
Contents

1. Contents
2. Editorial
3. Education News and Views
5. Banned chemicals: an over-reaction?
7. Banned chemicals? The potential impact of REACH regulations on practical science in schools and colleges
15. The importance of practical work
16. More small scale, hands-on experiments for easier teaching
By the late Viktor Obendrauf
27. Organic oxidations with KMnO_4 (instead of dichromate)
 1. Preparation of ethanol using KMnO_4
 2. Preparation of ethanoic acid using KMnO_4 Anne O'Dwyer
33. Balancing organic redox reactions
35. Chemistry in the Primary Science Curriculum Maeve Liston
41. Diary
42. The Element Makers: 12 Carl Wilhelm Scheele (1742-1786)
Adrian Ryder
46. Conference Reports:
 - 4th Eurovariety, Bremen Anne O' Dwyer & Sarah Hayes
 48. 9th ESERA, Lyon Muireann Sheehan and Marie Ryan
 50. 5th Chemistry Demonstration Workshop: Smoke and fire: putting the 'wow factor' back into science teaching Peter E. Childs & Sarah Hayes
 52. 30th ChemEd-Ireland Conference
 53. ChemTips
 54. Information Page

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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.

For subscription details etc. see inside back cover.

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Cover photo: Flaming gas bubbles at the 5th Chemistry Demonstration Workshop in Limerick (Photo: Press 22/University of Limerick)

Editorial

Remembering Viktor Obendrauf

The theme for this issue is chemical experiments and demonstrations, in memory of Viktor Obendrauf who died in 2010. I am pleased to be able to reprint one of his demonstration lectures given at the 20th ICCE in Seoul in 2008, although nothing can replace seeing him in real life (see p.16). The 22 ICCE/11 ECRICE conference in Rome 15-20 July 2012 will include the Viktor Obendrauf Memorial Demonstration Lecture, given by Bassam Shakashiri.

Viktor was an unassuming person but his lectures were dramatic and eye-catching. He visited Ireland several times and gave his lecture at two ChemEd-Conferences. He will be sadly missed by his family, his colleagues and science teachers worldwide.

In this issue you will find information on using potassium permanganate instead of potassium dichromate for organic oxidations (p. 27), as the use of dichromate is now banned (see p. 5). You will also find an illustrated report on p. 50 on this year's Chemistry Demonstration Workshop (see also the cover). There is an emphasis in this issue on practical work in chemistry, an essential part of the teaching and learning of the subject (see p.15).

New brooms sweep clean

The new Minister for Education and Skills, Ruari Quinn, is certainly making sweeping changes in the educational scene, after only a few months in office. Apart from the need to make cutbacks in many areas, ambitious plans are in progress to revise the Junior Certificate and to implement changes in the Leaving Certificate as well. The draft new syllabi in Chemistry, Biology and Physics have been published for consultation on the NCCA website. These will be discussed in detail in the next issue of *Chemistry in Action!*, but one of the major changes is the intention to introduce assessment of practical work in all the sciences, in part through school-based practical assessments.

Banned chemicals and bomb squads

Earlier in the year a bomb dropped into school prep rooms all over the country, with the release of Circular 0014/2011 from the DoES, banning

with immediate effect a number of chemicals – from potassium dichromate to cobalt chloride paper. These were banned because of the European rules regulating chemicals that say that any compounds with a significant risk must not be used – this includes compounds of chromium (VI) and all cobalt compounds. This seemed like an over-reaction and it was done without consultation. In a classic Irish solution to an Irish problem, schools cannot do dichromate oxidations but they will still be examined in theory! I forwarded this circular to Bob Worley at CLEAPSS in the UK, a body with great experience in evaluating school safety. Their response to this topic is found on p. 7 and concludes:

- *A blanket ban on the use of chemicals such as SVHCs is not appropriate because:*
 - *it limits the opportunities to develop vital skills*
 - *such a ban would continue to give to “H&S” a bad name which it does not deserve.- as is often seen in media reports*

This supported my own view that the DoES ban was an over-reaction and the result will be to impoverish further the teaching of chemistry as a practical subject.

Army bomb disposal makes chemical safe *Irish Times* 24/9/11

Later on at the start of the school year, the bomb squad was called out to several schools (in Asbourne, Coolock, Kilmallock and Croom) to dispose of old bottles of picric acid and 2,4-dinitrophenylhydrazine. The school year literally started with a bang in these schools. This may also have been an over-reaction and I have not heard of any school explosions due to the use of 2,4-dinitrophenylhydrazine. It should always be kept moist and bottles should be checked frequently to see they have not dried out.

Peter E. Childs
Hon. Editor

Education News and Views

New Junior Certificate course

After flagging the changes several times, the Minister of Education and Science has confirmed that plans to change the Junior Certificate course will go ahead in 2014. At present

IYC is over



International Year of
CHEMISTRY
2011

By the time you read this IYC 2011 will be over. The website is still active and you can still find out what happened and find useful ideas to promote chemistry in school.

<http://www.chemistry2011.org/participate/events>

New names confirmed

The periodic table of elements has three new names. The International Union of Pure and Applied Physics, meeting in London on Friday 4th November, approved the names for elements that hitherto have been known as Elements 110, 111, and 112, reflecting the number of protons in their nuclei. All are short-lived synthetic substances that were first manufactured at the Society for Heavy Ion Research Laboratory, in Darmstadt, Germany, in the 1990s. The new names, which were also approved by the International Union of Pure and Applied Chemistry, are darmstadtian (Ds), roentgenium (Rg, after the German scientist who discovered X-rays), and copernicium (Cp, after the Polish astronomer who displaced earth from the centre of the universe). So now the physicists and chemists are agreed, we can finally use the new names officially. I had thought this was settled some while back, but the wheels of officialdom grind slow.

1																	2				
H																	He				
3	4															5	6	7	8	9	10
Li	Be															B	C	N	O	F	Ne
11	12															13	14	15	16	17	18
Na	Mg															Al	Si	P	S	Cl	Ar
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54				
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
55	56			72	73	74	75	76	77	78	79	80	81	82	83	84	85	86			
Cs	Ba			Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn			
87	88			104	105	106	107	108	109	110	111	112	113	114	115	116	117	118			
Fr	Ra			Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo			
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71							
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu							
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103							
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr							

You can download and print this version of the Periodic Table at:

<http://education.jlab.org/itselemental/>, together with some useful elemental games.

50th. ISTA conference

2012 marks the 50th anniversary of the ISTA annual conferences. It will be held in Trinity College, Dublin from 20-22 April. An exciting programme is being organised and you should book these dates now.

www.ista.ie

Dublin City of Science 2012

Dublin is the European City of Science in 2012 and a series of events are being planned to celebrate this. July 12-15 will see the Euroscience Open Forum being organised in the Convention Centre, Dublin.



www.dublinscience2012.ie/

This is a major European event and Dublin won it against stiff competition.

The Euroscience Open Forum (ESOF) is Europe's largest, general science meeting and is held in a leading Europe city every two years. The first meeting was held in Stockholm in 2004, followed by Munich (2006), Barcelona (2008) and Turin

(2010). Dublin was awarded the honour of hosting ESOF in 2012, following an open competition. Copenhagen will host the event in 2014. ESOF is an interdisciplinary, pan-European meeting, held under the auspices of [Euroscience](#), which aims to:

- Showcase the latest advances in science and technology;
- Promote a dialogue on the role of science and technology in society and public policy; and
- Stimulate and provoke public interest, excitement and debate about science and technology.

Ireland doing well in science

The Minister for Research and Innovation, Séan Sherlock TD has responded to the recently announced Times Higher Education and QS World University rankings, and the positions of Ireland's universities. Ireland has 5 universities ranked in the top 300 globally.

Speaking during Science Week (22 Nov. 2011) Minister Sherlock said "While the headline rankings given to Irish Universities by both QS and Times Higher Education have been widely covered by the media, both here and abroad, there is much more to the Irish position in the wider academic landscape, where our educational institutions are continuing to compete strongly from a worldwide perspective."

"For example, in the Times Higher Education Survey 2011/2012, when the number of universities in the top 200 is considered against GDP, it shows that Ireland ranks 6th in the world."

"Such a high ranking reflects the Government's strategy of improving Ireland's entire academic ecosystem, rather than focusing on a very small number of elite institutions, as is done in some other countries."

"The effect of this is to ensure the quality of all graduates from Ireland's HEIs are of a high standard, a fact further borne out in the recent IBEC Employer survey, which found that 75% of employers have no problems recruiting suitable graduates from Irish HEIs, and the multitude of multinational corporations who continue to invest in R&D facilities in Ireland."

The Minister added "Furthermore, the overall rankings do not reflect Ireland's exceptional performance in certain fields, particularly the sciences."

Thomson Reuters Essential Science Indicators 2010, which measures the impact of countries' scientific research, ranks Ireland in 20th position in the world across all research fields – a dramatic rise from our placing of 36th as recently as 2003. Ireland is ranked even higher in areas such as in Immunology (3rd) and Materials science (8th).

Ireland continues to produce large numbers of highly educated and skilled workers, despite economic pressures, ranking 4th in the OECD and 1st in the EU in third-level attainment rates of 25-34 year olds.

In addition as captured in the World Competitiveness Yearbook (2011) IMD, Ireland ranks 1st globally for availability of skilled labour and openness to new ideas (up from 4th in 2010) and is ranked 4th globally for labour productivity per person employed per hour (up from 6th in 2010).

Minister Sherlock concluded by saying "Of course we know that we can continue to further improve elements right across our higher education and innovation system but it is through the quality of our people plus the exceptional work and research being performed at all of our institutions, that we can successfully build a true knowledge economy, one that will grow from strength to strength."

NWE IOSTE Conference

Science and technology education research and its impact on practice

The National Centre of Excellence for Mathematics and Science Teaching and Learning at the University of Limerick is hosting an IOSTE conference for NW Europe from April 18-20 2012. IOSTE is the International Organisation for Science and Technology Education. This conference was held in Reading in 2011. The local organisers are Sarah Hayes and Peter Childs, in conjunction with John Oversby, University of Reading. Closing date for abstracts: 11/2/12.

<http://ioste-nwe.wikispaces.com/>

Banned chemicals: an over-reaction?

In Feb. 2011 the Department of Education and Skills sent out a circular to schools (0014/2011), listing a number of chemicals which were banned for school use, with immediate effect. The circular is reproduced below. This information was sent to Bob Worley of CLEAPSS, the UK organisation for schools who advise on safety and other matters. Their comments on the topic of SHVCs (Substances of Very High Concern) are given after this letter and they also convened a one day conference in the UK on Nov.22nd 2011 on this topic. The conclusions on p. 9 are very significant as they suggest that a blanket ban is not necessary providing all necessary precautions are taken. Borax and boric acid are compounds frequently found in the kitchen and medicine cabinet at home, not just in a school laboratory.

Banned chemicals circular

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Circular 0014/2011

To the Principals and Boards of Management of Second level Schools

Discontinued Use of Chemicals – Substances of Very High Concern

A Consolidated EU Regulation on the Registration Evaluation and Authorisation of Chemicals (REACH EC 1907/2006) came into effect in June 2007. It is designed to improve the protection of human health and the environment from the risks that can be posed by some chemicals, and gives rise to new requirements on industry in this area. This Regulation is being implemented progressively.

As part of this process, the European Chemicals Agency (ECHA) has been identifying substances as Substances of Very High Concern (SVHCs). Substances identified as SVHCs are placed on a list (referred to as the ‘candidate list’) for possible inclusion in Annex XIV of the Regulation. Any substance cited in Annex XIV of the Regulation will eventually be subject to authorisation requirements under REACH. Substances are added to ECHA’s candidate list regularly, and Annex XIV will also be updated on a regular basis.

To date a number of substances that are currently used in schools have been designated as Substances of Very High Concern and have been cited on the candidate list and so may eventually be included in Annex XIV of REACH.

To date none of these substances have been added to Annex XIV of the Regulation. However, following a review and based on the advice of the Health and Safety Authority, the Department has decided that **the use of the substances listed hereunder should be discontinued in schools.** This list includes substances currently designated as SVHCs and a number of chemically related substances. Table 1 is set out overleaf giving details of areas where these substances are currently used in Leaving Certificate Chemistry and Junior Certificate Science.

Substances whose use should be discontinued include:

Sodium Chromate, Sodium Dichromate, Potassium Chromate, Potassium Dichromate, Ammonium Dichromate, Copper Chromate, Copper(II) Dichromate and all other chromium(VI) compounds; Cobalt(II) Chloride, Cobalt(II) Nitrate and all other Cobalt(II) compounds; any other chemically related compounds. The use of cobalt chloride paper should also cease.

The chemicals listed should be isolated, stored safely and retained at school level until the school is contacted by a chemicals disposal company. In addition, if schools have any supplies of **Boric Acid, or disodium tetraborate [tetraboron disodium heptaoxide] in either its anhydrous or hydrated forms [i.e. $\text{Na}_2\text{B}_4\text{O}_7$ and $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$]** they should also be isolated for disposal as part of this process.

If any of these substances are used in Art Craft and Design (for example in ceramics) they should also be discontinued. Schools are advised that the websites www.nsead.org and www.potclays.com give information on the composition of materials and the health and safety implications which should be considered in Art.

The curriculum implications of this decision are being examined in collaboration with the National Council for Curriculum and Assessment and the State Examinations Commission, and a further communication will issue in due course. In the interim, **these topics will remain as part of the syllabus in terms of the theoretical knowledge of the experimental procedure, and its outcomes, but students will not be required to have physically undertaken the procedure. These topics will, as heretofore, remain examinable in the Leaving Certificate Chemistry Examinations until notice to the contrary is given.**

The Department is currently arranging a tender for the disposal of the chemicals, but it will take some time to complete the procurement process. You will be notified as soon as the implementation arrangements are finalised.

An updated risk assessment and revision of the health and safety guidelines for science laboratories is being prepared in the light of the evolution of developments under the REACH Regulation.

General

Please bring this Circular to the attention of teachers of science and art in the school, and provide a copy to members of the school board of management. This circular may also be accessed at www.education.ie

Margaret Kelly, PO
Qualifications, Curriculum and Assessment Policy Unit

March 2011 Summary of chemicals to be discontinued and for disposal	
Ammonium Dichromate	Copper Chromate
Boric Acid	Disodium Tetraborate (tetraboron
Chromium(IV) compounds	disodium heptaoxide) in anhydrous or
Cobalt(II) Chloride	hydrated forms
Cobalt(II) compounds	Potassium Chromate
Cobalt Chloride Paper	Potassium Dichromate
Cobalt Nitrate	Sodium Chromate
Copper(II) Dichromate	Sodium Dichromate

□

Banned chemicals? The potential impact of REACH regulations on practical science in schools and colleges

Reasons for meeting

CLEAPSS, SSERC, the Association for Science Education (ASE) and the Royal Society of Chemistry (RSC) have increasing concerns regarding the potential impact that the REACH regulations may have on the quality and scope of effective and safe practical work that may be undertaken in schools and colleges in the UK.

CLEAPSS, SSERC, the ASE and the RSC would like to discuss the following:

- The implications and problems associated with the apparent shift of responsibility for assessing risk for a given scenario from the employer (COSHH) to the supplier (REACH).
- The applicability of exposure scenarios and Risk Management Measures (RMMs) to the use of chemicals in school science teaching.
- The particular status of Substances of Very High Concern (SVHCs) and the use of such chemicals in school science in the UK. There is concern that nominated SVHCs have *already* been banned in Ireland¹ without recourse to any discussion on exposure and control measures.
- How we can work together to ensure that high quality, hands-on, practical science remains an integral aspect of students' experience in UK schools.

Assessing risk and adopting appropriate control measures – problems with REACH

REACH switches the emphasis regarding responsibility for assessing risk (and determining appropriate control measures) from employer to supplier – as shown in the table below, adapted from the HSE website²:

Issue	COSHH	REACH
Who must assess risk?	The employer	The manufacturer or importer, mostly <i>[referred to as 'supplier' in text below]</i>
What substances?	Hazardous to health, including those arising from processes and 'germs' (i.e. pathogenic microbes)	Manufactured or imported in quantities of 10 or more tonnes per year in the EU.
What duty?	Control exposure in all uses by site- and process-specific measures	Develop exposure scenarios and identify 'Risk Management Measures (RMMs)' for named tasks and procedures

Implications and problems with the REACH 'approach':

- If it is incumbent on 'suppliers' to work out exposure scenarios for all 'downstream users' then it is likely that there will be some chemicals (i.e. those that are not large-scale use industrially) for which suppliers will decide it is uneconomic to do so. Supplies would cease - a *de facto* ban would result.
- Manufacturers/importers are highly unlikely to have any real understanding of how chemicals are actually used in science teaching (e.g. the wide range of 'exposure scenarios') and are not, therefore, in a position to assess the risks involved. It does not appear that any RMMs have been developed by suppliers for the use of chemicals for teaching purposes.

¹ Circular 0014/2011 from the Qualifications, Curriculum and Assessment Policy Unit, Department of Education and Skills, Bloc 2, Marlborough St, Dublin 1 [See Appendix 1]

² <http://www.hse.gov.uk/coshh/detail/reach.htm>

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- The REACH approach considers only the reagent supplied and takes no account of the product(s) of a chemical reaction. This seems a much less appropriate approach compared to current recommended good practice incorporating the use of model risk assessments which take such factors into account. For example, a common school experiment is the electrolysis of a concentrated sodium chloride solution to illustrate the chlor-alkali process. Chlorine is produced and could cause a problem but the level of exposure is controlled effectively by teachers following the model risk assessment as recommended by CLEAPSS/SSERC.

The importance of practical work in school science

The UK government itself clearly recognises the strategic and economic importance of upcoming generations developing high level skills in the sciences, engineering and mathematics³.

A strong supply of people with science, technology, engineering and maths skills is important to promote innovation, exploit new technologies, produce world-class scientists and for the UK to compete internationally.

The 2008 SCORE⁴ report⁵ on practical science in schools in the UK noted as a key finding that

... the importance of practical work in science is widely accepted and it is acknowledged that good quality practical work promotes the engagement and interest of students as well as developing a wide range of skills, science knowledge and conceptual understanding. In the words of one teacher put it "science without practical work is like swimming without water".

More recently (April 14th 2011), in its response to the Department for Education's Call for Evidence regarding the National Curriculum Review, SCORE⁶ stressed the importance of fostering scientific thinking and encouragement of laboratory work.

SCORE emphasises that 'essential knowledge' in the sciences includes ... the acquisition of procedural skills (particularly those associated with practical laboratory and field work, and analysis), as these are essential for acquiring and testing scientific knowledge.

The essential use of chemicals in school science

Chemicals are used in school science teaching to

- carry out diagnostic tests and to analyse contents of a mixture,
- show how we can convert one substance to another (the basis of industrial chemistry and applications),
- illustrate the basic principles of chemistry (and biochemistry),
- illustrate the chemical properties of the elements and their compounds .

All the above enable pupils to develop the key manipulative and problem solving skills so highly regarded by Higher Education institutions and industry. Practical work also provides a vital opportunity for pupils to learn how to safely handle chemicals and to develop a balanced, reasoned understanding of the chemical world around them.

Are the chemicals designated SVHCs essential to school chemistry?

Examples of the use of these chemicals in current curricula, is described in the tables shown in Appendices 2 and 3.

³ National Audit Office Report HC492, November 2010

⁴ Science Community Representing Education (ASE, RSC, Institute of Physics, Royal Society, , Society of Biology)

⁵ PRACTICAL WORK IN SCIENCE: A REPORT AND PROPOSAL FOR A STRATEGIC FRAMEWORK (SCORE, December 2008)

⁶ <http://www.score-education.org/media/3668/report.pdf>

Conclusions

- In education, employers have a much more *in-depth* understanding of the working procedures employed in schools, especially those who subscribe to organisations such as CLEAPSS or SSERC and make use of the model risk assessments they produce.
- CLEAPSS and SSERC can act as the ‘agents’ of schools (the ‘downstream users’) and can develop appropriate exposure scenarios and Risk Management Measures. These would be based on existing model risk assessments and would take into account generic features of practical work in school science such as the small-scale, infrequent use (especially of SVHCs) of any particular chemical, typical class size, ventilation, room dimensions etc (as is already the case with the model risk assessments produced by CLEAPSS and SSERC).
- It should be noted that the existing model risk assessments already in use also take account of the product(s) of chemical reactions when determining appropriate safe control *and* waste disposal measures.
- Currently, schools adapt the model risk assessments to take account of local circumstances (e.g. personnel and working environment).
- A blanket ban on the use of chemicals such SVHCs is not appropriate because:
 - it limits the opportunities to develop vital skills
 - such a ban would continue to give to “H&S” a bad name which it does not deserve.- as is often seen in media reports
- Assessing the safety of chemicals on the basis of hazard rather than risk (the REACH ‘approach’) is not appropriate in an education setting.
- The principles behind COSHH have served us well for many years. Given that there are risks inherent in experimental work (as there are in many other activities in life), good advice is obviously needed about reducing and managing these risks.
- CLEAPSS, SSERC, the ASE and the RSC are constantly seeking to find the right balance between minimising risk and encouraging good practical work. Where we feel the risks are inappropriately high, this is made clear and alternatives are suggested. As a result of the ongoing work of these organisations and the responsible approach of teachers, pupils are safer carrying out experiments in the school science lab than they are in many other areas of the school, at home and ‘abroad’.
- The organisations represented here all believe that we should, on an ongoing basis, critically examine the use of chemicals in school science, look for safer alternatives, and establish safer procedures. We would welcome the opportunity to work with other expert chemists to examine possible alternatives and to establish codes of good practice with chemicals such as borax.
- Whilst we accept that it may not be possible (or appropriate?) to achieve an exemption from REACH for teaching purposes we do feel that there needs to be clear guidance given regarding the interpretation of the following section of the REACH regulations

Scientific research and development means any scientific experimentation, analysis or chemical research carried out under controlled conditions in a volume less than 1 tonne per year (Article 3(23)).

As the HSE itself noted, the principles of sensible risk management⁷ are about “*Enabling innovation and learning not stifling them*” and not about “*Stopping important recreational and learning activities for individuals where the risks are managed*”.

Appendix 1: Circular 0014/2011 from the Qualifications, Curriculum and Assessment

⁷ <http://www.hse.gov.uk/risk/principlespoints.htm>

Appendix 2: Present use of SVHCs for practical work in school science

Chromium(VI) compounds: are now accompanied with an horrendous list of hazard warnings. For instance, potassium dichromate(VI) comes with these hazard warnings under the GHS system:

H272	May intensify fire; oxidizer	H312	Harmful in contact with skin
H350	May cause cancer (1B)	H314	Causes severe skin burns and eye
H340	May cause genetic defects	H334	damage
H360FD	May damage fertility or the unborn child		May cause allergy or asthma symptoms
H330	Fatal if inhaled	H317	of breathing difficulties if inhaled
H301	Toxic if swallowed	H401	May cause an allergic skin reaction
H372	Causes damage to organs through prolonged or repeated exposure	H410	Toxic to aquatic life
			Very toxic to aquatic life with long lasting effects

Potassium dichromate(VI) Reason needed: test for the presence of alcohols, a key tool for analysis and understanding of organic chemistry.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
To test for the presence of primary and secondary alcohols	Technicians will prepare a 0.1M (2.9%) solution. Occurrence: once a year (if that)	Each pair of pupils will use ~ 4 ml (Y10) or ~ 10 ml (post-16). Gloves & eye protection are available in all schools.	Potassium manganate(VII) solution can be used although it is not a diagnostic test.	There is no inhalation of dichromate(VI) aerosols. Quoted in all text books and in many specifications.

Sodium dichromate(VI) Reason needed: well-ried, effective reagent in synthetic organic chemistry.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
Semi-micro practical procedures in the oxidation of alcohols	Technicians transfer the solids to the laboratory	Each pair of Y12/13 pupils use ~ 4 g solid (dissolve into acid). Gloves and eye protection are available in all schools.	Procedure is standard in all text books and post-16 courses. Fenton's reagent [hydrogen peroxide with iron(II) sulfate(VI)] works but all teachers would be unfamiliar with it.	There is no inhalation of dichromate(VI) aerosols. Loss of sodium dichromate(VI) would be a major change to post-16 courses. Quoted in all text books and many specifications.

Ammonium dichromate(VI) Reason needed: for a unique demonstration of thermal decomposition.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment

Demonstration of a thermal decomposition (to chromium(III) oxide, water and nitrogen)	Technician will transfer solid from bottle to teacher. Demo performed in a fume cupboard in glass container with mineral wool plug	None	Unique as a reasonably spectacular and effective demonstration of chemical change with colour and energy changes.	There is no inhalation of dichromate(VI) aerosols. The products are low hazard.
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Potassium chromate(VI) <i>[NB sodium chromate(VI) is not used in school chemistry]</i> Reason needed: the reactions listed are essential techniques in inorganic chemistry and analysis.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
Precipitation of metal chromates	Technicians will prepare a 0.1M (1.9%) solution. This will happen once a year (if that).	Each pair of pupils will use ~ 4 ml (Y10) or ~ 10 ml (post-16). Gloves and eye protection are available in all schools.	There are no alternative to make other metal chromates! Precipitation can be carried out with other mixtures of chemicals. Restriction would reduce the variety of options.	There is no inhalation of chromate(VI) aerosols. The scale of the experiment can be reduced to very low volumes and very little waste. The products are also very toxic but volumes can be made small and exposure is extremely low.
Chemical equilibrium between dichromate(VI) and chromate(VI) ions by the addition of dilute acid and alkali		Staff only	This can be demonstrated with indicators on acids and alkalis.	The solution may be stored for removal by hazardous waste collector.
Indicator for silver nitrate titrations		Post-16 students may use ~ 2 ml of 0.1 M solution.	Other procedures are possible although this is visually the most straightforward	Very little is used and it all goes into the silver residues bottle for professional disposal.

Cobalt(II) compounds

The beautiful colour changes, typical of a transition element, exhibited by the compounds of this chemical, have been used in schools for decades. The hazard statements (GHS) for cobalt(II) chloride are as follows:

H350i	May cause cancer (inhalation) (1B)	H317	May cause an allergic skin reaction
H302	Harmful if swallowed	H400	Very toxic to aquatic life
H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled	H410	Very toxic to aquatic life with long lasting effects

Cobalt chloride loses all its water at about 110°C and melts at 740°C so it difficult to see how it can get into our bodies by inhalation.

Cobalt dichloride / cobalt(II) chloride				
Reason needed: essential for detecting the presence of water, a vital aspect of biology and chemistry teaching. Also an invaluable component in teaching principles of physical and inorganic chemistry.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
Cobalt chloride paper as a test for water	Technicians prepare the paper. This only needs to be once a year.	The paper can be handled with forceps. CLEAPSS advises the paper is placed on top of bandage, to protect skin from direct contact.	There is no alternative to the paper as a test for water.	This test has been standard for many decades with no problems in its use. It is quoted in all text books and in many syllabuses.
Invisible ink	The technician solution This only needs to be once a year.	Pupils write a message on paper using a paint brush. Gloves can be worn	Alternatives, such as sugar solution, are available.	The cobalt(II) chloride system is the most colourful. This experiment is used to illustrate a principle.
Cobalt ions used as a catalyst when tartrate salts are oxidised by hydrogen peroxide.	Less than a gram is used. In a demonstration	Not used by pupils.	The colour changes are spectacular and illustrate the changes in oxidation number of the cobalt ions	

Cobalt(II) carbonate				
When heated it produces cobalt oxide and carbon dioxide	Technicians obtain the solid in a bottle and may place the solid into test tubes from the pupils	Possibility of a dust raised in the heating but not if a delivery tube is attached.	Other carbonates are available.	Only used to confirm a hypothesis.

Boron Compounds

Boric acid				
Reason needed: a component of buffers, essential for a range of reactions underlying the study of life processes.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
For growth of pollen tubes:	Technicians make up the medium of 2 g domestic sugar (sucrose), 1.4 g thick flower honey, 2-3 small crystals of boric acid, a thin smear of Marmite (to cover about 1 cm ² of beaker surface) and 40 ml	Usually used at post-16, especially in investigations required by Awarding Organisations.	No alternative.	They are difficult to make grow, but it will be impossible without the boric acid. It is quoted in all text books and in many specifications.

	deionised water			
Buffer solutions	Technicians make up buffers.	Dilute solutions will be required.		Alternatives may inhibit some enzyme activities

Disodium tetraborate, in various forms Reason needed: it is a standard buffer and used in teaching the chemical basis of properties of polymers.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
0.1 M borax solution is a primary standard for calibrating pH meters	Preparing the solution and calibration process.	Only if carrying out an investigation	None	Not examined but an essential material "behind the scenes".
Buffer solutions	Technicians make up buffers	Requires dilute solutions.	Possible alternatives	Not examined as such but required incidentally.
Slime - mixture of borax/polyethenol that exhibits non-Newtonian flow characteristics.	Technicians make up a solution of borax for use by pupils	Pupils mix the liquids. Gloves worn if mixture is handled.	No alternative. Not examined but is used in investigative work.	Reactions used to demonstrate cross-linking in polymers. They have a "yuk" factor with teachers and pupils. Also used in many primary schools. Questionable if REACH would allow its use to continue. CLEAPSS recommends that the chemicals are NOT taken home (we are asked).
Custard balls: the solid is added directly to custard and PVA glue.	The solid will be handed out.	Pupils would not handle the solid and should wear gloves	No alternative. Not examined but is used in investigative work.	

Trichloroethylene Reason needed: required in filter fume-cupboard testing to comply with responsibilities under the COSHH regulations.				
Present uses	Staff exposure	Pupil exposure	Alternatives	Comment
To test the integrity of a filter in a filter fume cupboard	Prepared in the fume cupboard but might be detected in the exhaust during the test. Outside contractors and technicians carry out this test. Nearly every school in the country has at least one of these fume cupboards.	None	None. With efficiencies of over 99.5% required, very sensitive detecting tubes are needed which are unavailable for other vapours. The filters have to be specially impregnated with chemicals to remove the toxic vapours.	HSE have been contacted about the testing of filter fume cupboards in schools but have not responded at all.

Appendix 3: Examples of use of SVHCs in current curricula (England)

Chemical	How used (examples)	Specification / course (example)
dichromate (VI)	- oxidation of alcohols / carbonyls - chromate(VI) / dichromate(VI) equilibria – effect of acid/alkali – Le Chatelier - use of dichromate(VI) as test for SO₂ - redox chemistry of Cr₂O₇²⁻ / Cr³⁺ (stability of oxidation states) - redox titrations	- all AS/A2 and several of the new GCSE courses [theory and listed as possible practical assessments for AS/A2] - several AS/A2 (often as a demo) - Cambridge pre-U (and elsewhere) - Cambridge pre-U - Cambridge pre-U (and elsewhere)
chromate(VI)	- electrolysis of copper(II) chromate(VI) (ion migration demo) - chromate(VI) testing for (analysis)	- Edexcel AS/A2 - Cambridge pre-U
cobalt(II)	- testing for presence of water (paper) - stability of oxidation states/ligands - catalyst for H₂O₂/Rochelle salt reaction - preparation of hexamminecobalt(II) - exemplification of Le Chatelier's principle	- several (all levels) - Cambridge pre-U (and elsewhere) - Salters' A-level (and elsewhere) - AQA Practical Skills Assessment (A2) - various (post-16)
boric acid / sodium tetraborate etc	- Making PVA 'slime' and similar - pH buffers	- several (GCSE and AS/A2) - AS/A2 investigations (if applicable – already noted by Bob Worley of CLEAPSS)

□

You can contact CLEAPSS <http://www.cleapss.org.uk/> - they have some free publications available, though most of their facilities require membership to access, through a school or local authority.

The importance of practical work

Chemistry is above all a practical subject. It started in ancient times as an alchemical art making perfumes, pigments, medicines and other substances involving the chemical transformation of raw materials. The smelting of metals is chemistry, as is in a different way the brewing of beer. To understand chemistry you must first have a hands-on experience of matter and its transformations, just as a cook needs to be hands-on with food and the various processes to turn raw food into meals. In chemistry, but not in cooking, this will involve sight, smell and sometimes hearing, but not nowadays tasting!

How can you talk about elements and compounds in the abstract without having seen and handled examples of both? One of the weaknesses in secondary school science is a dependence on the textbook and theory, over against experience and experiment. Primary science on the other hand, emphasises hands-on experience rather than theory. Concerns about safety and lack of resources (equipment and chemicals) and shortage of time lead teachers to skip the practical work to concentrate on material for examinations.

A video clip or virtual experiment on a computer may be used as a substitute for the real thing, but does it do the same job? It is the difference between watching a football match and playing in one; watching a travel film or visiting a country; or even seeing a meal on the table and actually eating it. They are experiences of a sort but they are not the real thing. Surely it is important to give our students the experience of not only seeing chemistry in action but also being involved themselves in the action.

Chemical demonstrations can be very effective, as Viktor Obendrauf showed in his lectures, and it is possible to make demonstrations interactive, but it is still a second-hand, indirect experience. There is no substitute for doing something oneself.

How will a student ever learn to handle apparatus correctly, to measure out solids and liquids, to weigh, mix, filter, pipette, titrate, distil and heat, without actually doing them many times? We learn to do things by trial and error, by instruction and practice, by investigation and repetition, until we become confident and proficient. This applies

to all areas of life and learning, and also in practical science. We learn by doing (and making mistakes) and without the opportunity to try we will not master anything.

Science is built on experimentation and experience of phenomena and we need to give our students concrete experiences as a foundation on which to build their theoretical structures. Too often we try to build our scientific theories and concepts without a foundation in practical experience, and then we wonder why there is no understanding and only rote learning.

The fun of science for many students lies in the practical work. Why are they turned off science in secondary school? Why do they think science is boring and is only about learning off irrelevant facts? Maybe it is to do with the way they experience science and we the teachers teach it? Perhaps it is because of our concentration on written work and examinations, and the downplaying of practical experiences?

Practical work is more than formal experiments. It involves studying real objects and materials; making models; open-ended investigations and project work; learning and practising practical skills etc. As teachers we should try to avoid talking about something without also showing it in some way or giving an opportunity for pupils to have hands-on experiences.

For an interesting UK survey on Practical Work in School Science see:

<http://www.gettingpractical.org.uk/documents/PracticalWorkreportFINAL.pdf>.

The top 5 main purposes of doing practical work in science according to respondents were:

- *Helping learners to understand scientific concepts (88%)*
- *Making phenomena more real i.e. linking theory to practice (84%)*
- *Helping learners to develop skills e.g. observation, using equipment (82%)*
- *Motivating learners (81%)*
- *Helping learners to develop understanding of scientific enquiry (80%)*

□

More small scale, hands-on experiments for easier teaching

By the late Viktor Obendrauf

This article was reproduced from the Proceedings of the 19th International Conference on Chemical Education, August 12-17, 2006, Seoul, Korea, pp. 10-21, with permission of the Organizer.

“A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.” Albert Einstein (1879-1955)

Neurobiological research proves that lasting learning is closely linked to emotions. A ‘pretty’ reaction arouses emotions just like a dangerous or a dangerous-looking experiment. Many colleagues can confirm that most of the students remember nothing better than ‘beautiful’ or ‘dangerous’ experiments. Through aesthetically arranged and really exciting experiments they frequently grasp the associated theoretical concepts more easily.

Of course, definitely dangerous experiments must be cancelled in school. Chemical education should be as safe as possible for teachers and students. But chemical demonstrations, which are classified as possibly dangerous by the students, can support learning with emotions. Using micro-scale techniques many potentially dangerous reactions can be performed in a safe and inexpensive way.

There exists no scientific definition for aesthetic science phenomena. But there exists a general consensus that chemical demonstrations and student activities can be designed to be more or less pretty. Classical examples of aesthetic reactions and/or aesthetically presented processes are various coloured structures and crystallisations in Petri dishes, projection cuvettes and on microscope slides. For many people pyrotechnic effects are beautiful. Even the burning down of a simple ice candle can create emotions. Many burning ice candles arranged as pyrotechnic numbers and letters are much more than a simple reaction between heated titanium particles with oxygen of the air. For many students, unclear experimental arrangements are not elegant or even beautiful. They want to pick up the experiment and the concepts behind it as fast as possible. A simple and clear experimental procedure without many fixing stands and clamps, that is focused on a micro-scale level and enlarged with modern electronic equipment for large auditoriums, can sometimes improve both the aesthetics and safety of potentially dangerous experiments.

For many teachers and lecturers, experimental procedures are not elegant and pretty when they require expensive and time-consuming preparations and exhausting clean-ups with lots of waste. Going micro-scale can improve the aesthetics and the safety of chemical reactions by reducing the time, costs and waste. Six years ago it was a big honour and also a great pleasure for me to be invited to give a plenary lecture during the 16th ICCE in Budapest dealing with small scale and micro-scale gas reactions. The audience agreed that special video techniques can be very useful for performing time-saving and cost-saving small scale reactions in big lecture-theatres without polluting the environment. By enlarging the improvised low-cost-equipment with modern digital video projection techniques the properties of very poisonous gases can be safely demonstrated without using a fume hood. The experimental topics during the lecture in Budapest were: the generation of chlorine, acetylene, hydrogen, hydrogen sulphide, sulphur dioxide, ammonia and oxygen, the reactions between sodium and chlorine, hydrogen and chlorine, chlorine and acetylene, hydrogen and oxygen, hydrogen sulphide and sulphur dioxide.

The same low-cost equipment and digital video techniques - enriched with some special products from any European supermarket and a couple of improved ideas to generate, store and dispose small amounts of hazardous gases – were used for the lecture in Seoul.

In any case, the discussed small-scale experiments are not designed for combination with video techniques. For normal classrooms, the philosophy is that a badly arranged experiment in a fume hood or behind a safety shield is less impressive for creating emotions than a small-scale portable apparatus which needs no fixing stands and allows the lecturer to perform and repeat the experiments closer to the students. Detailed instructions and figures dealing with the special materials necessary for these low cost gas generations and small scale gas reactions are described in the Book of Abstracts of the 16th ICCE 2000 in Hungary. These materials have successfully been used for more than ten years in Europe and should be described again for those colleagues and teachers in Asia who have had no chance to pick up these experimental suggestions until now.

Materials for the low cost gas generation and gas reactions [1,2,3]

(a) **1 test-tube Schott Fiolax® 16/160 mm, bulged mouth.** In this test tube the gases are generated. The rather thin but fireproof material heats up the substances inside in a very short time; if it is necessary, this substance can be cooled down again in a water bath or with tap water in a few seconds.

(b) **1 soft rubber-stopper (Verneret18D) with 1 or 2 syringe needles (1.2/40 mm) pierced through the stopper as shown in Figure 1.**

The tips of the needles in the stopper must be cut off as shown in Figure 2. The blunt needles in the stopper work as micro steel tubes with Luer connections. Needles without tips are no longer needles. Even with different strong acids, the stopper works for many months without having to replace the tubes.

(c) **1 disposable syringe 2 mL (e.g. Braun ®)**

This syringe is used as a dropping funnel for liquids. The plunger (without washer) must be difficult to move. For this property a rough surface inside the syringe prepared with fine iron wool is very useful.

To suck up the needed liquid it is useful to have the chemicals in 10-20 mL narrow mouthed bottles. As a result, even concentrated hydrochloric acid or concentrated ammonia solution is no problem outside the fume hood. To avoid contact with the adhered chemicals after filling, the syringe must be cleaned outside with a paper towel or rinsed in a beaker with water or with tap water. Then the syringe can be placed tightly in the luer connection steel tube of the special stopper.

(d) **1 syringe 20 mL, eccentric Luer conus (ONCE ®)** This syringe is used to collect and store the generated gas and stoichiometric mixtures. To avoid pressures that are too high in the apparatus, the plunger must be easily movable when compared to the 2mL-syringe. Therefore the washer at the end of the plunger must be slightly greased with high boiling silicon oil.

(e) **1 10 mL syringe without a plunger, first filled with activated charcoal granular and then closed with 1 rubber stopper with 1 syringe needle in it as shown in Figure 1.**

This device is very useful to avoid excessively hazardous gases coming out of the gas generator when the 20 mL syringe is filled and no more gas is needed.

(f) **20 mL disposable syringe (ONCE®) with inserted piezoelectric sparker (Figure 3).**

This device, built from a 20 mL disposable syringe and a piezoelectric lighter, allows one to collect various explosive mixtures of gases to show the stoichiometric reactions in the syringe directly.

Constructing the device: A nail is heated in a flame and this hot nail is used to melt a small hole in the syringe; a stereo wire with blank metal ends is inserted through the

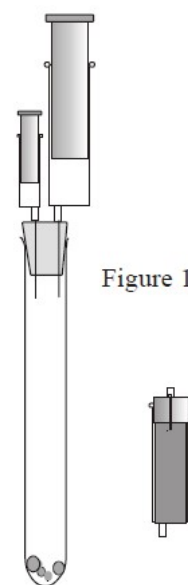


Figure 1

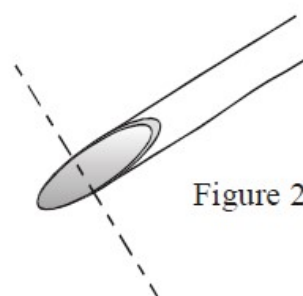


Figure 2

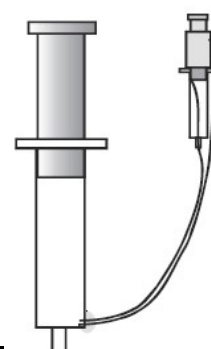


Figure 3

hole and the connection is sealed with hot-glue as shown in Figure 3. The other end of the wire must be connected to the piezoelectric sparker so that it works (see Figure 3).

(g) Steel tubes 1.2/40 mm with Luer connections (syringe needles with cut tips). The thin steel tubes with the Luer connections and the blunt end serve for jets, e.g. either a) to light hydrogen or acetylene pressed out from a syringe or b) to direct the wanted gas into a test-tube or into another syringe. The steel tubes placed the soft rubber stoppers or serving for jets work for many months without being destroyed in corrosion, even in contact with concentrated acids. To avoid corrosion during storage, the steel tubes must be rinsed inside with water and dried with air. This procedure consumes only a couple of seconds: using a 20 mL syringe press some water through the tubes and dry the tubes inside by sucking and pressing air through them.

(h) Steel tubes 0.8/120 mm with Luer connections (syringe needles with cut tips).

The long syringe needles can be used as a reaction tube with a very big (catalyzed or not catalyzed) surface inside e.g. to heat a stoichiometric mixture of sulphur dioxide and oxygen or as catalyst tube for the catalytic reaction between ammonia and oxygen (Ostwald procedure see Figure 4) etc. The modified and strongly heated long needle can also be used to decompose gaseous compounds e.g. ammonia or for thermolysis reactions (e.g. paraffin oil to gaseous hydrocarbons).

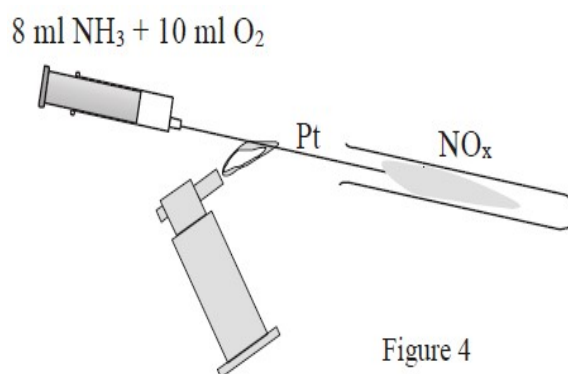


Figure 4

(i) **Micro burner.** Portable, with a piezoelectric sparker, refillable with lighter butane; burner time is not limited, size of the flame is adjustable, and it works in each position (see Figure 4)

(j) **15-20 cm long pieces of insulator from a stereo wire (copper wire removed), used as thin plastic tubes.**

(k) **100 mL disposable syringe with catheter connection** (Figure 5). This syringe is used to collect, store and weigh larger amounts of gases. The catheter connection fits to the Luer connection of smaller syringes and to the outlet of a special wine bottle opener, which works very comfortably with commercial chargers filled with carbon dioxide for soda bottles or nitrous oxide for whipped cream.

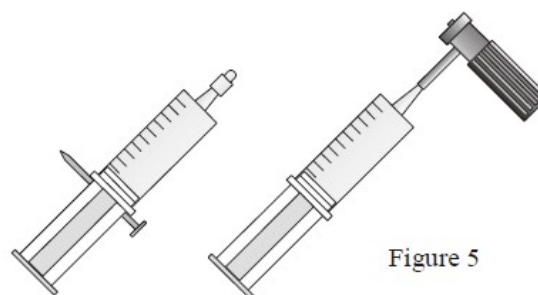


Figure 5

(l) Mobile small scale ozone generator

Using a silicon tube a normal small scale oxygen gas generator is connected to a test tube which contains a thin glass tube filled with a salt solution (e.g. copper sulphate). This solution is in contact with a small high voltage device (stun gun, see Figure 6). The second connection of the high voltage device leads to a sheet of copper or brass outside the test tube, so that discharges can be produced from outside the test tube to the thin glass tube inside the test tube. Pure oxygen inside the test tube can be converted partially into ozone using this device.

Ozone mixed with normal oxygen can be collected in a 20mL syringe (see Figure 6).

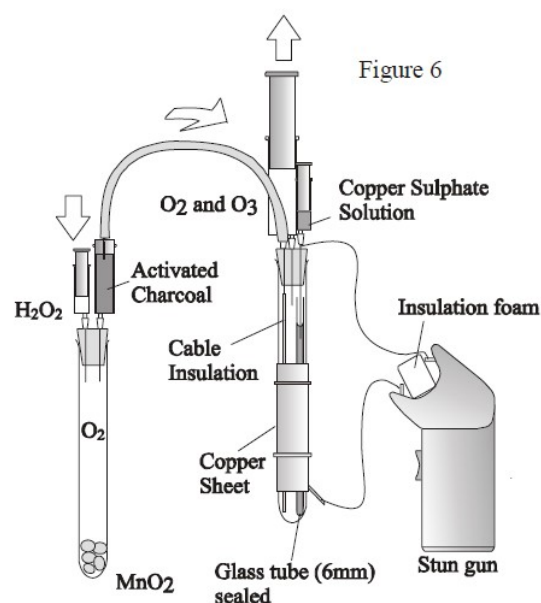


Figure 6

(m)Explosion Limits Film Can.

A Fuji® or other film can (with a snap cap) equipped with a piezoelectric device can be used to check the explosion limits of very low boiling organic liquids such as acetone or ethyl acetate. The volume of the film can is about 33 mL.

A very small but accurate amount of completely evaporated acetone or ethyl acetate should give a mixture within the explosion limits.

Example: Explosion limits of acetone (LEL: with

60 g acetone/m³ air = about 2 mg acetone/33 mL. UEL:

310 g acetone/m³ air = 10 mg acetone/33 mL.

1 very small drop of acetone is about 7-9 mg which means that 1 drop of acetone completely evaporated and mixed with the air inside the closed film can is within the explosion limit. 2 drops or more give a mixture which is too rich.

Special lighter fuel (not lighter gas) such as ZIPPO® lighter fuel consists of octane and familiar hydrocarbons with a proper vapour pressure of about 0.0147 bar so that excess liquid in the closed film cannot produce too rich mixtures.

Example: The calculated amount of oxygen in the film can is about 6.9 mL. The volume x of the vapour in the closed film can with excess liquid in it should not be more than about 0,5 mL. (x mL : 0.0147 bar = 33mL : 1.0147 bar) Compared to 6.9 mL is the mixture is the hydrocarbon vapour near the stoichiometric mixture: HC : O₂ = 0.5 : 6.9 = about 1:14. (C₈H₁₈ + 12.5 O₂ → 8 CO₂ + 9 H₂O). It is possible to produce many harmless explosions in the can after replacing the air and closing the container.

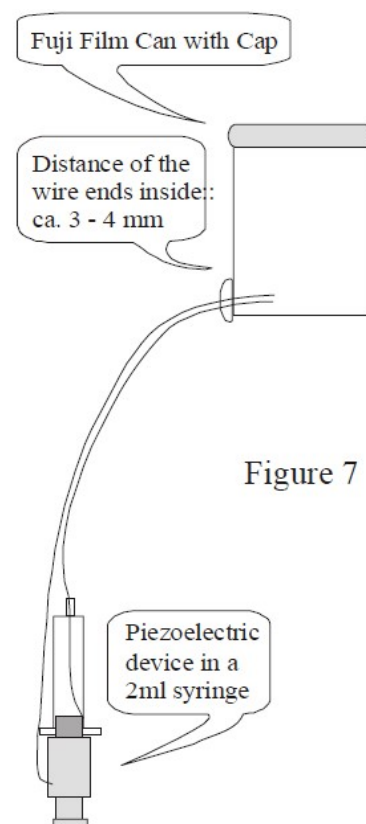


Figure 7

MORE EXAMPLES OF EXPERIMENTS WHICH ARE WELL KNOWN BUT ARE NEWLY DESIGNED, SMALL SCALE AND DONE WITHIN 3-5 MINUTES:

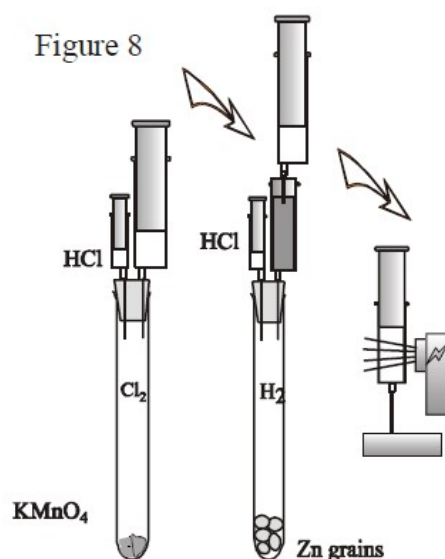
1. Photolytic reaction between hydrogen and chlorine

The air in the chlorine gas generator is replaced by generating chlorine; the air in the hydrogen gas generator is replaced by generating hydrogen. To make sure that the flash will work with the mixture every time, the hydrogen can be cleared of hydrochloric gas. Connect the 10 mL syringe filled with charcoal with the hydrogen gas generator and replace the air in the charcoal by hydrogen.

Then connect the 20 mL syringe filled with 10 mL pure chlorine with the Luer conus connection of the charcoal filled syringe.

Add 10 mL purified hydrogen (see Figure 8).

The syringe with the collected gas mixture is placed vertically using a cut needle on a foam base as a stand. If the sheet of the flash covers the attached 20mL syringe completely, the reaction will start every time without removing the UV filter from the flash (see Figure 8).



2. Generation of NO_x using copper and nitric acid, properties of NO, NO₂, N₂O₃, N₂O₄

After replacing the air in the gas generator the well-greased special 20 mL syringe is used to collect the generated NO_x. [NO_x is a mixture of NO and NO₂.] A 10 mL syringe without a plunger, first filled with granular activated charcoal and then closed with a rubber stopper, pierced by one syringe needle, functions as a portable fume hood, after the 20 mL syringe has filled up with the poisonous mixture. With the generated mixture in the 20 mL syringe the solubility of NO₂ in water, the equilibrium between NO₂ and N₂O₄, the formation of N₂O₃ and a couple of other properties of the gas mixture can be shown easily.

Using a gas generator for carbon monoxide the catalytic reaction between CO and NO to N₂ and CO₂ can be formed in a test tube which contains pieces of a normal car catalyst.

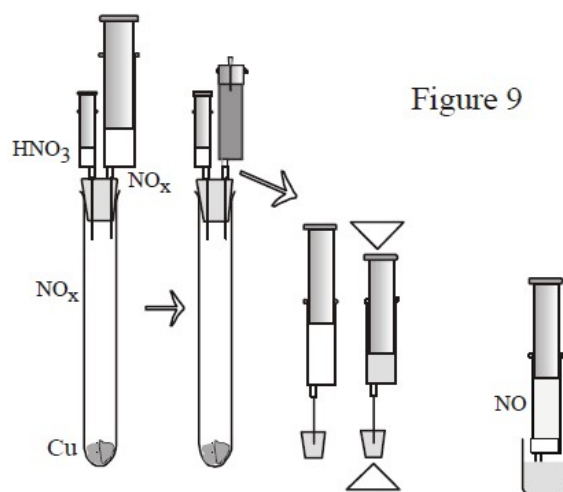


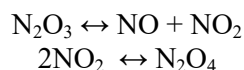
Figure 9

3. Instant chemistry: Micro-ampoules as pressure-resistant permanent preparations [4]

Thick-sided glass ampoules often serve as containers for liquefied gases and highly evaporable liquids. These chemical-physical, permanent preparations have the advantage that they demonstrate various phenomena without spending too much time on preparation and cleaning up. If you reduce the volume of the ampoules to a few micro-litres, the ampoules containing various substances can be sealed, given some care and experience, without the help of a professional glassblower. Modern soldering torches with accurate flames make the preparation of such micro-ampoules (2-3 mm in diameter!) a lot easier.

In spite of their thin glass the tiny tubes resist enormous pressure so that you can even seal liquefied carbon dioxide or nitrous oxide. This makes it possible to demonstrate the phenomenon of critical temperature of various substances in a surprisingly easy way. For example, the critical temperature of liquefied nitrous oxide, which is 36.5°C, can be reached with the help of a hairdryer within seconds, so that the liquid inside the ampoule suddenly disappears.

After all, the corresponding critical pressure amounts to only 72.6 bar. Similar experiments can be carried out with liquefied carbon dioxide (critical temperature 31.6°C, critical pressure 73.8 bar). A slight cooling ends this simultaneity of liquid and vapour and the liquid state is seemingly re-formed from nothing. Liquid, gaseous and - if liquid nitrogen is available - even solid chlorine can thus be produced just as quickly as the temperature dependent equilibrium between NO₂ and N₂O₄. If the mixture contains NO and NO₂, the deep blue N₂O₃ can be permanently preserved in quite a spectacular way even at room temperature (traditionally this is only possible through cooling). Above its melting point (-100.1°C) N₂O₃ decomposes according to the following equilibria:



If you do not keep on cooling the ampoule after sealing it, the light blue solid substance will melt, first into a deep blue liquid state which, because of the extremely high pressure, does not even disappear at room temperature (according to the principle of Le Chatelier). Heating up the micro-ampoule with

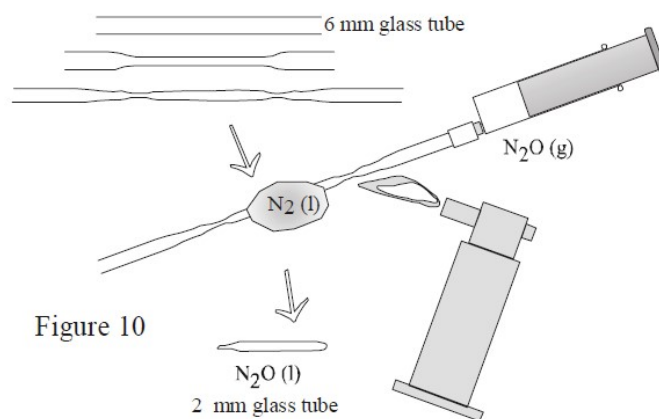
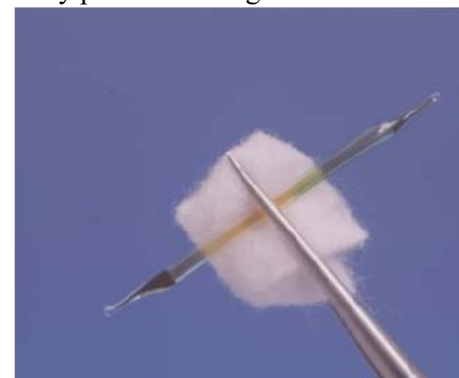


Figure 10



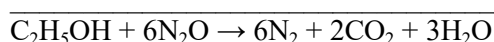
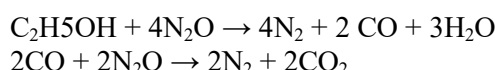
a hairdryer enables you to demonstrate the concentration of the brown gaseous state caused by the intensified production of NO_2 from N_2O_4 within seconds.

In addition to the described phenomena, micro-ampoules enable you to demonstrate lots of other temperature dependent chemical-physical processes (“Instant Chemistry”!) [4]. Even in very large lecture hall they can easily be visualized by means of modern video cameras and video projectors.

4. A wine bottle opener as a source for N_2O – the “barking dog” without NO and CS_2 [6]

N_2O (laughing gas) in high pressure steel ampoules is used to produce whipped cream. Special wine bottle openers work with the same type of steel ampoules containing carbon dioxide. Therefore those wine bottle openers can also serve as source for N_2O so that many experiments involving N_2O can be designed as “Instant Chemistry” examples [5,6,7,8,9]

E.g.: Using the wine bottle opener it is possible to fill a wide mouthed 1 litre glass bottle with laughing gas within one minute. Instead of poisonous CS_2 , normal rum (80% ethanol) is evaporated at hot tap water temperatures so that the noise and the blue flash of the famous “barking dog” can be performed with material bought exclusively from the supermarket. The nice reaction may follow this reaction path:



5. Micro-scale dry ice production and micro-scale liquefied laughing gas [10]

Two exciting and pretty examples of gases are well known in the kitchen: carbon dioxide and laughing gas. Both laughing gas and carbon dioxide are simple substances in everyday life. Both laughing gas and carbon dioxide are stored in very similar looking steel cartridges for whipped cream chargers and for soda siphon chargers. Both gases can be used in sufficient amounts for chemical education in a special wine bottle opener. [3,4,5]



Compared to carbon dioxide, nitrous oxide is a gas with very similar physical properties (see Table 1). Many similar physical data e.g. density, molar mass, solubility in water and critical temperature can be demonstrated in a very simple way. Experimental stuff from schools combined with special supermarket products is sufficient.

Table 1 Properties of N₂O and CO₂

	N ₂ O	CO ₂
Structure	N=N=O	O=C=O
Mass	44.01 u	44.01 u
Litre mass	1,997g/l	1,997g/l
Melting point	-90.8°C	-57°C (5.2 bar)
Boiling point	-88.8°C	-78.5°C (sublimation)
Critical temperature	36.5°C	31.06°C
Critical pressure	72.6 bar	73.83 bar
Critical density	0.457g/l	0.464g/l

The chemical properties and the physiological effects of nitrous oxide and carbon dioxide, despite the iso-electronic structures of its molecules, are completely different.

Laughing gas is not only used to make whipped cream. Many students know that nitrous oxide could be used for sniffing. Of course it is used in hospitals for anaesthesia; it is further more well-known as an very effective oxidizer in combustion engines. Using small amounts of laughing gas the properties as an oxidizing agent can be demonstrated in various simple and timesaving ways [4-7].

On the other hand, a soda siphon cartridge contains carbon dioxide which can be used as a fire extinguishing gas. A special recipe to produce small amounts dry ice from one single soda siphon charger gives us the chance to show the sublimation and the triple point in a small syringe even for a big audience [6-10].

6. The basis of a safety match [11]

Safety matches use a match head that is mainly KClO₃, struck against the match box surface, which consists of non-toxic red phosphorus (about 50%). Placed outside the match box, instead of in the match-head, the match can only be ignited through friction with the red phosphorus panel. This is the basis for the safety match, which can be shown without any laboratory equipment if only micro-scale amounts of the potentially dangerous chemicals are involved. The reaction on a micro-scale level, stoichiometry, calculation, and safety goggles prevent possible accidents.

Concerning the equation with 0.00010 mol (about 12.3 mg finely powdered) KClO₃ and 0.00012 mol (about

Microscale amounts of hazardous chemicals can be safe even between two fingers:



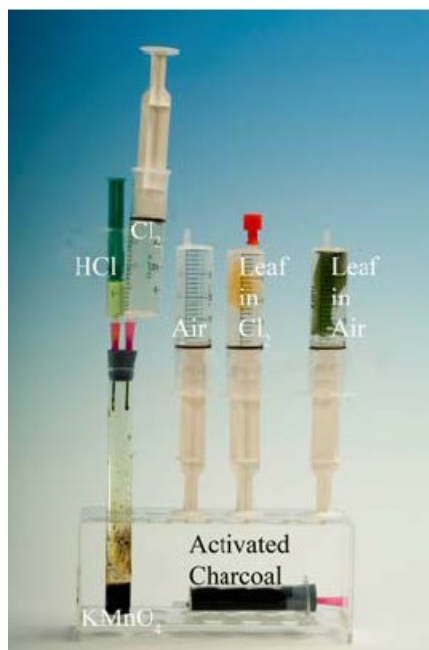
...the chemical reaction that takes place when one strikes a match



3.7 mg dried phosphorus) a nice flash can be produced in theory. To be sure that the red phosphorus will react completely with the solid oxidizing agent and cannot burn on the skin with the oxygen of the air, excess KClO₃ (about 40 mg) is necessary and essential!

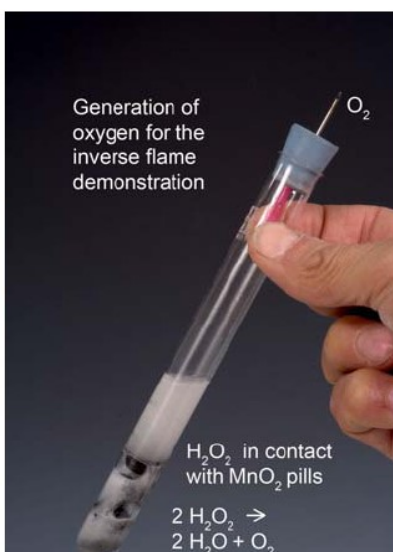
7) Pictures can say more than words

The described material for the low cost gas generation for many micro-scale gas reactions can be stored in two or three plastic video cassette boxes. Using this equipment more than hundred different and context based reactions can be performed. It should be noted that particular emphasis is laid on the described test-tubes, syringes and 'soft rubber' stoppers. The material used in these procedures is essential for being on the safe side with successful results. If somebody uses other test tubes, disposable syringes and normal 'red' or black rubber bungs as available in most science education suppliers' catalogues the described technique for a mobile low cost gas generation without a fume hood will probably fail. The following pictures should show the wide range of possibilities.⁹ The examples have been found to be particularly useful in demonstrating potentially very dangerous reactions relatively safely on a very small scale but still with a spectacular result. Chemical demonstrations and lab activities should be done as small as necessary, but not as small as possible.



7.1. Inverse flames

Is oxygen able to burn? This question could arise during the inverse flame experiment which was very

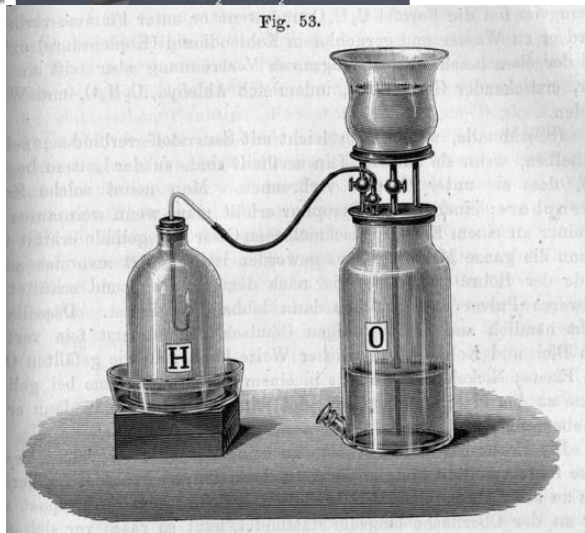


famous in the 19th century (see photo below). The potentially dangerous experiment is dealing with pure oxygen and pure hydrogen. In a pure hydrogen atmosphere pure oxygen delivered from a small tube seems to burn with a nice flame, if the reaction between the elements can be started before a very dangerous mixture can be formed. The reaction on a normal scale would be dangerous. This may be one of the reasons why the inverse flame experiment disappeared out of the sourcebooks for chemistry teachers.

Using the described low cost

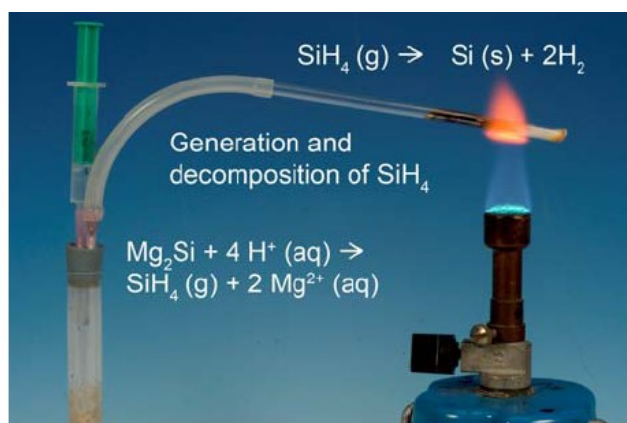
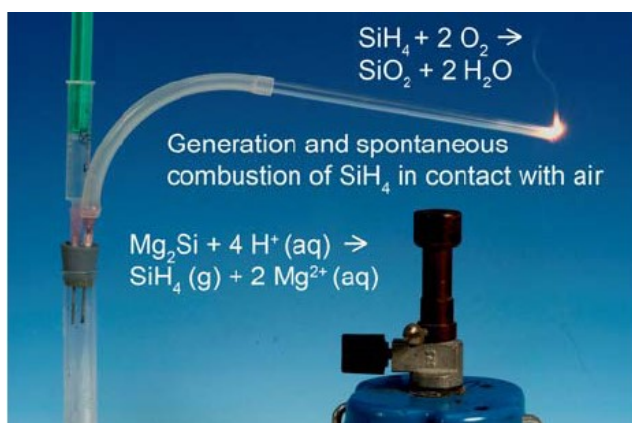
material© with special test tubes,

stoppers and syringes



the inverse flame experiment can also be performed with pure chlorine delivered from a syringe with a small steel tube (needle with cut dip) on it. Chlorine seems to burn in pure hydrogen.

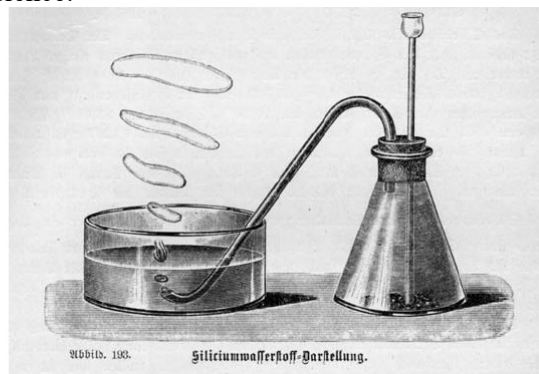
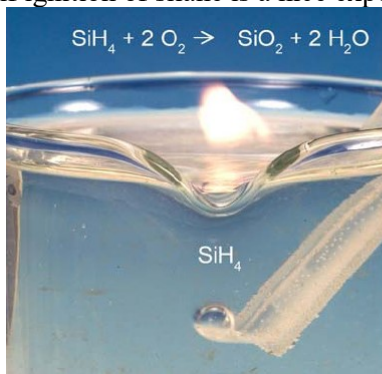
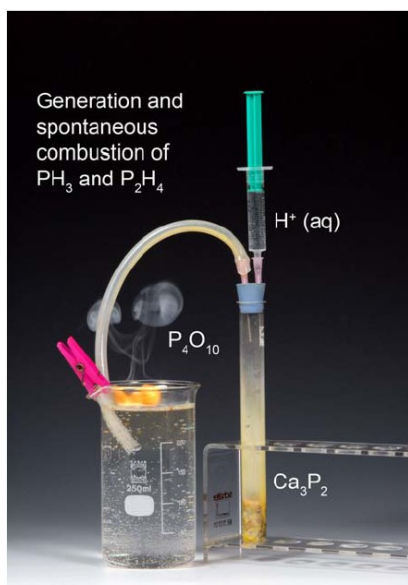
7.2. Chemical vapour deposition (CVD) modelling experiment [12]



Silane is generated by the reaction of magnesium silicide with 1M HCl (aq) in the special small test tube. Before this reaction can be initiated the air in the gas generator can be replaced easily using a cooling spray (FHC). The generated silane can burn only at the end of the glass tube as shown in the picture above. Through heating the glass tube the delivered gas will be decomposed inside so that a thin film of silicon appears. The produced hydrogen can be collected and detected.

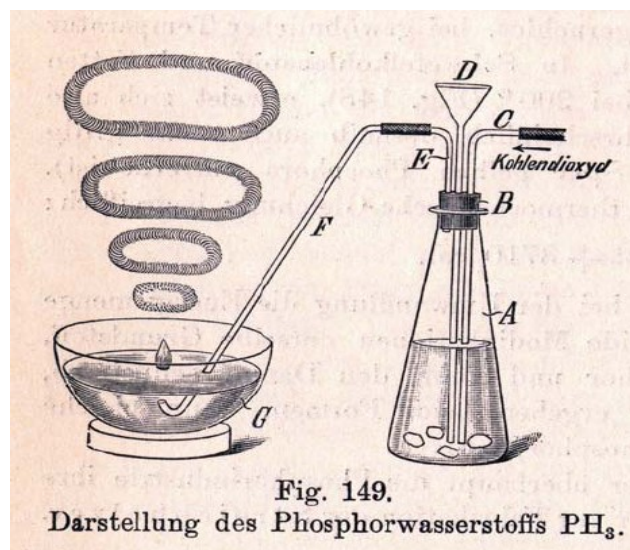


Using a micro flame the thin film silicon can be heated for demonstrating the semiconducting properties of the layer (CVD). In addition the self ignition of silane is a nice experience.

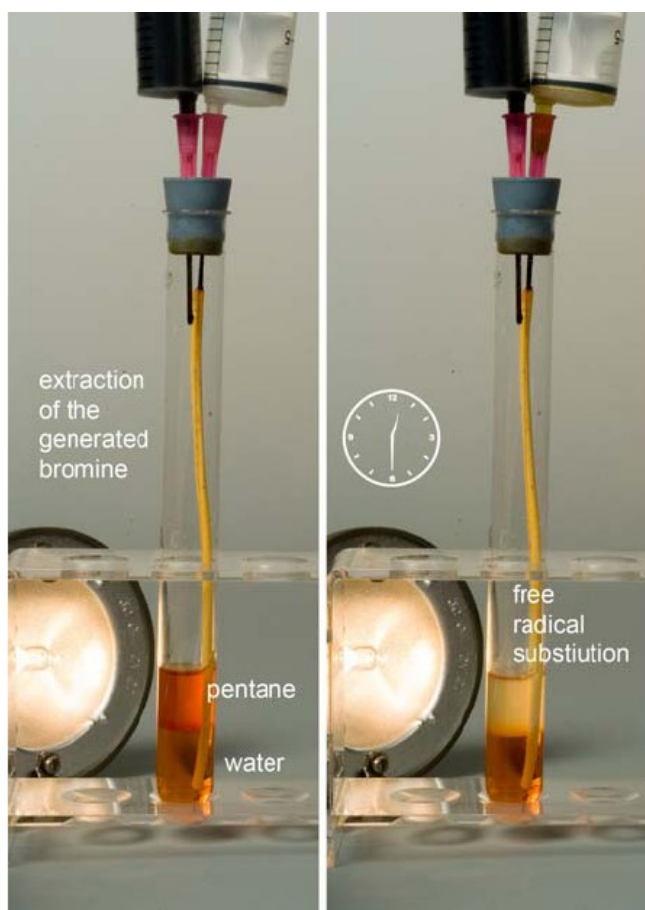
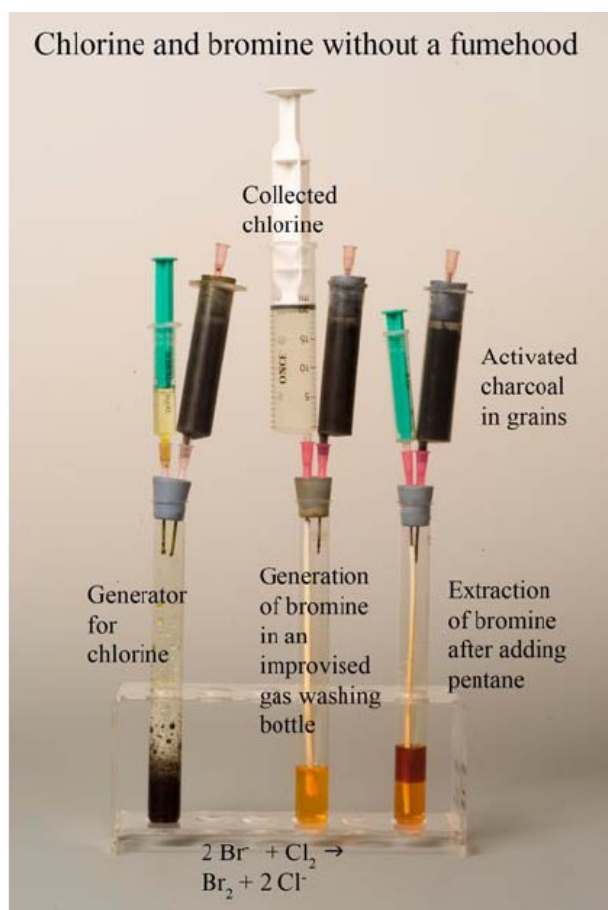


7.3. Self ignition of P₂H₄ [13]

With a commercial rodenticide containing 28 % of Ca₃P₂ the self-ignition of very poisonous PH₃contaminated with P₂H₄ can be shown similar to the self-ignition of silane. Small amounts of chemicals in the small gas generator reduce the danger and the time for the preparations.



7.4. Chlorine and bromine without a fumehood, photolytic reaction with pentane [14]



7. 5. Sparks from a piezoelectric device for at least 20 various explosive mixtures [3, 15]



Warning: The short description of the experiments shown in the pictures and figures above is only useful for this abstract. If somebody wants to perform these potentially dangerous experiments, the original literature [1-15] with detailed descriptions and helpful references for a safe troubleshooting is strongly recommended.

References (mostly in German)

- [1] V. Obendrauf, Low Cost Gas Generation for Small Scale Hands on Experiments, 16th ICCE, Budapest, 2000, Book of abstracts
- [2] V. Obendrauf, Experimente mit Gasen im Minimaßstab. *ChiuZ* 1996, 30 (3) 118
- [3] V. Obendrauf, Die Low-Cost-Lachgas-Kanone. *PdN-ChiS* 1999, 48 (3), 35
- [4] V. Obendrauf, Gläserne Hochdruckbehälter im Mikromaßstab, *PdN-Ch* 2000, 49 (5) 4
- [5] V. Obendrauf, Lachgas auf Knopfdruck, *Chem.Sch.(Salzbg.)* 2001, 16 (2) 4
- [6] V. Obendrauf, Der „Bellende Hund“ m. Mitteln des Alltags, *Chem.Sch.(Salzbg.)* 2001, 16 (4) 11
- [7] V. Obendrauf, Sichtbarer Kohlenstoff aus unsichtbarem CO₂, *Chem.Sch. (Salzbg.)* 2002, 17 (1) 13
- [8] V. Obendrauf, Von der Sahnepkapsel zur Modellrakete, *Chem.Sch. (Salzbg.)* 2003, 18 (3) 12
- [9] V. Obendrauf, 40th IUPAC Conference, Beijing 2005, Keynote Lecture, Book of Abstracts 2005
- [10] V. Obendrauf, Trockeneis aus dem Supermarkt, *Chem.Sch.(Salzbg.)* 2005, 20 (4) 6
- [11] V. Obendrauf, Amorces, Partyknaller, Knallkorken, Pyrotechnisches Spielzeug, *PdN-Ch* 2003, 52 (5) 22

- [11] V. Obendrauf, Inverse Flammen, „Kann Sauerstoff brennen?“ *Chem.Sch.(Salzbg.)* 2005, 20 (1) 9
- [12] V. Obendrauf, Chemical Vapour Deposition, Micro-scale-Experimente mit Silan. *PdN-ChiS* 2005, 54 (1), 43
- [13] V. Obendrauf, Phosphan – Historische Experimente aktuell *Chem.Sch.(Salzbg.)* 2006, 21 (2), 11
- [14] V. Obendrauf, Small Scale Hands On zum rotbraunen Gift T+ (Brom). *Chem.Sch.(Salzbg.)* 2006, 21 (1) 11
- [15] V. Obendrauf, Feuerzeugbenzin im Arbeitstakt. *Chem.Sch.(Salzbg.)* 2000, 51 (3) 8

Additional note by the author:

It is an overview what is possible with my special gas generators. It is also a conclusion about the advantages of micro-scale chemistry. The crucial point is to use the materials described in particular for the equipment. Otherwise the colleagues could be disappointed. Different syringes have different properties. If dangerous or poisonous gases are involved it is necessary to follow the instructions in detail.

□

Oxidations using KMnO_4

(instead of dichromate)

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The DoES circular 0014/2011 (see p.5) has banned all use of potassium or sodium dichromates (and chromates) in Irish schools. The main use of dichromate was in the oxidation of alcohols to produce an aldehyde or acid, and in distinguishing between primary, secondary and tertiary alcohols. These are important topics in organic chemistry and examining them just in theory (the recommended solution to the problem of banning them) is not an ideal solution. We should be able to do the chemistry without using dichromate. Anne O'Dwyer, a PhD student at the University of Limerick, tried out the alternative procedures using KMnO_4 or H_2O_2 as the oxidising agents. Both of these work but KMnO_4 is better as it also gives a visual indication of the reaction with a colour change, like dichromate did. The procedures for using permanganate instead of dichromate are given below. These materials are part of the *Organic Chemistry in Action!* curriculum project, devised by Anne O'Dwyer, which aims to improve the teaching of organic chemistry in the Leaving Certificate Chemistry course by applying ideas from chemistry education research.

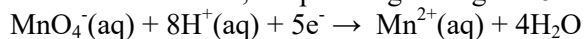
What oxidising agent can be used?

The pupils need to understand that a powerful oxidising agent is needed for the oxidation of alcohols to aldehydes and acids to happen.

The pupils can be asked to recall any oxidising agents that they have used before (e.g. KMnO_4 in redox titrations or perhaps hydrogen peroxide, H_2O_2).

Reaction Equation with KMnO_4 :

In acidic conditions, the permanganate gains 5 electrons:



Purple

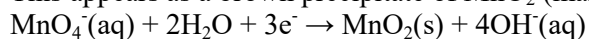
Colourless

Sulphuric acid (H_2SO_4) is necessary to provide the H^+ ions, and ensure that the MnO_4^- is reduced to soluble Mn^{2+} . KMnO_4 is also a more powerful oxidising agent under acid conditions.

Hydrochloric acid cannot be used as it would be oxidised to Cl_2 .

In neutral or basic conditions, the manganese ion is changed to an oxidation state of Mn^{4+} .

This appears as a brown precipitate of MnO_2 (manganese dioxide).

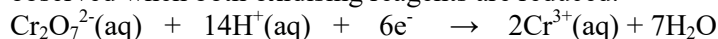


Purple

Brown Precipitate

Reaction Equation with $\text{Na}_2\text{Cr}_2\text{O}_7$ or $\text{K}_2\text{Cr}_2\text{O}_7$:

It is important in both half reactions that the pupils note the distinct colour change that can be observed when both oxidising reagents are reduced.



Orange

Green

Safety notes:

- Always wear appropriate Personal Protective Equipment when carrying out an activity in the laboratory.
- Adhere to the safety rules outlined by your teacher.
- Concentrated sulfuric acid should be handled with care. Always add the acid to water, and never the other way around. Wear plastic gloves when handling it.
- Potassium permanganate can stain if comes in contact with skin or clothing.

- Never leave a distillation set-up unattended. The heat source should always be monitored and adjusted accordingly for a controlled continuous reaction.
- Dispose of all organic waste according to the lab rules explained by your teacher. Never put organics down the sink.
- Make sure that the apparatus is securely clamped so that parts cannot fall off during the distillation.

1. Preparation of ethanol using KMnO_4

Materials required (per group of pupils):

Dropping funnel.
 Plastic pipette.
 50 cm³ pear-shaped flask.
 Liebig condenser.
 T-piece.
 Funnel.
 Two retort stands with clamps.
 Large beaker (to fit the pear-shaped flask).
 Small beaker (to fit the collection flask).
 20 cm³ beaker (to prepare the potassium permanganate solution)
 Collection flask (25 cm³ conical flask / round-bottomed flask).
 Leaving Arm.
 Thermometer.
 Hot plate.
 Weighing boat.
 Access to a balance.

Spatula.
 Stirring rod.
 Adapter (to fit thermometer).

Note:

If a heating mantle is available, the pear-shaped flask can be heated in this without the need for a large beaker of water.

Chemical required (per group of pupils):

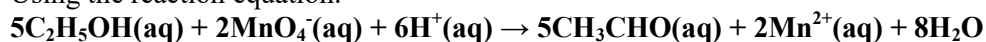
2 cm³ concentrated sulfuric acid.
 (CAUTION!)
 6 cm³ ethanol.
 5.5 g potassium permanganate crystals.
 A few anti-bumping beads.
 Ice.
 5 cm³ de-ionised water.

Safety:

All waste should be disposed of into the organic waste container. The teacher should check that all apparatus is set up safely and secured before the pupils begin any heating.

Calculating the excess of ethanol

Using the reaction equation:



The mole ratio of ethanol: permanganate is 3:1.

We want ethanol to be in excess:

6 cm³ of ethanol = 4.8 g ethanol (density = 0.8 g/cm³)

4.8 g ethanol = **0.104** moles (RMM = 46 g/mole).

5.5 g potassium permanganate crystals = 0.0348 moles (RMM = 158 g / mole)

Given the mole ratio 5:2, 0.0348 moles of potassium permanganate would react with 0.087 moles ethanol. Since there is 0.104 moles ethanol present in this preparation, ethanol is in excess.

Procedure:

1. Using the plastic pipette place 6 cm³ of water into the pear-shaped flask.
2. Slowly add 2 cm³ of concentrated sulfuric acid using a clean plastic dropper to this water in the flask.

Caution: Never add the water to the acid. Always add conc. sulphuric acid to excess water.

Think! – when concentrated sulphuric acid and water are mixed, heat is generated from the reaction (enough to boil the water). This can cause a vigorous acid spray. Given the RMM of sulfuric acid = 98 g / mole and the RMM of water = 18g/mole, why is it safer to add the acid to the water, rather than the other way around?

3. Add a few anti-bumping beads to the flask also.
4. Clamp this flask using the retort stand.
5. Carefully weigh 5.5 g of potassium permanganate on a weighing boat using the balance.
6. Transfer this into the small 20 cm³ beaker. Add 5 cm³ of deionised water and stir using the stirring rod.
7. Add 6 cm³ of ethanol to this beaker also.
8. Set up the apparatus as shown in the diagram.
9. Use a retort stand to clamp the neck of the pear-shaped flask and the Liebig condenser securely in position.
10. Using a beaker of hot water on a hot plate, gently heat the dilute sulfuric acid in the pear-shaped flask.
11. Use the thermometer to monitor the temperature. Heat the dilute acid to 70° C.
12. When the dilute acid is heated, remove the beaker of water and hotplate.
13. Transfer the permanganate and ethanol solution from the beaker into the dropping funnel using the funnel.

Record the colour of the oxidising agent at the beginning of the reaction:

-
14. Slowly add the contents of the dropping funnel to the pear-shaped flask (in a drop-wise manner). Notice the reaction in the pear-shaped flask is exothermic.

15. When all of the potassium permanganate and ethanol is added, remove the dropping funnel, and place in a thermometer. Observe and record any colour changes in the reaction vessel (pear –shaped flask).

-
16. Start heating the pear-shaped flask for distillation using a beaker of water on a hotplate.
 17. Place the collection flask in a beaker of ice. The boiling point of ethanal is 21°C. Why do you think the collection flask for this distillate is surrounded by ice?

-
18. Note the temperature on the thermometer. The ethanal will be distilled off, but the process is rather slow by the time the temperature reaches 95°C.
 19. The ethanal is collected in the conical flask surrounded by ice. Describe the appearance of the ethanal collected:

Transfer the ethanal to a small graduated cylinder to measure the volume of the product collected.

Record this volume: _____.

What impurities may be in this distillate? _____

How could water be removed from the distillate? _____

The manganese in the acidified KMnO₄ is reduced from MnO₄⁻ (purple) to Mn²⁺ (colourless), as the ethanol is oxidised to ethanal. An intermediate brown colour is observed during the distillation at first before the solution becomes colourless:

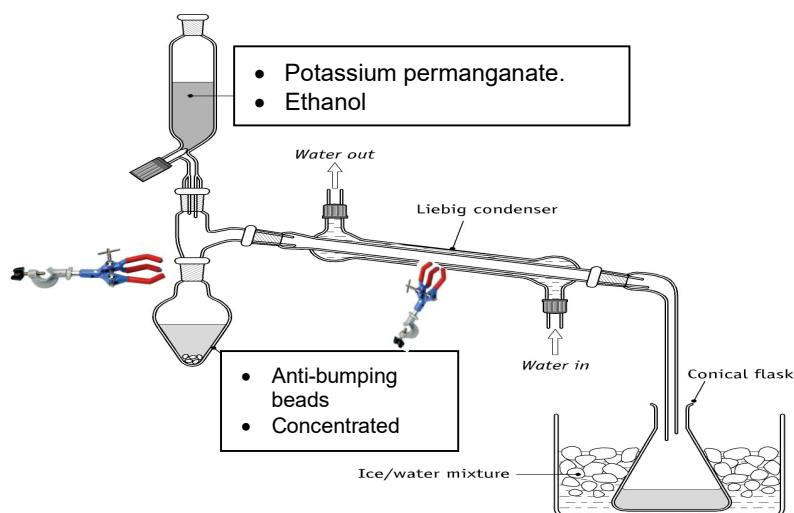


Diagram of apparatus for preparation of Ethanal

Notice in the photographs that only one clamp is shown because micro-scale apparatus was used. Two clamps are necessary when using larger Quickfit apparatus.

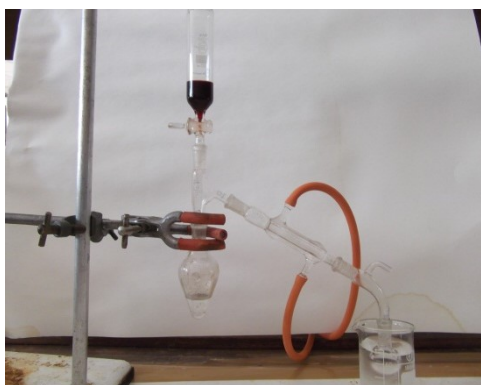


Photo of apparatus before addition of acidified KMnO_4 and ethanol solution.

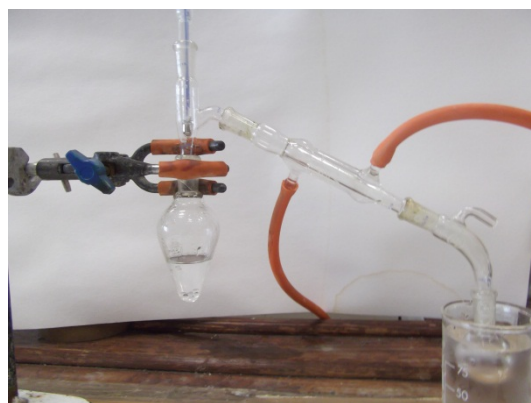


Photo of the colourless solution in the pear-shaped flask at the end of the distillation showing that all the MnO_4^- has been used up.

2. Preparation of ethanoic acid using KMnO_4 :

Materials required (per group of pupils)

- | | |
|--|---------------------------------|
| - Dropping funnel. | - Collecting flask. |
| - Funnel. | - Thermometer. |
| - Plastic pipette. | - Hot plate. |
| - 50 cm ³ pear-shaped flask (or round-bottomed flask) | - Weighing boat. |
| - Liebig condenser. | - Access to a balance. |
| - T-piece. | - Spatula. |
| - Two retort stands with clamps. | - Stirring rod. |
| - Large beaker (to fit the pear-shaped flask). | - Adapter (to fit thermometer). |
| - 25 cm ³ beaker. | - Tripod stand. |
| - Leaving arm. | - Wire gauze. |
| | - Bunsen burner. |

Chemicals required (per group of pupils)

- 3.5 cm³ concentrated sulphuric acid.
- 3 cm³ ethanol.
- 8 g potassium permanganate.
- Anti-bumping granules (a small amount)
- Ice.
- 6 cm³ de-ionised water.

Preparation before class

It is important to have all of the apparatus and chemicals prepared (not assembled) before the class to facilitate the pupils' completion of the preparation of the preparation and testing of ethanoic acid.

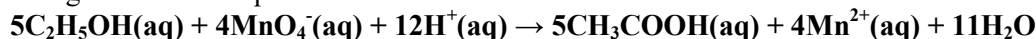
Safety

All waste should be disposed of into an organic waste container. The teacher should check that all apparatus is set up safely and properly clamped before the pupils begin the experiment. Care needs to be taken when using a bunsen burner with organic solvents, as they are highly flammable. A hot plate and sand bath or heating mantle is safer.

The pupils should recall why the acid is added to water (to prevent acid spray) as learned in the preparation of ethanal. The pupils should notice the exothermic reaction of the addition of ethanol to potassium permanganate and dilute acid. They should note the colour changes as the potassium permanganate is reduced: manganese in the acidified KMnO₄ is reduced from Mn⁺⁷ (purple) to Mn⁺² (colourless) as the ethanol is completely oxidised. An intermediate brown colour (MnO₂, +4 O.S.) is observed at the beginning of the reflux.

Potassium permanganate (oxidising agent) in excess:

Using the reaction equation:



The mole ratio of ethanol: permanganate is 5:4 (1.25:1).

The oxidising agent (KMnO₄) must be in excess for complete oxidation:

3 cm³ of ethanol = 2.4 g ethanol (density = 0.8 g/cm³)

2.4 g ethanol = **0.0522 moles** (RMM = 46 g/mole).

8 g potassium permanganate crystals = **0.0506 moles** (RMM = 158 g / mole)

Given the mole ratio 5:4 (1.25:1), 0.0506 moles of potassium permanganate would react with 0.0632 moles ethanol.

Since there is just 0.0522 moles of ethanol present in this preparation, ethanol is the limiting reagent and potassium permanganate is in excess.

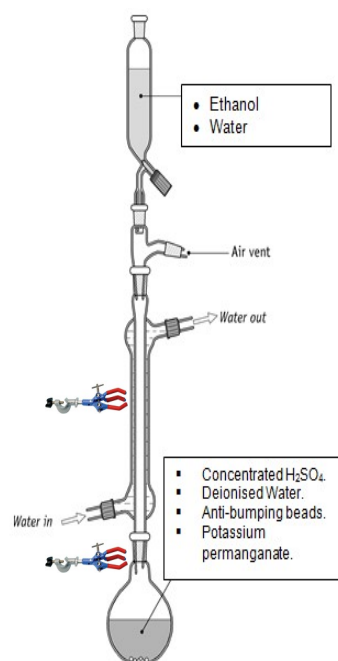
Procedure

1. Using the plastic pipette place 6 cm³ of deionised water into a pear-shaped (or round-bottomed) flask.
2. Carefully add 3.5 cm³ of concentrated sulphuric acid to this in the flask using the plastic pipette. **Wear plastic gloves when handling conc. Sulphuric acid.**

Recall...

Why is the acid added to the water and not the other way around?

3. Weigh out 8 g of potassium permanganate on a weighing boat.
4. Use the funnel to transfer the solid potassium permanganate into the flask with the dilute sulphuric acid.
5. Add anti-bumping beads to the flask and clamp it at the neck with



a retort stand. .

6. Set up the apparatus as shown in the diagram at the right.
7. Use a second retort stand to clamp the Liebig condenser in position securely.
8. Add the mixture of 3 cm³ ethanol and 5 cm³ of water to the dropping funnel.
9. Immerse the flask in a beaker of cold water with ice. The level of the water should be above the shoulder of the flask.

Note the colour of the potassium permanganate in the flask:

10. Slowly add the ethanol and water mixture drop-wise to the flask.

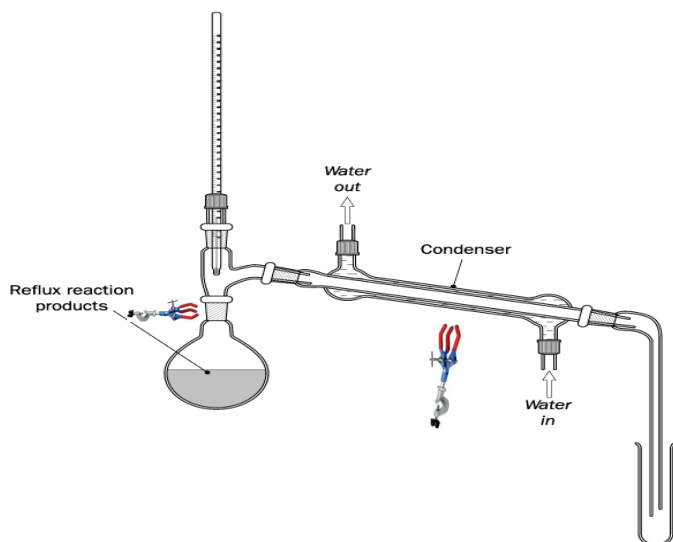
What do you observe in the flask as the ethanol and water is added? Is the reaction endothermic or exothermic?

11. When all of the ethanol is added, remove the dropping funnel.
12. Set up to heat the flask for reflux using a beaker of hot water on a hot-plate.

Note the colour of the potassium permanganate as the flask is heated:

13. To rearrange for distillation (See diagram below) :

- a) Remove the heating mantle / hotplate and the beaker of water.
- b) Remove the Liebig condenser.
- c) Leave in place the retort stand clamping the flask.
- d) Place a T-piece to the top of the pear-shaped flask.
- e) Fit a thermometer into this. Ensure that the bulb is below the T-outlet to the Liebig condenser.
- f) Re-clamp the Liebig condenser horizontally and slide into the T-piece.
- g) Attach a leaving arm and collection flask.



Reflux set-up

The boiling point of ethanoic acid is 118° C.

Why do you think a bunsen burner is needed to heat the flask for this distillation and not a beaker of water as before?

14. Set up a bunsen burner beneath a tripod and wire gauze to distill the reaction mixture.
15. Notice the temperature on the thermometer. The ethanoic acid will be distilled off when the temperature reaches 118°C.
16. The ethanoic acid is collected in the collection flask.
17. Transfer the ethanal to a small graduated cylinder to measure the volume of the product collected.
Record this volume: _____.

What impurities may this distillate also contain?

How could water be removed from the distillate?

It should be noted that only one retort clamp is used in the photo of the experimental reflux set-up because micro-scale apparatus is being used. This is safer and saves on chemicals and the reactions take place faster. If larger Quick-Fit apparatus is used then more clamps are needed, particularly in the distillation.

□

Balancing organic redox reactions

Often organic redox reactions e.g. oxidation of alcohols by dichromate or permanganate, are learned off by heart and pupils (and teachers) do not check to see if they are right or not. Organic redox reactions are more complex to balance than most inorganic redox reactions but can be done using the oxidation number method. This will be illustrated by balancing the reactions of ethanol with permanganate to give either ethanol or ethanoic acid, as described in the procedures in this issue. If you get the equation wrong then the mole ratios are wrong and thus the wrong quantities will be calculated.

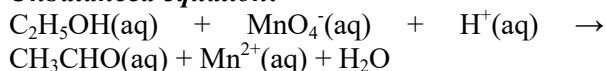
To balance redox equations we need to do three things, in this order:

1. **Balance the electrons transferred in the redox process.**
2. **Balance the ionic charges.**
3. **Balance the remaining atoms.**

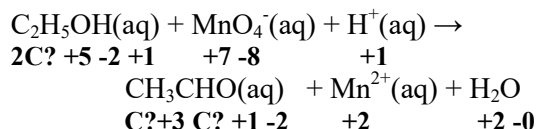
Oxidation of ethanol to ethanal

Start with the unbalanced equation. In acid solution water usually appears on the RHS and $\text{H}^+(\text{aq})$ on the LHS. Permanganate ions, $\text{MnO}_4^- (\text{aq})$, are the oxidant and the carbon in ethanol is oxidised (loss of electrons) to carbon in ethanal. For simplicity we do not need to include the $\text{K}^+(\text{aq})$ ions.

Unbalanced equation:



Under each atom write its O.N. to check on the electron balance.



Sum of O.N.s = overall charge on the ion or molecule.

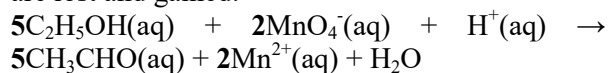
Thus in ethanol, the 2C have an overall O.N. of -4 (-2 per C) and in ethanol the 2C have an overall charge of -2 (-1 per C).

Thus the O.N. change for carbon in going ethanol to ethanal is from -4 to -2, a loss of 2e, i.e. an oxidation.

For Mn the O.N. changes from +7 in MnO_4^- to +2 in Mn^{2+} , a gain of 5e, i.e. a reduction.

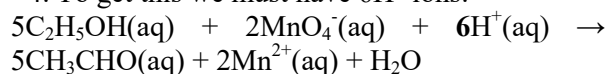
For redox reactions: number of electrons lost in oxidation = number of electrons gained in reduction.

The simplest way to make this happen is to multiply MnO_4^- by 2 and $\text{C}_2\text{H}_5\text{OH}$ by 5, thus 10 e are lost and gained.



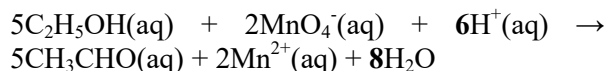
The next thing to balance is the ionic charge: total charge on LHS and RHS must be equal.

We have 4+ on the RHS from 2Mn^{2+} ions and thus the overall charge on the LHS must also be +4. To get this we must have 6 H^+ ions.



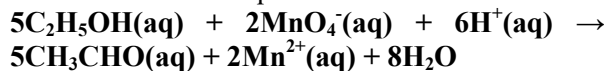
The final step is to balance the O and H atoms so we have the same number on LHS and RHS. On the LHS we have a total of $30+6 = 36$ H. On the

RHS we have only 22H so we need 14 more, i.e. 7 more H₂O molecules. This means we need 8H₂O on the RHS.



If this is correct it should also balance for O atoms: 13O on LHS and 13O on RHS.

The final balanced equation is:



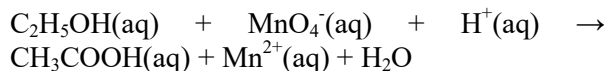
Thus the ratio of ethanol: permanganate is 5:2 or 2.5:1. Thus 5 moles ethanol (5 x 46 = 230g)

would react with 2 moles KMnO₄ (2 x 158 = 316g).

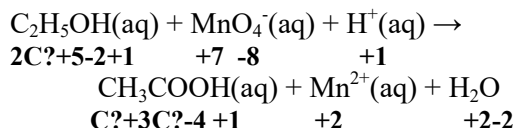
So could you use 6 cm³ (density = 0.8g/ml, mass = 4.8g) of ethanol which would be 0.104 moles ethanol, and 5.5g of KMnO₄ which would be 0.0348 moles. This allows for the mole ratio of ~ 3:1 to ensure ethanol is in excess.

Oxidation of ethanol to ethanoic acid

Start with the unbalanced equation. In acid solution water usually appears on the RHS and H⁺(aq) on the LHS. Permanganate ions, MnO₄⁻(aq), are the oxidant and the carbon in ethanol is oxidised (loss of electrons) to carbon in ethanoic acid.



Under each atom write its O.N. to check on the electron balance.



Sum of O.N.s = overall charge on the ion or molecule.

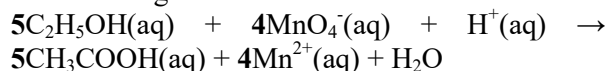
Thus in ethanol, the 2C have an overall O.N. of -4 (-2 per C) and in ethanoic acid the 2C have an overall charge of 0 (0 per C).

Thus the O.N. change for carbon in going ethanol to ethanoic acid is from -4 to 0, a loss of 4e, i.e. an oxidation. (Note that it is oxidised further in this case than with the oxidation to ethanal.)

For Mn the O.N. changes from +7 in MnO₄⁻ to +2 in Mn²⁺, a gain of 5e, i.e. reduction.

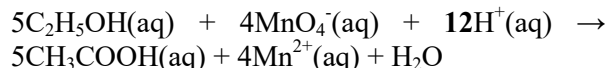
For redox reactions: number of electrons lost in oxidation = number of electrons gained in reduction.

The simplest way to make this happen is to multiply MnO₄⁻ by 4 and C₂H₅OH by 5, thus 20 e are lost and gained.

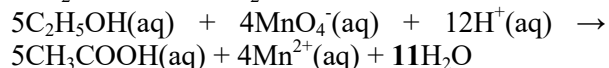


The next thing to balance is the ionic charge: total charge on LHS and RHS must be equal.

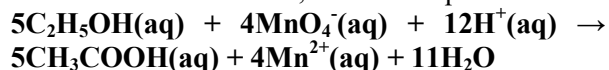
We have only 8+ on the RHS and so the sum of charges on the LHS must be +8. We thus need 12H⁺ ions.



The final step is to balance the O and H so we have the same number on LHS and RHS. On the LHS we have a total of 42H atoms and on the RHS only 22. So we need to add 20H i.e. add 10H₂O to make 11H₂O molecules.



If this is correct the O atoms must also balance. We have 21O on the LHS and 21O on the RHS, so it is correct. The final, balanced equation is:



Thus the mole ratio of ethanol to permanganate is 5:4 (1.25:1) and to make sure all the ethanol is fully oxidised we need an excess of permanganate. Thus 5 moles of ethanol (5 x 46 = 230g) would react with 4 moles KMnO₄ (4 x 158 = 632g).

So in the preparation you could use 3 cm³ (density = 0.8g/ml, mass = 2.4g) of ethanol which would be 0.0522 moles ethanol, and 8 g of KMnO₄, which would be 0.0506 moles.

This allows for the mole ratio of ~ 1:1 to ensure KMnO₄ is in excess.

It is important that pupils can balance such reactions as this reinforces key principles of redox reactions, it shows that the same method can be used for complex reactions, and that organic and inorganic reactions follow the same rules. This is conveniently taught by going through the procedure step by step and altering the coefficients step by step. You should get your pupils to practice on the corresponding reactions using dichromate and hydrogen peroxide as the oxidants.

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Chemistry in the Primary Science Curriculum

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A recent study of Irish post-primary teachers, who taught Junior Certificate Science, found that 58% were unfamiliar with the science content and 69% were unfamiliar with the science process skills in the Primary Science Curriculum for fifth and sixth class pupils (Eivers *et al.*, 2006). These results highlighted the relatively limited teacher's knowledge of aspects of the Primary Science Curriculum. Less than 6% of teachers surveyed were very familiar with the science content or processes of the curriculum and only half of the teachers claimed to be familiar with the nature of the primary curriculum. Therefore there is a need for post-primary science teachers to be introduced to and become more familiar with the primary school curriculum, in order to allow for effective planning and pitching of lessons post-transfer from primary to second level education.

A report by Smyth *et al.* (2004) on the transition from primary to second level in Ireland highlighted the need for a greater awareness among post-primary teachers of the primary curriculum. They also recommended that information needs to be provided to primary teachers about the post-primary science curriculum and teaching and learning approaches taken within post-primary education. Further recommendations include the need for greater co-operation between the primary and post-primary sectors in terms of curriculum development and transfer of good practice in relation to teaching methodologies (Smyth *et al.*, 2004).

Therefore this article aims to provide a brief introduction to the different Strand and Strand Units covered in the Primary Science Curriculum and an overview of Chemistry and main concepts in Chemistry taught in the Primary Science Classroom. This article also

highlights findings of Irish primary pupils' attitudes towards Chemistry in the Science Curriculum.

Scientific Knowledge and Skills

The Primary Science Curriculum supports children in learning about physical, chemical and biological aspects of the world. It aims to develop pupils' knowledge and understanding through the skills of working scientifically and designing and making. Knowledge and understanding for each age group is presented in four Strands: Living Things; Energy and Forces; Materials; and Environmental Awareness and Care. Each of these strands is further divided into Strand Units as shown in Table 1.0 & Table 2.0

Strand	Infant classes	First and second classes
	Strand units	Strand units
Living things	•Myself •Plants and animals	•Myself •Plants and animals
Energy and forces	•Light •Sound •Heat •Magnetism and electricity •Forces	•Light •Sound •Heat •Magnetism and electricity •Forces
Materials	•Properties and characteristics of materials •Materials and change	•Properties and characteristics of materials •Materials and change
Environmental awareness and care	•Caring for myself and my locality	•Caring for myself and my locality

Table 1 Summary of Strands and Strand Units in Primary Science from Infants to Second Class (DES, 1999b)

Strand	Third and fourth classes	Fifth and sixth classes
	Strand units	Strand units
Living things	•Human life •Plants and animals	•Human life •Plants and animals
Energy and forces	•Light •Sound •Heat •Magnetism and electricity •Forces	•Light •Sound •Heat •Magnetism and electricity •Forces
Materials	•Properties and characteristics of materials •Materials and change	•Properties and characteristics of materials •Materials and change
Environmental awareness and care	•Environmental awareness •Science and the environment •Caring for the environment	•Environmental awareness •Science and the environment •Caring for the environment

The main concepts of chemistry are explored in the Materials Strand. Table 3- 6 below provides details of the topics covered and their learning outcomes for each class group (DES, 1999a).

Table 2 Summary of Strands and Strand Units in Primary Science from Third Class to Sixth Class (DES, 1999b)

Strand: Materials	Strand Unit: Properties and characteristics of materials	Strand Unit: Materials and change
Infant classes	The child should be enabled to: observe and investigate a range of familiar materials in the immediate environment (<i>water, wood, textiles, food, plastic, metal, rock</i>). describe and compare materials, noting the differences in the colour, shape and texture. know about some everyday uses of common materials. group materials according to certain criteria (<i>strength, colour, texture, flexibility</i>). investigate materials for different properties, for example <i>materials that are attracted by magnets</i> <i>materials that keep us warm</i> <i>materials that absorb water and those that are waterproof.</i>	The child should be enabled to: explore the effects of water on a variety of materials observe and describe materials when they are wet and when they are dry (<i>soil and paper</i>) identify some materials that are waterproof (<i>raincoat, umbrella, boot, feather, skin, suggest materials suitable for rainy days design and make a waterproof outfit for a toy character or doll</i>). explore the effects of heating and cooling on everyday objects, materials and substances (<i>ice-cream, butter, chocolate, water</i>).

Table 3 Topics Covered and their Learning Outcomes in the Strand Units: Properties and Characteristics of Materials & Materials and Change in the Infant Classes.

Strand: Materials	Strand Unit: Properties and characteristics of materials	Strand Unit: Materials and change
First & Second Classes	The child should be enabled to: identify and investigate a range of common materials used in the immediate environment (<i>food and its ingredients, materials used to construct buildings, materials used to make furniture, materials used to make clothes, materials used to make tools, materials used to make toys, school equipment</i>). describe and compare materials, noting the	The child should be enabled to: Heating and cooling explore the effects of heating and cooling on a range of liquids and solids (<i>water, toffee, syrup, Blu-tack</i>). become aware of and investigate the suitability of different kinds of clothes for variations in temperature (<i>recognise that some fabrics keep us warmer than others, design and make or assemble an outfit for</i>

	differences in colour, shape and texture. begin to distinguish between natural and manufactured materials. group materials according to their properties (<i>flexibility, transparency, magnetism, strength</i>). identify and investigate materials that absorb water and those that are waterproof (<i>investigate the absorbency factor of various fabrics and materials and design and make a new kitchen cloth or roll</i>). begin to explore how different materials may be used in the construction of homes suited to their environments (<i>homes, homes of animals, models, structures</i>).	<i>someone who is going on holiday to a very warm or cold place</i>). explore ways in which liquids and solids may be kept hot or cold (<i>effect of wrapping or covering using different materials, such as paper, fabrics, foil use of vacuum flasks</i>).
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Table 4 Topics Covered and their Learning Outcomes in the Strand Units: Properties and Characteristics of Materials & Materials and Change in First and Second Class.

Strand: Materials	Strand Unit: Properties and characteristics of materials	Strand Unit: Materials and change
Third & Fourth Classes	The child should be enabled to: identify and investigate a range of common materials in the immediate environment (<i>water, air, rock, fabrics, paper, metal, wood, plastic</i>). recognise that materials can be solid, liquid or gaseous describe and compare materials, noting the differences in colour, shape and texture distinguish between raw and manufactured group materials according to their properties (<i>flexibility, transparency, magnetism, conductivity or insulation properties, strength, shape, ability to muffle sounds, perishable and non-perishable, solubility</i>). investigate how materials may be used in construction	The child should be enabled to: Heating and cooling explore the effects of heating and cooling on a range of liquids, solids and gases (<i>the effects of heating and cooling on water, heat causing air to rise, design, make and flavour ice-cream</i>). investigate the suitability of different kinds of clothes for variations in temperature (<i>recognise that some fabrics keep us warmer than others</i>) experiment to establish which materials are conductors of heat or insulators (<i>explore ways in which liquids and objects may be kept hot or cold, design and make a tea-cosy or a cover for a hot-water bottle</i>).

Table 5 Topics Covered and their Learning Outcomes in the Strand Units: Properties and Characteristics of Materials & Materials and Change in Third and Fourth Class.

Strand: Materials	Strand Unit: Properties and characteristics of materials	Strand Unit: Materials and change
Fifth & Sixth Classes	The child should be enabled to: recognise that materials can be in solid, liquid or gas form identify and investigate a widening range of common materials in the immediate environment (<i>water, air, rock, fabric, paper, metal, wood, plastic, food</i>). explore the origins of these materials (<i>identify natural and manufactured materials understand how some of these materials are processed or made</i>). group materials according to their properties and/or composition (<i>properties (e.g. flexibility, transparency, magnetism, conductivity, insulation, strength, shape, perishable or non-perishable foods, solubility), composition (e.g. foods containing proteins, carbohydrates and/or fats; soil containing clay, silt, sand and/or gravel)</i>) identify how materials are used (<i>relate the properties of the material to its use, examine how shape affects the strength of structures, design and make a bridge that takes account of flexibility, form, stability and strength</i>). recognise that a gas, such as air, occupies space, has mass and exerts pressure (<i>investigate evidence for atmospheric pressure, explore the effect of air resistance, design and make a glider</i>). recognise that some materials decay naturally while others survive a long time in the environment (<i>biodegradable and non-biodegradable waste environmental problems caused by non biodegradable waste materials that may be recycled</i>). become aware that air is composed of different gases (<i>including oxygen and carbon dioxide</i>). become aware of some of the practical applications of these gases in everyday life (<i>use of carbon dioxide in fizzy drinks and in fire extinguishers</i>).	The child should be enabled to: Heating and cooling explore the effects of heating and cooling on a range of solids, liquids and gases (<i>temporary changes (e.g. from solid to liquid to gas, expansion of water on freezing, evaporation of water on heating, permanent changes (e.g. those caused by baking bread in an oven)</i>). experiment to establish which materials are good conductors of heat or good insulators (<i>explore ways in which liquids and solids may be kept hot or cold</i>). identify ways in which homes and buildings are heated and insulated recognise how heating and cooling can be used to preserve food Mixing, separating and other changes investigate how a wide range of materials may be changed by mixing (<i>mixing and dissolving materials in water solutions, exploring liquids that will not mix</i>). investigate the effects of light, air and water on materials (<i>discoloration and fading, rusting of iron and steel, investigate how rusting can be controlled, characteristics of materials when wet and dry</i>). examine the changes that take place in materials when physical forces are applied (<i>when materials are beaten, whisked, mixed, squashed, pulled, bent</i>). recognise that oxygen is required for burning explore some simple ways in which materials may be separated (<i>using sieves of varying meshes, using a magnet, using ruler charged with static electricity, allowing sediment to settle in a jar of liquid, separation of salt and water by evaporation, separation of water and soil using simple sieves (filtration)</i>).

Table 6 Topics Covered and their Learning Outcomes in the Strand Units: Properties and Characteristics of Materials & Materials and Change in Fifth and Sixth Class

Key Concepts Covered in the Strand: Materials

The following figures summarises the key concepts in the Strand Units: Properties and Characteristics of Materials and Materials and Change that pupils become familiar with and which are covered in the curriculum.

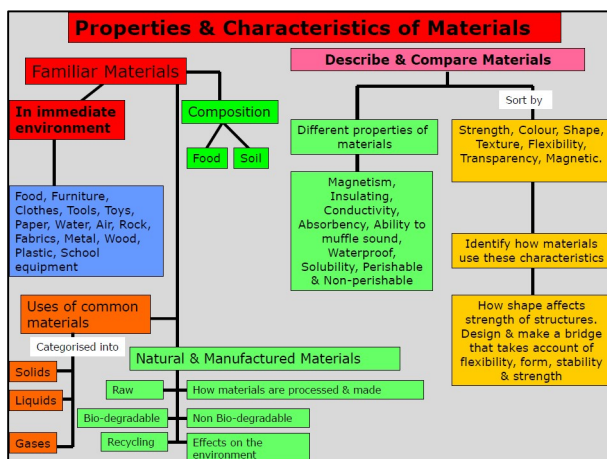


Figure 1 Key Concepts Covered in the Strand Unit: Properties and Characteristics of Materials in the Primary Science Curriculum.

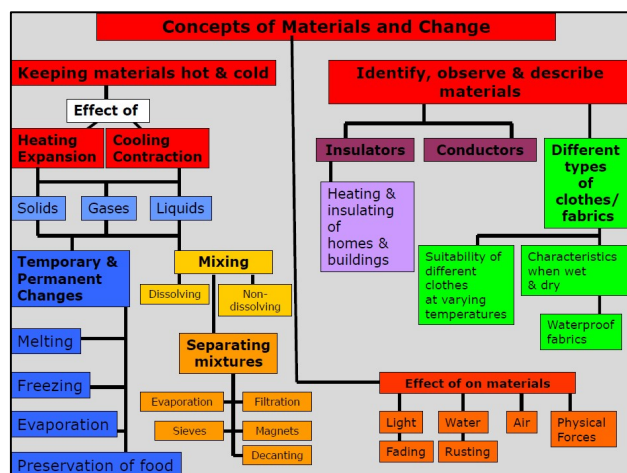


Figure 2 Key Concepts Covered in the Strand Unit: Materials and Change in the Primary Science Curriculum.

A brief summary of the Chemistry content covered in the Primary Science Curriculum is as follows: An Introduction to Matter, States of Matter, Different Properties of the Three States of Matter, Changes of State, Chemical and Physical Changes, Effects of Heating and

Cooling of Materials, Mixtures and Solutions, Separating Mixtures, Properties and Characteristics of Different Materials.

Primary Pupils' Attitudes Towards Chemistry

A review of the implementation of the revised Primary Science Curriculum was conducted by the NCCA in 2008. As part of this review, pupils' attitudes (3rd to 6th class) towards primary science were investigated (Varley *et al.*, 2008). 75% of the participating pupils (N= 1030) stated that they found school science interesting with only 55% of these pupils finding school itself interesting (N=

Table 4.11: Pupil responses to "Describe your favourite science lesson"

	No. of responses
Energy and forces	339
Living things	258
Materials	200
Topics not in Primary Science Curriculum	54
Trip/ visitor	46
Design and make	43
Experiments (unspecified)	29
Environmental awareness and care	29
Blank/ don't know	26
Outside (topic unspecified)	12
Like all science lessons	10
None – don't like any science lessons	5
ICT lesson	3
Total	1054

n for question = 1011. Of these, 38 pupils gave responses that fitted into more than one category, each of which was coded. Total number of coded responses is therefore 1054.

1030). Pupils' experiences of science lessons relating to the strand Materials will now be discussed.

Figure 3 Irish Primary Pupils' 'Favourite Science Lessons' (Varley *et al.*, 2008)

The results in Figure 3 show that pupils enjoy lessons on Materials. They described lessons in Chemistry which they liked, for example: "when we poured different liquids into a jug to find out which was the lightest" and "when we do a cool experiment like we checked would stuff dissolve quicker or slower in hot water".

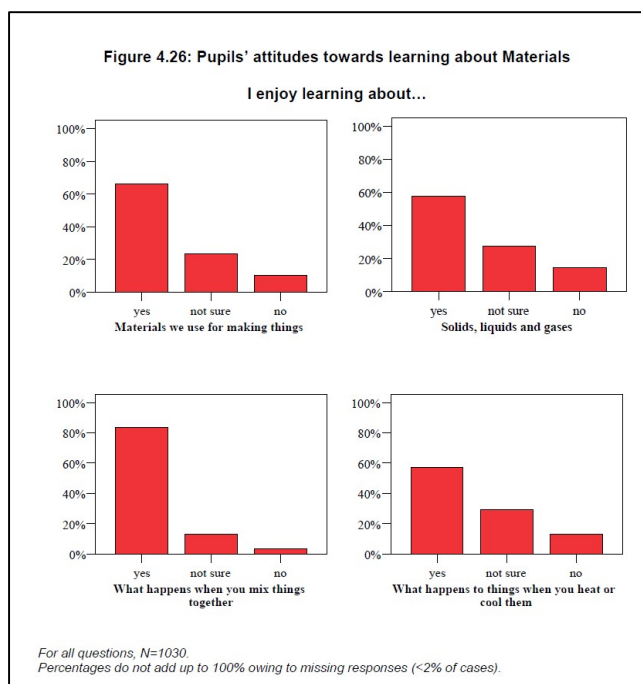


Figure 4 Irish Primary Pupils' Attitudes Towards Learning About Materials (Varley *et al.*, (2008))

*'Within the strand of Materials, pupils showed the strongest positive attitude towards learning about what happens when you mix things together (83% yes). Pupils' attitudes towards solids, liquids and gases and what happens to things when you heat or cool them scored the lowest positive attitudes (both 57%) although in this strand, no topic was especially negatively construed' (Varley *et al.*, 2008).*

The pupils were asked to provide more details on examples of their favourite lessons from the Materials Strand, which included: mixing liquids, making ice, making "lava lamps" and "fizzy rockets" and creating "volcanoes" out of vinegar and baking soda. A total of 200 pupils described favourite lessons that were coded within this strand (19% of responses). Pupils enjoyed these experiences see Figure 4) and found them to be memorable, especially activities involving fizzing or 'exploding' material. Group interviews were conducted, with a total of 45 children from first to sixth class being interviewed. These group interviews were conducted after the observed science lessons. The interviews explored the children's experiences and

perceptions of science in school. The children's recollections of their experiences with materials were extremely positive.

Conclusion

The Primary Science Curriculum provides pupils with a basic introduction and a grounding in Matter, the States of Matter, Changes of State, Chemical and Physical Changes, Mixtures and Solutions, Heating and Cooling, and Properties and Characteristics of Different Materials as described above. It is hoped that this article has provided an informative description of the Primary Science Curriculum and has helped familiarise teachers of first year science with what is taught in primary school. This should help in the planning and pitching of future Chemistry lessons in the Junior Cycle Science Classroom, post-transfer from primary school. Teachers can use the information above to begin a lesson with the pupils' prior experiences and ideas, elicit their ideas and build on these as required by the Junior Certificate Science Syllabus.

Pupils have a very positive experience of Chemistry in primary school. This article provides details of what areas and what demonstrations and activities in particular they enjoyed and teachers could use these demonstrations and activities as starting point in their science lessons to engage pupils in the topic being covered.

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Comment: This is an interesting insight into what pupils experience in science in primary school, particularly in Chemistry. One of the problems is the change of teaching approach from primary to secondary school, from a more active, child-centred approach with no focus on examinations to a more didactic teaching style, with the Junior Certificate examination in mind. A second problem is the overlap between what is covered in

primary science and in Junior Certificate science. Many of the topics covered under Materials are also in the Junior Certificate science syllabus and many of the exciting experiments mentioned by primary pupils are often done at second level. So we have the problem of over-exposure and the cry of 'we've done that before', which undermines what the teacher is trying to do. I have heard it said that primary science does all the best bits and does the interesting experiments and demonstrations, so that when they are repeated in second level pupils become bored. A third problem is the focus on examinations and learning content, over against experiencing science in the primary school. Once again this can be a turn-off for pupils and a cause of the complaint that science is boring and is all about learning off too many facts. These issues point out the need for more integration of the primary and second-level science curricula, both in content and in methodology, so that there is a more seamless transition from one level to the other.

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The Element Makers:12

Carl Wilhelm Scheele (1742-1786)

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Carl Wilhelm Scheele was born in Stralsund, on the northern coast of what is now Germany but which was then part of Swedish Pomerania, on the 19th of December 1742, the seventh of thirteen children of Jochim Christian Scheele, a carpenter, and Margaretha Eleonora Warnekros. After a good elementary education Scheele, by choice, opted for pharmacy as a career and his parents found him an apprenticeship with Martin Andreas Bauch. Bauch came originally from Mecklenburg in Germany, but was now living in Göteborg on the west coast of Sweden. As a result of the Swedish occupation of his country, many Germans moved to Swedish cities to get away from the constant presence of occupation forces. Scheele's eldest brother, Johan Martin, had earlier been an apprentice with Bauch.

Scheele now found himself in a large German enclave in Sweden. Although he was able to and had to converse in Swedish, German was to remain his choice of language for reporting his scientific findings throughout his life. Bauch encouraged his apprentice to experiment in chemistry, giving him access to his own small chemical library, which had some of the foremost chemical texts available at the time. These included the two most famous chemical handbooks of the time: Johann von Knuckel's *Laboratorium chymicum* (1716) and Caspar Neumann's (1648-1715) *Praelectiones chemicae*. Scheele, in his free time, spent much time in repeating the experiments detailed in the books and gradually built up expertise in chemistry.

After serving six years as an apprentice, Scheele remained on as an assistant at the pharmacy until it was sold in 1765, whereupon he found a position at the Fläkta Örn (Spread Eagle) pharmacy of Peter Magnus Kjellström in Malmö, on the southern coast of Sweden. Here Scheele was also permitted to experiment in chemical matters and spent his spare money on acquiring chemical literature from nearby Copenhagen. Here Scheele met Anders Retzius, a former

pharmacist and now attached to the Chemistry Department of the University of Lund. This was Scheele's first contact with the academic world. Retzius and Scheele were to become life-long friends, experimenting together and keeping up a correspondence on chemical matters. Retzius was to complain (tongue in cheek) that when he and Scheele met to share a meal he got no time to eat, as Scheele was bubbling with new observations on experiments and almost dragging Retzius to his work-bench to demonstrate these.



Carl Scheele: a posthumous portrait by Falander

In 1768 Scheele moved again, this time to Stockholm as an assistant at the Förgyllda Korpen (Gilded Raven) Pharmacy run by Johan Scharenberg. Scheele hoped to make contact with the Royal Swedish Academy of Sciences located in this city but to his dismay he found that he was not permitted to experiment in the pharmacy: he was only allowed to prepare prescriptions and so within two years he was again on the move, this time becoming a laboratory assistant at the Uplands Wapen (Upland's Arms) pharmacy in Uppsala run by Christian Ludwig Lokk. Here he was given a

work-bench on which he was able to pursue his chemical experimentation. Scheele now presented a paper on the isolation of tartaric acid to the Academy but this was ignored as he had no standing with the formal academic world. Scheele was upset by this rejection but when Retzius offered to take the paper and re-work it for presentation, Scheele agreed. Retzius did some follow-up experiments on the subject and presented the new piece under his own name but acknowledging the former results and work of Scheele. This was accepted and published in 1770.

Scheele continued to experiment and through the pharmacy met an assistant to the renowned chemist Torbern Olof Bergman (1735-1784), named Johan Gottlieb Gahn (1745-1818), who discovered of the element manganese in 1774. Scheele so impressed Gahn that he was brought to Bergman's attention. Bergman quickly recognized the potential genius of Scheele and encouraged him to experiment in various new directions. From this time on Scheele's work was promoted under the wing of Bergman, which quickly brought Scheele's name to the forefront of European chemistry. The Pharmacist's Assistant had found his place in academia.

The following few years saw Scheele producing his far-reaching work on air and chlorine. By 1773 Scheele had completed his investigation on the composition of air, recognizing two distinct components that he called fire-air and vitiated air. By ingenious experiments he isolated these gases some years before Joseph Priestly (1733-1804) but due to delay in publishing, mainly due to Bergman's delay in writing the agreed foreword, the work, Scheele's only book, was only to come on the market in 1777. The book, *Chemical Observations and Experiments on Air and Fire*, immediately earned him international recognition and was translated into French and English, making Scheele a recognized authority in Chemistry.



Scheele's diagrams for the collection of, and experimentation with gas. The gas-bags used to collect the gas, Fig, 3 and 4 in the diagram, were formed from animal bladders tied off at the ends.

In his book Scheele described the preparation of pure oxygen in various ways:

1. Reacting nitric acid with potash (KOH or K_2CO_3) giving potassium nitrate, which on distilling with sulphuric acid gave nitrogen dioxide and oxygen, the nitrogen dioxide being absorbed by saturated calcium hydroxide solution.
2. By the action of heat on mercuric oxide.
3. By the action of heat on manganese dioxide.
4. By the action of heat on silver carbonate, the liberated carbon dioxide being absorbed by potassium hydroxide solution.
5. By the action of heat on the carbonate of mercury, with subsequent absorption of the carbon dioxide in potassium hydroxide solution.

By 1774 Scheele had isolated chlorine but was convinced that it was a compound. It fell to Humphry Davy to recognize its elemental nature.

In 1775 Scheele, backed by Bergman, was elected to the Stockholm Royal Academy of Sciences, the only apothecary's assistant ever to be so honoured. It has been said that Bergman's greatest contribution to chemistry was his support for Scheele. Throughout Scheele's career he was to rely heavily on Bergman for theoretical advice and then to act on this in a practical, experimental manner.

Since first finishing his apprenticeship in 1762, Scheele had worked as an assistant in the various pharmacies mentioned above but now felt he wanted to better his position. Sara Margaretha

Sonneman, the daughter of a councilman in Köping, had married a pharmacist, Herman Pohl in 1772. Pohl, however, was taken ill and died in 1775. Scheele reached an agreement with the widow to manage the pharmacy independently for a year and then to buy it outright. Various legal problems arose but finally Scheele managed to meet the required fee and from that time on worked in Köping. He left the town just once, in 1777, when he went to Stockholm to take the qualifying examination as a master pharmacist, taking the required Oath on November 11th. While in Stockholm he took his seat as a member of the Royal Swedish Academy, to which he had been elected in 1775. Scheele was now in his element, working in his spare time in a wooden shed at the rear of the pharmacy, until he had earned sufficient money to undertake the building of a solid structure in which to experiment. Later on in 1777 the Royal Academy made Scheele an annual support of 100 riksdaler to encourage his experimentation.



The Scheele house and pharmacy

Scheele's output of formal papers multiplied once he was master of his own pharmacy. From two papers presented to the College of Pharmacy in 1775, the number of papers rose to five in 1780 and to thirteen in 1785, and these were apart from his communications to the Royal Academy. His interest in the acids of plant origin saw him produce lactic, mucic, pyromucic and uric acids in 1780; prussic acid in 1782; citric acid in 1784; malic and gallic acids in 1785; and pyrogalllic acid in 1786. Scheele's discovery of simple substances (elements) was prolific and when Lavoisier listed twenty-six elements in 1789, five of these had been initially produced by Scheele.

Scheele's experiments, in unventilated rooms, were probably the cause of his early death. Even from 1777 Scheele began to suffer from ill health, probably from the inhalation of the noxious gases and the tasting of poisonous substances produced by him. Hydrogen cyanide gas and arsenic compounds are not the best for one's health! Scheele attributed his ill health to '*the trouble of all apothecaries!*'

Some time after acquiring the pharmacy, Scheele felt the need for a house-keeper and entered into an agreement with Sara Pohl that she would come to keep house for him and share expenses. The arrangement worked well and Scheele came to grow fonder of Sara and intended to ask her to marry him at an appropriate time. Scheele's intentions were to be frustrated by the fatal illness that he suffered in 1786 brought on, probably, by his incautious experimentation with noxious chemicals. On May 18th 1786, on his death-bed, Scheele married Sara and made a will leaving all his property to her. Scheele passed away on the 21st of May 1786, an international figure of repute and an icon to future generations of Swedish chemists. Scheele has a pigment, Scheele's green (copper arsenite) and a mineral, Scheelite (calcium tungstate) named in his honour.



A 700 carat specimen of Scheelite in the Author's collection

Scheele was an inveterate experimenter, the pharmacy side of his work being merely to bring in an income. A letter to Gahn in December 1774 shows his fascination with his chemistry ..

"Oh, how happy I am! No care for eating or drinking or dwelling, no care for my pharmaceutical business, for this is mere play to me. But to watch new phenomena this is all my care, and how glad is the enquirer when discovery rewards his diligence; then his heart rejoices"

Scheele discovered more substances, including several elements, than any other person before or after him. He is credited with the discovery of oxygen, chlorine, hydrogen fluoride, silicon fluoride, hydrogen sulfide, hydrogen cyanide, the isolation for the first time of glycerol, benzoic acid, oxalic acid, lactose, arsenic acid, molybdic acid, tungstic acid and the various organic acids mentioned earlier. He was also the first person to report on the action of light on silver salts (the basis later for photography). He found it possible to preserve vinegar by heating it in a container placed in a kettle of boiling water. Here he was to invent 'pasteurization' a hundred years before Pasteur but failed to realize the importance of his discovery.

Scheele has been publicly honoured by both the Royal Swedish Academy and the Apothecaries' Society of Sweden. The Royal Academy struck medals in his honour in 1790 and 1827, both bearing his likeness. The inscription on the first reads:

"Ingenio stat sine morte decus"
(The beauty of his genius stands immortal)

The inscription on the later medal reads:

"Naturae sacra orgia movit"
(He stirred the holy mysteries of nature.)

In 1827 the Apothecaries' Society of Sweden erected a plaque with a relief portrait of Scheele in the Lutheran Church in Köping, the congregation of which Scheele had been a regular member.



Statue of Scheele in Köping

In 1892 the Apothecaries' Society of Stockholm erected a statue in his honour in the "Humble Garden", one of the city parks.

The two inscriptions above stand as suitable requiems for this short-lived but prodigious Swedish chemical genius.

Scheele is one of many scientists honoured by the international scientific community by having a moon crater named after him. Of the thirteen men in this series some seven have been so honoured. They are:

No. in Series	Name	Diameter of Crater	Co-ordinates	
1	Sir Humphry Davy	34 km	11.8° S	8.1° W
2	Jöns Jacob Berzelius	50 km	36.8° N	50.9° E
3	Sir William Ramsay	81 km	40.2° S	144.5° E
5	Robert W. E. Bunsen	52 km	41.4° N	85.3° W
6	Martin H. Klaproth	119 km	68° S	22° W
10	William H. Wollaston	10 km	30.6° N	46.9° W
12	Carl Wilhelm Scheele	4 km	9.4° S	37.8° W

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Conference Reports 2011

4TH Eurovariety in Chemistry Education

Conference, Bremen, Germany

September 1st- 3rd 2011

Anne O' Dwyer & Sarah Hayes

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Background

The 4th Eurovariety in Chemistry Education conference took place in Bremen, Germany from the 1st to 3rd of September 2011. The conference was organised by Prof. Dr. David DiFuccia, University of Kassel and Prof. Dr. Ilka Parchmann of Kiel University.

The conference provided opportunities for those involved in teaching chemistry at third level, as well as those involved in chemistry education research, to meet both formally and informally to share and discuss ideas. The Division of Chemical Education of EuCheMS met on the morning of the first day of the conference. There was one keynote lecture on each day and a number of contributed talks on chemistry education. There were approximately 50 attendees at the conference, with most of these presenting their research.

Keynote Lectures

The conference featured an impressive list of invited presentations

- Dr. Natasa Brouwer-Zupancic - Educational Service Centre, Faculty of Science, University of Amsterdam, The Netherlands on 'Training the teachers also at the university – An Educational Perspective'
- Prof. Dr. Holger Butenschön - Institute of Organic Chemistry, Leibniz University Hannover, Germany; Chair of the division "Chemical Education" of the German Chemical Society on 'Demands and challenges in chemical education from a Chemist's perspective'
- Dr. Vanessa Kind - School of Education, Durham University, Great Britain, on 'Demands and challenges in chemical education from a Chemist's perspective'

- Prof. Ron Naaman - Chemical Physics Department, The Weizmann Institute of Science, Israel, on 'Argumentation in the chemistry laboratory: inquiry and confirmatory experiments'
- Prof. Anthony Smith - CPE LYON Ecole Supérieure de Chimie Physique électronique de Lyon, France, on 'Projects, project organisation and funding possibilities - the example of the EC2E2N-network'

Theme of the conference

The presentations were grouped under two main themes-Teaching Skills, Methods and Challenges and Exemplary Topics for Higher Education.

The oral bites (5 minutes talks) as well as the longer contributed talks provided an insight into:

- Innovative methods in lecturing, tutoring, lab work and assessment.
- Student centered learning.
- Partnerships and networks between universities and other institutions/enterprises.
- Future fields of necessary innovations in teaching and learning Chemistry.



The conference provided a great perspective on practices from other countries within and outside Europe. Seeing the organization of teacher training undertaken in European universities highlighted the need to provide more resources and pedagogical training to all involved in teaching Chemistry at third level, as well as those that are teaching and preparing our future second level teachers in Ireland.

Representation from Ireland

Members from the Chemistry Education Research Group in the University of Limerick attended this conference: Peter Childs, Muireann Sheehan, Sarah Hayes and Anne O' Dwyer. Odilla Finlayson from Dublin City University also attended from Ireland.

Peter Childs presented the findings from a research study carried out by Áine Regan at the University of Limerick. This study 'From Diagnosis to Cure: Retaining weaker students in Chemistry' was an intervention programme carried out in the University of Limerick to diagnose and address the misconceptions and difficulties held by third level students who are often learning Chemistry for the first time at university.

Sarah Hayes presented a 'Hands-on, Minds-on' approach to teaching pre-service Science teachers to make them more adaptable and capable within the classroom. Muireann Sheehan presented the findings of her research investigating the chemical misconceptions of trainee Science teachers in Ireland. Many of lecturers from other countries were able to relate to the findings presented and discussed by Muireann. It is evident that such chemical misconceptions among pre-service Science teachers are not unique to Ireland.



Muireann Sheehan giving her talk

Anne O' Dwyer presented the preliminary findings of research carried out involving students studying introductory Organic Chemistry in three third level institutions in Ireland. This investigation found that many of the topics identified as difficult at second level in previous studies were again identified as difficult in this study. These findings support the need to address how Organic Chemistry is taught at both second level and introductory third level in Ireland.

Overall impressions

The conference was successful in bringing together lecturers and researchers to promote discussion and sharing on best practice in different European countries. The countries represented were Netherlands, Finland, Germany, Italy, Czech Republic, Croatia, Denmark, Taiwan, Poland, Israel, France as well as two speakers from the United States.



Liberato Cardellini and Peter Childs, with Muireann Sheehan looking on

The small scale of the conference allowed for a very good interaction and exchange among participants which initiated considerable exchange of ideas and potential collaborations. Although, the conference was focused on Third Level education, many of the topics and issues discussed were relevant to Second Level Chemistry education also. Details of the conference are available at the conference website: <http://www.eurovariety2011.de/>.

The 2012 Eurovariety Conference will be held at the University of Limerick, probably in July 2013.

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9th European Science Education Research Association (ESERA) Conference, Lyon, France

Muireann Sheehan and Marie Ryan

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Background

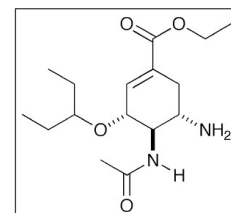
The 9th ESERA conference took place from the 5th to the 9th July 2011 in the Lyon Convention Centre. The centre is part of a larger complex 'la Cité Internationale' which lies between the Rhône and the Parc de la Tête d'Or. The theme of this year's conference was 'science learning and citizenship' and was designed for those involved in the research, policy or practice of science education at primary, secondary or third level internationally. The conference took place over five days and included plenary lectures, single oral presentations, symposia and poster sessions. There were 1200 participants and presentations and posters were run as parallel sessions divided into fourteen strands making this a very busy conference.

Plenary Lectures

The first plenary speaker, Isabelle Stengers, spoke about the relationship between citizenship and science. Citizens' understanding of and trust in science and scientists was discussed with an emphasis on moving toward "connoisseurship of science" whereby connoisseurs can evaluate, discuss and critically analyse information which they receive. The inclusion of socioscientific issues in science curricula and the challenges which this poses for teachers was the topic of a lecture by Laurence Simonneaux. One of the challenges highlighted by the speaker was the inter- and trans-disciplinary nature of these issues which often extend beyond traditional boundaries to include social knowledge. Gregory Kelly discussed how students learn to use evidence to support arguments in their writing and the development of a professional vision among trainee teachers through the use of reflection. Finally, Sibel Ersduran spoke about the current lack of models of knowledge growth in science teacher education due to the practical realities of the science classroom and the need for science teachers to embrace such models.

Relevance for the Irish Chemistry Teacher

A symposium in the in-service science teacher strand of the conference focused on nanoscience and the introduction of 'nanoeducation' to second level science teachers. One of the difficulties which pupils have within this area is the size of particles on the nanoscale. Some suggested links which can be used to link nanoscience with STS issues are data security, modification of human beings and transhumanism, as well as health and environmental issues.



Chemical structure of Tamiflu

The effect of using context-based chemistry in a second level school in Sweden was

the topic of another presentation. One example of an everyday life context is the use of Tamiflu for the treatment of swine flu. Pupils were asked to identify the functional groups and benzene ring in the chemical structure of Tamiflu. Pupils' attitudes toward chemistry improved. However, when assessed they had difficulty related their chemistry knowledge to everyday contexts.

The Irish Participants

Ireland was well represented at the conference with researchers from the University of Limerick (UL) and Dublin City University DCU. Representatives from DCU included Odilla



Some of the Irish and German participants enjoying dinner

Finlayson, Richard Hoban, Leanne Doughty, Colette Murphy and Eilish McLoughlin. Jonathan Dunne (UL) presented the findings of a small

portion of his research.

He examined three textbooks commonly used by Irish primary school teachers to guide the planning of their science lessons. He noted that some books focused mainly on science content while others focused on appropriate pedagogical methods for teaching science and suggested that such books may have value for teachers depending on their area of weakness: content knowledge or pedagogical knowledge. This sparked an interesting debate among participants from other countries as they discussed whether such books could be of value to primary school teachers.



Participants of PCK symposium

Muireann Sheehan (University of Limerick) presented the findings of her research on the chemistry misconceptions of pre-service teachers as part of a symposium entitled “Explorations of content knowledge and pedagogical content knowledge for chemistry teaching”. A snapshot of the misconceptions of pre-service teachers in each year of study in a university in Ireland was taken and it was found that the number and type of misconceptions were the same across all years of study. This suggests that the content knowledge of pre-service teachers is lacking.

Peter Childs presented the research of Maria Sheehan (University of Limerick) on the effects of an intervention programme, ITS Chemistry. The programme was found to improve the cognitive development of pupils and reduce the number of chemistry misconceptions held by chemistry pupils. Aine Regan’s (University of Limerick) research was presented by Sarah Hayes. She also designed, implemented and evaluated an intervention programme. The programme was designed to retain weaker chemistry students in third level education by running tutorials that utilised peer learning and the use of conceptual questions. The results of pre- and post-diagnostic tests suggested that the intervention programme

had a positive effect on students’ understanding of chemistry.



Anne O'Dwyer presenting the findings of her research

Second level pupils’ and teachers’ views of the difficulties in organic chemistry were the areas of research presented by Anne O’Dwyer (UL). A number of common topics were identified by both teachers and

pupils as being difficult: namely structural formulae, functional groups, characteristics of organic compounds, organic reactions and laboratory work. The next stage of this study is the evaluation, by teachers and pupils, of teaching materials developed to address these areas of difficulty.

Dermot Donnelly (UL) presented a conceptual framework for pedagogical content knowledge (PCK) to those attending the conference. The goal of this framework was to return to the simplicity of the original PCK construct while also encompassing ideas from other more complex models of PCK.



City Hall, Lyon

Social Events

The conference was full of opportunities to engage with participants from across the world. The two main social events of the week were the welcome reception and the gala dinner. The welcome reception took place in the majestic surroundings of the Lyon city hall, Hôtel de Ville de Lyon. The city hall was built between 1645 and 1651 and is one of the largest historic buildings in the city. Our first impressions of this building (the more enthusiastically inclined of us at least) were of sheer admiration for its amazing

architecture both internally and externally. The opening reception consisted of a welcoming speech followed by a generous supply of wine, tea/coffee and finger food which were enjoyed while mingling with some of the participants. In typical Irish fashion, this event was also a perfect opportunity to make our dinner plans for the evening with our German acquaintances. Dinner each evening proved to be another important social event, with each night strategically planned to maximise our Lyonnaise culinary experience. The Lyonnaise salad was a favourite of our group.



The Chemistry Education Research Group on their way to the Gala Dinner

The Gala dinner on Thursday evening (8th September) in the famous Beaujolais vineyard was the highlight of the week's social events. The guests were transported from outside the convention centre to the "Cuvage de Lacenas", one of the most prestigious press houses (built in 1786) in the heart of Beaujolais region, 35km north of Lyon.

On arrival at the vineyard, guests were greeted by a jazz band and an opportunity to taste Beaujolais wine and stroll around the vineyard tasting the grapes, before the meal of sumptuous French cuisine. The focal point of the dining area was a huge historic wine press denoting the building's previous use as a press and fermenting area of Beaujolais grapes. This special and enjoyable evening ended with dancing in the basement area which possessed a remarkable vaulted ceiling.

Overall Impressions

This conference was well organised and the scheduled events ran very smoothly. Credit must be given to the organising committee, consisting of 20 researchers working in the field of science education from the Rhône-Alpes region, for their dedication in organising such a productive and enjoyable event. The city of Lyon is known for its historical and architectural landmarks and is a UNESCO World Heritage site. The combination of a beautiful city with remarkable architecture and good cuisine and the well organised conference led to a very enjoyable week being had by all.

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5th Chemistry Demonstration Workshop, 13-17 June 2011

"Smoke and fire: putting the 'wow factor' back into science teaching"

Peter E. Childs and Sarah Hayes

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From June 13-17th the University of Limerick was the venue for the annual Chemistry Demonstration Workshop for science teachers and trainee science teachers. This year's was the largest yet with 19 participants, including 3

teacher trainers from abroad (2 from Georgia and 1 from Moldova), members of a Tempus project, of which UL is a member. The workshop was led by Peter Childs and Sarah Hayes (the resident chemical magicians). The participants also

included 7 science education students from 3 universities.

The workshop was run by the Department of Chemical and Environmental Sciences, in collaboration with the National Centre for Excellence for Mathematics and Science Teaching and Learning, and was supported by sponsorship from the Royal Dublin Society Science Live for Teachers, Pharmachemical Ireland and the Professional Development Service for Teachers. Pharmachemical Ireland provided scholarships for 7 students, all science education or HDipEd students: 1 from DCU, 2 from UCC and 4 from UL.



This photo shows 6 of the 7 trainee science teachers on the course. From L to R: David O'Connell (UCC), Danielle Broomfield (DCU), James Levis (UCC), Marie Ryan (UL), Nicholas Ryan (UL), Martin Sheehan (UL) - missing Damien Coman (UL)



Encased in a giant soap bubble.

The first purpose of the workshop is to introduce science teachers to chemical demonstrations, and to give them confidence and competence to do them in school. They get to try out and perfect a range of simple demonstrations, including some spectacular ones, that can be used in school. The second purpose is to help them design and then present a science magic show themselves, so they can take these skills back to school and use them for promoting science. Since the workshops began in 2007 nearly 60 teachers have been trained in this way. Their response has been very enthusiastic and everyone has gone away fired up (literally) to do more demonstrations in school.

The methane mamba (aka the flaming bubbles) and the screaming jelly baby are always popular demonstrations, and this year we added the human candle (definitely a one-off as it needs a completely bald head), the thunderstorm in a test-tube and the exploding Pringles can. It is possible find most of these demonstrations on-line or in books or videos, but there is no substitute for trying them yourself and getting to know how to do them safely and what works and what doesn't work.



Some of the participants taking a break.

The workshop is residential and most of the participants stayed in one of the university villages and ate together on campus in The Paddocks (see above). This gives the workshop an important social dimension and helps the teachers and students work effectively together. It is also great fun and once again the participants at this year's Workshop bonded well and there was a lot of laughter as usual. The workshops show that chemistry can be fun and teachers appreciate the

chance to step aside from the pressures of teaching and having time to try out new things.



One of the science magic shows.

The workshop culminates with the science magic shows, where the participants work in pairs to put on a show, using some of the ideas learnt during the week. These are always excellent and show great imagination and versatility by the teachers, and this year was no disappointment as we had 9 excellent shows.

We hope to run another one next year, probably in late June or early July, and anyone interested should contact Peter Childs (peter.childs@ul.ie) or Sarah Hayes (sarah.hayes@ul.ie).

The workshops costs teachers €100 and the rest of the costs are borne by the sponsors. We continue to be grateful to the sponsors for making this Workshop possible and to the Department of Chemical and Environmental sciences for

providing the facilities, technical support and materials.



The human candle – Nicholas Ryan with a demonstration that requires a shaved head. You have to be mad to try this one!

During the school year we offer a Science Magic Show in schools, designed to fit in a single class period and including information on careers and courses in science at UL.

If you are interested in a Show in your school during 2011-12 please contact Marie Ryan at marie.c.ryan@ul.ie.

N.B. You can buy a giant bubble maker from Amazon UK.

30th ChemEd-Ireland Conference

"Preparing for the Future of Chemical Education"

October 22nd

University College Cork

As usual in Cork this was well attended (~180) and well organised by Declan Kennedy and his team of teachers and students. It is hoped to print most of the talks in the Proceedings in the Spring issue (#96) and to include a fuller report with pictures. The new Eureka Science Education Centre was on display and during the lunch break there were demonstrations of various experiments. Discussions of the examinations (by Tim Desmond) and the new LC Chemistry syllabus (by Anna Walshe) were lively. The first talk on

Nanoscience by Justin Holmes from UCC was excellent. John Daly talked about the RSC course for non-specialists, which it is hoped to run in Ireland, and showed some of their experiments. Some of the presentations from the conference are available on the ISTA website, together with photos, at:

<http://www.ista.ie/news/chemed-conference-2011>.

ChemTips

Don't get rid of your OHPs!

Most school classrooms and laboratories are now equipped with video projectors or electronic whiteboards and the that old AV workhorse, the overhead projector, is nowhere in sight. They may be mouldering in a cupboard and have been recycled as electrical waste. This is a plea to the science teacher to rescue the OHP and make sure it is still kept in the laboratory and functioning. The use of the OHP for presenting visual material is past, as the computer, projector and PowerPoint as much more versatile. But the OHP should be retained for use in chemical demonstration (see CinA! #). Many things can be demonstrated on the OHP, giving a large visible image that everyone can see e.g. indicator colour changes, precipitation, metals reacting with water or acids, complexation, electrolysis etc. This is not the same as seeing it in a video clip as the teacher is actually doing real chemistry in front of the class and the students are seeing live action chemistry. Such OHP demonstrations use very little chemicals, simple apparatus, they are easy to set up and quick to perform, and easy to clear up. Everyone can see and since students stay in their places, safety and discipline are improved. Using the OHP for demonstrations is a valuable tool in the chemistry teacher's armoury. Don't get rid of your OHP – in fact beg, borrow or steal one (and spare lamps) so that your lab is fully equipped.

Cheap weighing boats

Various things can be used for weighing out solids – watch glasses, filter paper, plastic weighing boats. It is helpful to have something that is cheap, light and disposable. Paper bun cases can conveniently be used for this purpose and thrown away after use.

Spray bottles

There is often a need to have a spray bottle for various reagents e.g. spraying chromatography plates, demonstrating flame tests (by spraying a mix of metal salt and methanol into a flame), showing colour reactions etc. You can buy cheap spray bottles in a garden centre, but they often don't work well and they cost money. Every household uses and throws away a variety of spray bottles, used for cleaners. When empty these can be washed out, the labels removed and replaced, and they can be used in the laboratory. They cost nothing and work well. Their only disadvantage is that they tend to be quite large, but they don't need to be filled and work well as long as the end of the spray tube is covered.

Aluminium pie dishes

The disadvantage of paper and plastic is that they can't be heated and they burn. Aluminium dishes are available in shops in various sizes for disposable cookware (as well as being used in many ready and takeaway meals). Aluminium doesn't catch fire, nor does it colour a flame. Aluminium pie dishes can thus be used to

demonstrate flame tests by burning a mixture of methanol and metal salt (see the Tested Demonstration #, p.). You may be able to think of new uses for them.

Refillable barbecue lighters

Lighting Bunsen burners is always a pain and the piezoelectric lighters are expensive and don't always work. Gas lighters are fiddly and the flame is close to one's hand. However, many places sell refillable gas lighters for use in the kitchen or on barbecues. They are cheap, work well and the flame is a good way from the hand. They can be refilled using butane canisters. They are cheap, reliable way of lighting a Bunsen or for other lab uses. Recently in Georgia I came across long ones (around 30 cm), which are great for a number of chemical demonstrations where you want your hand to be a good distance away from the flame e.g. burning ice cubes, whoosh bottle. Every chemistry teacher's labcoat should have one in the pocket!

If you have some good ChemTips please send them in.

Wanted:

Old photos of school laboratories in action for a series on "The way we were". Please send a scanned image indicating the date and location to the Editor.