUM OXIDE 014/250		CODE:
POWDERED MAGNESIUM OXIDE		BATCH:
	THE DANGEROUS CHEMICAL COMPANY	PRODUCED:
	HARMFUL SPECIALIST ADVICE No.	NET WT. KG.
0161 123 4567		STORE IN DRY CONDITIONS HARMFUL BY INGESTION AVOID EYE CONTACT

Making solutions

The label on a jar/bottle when purchased will always state:

- The name
- The formula
- The quantity
- The risk/safety code
- The molecular mass (g/mol)

The molecular mass in grams dissolved in water and made up to 1000 cm³ in distilled water is a 1M solution.

From this information a solution of any molarity can be made: e.g.

0.01 We want to make up 0.01 M NaOH :

mol mass = 40 g/mol

1M NaOH = 40.0 g/L

0.01M NaOH = 0.40 g/L

(A more detailed treatment was published in ChemTips: 4, 'Making up solutions', *Chemistry in Action!* #67 Summer 2002)

Solutions of acids (and ammonia) are more complicated as we are starting with a liquid, not a solid.

Below is a table for making up stock solutions (usually 1 M) of some common chemicals:

* The molarity supplied when purchased as concentrated solutions

Ammonia (17 M)*	Ethanoic acid (17 M)*	Hydrochl oric acid (11.6 M)*	Sulphuri c acid (18 M)*	Nitric acid (15.8 M)*
53 cm ³ /L = 1M *	58 cm ³ /L = 1M	90 cm ³ /L=1 M	48 cm ³ /L=1 M	63 cm ³ /L=1 M
*3M solution normally used – thus 162 cm ³ /L = 3 M				

If you need 2M, 4M etc. just multiply the volumes by the appropriate figure above and make up to 1 L. You might decide to make up e.g. a 4 M

stock solution, which can be diluted as needed to 2 M, 1 M etc.

Please note that these are not standard solutions as the initial solutions have a variable composition. They can be used as stock chemicals but for analytical use they must be standardised.

All solutions should be labelled when made in the following format, using waterproof ink.

Name , molarity quantity/litre,	
date	initials (of the person who made it)

Example:

H ₂ SO ₄ 1.0M 48cm ³ /L	
1/11/12	AM

Useful tips:

- Get into the habit of always putting the lids back on containers of chemicals.
- Get into the habit of always putting chemicals back after you use them.
- Always label immediately you make up solutions.
- When in doubt, "Don't throw it out", contact a disposal company.
- Don't pour chemicals back into the container after use.
- Dispose of any unwanted chemicals properly (consult MSDS sheets).

□

Have you got any good laboratory tips to share with others? If so, please send them in and share them with your colleagues.

Chemlingo: Grass is green

Peter E. Childs

My Chemlingo column, on the history of words in chemistry, has been appearing in *Education in Chemistry* since 1993 but the editor has just decided to discontinue the feature. I hadn't run out of ideas but Chemlingo will now continue in *Chemistry in Action*! Many of the previous ones are available on line from the RSC – search for Chemlingo. This is actually #49 in the series!

In a previous article (Chemlingo #46, which appeared in *Education in Chemistry*, January 2010, available at <http://www.rsc.org/Education/EiC/issues/2010Jan/Cemlingo.asp>), I looked at some of the names for green with chemical connections.

You may feel jaded by this concentration on a single colour, but jade is yet another green mineral, highly prized by the Chinese, from which we get the term jade-green. The most valuable jade is jadeite, a sodium aluminium silicate. Jade was supposed to cure nephritic colic and the Spanish named it *piedra de ijada*, stone of colic. This was corrupted into French as *le jade*, hence jade. The less valuable form of jade is called nephrite. What is the connection with kidneys? This form of jade used to be called *lapis nephriticus* or kidney stone, because it was once thought to be a cure for kidney stones.

Grass is green and in Ireland comes in forty shades! Verdant means green and is often used to refer to landscapes, as in the phrase 'verdant pastures' and derives from the Latin *viridis* = green, becoming *verte* in French. A verderer is a person who was appointed to look after the Royal forests in England and the post is still extant.

Chartreuse is a green liqueur and gives its name to a yellow-green colour. Absinthe is another green drink which has also given its name to a colour, and like chartreuse gets its colour from plant

extracts. Absinthe contains extract of *Artemisia absinthium*, also known as wormwood. In France it was known as 'the green fairy' and became notorious for its addictive qualities. Eau-de-Nil (water of the Nile) is the name for a light shade of green, although I don't know that Nile water ever became popular as a drink.

Olive green is named after the drab green colour of olives, and olivine is a green mineral containing iron. Lovat is named after the colour of Scottish tweeds from Lovat and sage is named after the colour of the herb, and both words used for gray-green.

The Latin name for emerald was *smaragdus* and smaragde became the English for an emerald, from which we get the adjective for green, smaragdine. Not a word that would catch on easily or trip off the tongue! In French this word became *emeraud* and this in time became our English word emerald.

Turquoise is a blue-green mineral which gives its name to the colour and the name may be derived from Turkish, since it was first traded into Western Europe from Turkey. A similar colour is aquamarine, named after the colour of the sea, and it is also the name of a mineral, a variant of beryl. Dark shades of blue-green are called teal and light shades cyan, as in the colour used in colour printers.

There are an amazing variety of colour words, describing different shades and hues, and green has a rich, etymological history.

□

Diary

2013

ASE meeting

2-5 January

University of Reading,
Reading, UK

<http://www.ase.org.uk/conferences/annual-conference/>

ASTE Annual Conference

*Science Education through
a Historical and Cultural
Lens*

9 - 12 January

Charleston, SC, USA

<http://theaste.org/meetings/2013conference/>

New Perspective in Science Education Conference

14 – 15 March

Florence, Italy

<http://www.pixel-online.net/npse2013/>

Deadline for submission:

14th Nov. 2012

2013 NARST Annual International Conference 6-9 April

Rio Grande, Puerto Rico

<http://www.narst.org/annual-conference/2013conference.cfm>

NSTA Annual Conference

11- 14 April

San Antonio, Texas, USA

<http://www.nsta.org/conferences/2013san/>

51st ISTA Meeting

12-13 April

Gorey, Co. Wexford

www.ista.ie

Gordon Conference: Chemistry Education Research & Practice

*Strengthening the Pillars of
Scholarly Work in
Chemistry Education*

9 – 14 June

Newport, RI, USA

<http://www.grc.org/programs.aspx?year=2013&program=chemedu>

Eurovariety 2013

*'Smarter teaching – better
learning'*

3-5 July

University of Limerick

www.eurovariety2013.ul.ie
peter.childs@ul.ie

Submissions: 1 November –
28 February

ChemEd,

28 July – 1 August

University of Waterloo,
Canada

<http://uwaterloo.ca/chemed2013/>
jhein@uwaterloo.ca

IUPAC 44th World Chemistry Congress

11 – 16 August

Istanbul, Turkey

<http://iupac2013istanbul.org/>

10th ESERA,

2-7 September

Nicosia, Cyprus

http://www.esera2013.org.cy/nqcontent.cfm?a_id=1
info@esera2013.org.cy

Submissions: **5 September**

2012 - 31 January 2013

ICASE 4th World Conference on Science and Technology Education

29 September – 3 October

Borneo, Malaysia

<http://worldste2013.org/>

32nd ChemEd-Ireland

Sat. October 19

Limerick Institute of
Technology, Limerick
Marie.walsh@lit.ie

**If you know of any relevant
conferences or events of
interest to chemistry
teachers, please send in
details to:**

peter.childs@ul.ie

*“Reading maketh a full man; conference a ready man; and writing an exact man.
Read not to contradict and confute; nor to believe and take for granted;
nor to find talk and discourse; but to weigh and consider.
Some books are to be tasted, others to be swallowed, and some few to be chewed
and digested.”*

Francis Bacon