Contents #110

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Editorial #110

First year down

The first year of the new Junior Science course is over and in two years the first students will take the examination. One thing I noticed when I visited several schools starting the new courses was that the Nature of Science (NoS) was being taught as a stand-alone topic. This is not the intention of the syllabus as NoS is supposed to be integrated across all the themes as appropriate. In many of the new textbooks NoS is dealt with at the start as a separate topic and this may be the cause of the way it is being taught. It is also true that only TUI members had received any in-service courses for the new course before it was introduced, due to the ASTI boycott of the new Junior curriculum. This is certainly an issue to be addressed by the Junior Science support team as teaching NoS as a topic may undermine its use in the course. It remains to be seen whether the new shorter course (200 versus 240 hours) is a good preparation for the senior cycle science courses.

Major science education conference in Dublin

From August 21-25 Dublin City University hosted the European Science Education Research Assocation's conference. ESERA is held every two years in a European city and this year's event was the largest ever with over 1500 participants. It was jointly organised by CASTel at DCU and EPI*STEM at the University of Limerick, although the lion's share of the work and organisation was done by the local team. The conference went off smoothly, despite having over 20 parallel sessions at times. The overseas visitors seemed delighted by their welcome and a .

chance to visit Ireland. Even the rain held off for most of the week. For a report see p. 56.

ChemEd-Ireland returns to UL

On Saturday October 21st ChemEd-Ireland returns to the University of Limerick. The theme of this year's conference is 'Chemistry and Society' and the organising team is led by Dr Sarah Hayes of SSPC. Registration will be available through Eventbrite. ChemEd-Ireland started on the UL campus in 1982 and ran for 25 years there before moving around the country, alternating now between the East and West coast. This year's bill of fare includes climate change and the chemistry of food. We hope to publish the Proceedings in the Spring issue (#111). The conference went off well despite Storm Brian and over 70 people attended.

Philip Ryan, RIP

I was very sad to hear of the recent death of James Philip Ryan, the long-serving secretary of the Institute of Chemistry of Ireland. For many people in the last 30 years he was the Institute and his hard work and cheerful manner will be greatly missed. He has done no small service to the cause of chemistry in Ireland.

New STEM Professor arrives

Following the departure of Professor Sibel Erduran to Oxford in Dec. 2017, UL has now appointed a new Professor of STEM Education. Professor Merriyln Goos, a maths education specialist from Australia, took up her position in October 2017. She is also Director of EPI*STEM, the National Centre for STEM Education in UL.

Peter E. Childs
Hon. Editor

In this issue:

I hope you enjoy this issue as it has a good range of articles and reports. This page highlights some of the items, as started in the last issue, to encourage you to browse.

We have several practical articles: by Enda Carr on using Ziploc bags to do safe chemistry (p. 34); and two TEMI ideas, one on density using the polydensity bottle(p.30) and one on the disappearing precipitate (p. 32); also an article on the chemistry of the brown ring test for nitrates (p. 28). (If you have anything like this that you want explaining, please contact peter,childs@ul.ie.)

Miriam Hamilton contributes an interesting Opinion article on the integration of the three main sciences in the junior science course (p. 23). Do you have strong opinions on something connected to teaching chemistry or science in school? Why not send in an article for the Opinion feature?

Emma Ryan, an ex-student of UL, describes her experience of teaching science in New York, after several years teaching in Ireland (p. 19).

Adrian Ryder continues his series on 'Chemists you should know', with an article on Niels Bohr, actually a physicist, but featured in every introductory chemistry course. (p. 12) This is followed by a famous Chemical Quotation by Niels Bohr.

I think it's important to have a historical perspective in science and also to link the present day to the past in Ireland. The latest in our series 'Places to visit', introduces the Glengowla Mine in Co. Galway, an example of Ireland's mining past. (p. 38)

You will have noticed the striking cover with the world's largest crystal model (of sodium chloride), constructed by an Austrian Crystallographer, Robert Krickl. You can read more about this amazing project on p. 16, which has gone into the Guinness Book of Records and featured on an Austrian postage stamp. If you are thinking of repeating this feat, think again, as it would be enormously expensive and time-consuming. Robert's model needed 42,875 model atoms and 11.8 km of sticks to join them.

The summer is always a busy time for conferences and workshops and in this issue we have a number of reports (pp. 46-59), ranging geographically from Belgrade, Serbia to Debrecen, Hungary; from Limerick to Cork to Dublin. One reason for putting in the reports is to whet your appetite for next year – maybe you would think of going to Cork for the BASF Chemistry Workshop or to Limerick next summer for the Chemistry Demonstration Workshop.

Practical work is important in science, something established in schools in England and Ireland since the 19th century. In many countries practical work does not have such a central place and science is often taught from the book. The Gatsby Foundation in the UK has funded a recent report on Practical Work in schools, written by Professor Sir John Holman, which lays down benchmarks for school practical work. There is much that we could learn from this report and summary is given on p. 7. After reading this summary, I would encourage you to download and read the full report.

With the move towards electric vehicles and the need to store the energy from renewable resources like wind and solar, lithium batteries have moved up the technology agenda and demand for lithium has soared. All of us now use and depend on lithium batteries in our smart phones and laptops. In this issue we look at the chemistry of lithium and where it is found (p. 41).

Did you know that eating the kernel inside cherry stones could be fatal? To find out why consult p. 61. Did you know there were two sorts of rubber, one hard and one elastic. Gutta Percha, the hard form, helped start a technological revolution in the mid 19th century (p. 62). It is a great example of the importance of geometrical isomerism on physical properties.

There's plenty to interest you in this issue and some useful ideas to put into practice.

Education News and Views

The Editor welcomes contributions and news of interest to chemistry teachers in this section.

The Ada Lovelace Initiative

The company Verify Recruitment launched the Ada Lovelace Initiative (ADI) in 2015 to encourage more girls to take up STEM subjects and careers. The initiative was launched in 2015 to mark the 200th anniversary of the birth of Ada Lovelace, a pioneer in computer programming.

They explain their aim as follows:

"Our aim with A.L.I is to work with our industry contacts to connect female professionals working in technology with Transition Year secondary school students to present to students an insight into working in technology by telling their story. Women from the technology industry will tell students about their educational background, their role type & how they chose their career path."

Female STEM professionals are encouraged to go into schools and spend an hour talking to girls about STEM careers. A booklet to help them prepare is available on the website. The initiative has reached around 5,000 students since its start.

(http://www.verifyrecruitment.com/ali)

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A case of title inflation?

Whilst at DCU for ESERA in August I discovered that all the academics in DCU had been retitled as Professor. This follows the example of Trinity College Dublin and University College Dublin. Traditionally in the UK and Ireland, the title of Professor was reserved for a few distinguished academics. Academia had a pyramidal structure with the professor at the peak. In America every academic is a professor, although distinguished as Associate, Assistant and Full professors. Some universities already had Associate Professors, an alternative title to Reader, which is common in the UK. However now all academics at DCU, TCD and UCD can call themselves professors. The distinction between the distinguished academic and everyone else has gone and one has to feel that the title has been devalued. It reminds me of the Gilbert and Sullivan song from the Gondoliers:

"When everybody is somebody, then nobody is anybody."

No doubt all the other Irish universities will follow suit so as not to be left behind.

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THES University Rankings

Nine Irish universities feature in the world's top 100 universities according to the Time Higher Education Supplement (THES) 2017 listing. Trinity College Dublin (TCD) is the top ranked Irish university, up 14 places from 2016. The THES survey looks at the top 1000 of the world's 20,000 universities. For a small country to have ine insttiutions in the top 800 is a major achievment. This year Oxford topped the list, with Cambridge second.

TCD 117
NUIM, UCD, RCSI 200-250
UCC (351-400)
DCU (401-500)
NUI Maynooth (401-500)
UL (501-600)
DIT (601-800)

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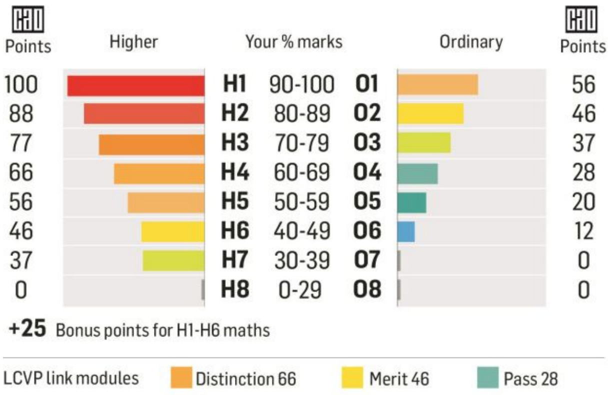
New grades and points system

This year saw the introduction of a new grading system for the LC examinations and a new points system for the CAO. These are shown below. The number of grades have been reduced and an H7 now gets some points. Pre 2017 results have a conversion value and the 2017 CAO entry system seems to have worked well.



See:
http://www2.cao.ie/downloads/documents/NewCommonPointsScale2017.pdf

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STEM Paths: Helping steer students to success

http://www.abbvie.ie/content/dam/abbviecorp/ie/docs/STEM-meeting-report.pdf

This is a report of a consultation hosted by AbbVie of various STEM stakeholders and published in January 2017.

SUMMARY OF SUGGESTIONS AND INSIGHTS

• Continue to drive awareness of existing initiatives at primary and post-primary level that will encourage early intervention, for example, The National Discover Primary Science and Maths programme.

• Develop better working relationships with post-primary guidance counsellors on career paths into and within STEM.

• Recognition that science teachers at post-primary level are an untapped resource for career advice; greater engagement with these key individuals.

• Explore reasons why certain STEM subjects (such as physics and chemistry) are not readily available for Leaving Cert students in all schools in Ireland; research must be carried out in this area to gain a better understanding of the issue.

• Greater exposure to industry should be facilitated through Transition Year programmes.

• Targeted interaction with third and fourth level students to encourage them to think beyond academia.

• Requirement to work in partnership with media to highlight young role models working within STEM disciplines.

• More funding needed for schools to build laboratories for post-primary STEM programmes. These laboratories could potentially be developed as shared resources within a community.

• Pharmaceutical companies and other stakeholders should improve relationships with local schools, working together to identify opportunities for representatives to visit classrooms to inform students about future career opportunities.

• The need for more organisations to support the Smart Futures programme and promote it to local schools as a resource to access industry role models.

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Announcement of the 2017 National Crystal Growing Competition

Martin McHugh*, Aimee Stapleton, Fiona McAuliffe and Sarah Hayes
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The Synthesis and Solid State Pharmaceutical Centre (SSPC), in partnership with iCRAG (Irish Centre for Research in Applied Geosciences), both funded by Science Foundation Ireland (SFI), are launching the fourth annual National Crystal Growing Competition on October 2nd. The number entering the competition has grown exponentially and this year we are expecting a record number of entrants. Moreover, our continued collaboration with the International Union of Crystallography (IUCr) means that students can also enter the international crystal growing competition.

The national competition asks students at both primary and secondary level, with the help of their teacher, to grow a crystal from a variety of compounds (of their/their teacher's choice): sugar, salt, alum or copper sulphate. Other compounds outside these may be submitted, but please send an email to SSPCCrystals@ul.ie prior to beginning crystal growth to ensure the compound is approved. Growing a single large crystal takes patience and experimentation. Students who enter will develop scientific inquiry skills along with an understanding of the scientific method as they take ownership of their learning. Growing a beautiful single crystal takes time and an almost daily follow-up! Entries will be judged by a panel of SSPC and iCRAG experts.

For the national competition, the winning student will receive an iPad mini along with a trophy, while the second and third students will receive **all4one** vouchers and trophies. The winning students and their classes will be invited to one of the national finals in either the SSPC headquarters in the University of Limerick (UL) or iCRAG in University College Dublin (UCD), depending on the location of their school, for the award ceremony which will take place during Engineers Week 2018 (24th Feb – 2nd March).

Students can also enter their crystals into the international crystal growing competition, as this year the SSPC and iCRAG will again be teaming up with the IUCr. For the international competition, students are asked to document their crystal growing process on a video and upload it on the IUCr website by the closing date of the **19th of November 2017** (the end of Science Week) -

http://www.iucr.org/outreach/crystal-growing-competition-2017
For both competitions, please view the Material Safety Data Sheets for Health and Safety instructions and indications for materials available on http://www.sspc.ie/crystal_growing

The deadline for entry into the **national competition is the 22nd of December 2017**. To find out more information, go to http://www.sspc.ie/crystal_growing or contact the SSPC Public Engagement Officer, Martin McHugh martin.mchugh@ul.ie/SSPCCrystals@ul.ie.

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6th BASF Summer School in Cork

Dr Declan Kennedy in association with BASF, organised another very successful summer school in UCC, June. Each day was over-subscribed with 35 teachers on each day. A full report is given on p. 51.

The group of chemistry teachers who attended the second day of the BASF Summer School. (Photo: Dr Trevor Carey)

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ChemEd-Ireland 2017

On October 21st ChemEd-Ireland returns home to the University of Limerick. The theme of the conference is 'Chemistry and Society'.

This year's conference included lectures by John Sodeau (UCC) on Climate Chnage, William Reville (UCC) on Science Technology and Society, Stephen Ashworth from the University of East Anglia on Kitchen Chemistry, Mike Zaworotko (UL) on the importance of crystals and Michael Scanlon (UL) on Clean energy. In addition there was a choice of 3 workshops and teachers could choose to attend two of them.

The Proceedings of ChemEd-Ireland 2017 will appear in issue #111 in Spring 2018.

Future ChemEd-Ireland conferences:

2018	TCD John O'Donoghue
2019	DIT (Grangegorman) Claire McDonnell
2020	UCC Declan Kennedy
2021	DCU Odilla Finlayson
2022	LIT Marie Walsh

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WiSTEM^{2}D: Women in STEMMD (Science, Technology, Engineering, Mathematics, Manufacturing and Design)

Recruiting more females into the male dominated STEM work force is an international goal. Johnson and Johnson (J&J) have partnered with ten higher level institutions around the world (e.g. Caltech, Harvey Mudd College, Massachusetts Institute of Technology, The University of Tokyo) in a bid to address the challenges faced by women in STEM. The University of Limerick is the only Irish university chosen to participate in the global initiative, which focuses on the importance of peer networking and mentoring support.

The second year of the WiSTEM2D Programme was launched on the 13th of September in the University of Limerick and focuses solely on the higher education sector. The programme consists of a research component, which is facilitated by Dr Regina Kelly, under the direction of Principal Investigator Dr Oliver McGarr. The research intends to explore if female students experience any barriers while pursuing a degree in STEM. The Award aspect of the programme consists of WiSTEM^{2}D Student Awards and WiSTEM^{2}D Team Projects. Both awards provide students with J&J industry mentors, opportunities for students to develop their STEM networks and some financial assistance.

For more information on the WiSTEM^{2}D Programme, please contact regina.kelly@ul.ie. Further details are also available on http://epistem.ie/

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Good Practical Science

John Holman
The Gatsby Foundation, Sept. 2017
http://www.gatsby.org.uk/education/programmes/support-for-practical-science-in-schools

This is an important report by Sir John Homan, a well-known chemical educator and currently President of the Royal Society of Chemistry. It is written for the UK but much of it will be of interest to Irish chemistry teachers. Schools were visited in Australia (Victoria), Finland, Germany, The Netherlands, Singapore, the USA (Massachusetts) to compare their experience of practical work with English schools.

This is the conclusion of the report, which you can read in full at the link above.

"Experiments are the essence of science and the appeal of practical science is the reason many scientists, engineers and technicians chose the career they did. But in a world where schools are under intense pressure to perform well in written exams, practical science is at risk. Our study has shown that many of the ingredients of good practical science are the ingredients of all good science learning – expert teachers, well-planned lessons and technical support. Government needs to create the right environment, with adequate funding for schools, a good supply of trained specialist teachers and an accountability system that encourages learning beyond exams alone. But in the end it is for headteachers and science heads to take the lead in prioritising practical science – and our benchmarks show what they need to do to get practical science that is world class. By achieving that, they will engage students, whether or not they pursue science in the future, in the essence of what it is to be a scientist."

THE BENCHMARKS FOR GOOD PRACTICAL SCIENCE (Summary, p. 4)

1 PLANNED PRACTICAL SCIENCE
Every school should have a written policy that explains why teachers use practical science, the outcomes they expect from it and how they achieve those outcomes. The process of producing the policy is as important as the policy itself.

2 PURPOSEFUL PRACTICAL SCIENCE
Teachers should know the purpose of any practical science activity, and it should be planned and executed so it is effective and integrated with other science learning.

3 EXPERT TEACHERS
Teachers should have subject-specialist training (both initial and continuing) in the subject (biology, chemistry, physics etc) and age range they teach, so they can carry out practical science with confidence and knowledge of the underlying principles.

4 FREQUENT AND VARIED PRACTICAL SCIENCE
Students should experience a practical activity in at least half of their science lessons. These activities can be short or long, but should be varied in type.

5 LABORATORY FACILITIES AND EQUIPMENT
Schools should have enough laboratories to make it possible for every teacher to do frequent practical science safely. Each laboratory should have sufficient equipment for students to work in small groups.

6 TECHNICAL SUPPORT
Science departments should have enough technical or technician support to enable teachers to carry out frequent and effective practical science.

7 REAL EXPERIMENTS, VIRTUAL ENHANCEMENTS
Teachers should use digital technologies to support and enhance practical experience, but not to replace it.

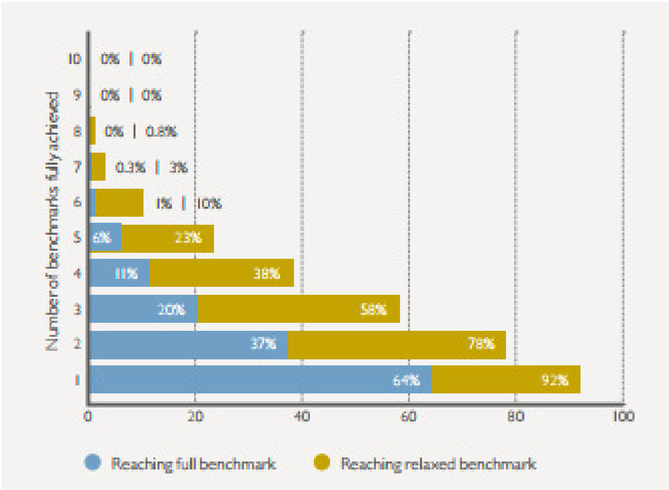
8 INVESTIGATIVE PROJECTS
Students should have opportunities to do open-ended and extended investigative projects.

9 A BALANCED APPROACH TO RISK
Students' experience of practical science should not be restricted by unnecessary risk aversion.

10 ASSESSMENT FIT FOR PURPOSE
Assessment of students' work in science should include assessment of their practical knowledge, skills and behaviours. This applies to both formative and summative assessment.

How do schools measure up?
The report commissioned a survey of 10% of schools in England to see how they measured up to the benchmarks. The results are shown in the figure below. No schools achieved all 10 and only 29% achieved 5.

PERCENTAGE OF SCHOOLS REACHING DIFFERENT NUMBERS OF BENCHMARKS



The report concludes that most schools struggle to achieve benchmark 4 (practical work in at least half of students' science lessons). It recommends that schools prioritise benchmarks1 (Planned practical science), 3 (expert teachers) and 6 (Technical support).

This is an important report and it would be interesting to see how Irish schools measure up to these Benchmarks.

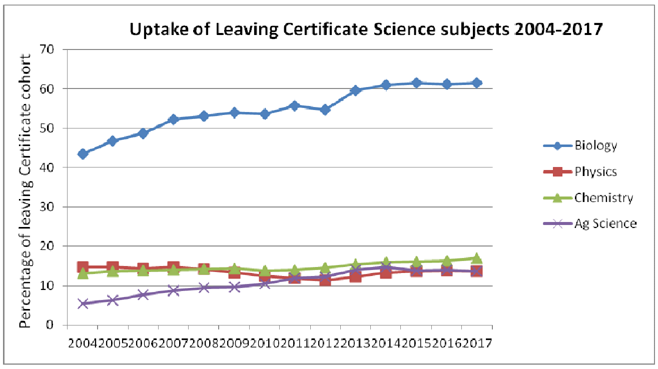
This should be required reading for all concerned with the health of school science in Ireland and the role played by practical work.

LC Science uptake 2017

The 2017 LC results were released on August 17th 2017, using the new grading system (see above). A total of **55,770** (55,708 in 2016) students offered the LC in **2017**. The science results are shown below for 2017 and 2016. Biology and Chemistry both increased in numbers and in % share, while Ag. Science and Physics both declined slightly. The graph below shows the % uptake of science since 2004 and Biology shows the most dramatic increase, with slow increases for Chemistry and Ag. Science. The LC science results are given below.

LC Science numbers and % uptake 2017 (2016)

Subject	HL	OL	Total	%
Biology	**26,684** (25,212	**7,608** 8,890	**34,292▲** 34,102	**61.5 ▲** 61.2)
Chemistry	**8,162** (7,658	**1,306** 1,431	**9,468▲** 9,089	**17.0 ▲** 16.3)
Ag. Science	**6,376** (6,270	**1,284** 1,624	**7,660▼** 7,894	**13.7 ▼** 14.1)
Physics	**6,271** (6,003	**1,314** 1,749	**7,585▼** 7,752	**13.6 ▼** 13.9)



New MA in STEM atMIC

A new MA in STEM education for primary teachers has started at Mary Immaculate College, Limerick. (MIC) This is a 2-year, part-time course, and the first cohort of 8 teachers has started the course. MIC has also created a new Department of STEM Education to recognise its importance in the training of primary teachers.

Irish Success at International Chemistry Olympiad

Odilla Finlayson, DCU
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Three members of Team Ireland have been awarded Bronze medals at the 49th International Chemistry Olympiad in Thailand. Nearly three hundred students from seventy six countries took part in the Olympiad. The competition involved both practical and theoretical tasks in Chemistry, spanning all aspects of Organic, Physical, Analytical and Inorganic chemistry. The Irish students performed well in the laboratory work and were able to tackle complex theoretical problems.

Ireland team – Michael Yuan Hong, Diarmuid O'Donoghue, Alicia Huntley and Aaron Hannon

The Ireland team were: Aaron Hannon, St Muredach's College, Ballina, Co. Mayo,
Alicia Huntley, Regent House School, Newtownards, Co.Down (Bronze medal winner)
Diarmuid O'Donoghue, Ashton School, Blackrock Road, Cork (Bronze Medal winner)
Michael Yuan Hong, Methodist College, Malone Road, Belfast (Bronze medal winner)
The team were accompanied by two mentors – Dr Cormac Quigley (GMIT and a former Chemistry Olympian) and Asst Professor Mercedes Vazquez (School of Chemical Sciences, DCU).

These students were selected on the basis of two selection rounds in DCU over the last 6 months. Since completing their Leaving Certificate and A-levels, the team have been participating in a full time training schedule in DCU tackling specific topics in Chemistry with expert staff. During the training programme, the students worked very well as a team, supporting and challenging each other in their preparation for the competition in Thailand. This is a very important aspect of the training, as the team members rely on each other's support when at the competition. Carrying out laboratory work efficiently and accurately in temperatures of 35°C and a humidity of about 80 % with no air conditioning is not an easy task! Nevertheless, the team showed excellent concentration and commitment on the day, not stopping until their 5 hour practical exam was completed, even though they were encouraged to take a break for drinks and snacks in order to avoid cases of dehydration and exhaustion.
Ireland has participated in the International Chemistry Olympiad since 1997 (with the exception of 2016) and up to now has achieved 17 Bronze Olympic medals and 2 Silver Olympic medals as well as 8 highly commended awards. Now that number of Bronze Medals increases to 20. Not since 1999 have Ireland achieved such a number of awards in the one year. This indeed is a remarkable achievement for the students, their teachers, mentors and lecturers.

DCU co-ordinate Ireland's involvement in three Science Olympiads, namely International Junior Science Olympiad (IJSO), European Union Science Olympiad (EUSO) and International Chemistry Olympiad (IChO), through CASTeL. For further information on the Olympiads, see:
http://castel.ie/olympiads/irish-chemistry-olympiad/
or contact Professor Odilla Finlayson, Olympiad Co-ordinator at the School of Chemical Sciences, DCU.

Many thanks to the staff from the School of Chemical Sciences who have assisted in preparing the team, namely: Professors James Walsh, Anthony Reilly, Emma Coyle, Mercedes Vazquez, Pat O'Malley, Apryll Stalcup, Vickie McKee and Odilla Finlayson and the technical support provided by Aisling McCarthy and John McLoughlin. Many thanks to all the Schools in Ireland who participated in the National IrChO competition and to their corresponding Chemistry teachers for preparing their students so well that they can successfully compete at such high international level. Also, we gratefully acknowledge financial support from the Department of Education and Skills (North-South Co-operation Section) and the RSC.

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ARTIST - Action Research To Innovate Science Teaching

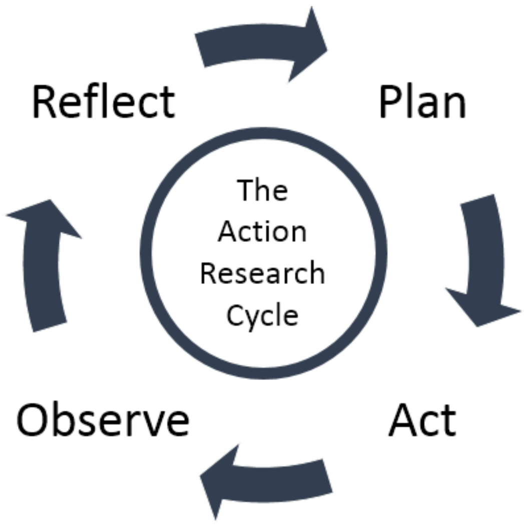
Sarah Hayes, Peter Childs and Aimee Stapleton

http://www.erasmus-artist.eu/index.html

The international ARTIST team at their recent project meeting in Vienna, Austria (Sept. 2017).

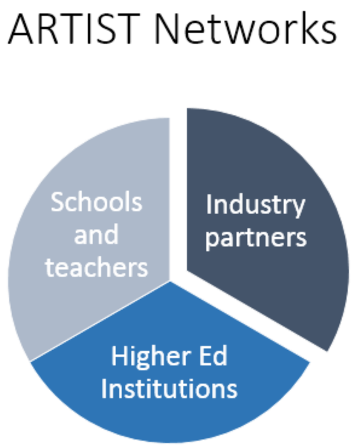
The University of Limerick (UL) has embarked on a new Action Research project called ARTIST – Action Research to Innovate Science Teaching. The project is funded by Erasmus+ and will run from 2016-2019. The aim of ARTIST is to innovate science education through Action Research. The project is truly international with ten partners from seven different countries including Ireland, Germany, Austria, Turkey, Israel, Georgia and the Philippines. Sarah Hayes, Peter Childs and Aimee Stapleton are co-ordinating the Irish ARTIST project in UL.

Many of *Chemistry in Action!* readers will be familiar with the idea of Action Research – or perhaps are seasoned practitioners of Action Research. Action Research is a cyclical process: each cycle involves innovation, research, reflection and improvement. In ARTIST, the type of Action Research will be teacher-centred. Teachers will create, implement, research, reflect on and improve their classroom innovations with the support of science education researchers. ARTIST considers Action Research to be of the most promising strategies for innovating science education and creating evidence-based classroom practices.



We believe that participation in ARTIST will contribute positively to the continuous professional development of both teachers and teacher-educators. Teachers and teacher-educators in those countries where Action Research is a relatively new idea will benefit from the experience of those in countries were Action Research is established already. By sharing the philosophy and methods of Action Research, we intend to create the foundation for solid research-based innovations in science classrooms. In 2018 workshops will be held in the Philippines, Georgia and Israel, with two HEIs involved in each country.

While there are many programmes that use Action Research methods, a unique feature of ARTIST is that it will involve industry partners. Each Higher-Education Institute (HEI) in ARTIST will create a regional network, which consists of the HEI, schools and industrial partners. We hope that innovative, authentic activities for science classrooms will emerge from the dialogue between teachers, teacher-educators and industry representatives.



Many companies are concerned about their employment pipeline. Having a steady stream of candidates for employment with the correct skillset and knowledge base is essential to a growing business. Too often, companies say that their new-hires are missing key skills, perhaps team-working abilities or specific technical expertise. ARTIST may offer a solution to this problem. With businesses and schools discussing the needs together, it may be possible to create authentic classroom activities that develop skillsets that students will need in their future places of work.

We also hope that students will benefit from ARTIST in terms of their awareness and perception of STEM careers. The authentic classroom activities should equip students with a better understanding of their career options and the employment opportunities in STEM areas.

Based in the Synthesis and Solid State Pharmaceutical centre (SSPC), the ARTIST team in UL are helping to build the regional networks. SSPC is a pharmaceutical research centre that works with 24 industry partners. The team has experience combining research and industry with education and outreach activities. In the past, the team has worked with *Limerick for Engineering*, *BT Young Scientist and Technology Exhibition* and *Smart Futures*. The team in UL will deliver training to the less experienced institutions in ARTIST so that they can build and maintain their own regional networks. Dr Sarah Hayes is the UL coordinator for ARTIST. (Sarah.hayes@ul.ie)

ARTIST will develop new courses and teaching materials about how to do Action Research and how to establish and maintain networks of schools, HEIs and industry partners. It will create useful resources such as training materials, teaching guides, slide shows and handouts. Finally, it will develop an Action Research Guide to help secondary and tertiary science teachers to plan, conduct and evaluate their research. A journal called *Action Research in Innovation in Science Education* (ARISE) will feature case studies that illustrate aspects of inquiry-based learning, teaching and learning in science and career orientation in science education. ARISE is scheduled for publication starting in 2018.

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Chemists you should know: #2

Niels Bohr – into atomic orbits

(7/Oct/1885 – 18/Nov/1962)

Adrian J. Ryder
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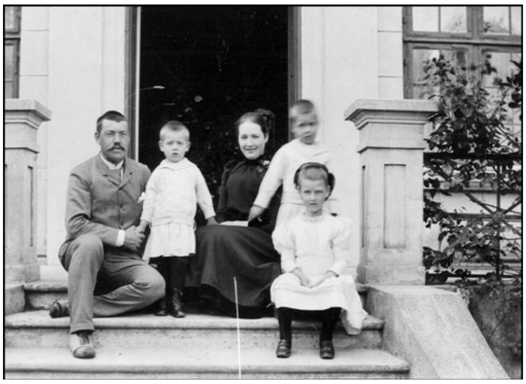
Introduction

Born in Copenhagen, Denmark, on October the 7th 1885, Niels Bohr was the second of three children of professor of Physiology Christian Harald Lauritz Peter Emil Bohr (14/Feb/1855-3/Feb/1911) and his wife Ellen Adler (7/Oct/1860-30/Nov/1930), who named him Niels Henrik David. His mother was one of six children from a wealthy Jewish family, who were prominent in banking and parliamentary circles.



The Bohr family in front of their home in Bredegade, Copenhagen in 1890

His siblings were Jennifer, (9th March 1883 – 5th May 1933), who became a teacher, and Harald August (22nd April 1887-22nd Jan 1951), a mathematician who played football for Denmark at the 1908 summer Olympics in London, gaining a silver medal. Niels also liked football and played in goal for the local Akademisk Boldklub, with his younger brother Harald playing in defence.

Bohr as a young man

Education

Niels entered Copenhagen University in 1903, majoring in physics and taking astronomy, mathematics and philosophy as minor subjects. In 1905, a prize for the best thesis on the surface tension of water jets was offered by the Royal Danish Academy of Sciences and Letters. Niels decided to enter and following an exhaustive series of experiments in his father's laboratory at the university, which involved making the necessary glassware himself, he presented his thesis in 1906 and was awarded a gold medal in 1907. His thesis was published in the British journal *Philosophical Transactions* in 1908. This paper was the first of over a hundred written by Niels during his life.

The two sides of the 1907 gold medal

Although two years younger than Niels, his brother Harald was to remain very close to Niels throughout his life with, no doubt, a certain amount of rivalry between them. Harald was to gain his Master's degree in April 1909 and Niels his, nine months later. Again Harald was to beat his more famous brother to the punch in gaining his Doctorate in 1910, while Niels defended his thesis on the 13th of May 1911.
Gaining a scholarship from the Carlsberg Foundation, Niels now left for England to do post-doctoral research under J.J. Thomson in Cambridge and in Ernest Rutherford's laboratory in Manchester. He returned home the following year as a lecturer in Copenhagen University, becoming an associate Professor in 1914 and Professor of Theoretical Physics in 1916.

His work on atomic structure

Every student of chemistry has met with Niels Bohr's theory of the atom. He had been working on for the best part of ten years and he formulated it in 1913. In order to explain the spectrum of the hydrogen atom Bohr suggested that electrons in an atom could only travel in certain orbits and only a limited set of stable orbits were available to any atom. Also the outer orbits in an atom could hold more electrons than inner ones and these would determine the atom's characteristics. When electrons jumped from an outer orbit to an inner one, they would emit light radiation. It is often described as planetary model as the picture of the atom is like that of the solar system.

This was a revolutionary idea and was not readily accepted by the scientific community. The model explained the number and energy of the libes in the hydrogen spectrum exactly, but broke down for heavier atoms. However, Niels continued to develop his theory and was awarded the Nobel Prize in 1922 for *"his investigations of the structure of atoms and the radiation emanating from them"*.

Personal life

Niels married Margrethe Nørlund (7th March 1890 – 21st Dec. 1984), a teacher of French he had met in 1910, in a civil ceremony at the town hall in Slagelse on August 1st 1912. Margrethe being Jewish, Niels resigned from his membership in the Church of Denmark earlier in the year in order to marry her. The pair postponed their honeymoon for a week in order for Niels to finish a paper on his atomic theory for publication. Some six years later his brother Harald also left the Church to get married.

Neils and Margrethe Bohr

The death of Niels in 1962 brought the marriage to an end, with the couple having had six children, all boys, in the intervening years.

The children were Christian, (25th Nov.1916 - 2nd July 1934) who drowned while on a family sailing trip when a sudden storm blew up, Hans Henrik, (7th April 1918 – 12th July 2010) who became a physician, Erik, (23rd June 1920 – 1st April 1990) who became a chemical engineer, Aage Niels, (19th June 1922 – 9th Sept 2009) who became a successful physicist and was awarded the Nobel Prize in Physics in 1975, Ernest David, (7th march 1924 – 27th June 2012) who became a lawyer, (Ernest played field hockey for Denmark at the 1948 Summer Olympics in London), and Harald, (12th Mar 1928 – 1938, aged 9) who died from childhood meningitis.

Margrethe not only looked after the needs of the family but was to be more of a personal assistant to Niels, taking dictation, typing up his material and editing the various drafts of his scientific work for publication. She died in her 95th year in 1984 and her ashes were buried with him in the Assistens Kierkegaard cemetery in Copenhagen.

His academic career

The working conditions at the University of Copenhagen were poor with a lack of proper classrooms and laboratories, so in April 1917 Niels proposed the foundation of an institute of Theoretical Physics. Gaining the support of the Danish government and the Carlsberg Foundation and with contributions from industry and private donors, many of whom were Jewish, legislation to establish the Institute was passed in November 1918 and its doors were opened on the 3rd of March 1921, with Niels as its Director. The Institute was later named after him. Niels and his family had an apartment on the first floor. The Institute was to be a focal point for international researchers into quantum mechanics through the twenties and thirties until disrupted by the events of World War 2.

Niels Bohr Institute in Copenhagen

With the coming to power of Hitler in 1933, Jews in Germany came under severe pressure, with businesses being taken over and professional people being removed from their posts. Denmark, with its high Jewish population set up the Danish Committee for the support of Refugee Intellectual Workers, with Niels and Harald sitting on the executive board from its creation. Their aim was to get Jewish physicists out of Germany to spend some time at the Institute before obtaining permanent positions abroad, especially in the United States.

German forces invaded and took over Denmark in April 1940 but allowed the King, Parliament and Universities to continue to operate. Niels continued his work in Denmark until Germany declared martial law on the 29th of August 1943 following the non-cooperation of the Government. Invited by James Chadwick to come to work in England, Niels initially declined but warned that a purge of Jews and others sympathetic to them was about to take place, he left Denmark by boat on 29th September 1943, with the help of the Danish Resistance, for Sweden together with his family. The invitation to go to England was repeated and Niels and his son Aage were taken by military airplanes to Scotland and from there initially to London and then to America as part of the British mission on the construction of the Atomic bomb, the Manhattan Project.

Following the defeat of Germany and the dropping of the atomic bombs on Japan, Bohr was permitted to return home on the 25th of August 1945, where he was given a hero's welcome and resumed his work in the Institute where he predicted the existence of a new zirconium–like element, which was later found and named Hafnium after the old name for Copenhagen. He was re-elected President of the Royal Danish Academy of Arts and Sciences on the 25th of August 1947, a position he first assumed in 1938 and retained it until his death. King Frederik IX conferred on him the Order of the Elephant on the 21st of September 1947, an award usually given to Royalty and Heads of State. He took a deep interest in the development of atomic power for peaceful use, being central in the post-war research facility at Risø, a few miles outside Copenhagen, in the establishment of CERN near Geneva and in the Nordic Institute for Atomic Physics, close to his Institute where he became its first Chairman in 1957. He was awarded the first U.S. Atoms for Peace Award in1957.

Niels Bohr died following a stroke on November 18th 1962, was cremated and his ashes inserted into the family plot. Apart from the many medals and other honours conferred on him during his life, other various honours were subsequently made to his name. The element Bohrium, atomic number 107 in the Periodic Table, was named after him. Asteroid 3948 Bohr and the Lunar crater Bohr (12.8° N 86.4° W 71Km wide) were also named after him. The Institute which he had set up was renamed the Niels Bohr Institute in his honour in 1965.

References

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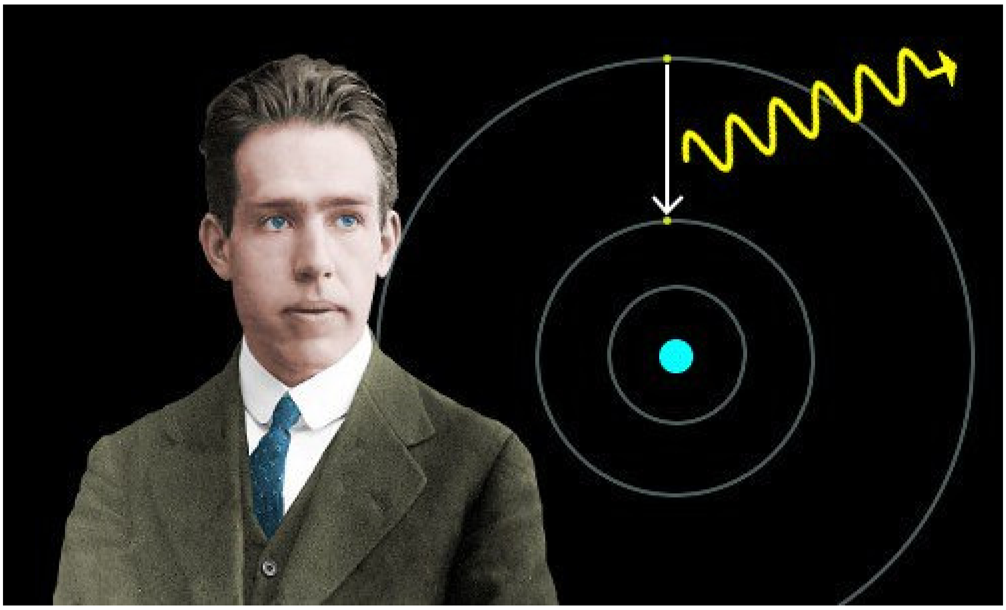
A bohring limerick

There was a young Dane named Niels Bohr
In whose theory we once set great store
But it turned out to be wrong
And so it didn't last long
So why teach it in school anymore?
P.E. Childs

Classic Chemical Quotations: 8

Niels Bohr (1885-1962)

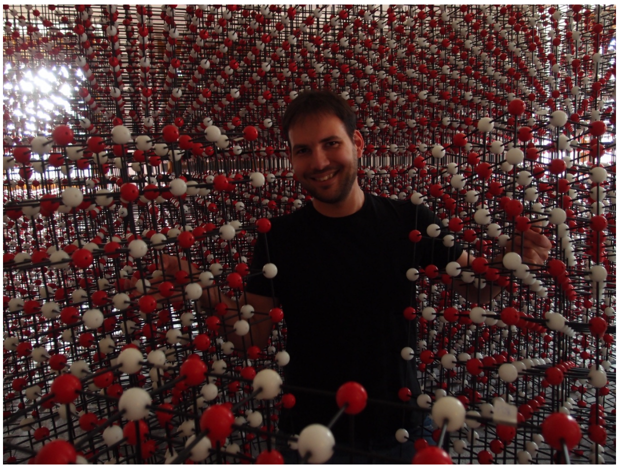


"If quantum mechanics hasn't profoundly shocked you, you haven't understood it yet."

Niels Bohr

The world's largest crystal model

Robert Krickl
mail@r-krickl.com



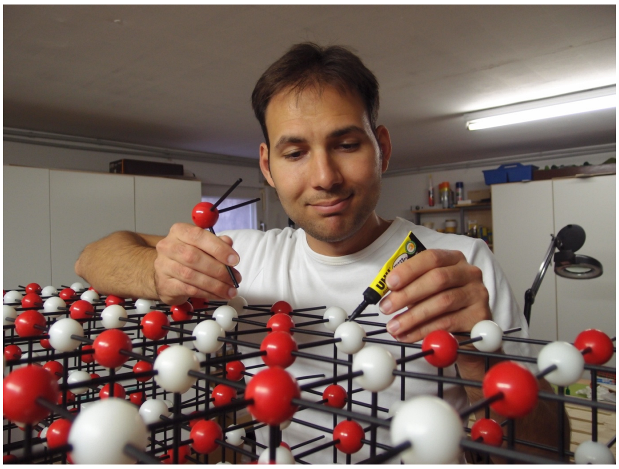
Robert Krickl surrounded by his model of NaCl

Why build such a large model?

The author is an academic crystallographer who has dedicated his life to research and especially to science communication. To explain the concept of a crystal and visualize the atomic arrangement of atoms in such a solid (not only just a unit cell, but multiplied in 3D by translational symmetry) – the very special project of building the largest crystal structure model in the world was undertaken. Furthermore, it was a tribute to some great achievements in the past, as in 2015, there were a lot of anniversaries of important milestones in science history (especially connected to crystallography): 150 years ago, Wilhelm Conrad Roentgen began his academic studies which culminated in his discovery of X-rays, which happened exactly 120 years ago; 100 years ago, Max von Laue was awarded the Nobel Prize (for the year 1914) for discovering the diffraction of X-rays by crystals – proving that the latter exhibit a periodic arrangement of atoms. This is exactly what is visualized in the model. Also 100 years ago, the father and son team, William Henry Bragg and William Lawrence Bragg, were awarded the Nobel Prize for 1915 for the first crystal structure determinations via X-ray diffraction. This had a major impact on science and our understanding of the world. One of the very first structures solved was that of NaCl – the one shown in the model.

How big and how many?

The model is a cube with edge length over 3.1 m, consisting of 38,880 balls of red and white colour, representing the sodium and chloride ions, and, when put side by side, over 10.5 km of connecting sticks. It visualizes the periodic arrangement of atoms in face-centred cubic crystals of the NaCl-structure-type, exhibited by many materials, essential to our daily lives.



Robert making the model

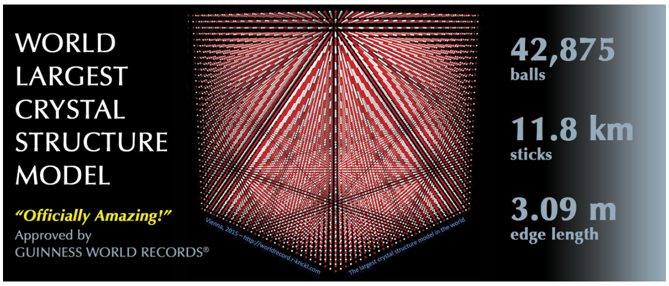
How was it constructed?

The balls were specially produced for this project in order to fit the very high requirements of statics, durability and precision (bond angles and lengths have to be very, very accurate – otherwise you soon get a problem when stacking dozens of balls). The construction took over a year and over 400 tubes of super glue! The assembling was performed in public space, in the courtyard of the City Hall of Vienna (Austria). For several months, a lot of school classes, kindergarten groups and the general public from over 50 countries visited the model, receiving lectures on crystals and science history. The model also served as a place to celebrate the above-mentioned anniversaries of science history. The author was moved to tears when receiving a message from the descendants of W.H. and W.L. Bragg, who had heard about the tribute via a BBC coverage on the model. These sentences are taken from a letter they sent, to be read out loud to the public and scientific community at the official record-setting festivity:

"Congratulations on your great achievement. My sister and I, the two daughters of William Lawrence Bragg, have been thrilled by your tribute to our father. He himself would have loved the whole idea. He was such a visual person. You could not have found a more original and satisfying way to celebrate his scientific legacy. (…)"
They also took up a unique chance offered in the course of the project: Everyone can eternalize oneself, one's beloveds or their company in the model by sponsoring balls, which will henceforth be dedicated to someone with an individualized wording. All dedications are visible on the project home page and at the site the model is displayed. There are certificates and several other benefits – which were even already used as very special presents for weddings, birthdays and other occasions.

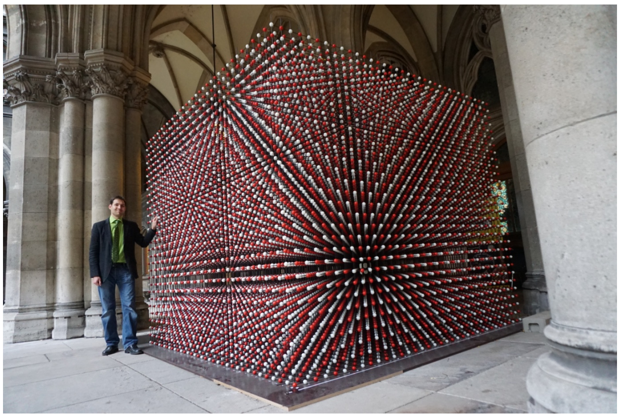
Awards and recognition

A special Austrian postage stamp was issued on the world record model in 2015. It was launched at the site of the model on different special envelopes with special stamps (you can find all the information here http://worldrecord.r-krickl.com/en/stamp), mostly on the occasion on the mentioned anniversaries of science history.



The record was rigorously reviewed by the Guinness World Records and independently by Rekord Institut für Deutschland – which both officially accepted and confirmed the world record. It is officially the largest crystal structure model in the world, i.e. the largest section of the atomic arrangement in this kind of solid that was ever modelled in 3D.

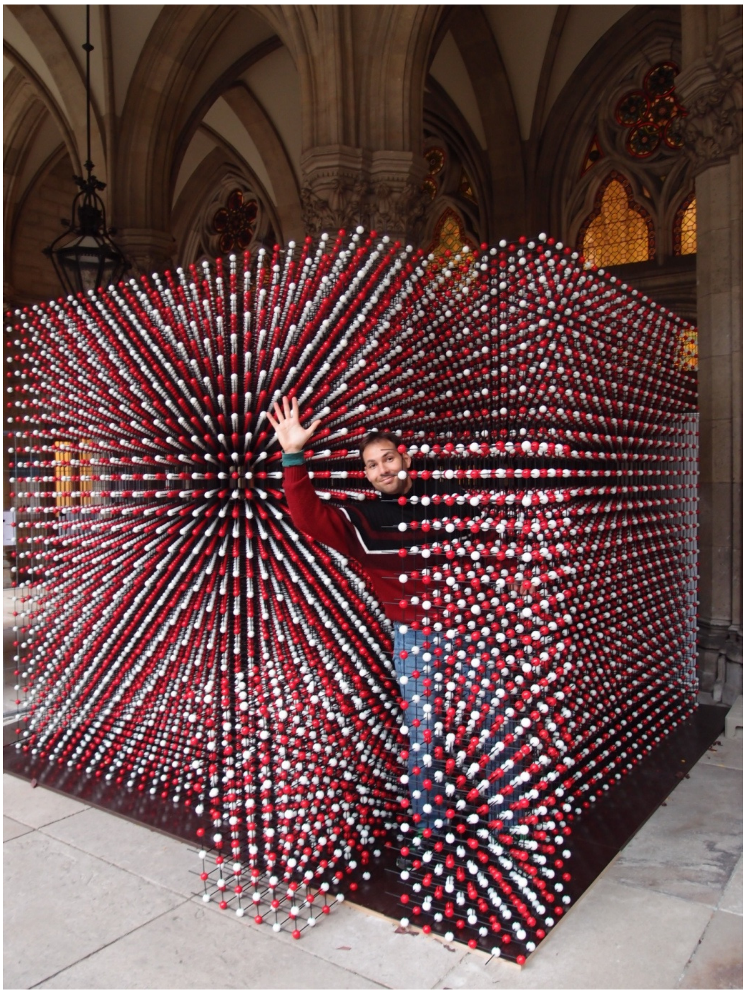
The Austrian postage stamp featuring the model



This picture shows the size of the model

Future plans

The record has been set, but the project goes on. The model was built for educational purposes, i.e. to communicate science and visualize the nanocosm. Parts of it were already displayed at different fairs and exhibitions in Austria. At the very moment when writing this article, a big part of the model is aboard a ship in the Atlantic Ocean, on its way to India. At Hyderabad, it will be an exhibitional highlight of the General Assembly of the International Union of Crystallography.



Getting into chemistry has a whole new meaning

Everyone who wants to exhibit the model, is gladly welcome to get in touch. At last, you can experience the building of crystal structures yourself: with the huge experience collected in the course of the construction, we have developed a special kit, which can be used at schools and universities, to easily build a lot of different crystal structures – also huge ones. It is filling an existing gap in teaching aids for inorganic chemistry. It is a unique aid and can be used to teach and communicate physics, chemistry and crystallography. You can find all the information on the projects homepage (see below).

With the model and the new kits, the author hopes to contribute to the communication of science and the beauty of nature at all scales.

You can find pictures and all information at: http://worldrecord.r-krickl.com https://www.facebook.com/worldrecordcrystalmodel

Biography

Robert Krickl (1981-) is a mineralogist and crystallographer with emphasis on interdisciplinary topics connected to other geo-, bio- and material- as well as historical sciences. Besides scientific research, he dedicated his life to the communication of science to general public of all ages. After finishing his PhD in 2009, he does project-based research and is self employed, devoting himself to outreach, i.e. journalism, giving lectures, organising exhibitions, roadshows, school and kindergarden activities. He is known and recognized for his new and innovative ways of communicating science to everyone (inter alia winner of the British Council's FameLab competition) and has a wide national and international network (inter alia board member of the Austrian Mineralogical Society and National Focal Point of the Earth Science Matters Foundation).

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Teaching science in the USA

Emma Ryan
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How does getting a teaching position in the USA differ from Ireland?

The motivation to work abroad came after I had been teaching science for 7 years in Kilkenny. The numerous constraints of teaching in Ireland drove me to search for something else, something different, just something! I had the preconception that teaching in the US would be more challenging and offer more freedom in terms of curriculum content and teaching methodology, with a focus not just on final exams but on skill set and innovation. I spent 6 months researching and applying to numerous private and charter schools in New York. Why these schools? Because they offer visa sponsorship, and public schools do not. The challenge of finding a school before I moved over was a priority for me and definitely took perseverance. I applied to many teaching positions, had Skype interviews and finally settled on a Charter school in Brooklyn. The difference in how teachers are hired in the US was striking, even for foreign hires. The interview process was more detailed when compared to Ireland. In total, I had 3 Skype interviews and one in-person interview. Prior to flying out to New York, I had to design a lesson plan and when there, teach a class. The lesson was assessed and then I had a final interview. It was rigorous and based on merit. They embraced inquiry teaching and I was hired. This was unfortunately short-lived, as I quickly learned that one of the challenges of the US teaching system is the high turnover of staff in Charter schools. As I started teaching in this Charter school I realised there was a strict vision on how they wanted their teachers to teach. After only 3 months I decided to leave due to this misalignment of teaching methodologies and values. Things move fast in New York though. Within a week I had been through the process again with a private school, Dwight College, was hired and have been here for 2 years now.

The Dwight Private School

The science curriculum in the USA

The Charter school I taught in used a curriculum called 'Investigating and Questioning our World through Science and Technology - IQWST'. These are standards that set the expectations for what students should know and be able to do. The lessons were intriguing, fun and content-driven and allowed for inquiry and investigations. I was asked to remodel these predesigned science lessons and accompanying worksheets into a lesson that fitted their strict classroom management, countdowns and silence rules. Naturally, in a science lab, this is extremely difficult and in the end, did not work. I looked for another school that wouldhave vision and a teaching methodology that matched my own.

I found it in a private International Baccalaureate (IB) school in Manhattan. I started teaching middle school, 6th and 8th grade science and instantly found my feet. The curriculum was similar in content to that of Ireland but the method of delivery was very different. The IB Middle Years Program (MYP) encourages students to develop self-knowledge and skills that they need to enjoy a lifetime of learning. This is achieved through four science criteria that emphasise: content knowledge, investigations - designing and carrying out, analysing and evaluating, and reflecting on the impacts of science globally. There is both formative and summative assessment throughout the year that emphasise skills as much as content. More interestingly, students are given a choice.

View from the science teacher's bench

Throughout all their projects, presentations and investigations, students get to choose the number of variables or problem to research, and the method of presenting their findings. Students also engage in interdisciplinary units with one or two other subjects, which bring more meaning and purpose to a concept or issue being studied. Also there is no final state written exam in Middle school for science, which allows for flexibility and spontaneity, should we decide we want to spend time focusing on current science events that may arise. Time, flexibility and no end exam makes a big difference in the day-to-day running of a science class. Even with all of these positives, there is always room for improvement. I am currently working on our science MS curriculum as it had not been changed in the past 20 years. The curriculum change would be towards a spiral system, with each grade having a biology, chemistry, physics and earth science unit, which incorporates inquiry and investigations. Although we have complete autonomy over what topics we think our students should be learning and how it's presented, as I experienced, sometimes change doesn't happen for various reasons. Asking for change can make all the difference.

Emma Ryan (right) helping a student at Dwight College

Teaching methodology

I have always been comfortable teaching through inquiry. Do less! Encourage the students to do more! I dislike ruining the surprise of discovery, so it was always the way I liked to learn and hence, like to teach. In Ireland I taught Junior Certificate science in an inquiry-based teaching method, when and where possible. But, due to the time constraints and quantity of content to cover for the Junior Certificate exam, I didn't get to do this as often as I wanted. This only intensified for my senior classes who wanted to use every minute in class to study only what appeared in the curriculum and finally, on the exam. Parallel to this was my transition year classes, who engaged in only inquiry lessons. I designed numerous biology and chemistry units based on the 5E Model, that was embraced by the students. Transitioning from didactic teaching and passive learning to inquiry-based learning is something that is difficult to do, because the end result for the Leaving Certificate science exams is a 100% written test. In my experience the style of teaching may not be fully embraced because of how uncomfortable it makes some teachers and the pressures to complete the curriculum may not allow for such freedom.

In the USA, my experience teaching middle school science has varied. In the Charter school, I battled between my own inquiry method and their strict regime of countdowns, formal sitting, and hand symbols to communicate. There seemed to be more of an emphasis on keeping the students silent. And the silence became deafening. Each teacher was expected to teach the same way and you were reprimanded if you did not. You had to also video your classes and submit them for assessment to ensure you were following protocol.

The one comparison I have witnessed between Irish and American students is in the attitude and willingness of students to learn. The fixed path of secondary school education in Ireland, in my experience, tends to squash any excitement or exploration they may have and the students lose their willingness to question and wonder. However, the Irish education system does seem to ensure most students have a solid and in-depth understanding of the science content and they are assessed fairly and equally.

In my Private school, I can set and amend the curriculum and have ownership over how it is taught. I facilitate and guide the students through their discovery of a scientific problem using the IB MYP framework. I am helped by the willingness of the students, who constantly ask questions and inquire, and I am supported by the management who trust that I can guide the curriculum and students. Inquiry also calls for evaluation and although the students take summative assessments they also have to self and peer assess their own and each other's quizzes, lab reports and projects throughout the trimester. More importantly, they get assessed on skills and in particular, their lab investigations.

How does teaching a science class differ between Ireland and the USA?

In both the USA schools I have taught in, a science class lasts 45 minutes long, similar to Ireland. There are no double classes, which is in my experience, a hindrance to cohesive learning and affects the flow of the class, particularly when doing experiments. But the students adapt and learn to manage their time. In the Charter school, the timetable did not allow any time to move from their assigned 'home classroom', where they spent all of their classes except science. As a result, by the time they got to walk silently to my room, line up silently outside and filter into class and repeat for leaving, the 45 minutes teaching time became a minimal 20 minutes! Sometimes they could not complete this task and so did not have science that day at all. The students had notebooks and took down notes from the board, and worked on handouts - the photocopying was non-stop. In the Private school the schedule does allow for movement, there are no home rooms and students must migrate from class to class, sometimes crossing over the street to the other campus. These little freedoms and trust is something that was lacking in the Charter school. There are also no bells to signal the end of class so classroom management is important. Each student here has their own laptop and they are expected to submit assignments online via Google classroom, respond to my emails to them and email me if there are any issues. I email students if there are behavioural problems or achievements and ccopy their parents or the principal of the school. It is time consuming to do this but the paper trail is very useful especially if end of trimester grades are low. In science, I try to limit the useof laptops in class as the technology,although very useful, can be a distraction.

A typical science class in the Private school would begin with routines, similar to Ireland, while checking the investigations board for groups and announcements. At the beginning of class, the aim of the class is concise and written on the main board, and if we are at the start of a new unit, students will begin by creating large brainstorm sheets with previous knowledge, misconceptions, keywords and questions. From this point, we discuss a question or problem associated with the unit, using their brainstorms and linking their thoughts and keywords to appropriate scientific terms. We research the questions or problem to gain some background information and then investigate it.

This is different to Ireland where the topic and content itself was just studied and expected to be learned. We would study phototropism and then demonstrate this with an experiment. The human kidney was learned through a series of diagrams, definitions and tests. In the Private school in the USA, the topic is unfolded and we move towards a question to investigate - one for which they do not know the instant outcome until they actually experiment. For example, we were studying potential and kinetic energy and the question arose - 'how will the angle of launch affect the kinetic energy of a rubber band?' From here, the students had to build their own 'rubber band cannon' and through trial and error, formulate an hypothesis. It would take 1 -2 classes to discuss and research the question, 1 - 2 classes to set up, trial and error and finally they could begin their investigation. The investigation could last 3 - 5 days depending and sometimes, things went wrong or they discovered their hypothesis was not testable, and would have to revert back to the drawing board and start again. Or if their data or graphs looked incorrect or off, they would have to retrial until it was accurate. I set deadlines but am flexible if they need more time, and this varies from year to year depending on the students. For these students, they would come during a study hall or after school to complete it and it was no big deal. For homework, they would have to work on their lab report and finally, present their findings to each other in class. Projects tend to investigate global science issues, with students having a choice on how they present it. I have had students write lyrics, animate a cartoon sketch, advertisement video or design a poster board. We have the flexibility to incorporate current world issues like for example, the USA pulling out of the Paris Climate Agreement and the impacts this would have on the environment, or the discovery of new exo-planets. Some 6th grade students asked if they could dissect an eye when they were studying cells. In Ireland, because our school was near an abattoir, I was a big fan of dissection and always incorporated it where I could and that always sparked their interest! Here, I do the same, except I order from Amazon. Even though it was their first time using a scalpel and dissecting, they rose to the challenge and elaborated naturally on the cells unit. Having the flexibility to work this way makes teaching science more meaningful. In Ireland sometimes I felt like I was rushing the students to get to a certain end point, and it takes the enjoyment and discovery out of learning.

In the Charter school, there were regular visits by the principal to my class and they would video me teaching or take notes. Similarly in the Private school, I am assessed by the head of the school, my middle school principal, and vice-principal. They would be regularly present in my class but I would have two formal visits that would be assessed based on planning and preparation, classroom environment, instruction and professional responsibilities. I am also assessed once a year by the students who complete an online survey. These assessments help determine how well you are doing but also can generate the grounds for dismissal should they need to do so. I find this to be the greatest difference between Ireland and the USA. In Ireland, my science department was assessed once in my 7 years of teaching and I wasn't even chosen to be examined that year either. Although some see it as a burden or intrusion, I think it should be normal that teachers are assessed on how well they are doing. Maybe then A or B posts within schools could be allocated to teachers based on merit and not on how long they have been in the school.

Although there are many differences between teaching in the USA and Ireland, each has its positives and negatives. From my experience of Charter schools, and for my personal teaching style, I would choose not to teach there again. The Private school is what I envisioned when I thought about teaching in the USA. In my 2 years here, I have progressed from a science teacher to head of middle school science. I had forgotten what it feels like to be valued and respected professionally. I understand with curriculum freedom comes responsibility to ensure my students gain an understanding and in-depth knowledge in science. But in my opinion, passion and excitement for science is equally important.The world needs science now, more than ever.

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Irish Laboratory Awards 2017 Success

Professor Gavin Walker and the Process Engineering Lab team at the Bernal Institute, UL received three top honours, including the prestigious Academic or Research Lab of the year at the recent Irish Laboratory Awards 2017 ceremony in Dublin. This event recognises and celebrates the successes and achievements of Ireland's internationally renowned scientists in areas such as innovation, leadership, and collaboration. The Process Engineering Lab was honoured in the Chemical Laboratory and Pharmaceutical Laboratory categories, and most notably as the Academic or Research Laboratory for 2017. In awarding these honours, the jury mentioned the lab as being 'unrivaled', a reflection and recognition of the positive impact of the research activities undertaken by Professor Gavin Walker and his team at the Bernal Institute.

The Bernal Process Engineering Laboratory, uniquely hosts three international leading research centres based in the University of Limerick: the Science Foundation Ireland funded Synthesis and Solid State Pharmaceutical Centre (SSPC); the industry and Enterprise Ireland (EI) funded Dairy Processing Technology Centre (DPTC); and, the EI and IDA funded Pharmaceutical Manufacturing Technology Centre (PMTC).

The group is led by Professor Gavin Walker, Bernal Chair of Process Engineering and supported by several young research active staff including, Dr Denise Croker, Dr Emmet O'Reilly, Dr Luis Padrela, Dr David Egan, Dr Darren Whitaker and Dr Ahmad Albadarin.

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Opinion:
Science Integration as a Precursor to Effective STEM education

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Introduction

How could a biologist teach food science without connecting this learning the chemical compositions of biomolecules and role of enzymes? Could a chemist teach the abstract concepts associated with atomic theory and sub-atomic electrons more effectively, by grounding it in a concrete biological example, such as the photosynthesis of green plants? Should a physicist teach heat without considering changes of state and solubility, given the strong conceptual connections between energy and its applications to the water we drink and the air we breathe? How can planetary motion and origin be devoid of discussion about astrobiology and exobiology? What about movement, speed, heart rate and the role of chemical processes in the release of energy required for metabolism. Think, carbon nanotubes in electronics, gene therapy merging biology and engineering technologies and how inorganic chemistry explores the chemistry of substances not associated with living things, but significantly affects living things abiotically. Finally, the fuzzy positionality between theoretical chemistry and its connection to quantum mechanics highlights the unavoidable and intrinsic connections, which exist between the sciences. Then, why do many teachers still teach science separately as physics, chemistry or biology *topics* prior to Leaving Certificate (LC), where understandably the requirement for a more thorough understanding of each sub-discipline demands more specificity in teaching approach at LC level? This article presents and incorporates the musings and lived professional experiences of a *teacher* turned *teacher-educator*, who is passionate about *education* primarily, with a particular interest in *science education*, and an undergraduate degree in science education (Specialism-*Biology*-yes I know there are far too many of us!). Perhaps all these labelled categorisations we embody are in the process of transgressing into a communal morphing of all things 'science, maths, engineering and technology', called *STEM education,* where we all become *STEM educators*?

I have two foci for this short article. Firstly, I will present a perspective on some aspects of the recent Irish STEM Report (STEMERG, 2016) with a view to problematising some of the proposed actions, with an alternative conception. Secondly, I propose that many of the challenges raised in the report could be addressed by authentically positioning science as science, rather than science as a trichotomous entity, at primary and lower secondary levels. Indeed, as STEM becomes the hybrid STEAM, (with many more iterations potentially lining up to gain traction on the fast moving bandwagon that is STEM), could we, as science educators, be in a polychotomous position, struggling to hold on to the remnants of an identity as a biologist, chemist, physicist, let alone scientist?

Who are you?

For you science practitioners reading '*Chemistry in Action!*' how do you identify yourself? Are you a scientist, chemist, biologist, physicist, science educator, STEM practitioner or STE(A)M educator? Have we stopped to interrogate what it is and what it means to be part of STEM education? Where do we fit into this integrated discipline and how is this integration operationalised in an education system that structures curriculum as discipline specific, from infants in primary school to second level and indeed, on into third level. Is STEM a discipline in itself, an integrated cohesive paradigm, a visionary curriculum or a collection of disciplines, with conceptual commonalities? STEM is messy and when I speak to other science teachers about what they perceive STEM to be, they provide a personal (albeit situated) perspective, which often belies their positionality and comfort/discomfort with the acronym. Yet, despite this relatively sudden phenomenon arriving on our shores, we find ourselves in the grip of STEM fever. We have (in no particular order): STEM fairs, initiatives, critical perspectives, CPD, resources, programmes, projects, research calls, publications and since 2016, the emergence of a key STEM policy document, framing a vision for STEM education in Ireland, for the future. While I have no significant issue with the movement towards STEM given the strong rationale for its inception, (though perhaps overly focused on economic growth), I do feel we should proceed with caution.

Science Education in Ireland

There is a complexity to STEM which has received a groundswell of support, but with perhaps a dearth of debate at the coalface of education, in our schools and among our teachers. The STEM report (STEMERG, 2016) is a welcome document as it highlights significant issues across and within the disciplines that comprise STEM. However, it presents actions, which shift from specific disciplines (e.g. science education), to sub-disciplines within science (e.g. physics/chemistry/biology teacher education), to integrated STEM-based actions. I am not sure it clarifies STEM sufficiently for those of us already struggling with the concept. There are proposed actions in the STEM report worthy of comment before I present an integrated vision for science teaching up to Junior Cycle level (NCCA, 2016a).

I see an argument for *Science* as a LC subject. Could a significant re-structuring of initial teacher education (ITE) enable preparation of teachers to teach integrated science at LC? Would this go some way to addressing some issues raised in in the STEM report (STEMERG, 2016)? Such issues relate to SMK and confidence deficits among science teachers at primary level and at Junior Cycle level, due to them having studied some sciences and not others at LC. In addition, fewer teachers have a specialisation in ITE in physics and chemistry, when compared with biology. Perhaps the sort of specialisms we currently have at LC may be better suited for study at third level? Would it be a radical idea to offer science as a single integrated subject at LC, free from the gender stereotypes and assumptions which intersect with girls' uptake of physics, because it wouldn't be split into sub-disciplines so early? Science as a LC subject could certainly provide a great grounding in physics, chemistry, biology, and Earth science and would demand fair treatment of the inherent concepts, given the high stakes nature of the LC. Once science educators have truly considered the opportunity the Junior Cycle Science Specification (NCCA, 2016a) affords teachers to teach science in a more integrated way, only then can we begin to consider the valuable complexities that STEM integration can offer.

We have a situation emerging (in light of some of the STEM proposed actions) where the positioning of physics, chemistry and biology could become a hierarchy, one in competition with the other, rather than conjugated as parts of a whole, as an integrated discipline called 'Science'. I would also like to challenge the salient sub-discipline hierarchies that undoubtedly persist within science, as an integrated discipline. It is timely that we consider 'science' as inherently linking physics, chemistry, biology, with the current proposals for primary education suggesting a move away from subjects to ameliorate the curriculum overload there, by introducing an enhanced thematic teaching approach, potentially up to 5th class (NCCA, 2016b) This could mean science is formally introduced to children much later than at present, with a potential situation whereby teaching science-specific concepts happens for the first time in late primary school.

Observations and Comments in relation to some *STEM actions*

Term of Reference 1: Preparation of teachers (at primary and post-primary level) for STEM education in Ireland

Proposed Actions:

Students of ITE (primary) programmes should undergo an audit of subject-matter knowledge (SMK) in STEM subjects (mathematics and science) over the course of their programme. Self or peer-evaluation may be helpful in this regard. Supports should be provided to ensure that students address deficits in their knowledge, e.g. mathematics-learning support.

This action is informed by widely acknowledged and available research (see STEMERG, 2016), which highlights the low percentages of students entering ITE courses who have studied physics or chemistry for the LC, with a high percentage of students having studied biology. This is a reflection of the numbers taking these subjects at LC level, where four times as many students take biology as take chemistry and physics. Poor scientific matter knowledge (SMK), leading to a lack of confidence in teaching those subjects, has been linked to an avoidance of teaching curriculum areas (in some cases) with which the teacher is less familiar. Firstly, while this is a valid issue, the SMK audit may not ensure more effective science teaching and it would be important to keep a strong connection between SMK and pedagogical content knowledge (PCK) in addressing any identified deficit.

Additionally, in terms of addressing an SMK deficit in science and maths, such deficits are likely to exist across a multitude of the 13 subject areas a generalist primary teacher is required to teach, and the ITE programmes at primary level are very heavy in terms of contact hours, when compared with other undergraduate programmes. Therefore, the provision of 'learning support' hours is a significant challenge. While the SMK issue is a significant concern, the inference that deficits in knowledge and skills all need to be addressed by the end of ITE, evidenced by success in final examinations, is unrealistic. This is not in keeping with a continuum of learning *in* practice and could lead to further confidence issues for pre-service primary teachers. This is because pre-service teachers could become overwhelmed with an unmanageable volume of learning across so many disciplines. We need to develop a CPD trajectory with effective induction and probation which *Droichead* (Teaching Council, 2016a) aims to achieve effective in-service CPD which the *Cosán*, National Framework for Teachers Learning, (Teaching Council, 2016b) may go some way to prioritising. Is it realistic for ITE to address all aspects of teacher formation, development and quality?

**Offer incentives (e.g. targeted bonus points per STEM subject up to a maximum of two subjects, for example) to Senior Cycle students seeking to enter concurrent STEM Teacher Education degree programmes (for post-primary) generally but especially in mathematics, physics, chemistry and engineering*.*

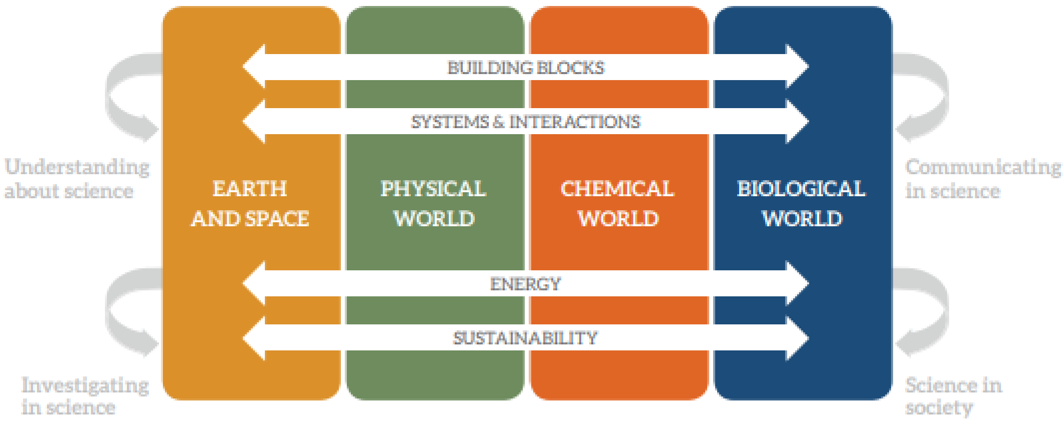
This is not entirely clear to me, what does *especially* mean here? If this proposed action precludes biology from the bonus point arrangement, I feel this would be a retrograde step. This would present a strong example of the hierarchies that subtly play out regularly in the sciences. It could send a strong message to students that physics and chemistry are more valuable than biology, as sub-disciplines of science. This could diminish biology as a subset of *real* STEM disciplines. It could transpire that, rather than increased uptake of physics and chemistry, this action (if not inclusive of biology) might, inadvertently reduce applicants for STEM teacher education. This is worthy of greater discussion among science teachers.

**Include a formal consideration of STEM education during mentoring of student teachers during their primary school placement*.*

At primary level, science is a non-core subject, located under the auspices of SESE (science, history, geography). While this appears a worthy action to pursue, in practical terms I am unsure *who* would provide such a formal and specific consideration and indeed what such a consideration might entail. This is quite vague and given the breadth of the curriculum, the action may be difficult to implement in practice. As science is taught for one hour per week (less in infant classes) at primary level, qualified primary science teacher educators are scarce, when compared to language, literacy and mathematics lecturing staff. The chance of having such a mentor during school placement is small.

Science Integration at Junior Cycle

The STEM report poses many interesting suggestions alongside some practical and logistical dilemmas. I am wondering whether sustained CPD for in-service teachers about the importance of an *integrated* science experience *for primary pupils and Junior Cycle students*, might be a productive way of addressing the cited imbalances and emphases in physics, chemistry and biology teaching at Junior Cycle. Could science teachers move further beyond the discrete teaching of biology, chemistry and physics topics, by making explicit links across the sciences, by teaching more thematically, by regularly engaging with cross-cutting concepts to provide students (and teachers) a more holistic understanding of 'science'? The existence of elements, which traverse the contextual strands in the new science specification, are of crucial importance, as is the Nature of Science strand. This is because these components of the science specification scaffold and encourage teachers to take a more integrated, thematic approach to science teaching (see Figure 1.)



Elements

Building blocks	Focuses on the essential scientific ideas that underpin each strand.
Systems and interactions	Examines how a collection of living and/or non-living things and processes interact to perform some function/s: there is a focus on the input, outputs, and relationships among system components.
Energy	A unifying concept that students can develop across the strands: it is an obvious integrating element as all phenomena we observe on earth and in space involve the transformation and variation of energy.
Sustainability	Focuses on the concept of meeting the needs of the present without compromising the ability of future generations to meet their needs.

Figure 1-Basis Structure of the Junior Cycle Science Specification- Elements

Learning Outcomes in Science Specification for Junior Cycle

It is an interesting exercise to take a look at some of the learning outcomes in the specification and to consider whether they lie *under* the biological, chemical, physical or Earth and space contextual strands, notwithstanding the important role the Nature of Science strand plays in actualising the teaching of these outcomes.

Where would you position the following learning outcomes? ***Student will be able to***:

- *Investigate the effect of a number of variables on the rate of chemical reactions including the production of common gases and biochemical reactions*
- *Explain energy conservation and analyse processes in terms of energy changes and dissipation*
- *Consider chemical reactions in terms of energy, using the terms exothermic, endothermic and activation energy, and use simple energy profile diagrams to illustrate energy changes.*
- *Describe respiration and photosynthesis as both chemical and biological processes; investigate factors that affect respiration and photosynthesis*
- *Explain how matter and energy flow through ecosystems.*
- *Research different energy sources; formulate and communicate an informed view of ways that current and future energy needs on Earth can be met.*

If we examine these learning outcomes, which all relate to the element 'energy', it becomes apparent how concepts across the science specification contextual strands connect, overlap and intersect. I wonder whether it would be possible to teach any of these learning outcomes **without** referring to numerous physics, biology and/or chemistry core concepts and taking time to explore and investigate them. Therefore, I suggest that taking up the challenge of the *elements* and considering a thematic or integrated set of outcomes that cut across and through the science sub-disciplines, could enhance science teaching and develop competence and confidence in teachers across physics, chemistry, biology and the new strand, 'Earth and space'. The Junior Cycle for Teachers' (JCT) science team are providing great elective and core CPD opportunities for teachers to begin discussing a more integrated approach to Junior Cycle science teaching (see www.jct.ie). It is important for teachers to continue these conversations and to develop resources and shared ideas for a new and innovative approach to the science specification elements.

Conclusion and Considerations

The STEM report (STEMERG, 2016) mentions a need for upskilling science teachers to have high competence in all three sciences. Do you feel this is necessary? Should such upskilling (if necessary) be formally accredited learning or informal CPD, with ownership maintained among science departments in schools and structured via collaboration and cooperation? There is no better place to become more proficient (in my opinion) than in the classroom, trialling innovations and experimenting with pedagogies. Perhaps we could begin with enhanced collaboration within the science department and fostering a school culture of peer support. In doing this, we may begin to address concerns about teaching quality, student uptake of science and student experience of science. How might this collaboration be structured and supported? Do you think it is more useful to address issues related to science integration across physics, chemistry and biology, before immersion in the concept/discipline of STEM integration? This is especially important until changes to our education system at senior cycle and greater dialogue with regard to the meaning of STEM in practice are discussed and clarified. There is much to consider and contemplate as we continue on a trajectory of rapid curricular and educational re-structuring. In the meantime, it is crucially important for teachers to generate discussion and dialogue and to keep abreast of the shifting landscape in science and STEM education.

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Biography:

Dr Miriam Hamilton has taught post-primary science at Junior Cycle and Biology at Senior Cycle for many years (1988-2013) in a number of schools and more recently has worked in teacher CPD with three different support services. With the National Induction Programme for Teachers (NIPT), Miriam worked as a facilitator of teacher induction workshops, in the Professional Development Support Service (PDST) as a science advisor and with the Junior Cycle for Teachers support services (JCT) as team leader for the Junior Cycle science national CPD programme development. Miriam commenced a science lecturing position with pre-service primary teachers in Mary Immaculate College, in August 2015. Research interests include: science pedagogy, equality in education and teacher professional development.

Comments wanted:

If you have views on this topic please send them in to the Editor at peter.childs@ul.ie.

How does it work?

The chemistry of the brown ring test for nitrate ions

Testing for nitrate ions is on the LC Chemistry syllabus. However, schools cannot now buy sodium or potassium nitrate without a licence, as they are restricted substances. The test requires a soluble nitrate of a cation which does not form a precipitate with sulphate ion or react in any way during the test or have a colour that would confuse the test. This is why the test was usually done with either sodium or potassium nitrate solution. What to do if they aren't available? You could use dilute nitric acid as the source of nitrate ion you could neutralise sodium or potassium hydroxide with nitric acid to pH 7 (it's a strong acid-strong base reaction); or you could use zinc nitrate solution. The question fo what to use set me thinking about the chemistry of the test.

The brown ring test for nitrate ion

Acidified 0.1 M iron(II) sulphate solution is added to a soluble nitrate in a test-tube (1 cm depth of each will do). Conc. sulphuric acid (CAUTION!) is added by running it down the side of the test-tube until it forms a layer of equal depth at the bottom of the ttest-tube. (Conc. sulphuric acid is very dense and will form a layer at the bottom.) When nitrate ion is present a brown ring will develop at the interface between the two layers, due to formation of a coloured iron(II) complex, $[Fe(H^2O)_5NO]SO_4$.

CAUTION! Wear gloves when handling conc. sulphuric and be careful to avoid drips. Use a plastic dropper to dispense it. At the end of the reaction tip the contents of the test-tube into a sink or basin full of water to dilute the sulphuric acid. Do not pour water into the mixture. Wear eye protection at all times.

The chemistry involved:

$$2HNO_3 + 3H_2SO_4 + 6FeSO_4 \rightarrow 3Fe_2(SO_4)_3 + 2NO + 4H_2O$$

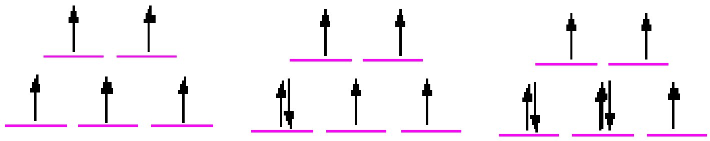
$$[Fe(H_2O)_6]SO_4 + NO \rightarrow$$

$$[Fe(H_2O)_5(NO)]SO_4 + H_2O$$

First the nitrate ion (O.S. +5) is reduced to nitric oxide (O.S. +2), and iron(II) is oxidised to iron(III). The NO ligand then complexes with the iron(II) aquo complex and this gives the brown colour.

There are various answers as what form the 'NO' species is in the complex and what the oxidation state of iron is. The overall charge on the complex ion, $[Fe(H_2O)_5(NO)]^{2+}$, is +2. However, there are three possibilities:
Fe^{3+}/NO^-; Fe^{2+}/NO; Fe^+/NO^+ - each gives an overall charge of +2.
(NO^- is the nitrosonium ligand; NO is the nitroso ligand; NO^+ is the nitronium ligand.)

How could we tell which one it is? The problem of determining the O.S. of iron in complexes is quite common, particularly in biological systems. The answer lies in its magnetic properties. Fe has an outer electronic configuration of $3d^64s^2$. When the Fe^{2+} ion is formed the configuration is $3d^6$ and the 6 d electrons are distributed among the 5 d orbitals, which are split by the octahedral ligand field in the complex ion. The d electronic distributions for Fe^{3+}, Fe^{2+} and Fe^+ ions are shown below.



	Fe^{3+}, d^5	Fe^{2+}, d^6	Fe^{+}, d^7
n	5	4	3
μ/B.M.	5.9	4.9	3.9

Each O.S. Has a different number of unpaired electrons (n) and thus a different magnetic moment μ (a measure of its magnetism), measured in Bohr Magnetons (B.M.) The experimental magnetic moment for the iron-nitroso complex is 3.9 B.M., which indicates that it has 3 unpaired electrons. Thus it contains Fe^+ and NO^+: the NO ligand has reduced the iron(II) to iron(I) and has itself been oxidised to NO^+.

(This is not on the LC Chemistry syllabus but you might want to revise your transition metal chemistry and ligand field/crystal field theory.)

Normally the colour of transition metal complexes is quite weak and is due to transition of electrons between the d levels, which is forbidden by quantum mechanics. In the $[Fe(H_2O)_5(NO)]^{2+}$ ion the colour is stronger as it involves a charge transfer between iron and NO, which is not forbidden. The brown ring is quite sensitive due to the strength of this colour: it is sensitive to 2.5 micrograms nitrate and a concentration of 1 in 25000 parts. The main problem with the test is that it does not distinguish between nitrite, NO_2^-, and nitrate, NO_3^-, ions.

Other tests for nitrate ion

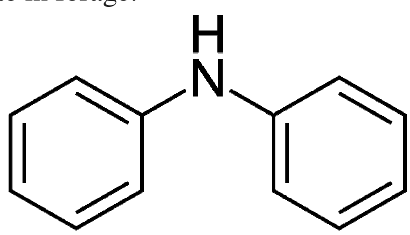
The brown ring test is not the only test for nitrate ions, although it is the one required by the syllabus. It would be good chemistry and good pedagogy if teachers and students were allowed to use other, alternative tests in the laboratory and in the examination. Here are some of the other tests for nitrate ion.

1. Devarda's alloy test:
Devarda's alloy is an alloy of aluminium, copper and zinc. In an alkaline solution this acts as a reducing agent and will reduce nitrate ion to ammonia. The ammonia can be detected by smell or by turning red litmus paper blue if nitrate ion is present.

$3NO_3^- + 8Al + 5OH^- + 18H_2O \rightarrow 3NH_3 + 8[Al(OH)_4]^-$

2. Diphenylamine test:
A solution of diphenylamine in 90% sufuric acid is used for this test. (Carefully dilute conc. sulphuric acid (80 cm^3) to 100 cm^3 with water (CAUTION) and then dissolve 0.5 g diphenylamine in the solution. It is now in the form of diphenylamine sulfonic acid.) In the presence of nitrate ions, diphenylamine is oxidised, giving a blue colour as a positive test. Two diphenylamine molecules first couple together to give diphenylbenzidine, which is oxidised reversibly by nitrate, to give a blue form, a diquinonediimine.

This reagent is also used as a test for DNA and nitrocellulose. Diphenylamine is also used as a redox indicator in redox titrations, with a colour change from colourless to red/violet. It is used in the Agricultural Science course as a qualitative test for nitrate in forage.



Diphenylamine

3. Copper turnings test:
If a nitrate is heated with copper turnings and conc. sulfuric acid (CAUTION!), the sulphuric acid converts the nitrate to nitric acid, which then reacts with copper turnings to produce the distinctive, brown NO_2 gas.

$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

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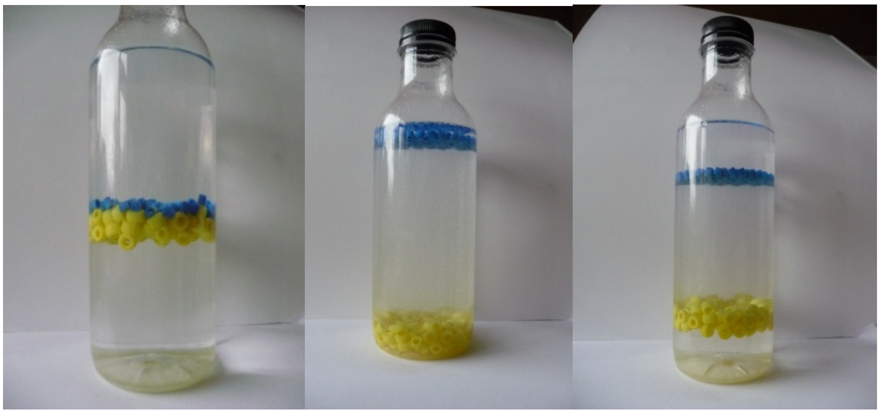
Ideas for the temification of your science lessons

The amazing polydensity bottle

Engagement: the mystery

You may have seen this demonstration on the web or at a conference. See the YouTube video:(https://www.youtube.com/watch?v=_75qjv MRVcc) A bottle has two layers of clear liquid. Two different coloured plastic beads sit at the interface. When it is shaken the two layers disappear, the coloured beads migrate to opposite ends of the bottle and then come together as the interface forms. You can repeat this as often as you like. How does it work?



Before shaking **After shaking** **Part-way back**

Explore

We have two clear liquids which don't mix but on shaking they mix for a time and then separate again. This is our first mystery. The formation of the two layers is in itself a mystery. Start with an empty 1 L clear plastic bottle. Pour 400 cm3 of propan-2-ol (isopropanol, rubbing alcohol) and 400 cm3 distilled/deionized water and shake with the cap on. The two liquids mix and dissolve in each other to give a single layer. Propan-2-ol is strongly polar due to –OH group and is completely miscible in water like methanol and ethanol. Now add 100 g of salt (sodium chloride) to the bottle and shake until dissolved. (Solubility of NaCl in water at 25^{o}C is 360 g per L) As the salt dissolves the liquid separates into two layers with the salt solution at the bottom as it is denser. When you shake this mixture, the two layers mix for a time and then separate out. Why does salt make the alcohol layer separate out?

To make the density bottle you need two sorts of plastic beads, of two different colours. Is there anything different between the beads besides colour? How could you measure their density? Add 100 of each the two sorts of beads to the bottle and close it. The beads will sort themselves out and sit near the interface one colour at the bottom of the top layer and the other at the top of the bottom layer. When the bottle is shaken, the layers mix, the beads separate and move to the top and the bottom, and then slowly move back to the centre as the interface reforms.

(Two sorts of beads are needed: one sort is known as pony beads, used for making necklaces, and they come in various colours. They are made from acrylic plastic and I got them from beadbubble.com at €1.56 a packet of 100 plus postage. The second sort of bead is the Hama (also known as Perler) beads, bought in sets from toy shops, and used to make designs. When heated these beads fuse together. A set with 6,000 beads costs €14.49 from Smyths. They are made of polyethene so they can be fused by a hot iron.)

The mystery is about density and to solve it you need to know the densities of the liquids and the beads. Your students should already have learnt how to measure the density of liquids and solids, so get them to measure the density of the two layers in the bottle and of the two sorts of beads and tabulate their results.

Explain

Get your students to think about why salt in the water causes the alcohol layer to separate out. Is it about density differences? Get them to think about polarity and solubility. The ionic salt dissolves in water and the two sorts of ions are bonded to water molecules. There is a competition for water molecules between the ions and the polar propan-2-ol molecules. The result is that the alcohol molecules are rejected from the salt solution and form a separate layer. The alcohol has a lower solubility in a solution of high ionic concentration (ionic strength). The alcohol layer will contain some water in solution. (This sort of behaviour is used in making soap, where the soap is salted out of solution by adding salt.)

We now have two layers of different density. The less dense alcohol layer floats on the denser water layer. The two beads also have different density. The pony beads are denser than the fusible beads. When the bottle is shaken, the two layers mix to form an emulsion (small droplets of one in the other), rather than true solution, and on standing it separates out into two layers again. The density of the emulsion is between that of the two layers: it is denser than the fusible beads (so they float to the top) and less dense than the pony beads (so they sink to the bottom.)

Elaborate

How could this be developed further? One could investigate the relation between the salt concentration and the separation into layers. How could you use the different densities of salt solutions to determine the density of a plastic bead? They could link it the salting out effect used in soap manufacture. Salting out is also used to separate out proteins from an aqueous solution.

Evaluate

Monitor the students' ability to observe and record accurately what is happening. Evaluate their ability to design and carry out experiments to measure density using previous knowledge. Assess how well they can use the measured densities of the liquids and the beads to explain what is happening in the bottle.

What you need:

1 L clear plastic bottle
400 cm^3 propan-2-ol (isopropyl alcohol)
400 cm^3 distilled/deionised water
100 g sodium chloride (salt)
100 each of acrylic Pony beads and fusible Hama beads in two different colours

How the mystery bead bottle works

http://scifun.chem.wisc.edu/HomeExpts/bead-bottle.htm

The mystery bead bottle contains two liquids, a concentrated solution of salt (sodium chloride) in water and isopropyl alcohol. The two liquids do not mix. Although isopropyl alcohol will mix completely with pure water, the salt dissolved in the water prevents the alcohol from mixing.

The salt solution is denser than the isopropyl alcohol. The density of the salt solution is 1.13 grams per cubic centimetre, 1.13 g/cm3. The density of the alcohol in the bottle is about 0.88 g/cm3. (This is greater than the density of pure isopropyl alcohol, because there is some water dissolved in the alcohol.) Therefore, the salt solution sinks to the bottom, and the isopropyl alcohol floats on top.

There are two different kinds of beads in the bottle. The larger pony beads have a density of 1.02 g/cm3. The smaller Perler beads have a density of 0.90 g/cm3. Both kinds of bead are less dense than the salt solution, so they float on the salt solution. They are both denser than the isopropyl alcohol, so they sink to the bottom of the alcohol. They rest were the two liquids meet, in the middle of the bottle.

When the bottle is shaken, the salt water and isopropyl alcohol are mixed together and form a temporary emulsion (tiny drops of each liquid mixed together). The density of the emulsion is the average of the densities of the two liquids, namely (1.13 + 0.88)/2 or 1.00 g/cm3. The density of the emulsion is less than the density of the pony beads, so the pony beads sink to the bottom in the emulsion. The density of the emulsion is greater than the density of the Perler beads, so the Perler beads float to the top of the emulsion. As the bottle rests, the emulsion separates into its two components. The salt water separates at the bottom and the alcohol at the top. The pony beads float to the top of the salt water, but stay below the emulsion. The Perler beads sink to the bottom of the alcohol, but remain above the emulsion. As the emulsion separates, the beads come together again at the middle of the bottle.

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Ideas for the temification of your science lessons

The mystery of the disappearing precipitate

Prior knowledge

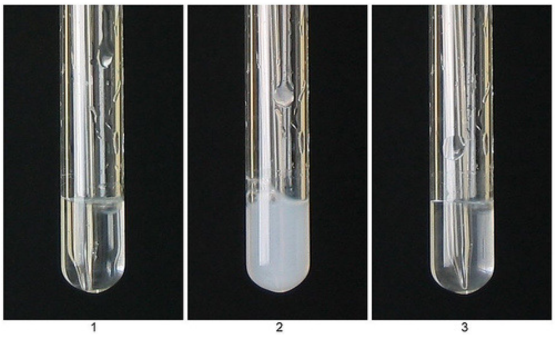
This assumes that students have done the test for CO_2 using lime-water. This TEMI activity would be a useful introduction to hard and soft water and temporary hardness in the LC Chemistry course.

Materials:

Per pair of students:
30 cm^3 lime water, boiling tube and straw.
Sparkling (Carbonated) water (50 cm^3)
Bunsen burner
Lime-water is a mild alkali and eye protection should be worn when using it. This activity should be supervised.
Time: Single period.
Location: Can be done in a laboratory or a classroom.

Engage:

One student blows into a boiling tube one-third full of lime water (saturated calcium hydroxide solution) (1) and after a while a cloudy precipitate forms (2). This is familiar as a test for carbon dioxide, although often the chemistry isn't understood. This shows that exhaled air contains CO_2.The student is then asked to continue blowing into the boiling tube. After a good while the cloudiness disappears and the solution is clear again. (3)
https://www.youtube.com/watch?v=DNtbKZR4_1U



https://sites.google.com/site/internationalgcsechemistry/year-10-topics/tests-for-ions-and-gases/4---test-for-common-gases

Explore:

Get students to discuss why the precipitate forms and then why it disappears again. What is happening here? Why does the precipitrate redissolve when more CO_2 is added?
How could they remove CO_2 to see the reaction reverse? (Try heating the solution carefully over a Bunsen burner). Describe and explain what happens.
What is the effect of blowing in CO_2 on the pH of the solution? (Will it get more basic or more acidic? Use a pH meter if available to monitor this.)
What would you expect to see if a drop of the solution was allowed to evaporate on a watch glass? (A white solid should be left.)
Could you set up an experiment to produce stalactites and stalagmites?
Would effect you expect a dilute acid to have on the solution – on its pH and clarity?
Explain what happens when an acid like dilute HCl or H_2SO_4 is added. Explain why gas bubbles are formed.
The experiment can be repeated using carbonated water and lime-water. Why does it go cloudy when carbonated water is added? (Fizzy drinks contain disslved CO_2 under presure). Adding more carbonated water makes the precipitate disappear. Using carbonated water the experiment can be done more quickly. Why is carbonated water more acidic than tap water?

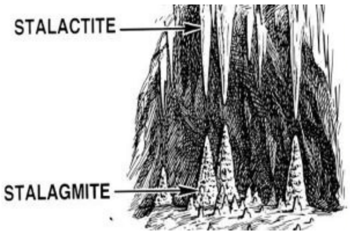
Explain:

Give a short scientific explanation of the mystery.
Lime-water is saturated calcium hydroxide solution, which is basic with a high pH and contains calcium ions. When the student blows into the solution (or carbonated water is used) CO_2 is added, which dissolves to give a weak acid (carbonic acid). This reacts with the base to give insoluble calcium carbonate (the white

precipitate). The precipitate will get thicker until all the calcium ions are used up.
$CO_2(aq) + Ca(OH)_2(aq) \leftrightarrow CaCO_3(s) + H_2O$
When more CO_2 is added to the solution it combines with the insoluble $CaCO_3$ to form soluble calcium hydrogencarbonate, $CaHCO_3$.
$CaCO_3(s) + H_2O + CO_2(aq) \leftrightarrow Ca(HCO_3)_2(aq)$
As the reaction proceeds the pH drops as the strong base (OH-) is converted into weaker bases.
Heating drives off $CO_2(g)$ and reverses the equilibrium so that calcium carbonate reforms. Further heating would drive off more CO_2 and reform calcium hydroxide. Allowing the solution to evaporate also removes the dissolved CO_2 and calcium hydroxide is left.

Extend:

This investigation can be linked to the formation and removal of temporary hardness in water; the effect of rain water on limestone and the formation of stalactites and stalagmites. Students should be able to explain how rain water containing dissolved CO_2 can dissolve limestone rock to produce temporary hard water. When this evaporates it leaves calcium carbonate behind.



https://www.pmfias.com/karst-landforms-cavern-arch-sink-hole-karst-window-bogas-stalactite-stalagmite/

Evaluation:

This activity tests observational skills and an understanding of solubility/precipitation and acid/base chemistry.

Students should:

- be able to explain the chemistry involved, why the reaction can be reversed and how it can be linked to the effect of rain water (saturated with CO_2) on limestone to produce temporary hardness.
- be able to explain the chemistry behind their observations and understand that the reactions are equilibrium reactions and can be reversed.
- be able to describe how this activity relates to the formation of temporary hard water and the formation of caves and stalactites and stalagmites in limestone areas.

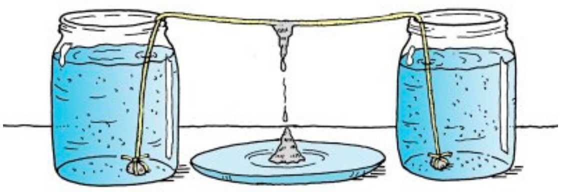
Limestone will also dissolve in acids like sulfuric or hydrochloric acids. Why are these reactions not reversible? What salts are produced when these are evaporated to dryness? This explains the formation of permanent hardness i.e. hardness which is notr removed by boiling.

The activity also develops observation; problem solving; presentation; practical skills.

The basic chemistry behind this experiment is covered in the section in textbooks on hard and soft water and the environmental chemistry of CO_2. However, this is an interesting way to introduce the environmental chemistry of CO2 in water using the mystery of the disappearing precipitate.

Modelling stalactite/stalagmite formation

Set up two jam jars or beakers containing calcium hydrogencarbonate solution (from above). Weight a string down at both ends as shown and allow it to droop between the two beakers. Solution will be carried up the string and drip from the centre.



http://lifestyle.howstuffworks.com/crafts/seasonal/spring/nature-activities-for-kids1.htm

The published experiment above uses saturated magnesium sulfate (Epsom salts).

□

Zippie Chemistry

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This lesson is directed towards enhancing student understanding of what it means to be a chemist for 15-16 year olds. It is conducted in the laboratory and has the following learning outcomes:

- Displaying the dexterous capacity to carry out a laboratory investigation;
- Working in a group;
- Recording results;
- Presenting results;
- Interpreting their own and results of others to develop a hypothesis.

It is a slightly adapted version of an experiment from the research literature by Selco et al. (2012) that bridges cognitive and affective dimensions of learning. This is because the experiments conducted by students automatically prompt their interest and curiosity to formulate a hypothesis and test it using inexpensive household materials. Therefore, a , 'hands-on' and 'minds-on' activity may become 'hearts-on'.

Students are free to select from available combinations of chemicals, mix and match them in zip lock bags and observe the results in an 80-minute lesson. The household chemicals involved in all reactions are available in supermarkets. The chemistry involved includes acid-base, energy changes and iodimetric detection of starch. A summary of possible student observations is illustrated in Figure 1.

Figure 1: Summary of Possible Student Observations

The classroom delivery of this activity offers a simple structure that indicates what inquiry based learning may look like. It can be adapted to lead into other learning activities (e.g. conservation of mass during chemical reactions, heat of reaction) or simplified and deconstructed to offer useful individual chemistry demonstrations involving indicators or gas production.

Materials used: Zip lock bags, Water, Red cabbage, Epsom Salts, Anhydrous calcium chloride, Baking soda, vinegar, corn-starch, iodine.

Note: Ziplok® is a proprietrary brand name for a brand of zip lock bags, which have a plastic zip closure and which are air and water tight. These are easier to use than the bags with a plastic strip closure.

Substances used

Powdered Materials:

A: Baking soda = sodium hydrogencarbonate
B: Washing Soda Crystals = Sodium carbonate
C: Anhydrous Calcium chloride
D: Epsom Salts = Magnesium sulfate heptahydrate
E: Corn starch

These can be placed in plastic containers and accessed using plastic spoons.

Solutions in 500 cm^3 bottles:

1: Vinegar with red cabbage juice
2: Water with red cabbage juice
3: Diluted lemon juice with red cabbage juice
4: Sodium hydrogencarbonate solution (1tsp per 500 cm^3) with red cabbage juice
5: Sodium Carbonate solution (1 tsp per 500 cm^3) with red cabbage juice
6: Diluted Iodine solution with red cabbage juice

Each of the solutions should be dark enough so that the colour is easily noticeable but not dark enough that you cannot see through the bottle. Plenty of vinegar needs to be used in solution 1. Solutions can be poured into plastic cups.

The materials used in this experiment included six powders labeled A to F and six liquids labelled I to

VI. One teaspoon each of two different powders is placed into a sandwich-sized zipper bag and approximately 15 cm^3 of a liquid is poured into a small plastic cup, and the identities of all components are recorded. The cup with the liquid is placed into the zipper bag without mixing it with the powders. All chemicals are accessible at all work stations throughout the room and an instruction sheet is provided to each individual student to facilitate data recording. This sheet could be modified to further challenge more senior students if deemed appropriate. Each group of students performed eight different tests with randomly chosen sets of chemicals and recorded their observations into a table of results. During this time, students should have been noticing (potential) patterns of results develop and making inferences as to what powders or liquids are most likely to cause a certain type of chemical change. This forms the basis for their hypothesis. Possible perceptions include: evolution of gas, colour change, (noticeable) temperature change, (noticeable) texture change. This activity is approximately 20 minutes in duration.

After performing 8 tests, the data from each group is shared with the entire class by a presentation.
The table used in the worksheet can be projected onto a whiteboard to assist student groups in their presentations. This approach serves to illustrate a large amount of class data relatively quickly. The presentation element of the work affords students who are not inclined to speak publicly or not inclined to speak about science, an opportunity to gain confidence from showing their observations to their peers. Following the presentations, students are then required to pause and collaborate with their partners to examine the data with the goal of generating a testable question. The idea is restricted to an investigation focusing on a single variable (e.g. using powders A and B, but using each available liquid, we will observe....)

In conclusion, advantages to using easily-available household chemicals include: availability, cost-effectiveness, safety while conducting the experiment and with disposal of materials afterwards, the possibility of conducting the experiment in a classroom if a lab is unavailable as the ziploc bags can remain sealed.

Advantages of linking household chemicals to an inquiry approach include: ownership of the work and full participation by students in the activity, excitement about chemistry leading to a wish to experiment more in order to identify patterns and test hypotheses, and a sense of what feels like be a "real" chemist.

Figure 2: The apparatus and chemicals needed

References/Sources:

Bernholt, S. and Parchmann, I. 2011. Assessing the complexity of students' knowledge in chemistry. *Chemical Education Research and Practice*, (12), 167–173.

NCCA 2012. Senior Cycle Science. Report on the Consultation. Retrieved Online: http://www.ncca.ie/en/Consultations/Senior_Cycle_Science/Senior_cycle_science_consultation.html.

Selco, J.I., Bruno, M. and Chan, 2012. Students Doing Chemistry: A Hands-On Experience. *Journal of Chemical Education*, 89 (6), pp.206-210.

□

Zippie Chemistry Worksheet

Safety:

Heat Changes, Safety goggles, lab-coat, disposable gloves

Equipment:

Measuring Cylinder, disposable gloves, Ziploc bags, Plastic cups, Safety Goggles

Instructions:

- Work in groups of two or three.
- Measure 15 cm^3 of a liquid with a measuring cylinder and place it in a plastic cup.
- Place the cup upright in an open Ziploc bag.
- Place a spoon measure of two powders of your choice beside the plastic cup in the Ziploc bag. Do not allow any mixing.
- Squeeze all air out of the bag and zip it closed.
- Mix the contents of the bag and record your observations.
- Record the number of the liquid and the letters of the two powders you used in the table below.

Observations:

Liquid	Powder	Powder	Observations

Note: Observations may be things such as: colour change, a gas was produced, heat change occurred, texture change occurred.

Be prepared to present your results so keep good records.

Given the results you obtained, develop a question or a testable idea that you have not yet tried out. What will happen if I combine two powders with any liquid e.g. will I always get a cold temperature if I use these two powders and any liquid?

My Question or Testable Idea

____
____
____
____

Conclusion – Describe your findings and indicate if your idea was correct.

____
____
____
____

Complete the reflections below on what you have learned during this class.
What I thought about Chemical Change at the beginning of the lesson:

____
____

What I have learned or think about it now:

____
____

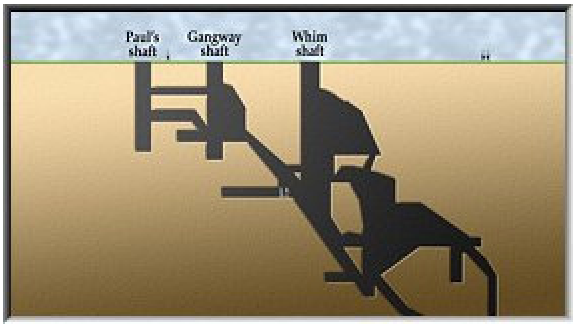
What made me change my mind:

____
____

Places to visit: Glengowla Mines, Co. Galway

info@glengowlamines.ie
www.glengowlamines.ie

Glengowla mines lies just off the road from Oughterard to Clifden and has been open as a show mine since 1999. The Glengowla Mine in Co. Galway was only in business from 1850 to 1865, and was run by the local landlord. While it operated it was an important source of work and income for the local population. The price of lead (used for bullets) dropped at the end of the American Civil War and it was not economic to keep it going. By the time the price of lead rose the mine had flooded and it was too expensive to reopen. Plans for a steam engine to pump out the lower levels of the mine were shelved and the mine remained closed, slowly filling with water.



Underground plan of the mine

The farmers on whose land it was located, Patrick and Keith Geoghegan, decided that this was an opportunity for a tourist attraction. The mine was dewatered, explored and slowly made suitable for visitors to descend safely. This process in ongoing and even deeper levels will become accessible in future. The show mine opened in 1999.

The mine offers guided underground tours with a very knowledgeable local guide, Jon Caine, plus a small museum with the history of the mine, samples of the minerals found there and a collection of old tools found when the mine was cleared out.

Display case in the museum of tools found in the mine

The tour takes you down several levels into the mine, and one can see where the miners worked to extract the ore. The blast holes and their picks are still there and traces of the ore can be seen in the rock walls.

The mine agent's cottage

On the surface you can see the mine agent's cottage and a reconstruction of the Cornish powder house, used for storing explosives, at a safe distance from the mine.

Cornish powder house: the explosives store

The main ore was galena, lead sulphide, with traces of silver, as well as zinc sulphide. In its first two years it produced 4 kilos of silver, a very valuable 'impurity' often associated with lead. A horse whim was used to bring up the ore. Galena is a dark gray, metallic looking mineral, found as intrusions in limestone rock. The ore was taken by horse and cart to Lough Corrib, for shipping to Galway, from where it went to smelters in Swansea, S. Wales. During its short working life the mine produced 390 tonnes of lead containing 28 kg silver.

Rock with lead ore (galena)

The mine is open daily from 10.00 to 18.00, last tours at 17.00.
Entry charges: Adults €10.50 Children €4.50 Students € 9.50 Family €27

In the 19th century and into the 20th century Ireland had many small lead mines, as well as mines for other metals such as copper. Glengowla was only one of many small mines as the section on lead mining in Cole's 1922 monograph shows (see below from Cole, 1922). Ireland is still an important produced and lead and zinc, with Tara Mines near Navan the only mine operating at present. Tara is a massive mine, the largest in Europe, and has many years still to run. Two smaller mines in Co. Tipperary, Galmoy and Lisheen, have closed recently and only operated for 10-15 years. There is still considerable interest in metal prospecting in Ireland and a large deposit near Pallas Green, Co. Tipperary may well be developed in the near future.

THE LEAD MINES NEAR OUGHTERARD

A number of lodes occur here, mined under various names, both in the metamorphic and granitic series and in the Carboniferous rocks. It may be presumed that all the ore bodies are later in date than Carboniferous times. The outputs seem to have been small, and, by the lack of reference in Kane, development took place mostly after 1844. Hely Dutton (Stat. Surv. Galway, p. 30, 1824) mentions an opencast, and the raising of 3 tons of lead ore on Mr. French's land a few miles from Oughterard barrack.
Glengowla (Glengola); 1" 95 (near S. W. corner). 6" Galway 64 SW. This lode is south of the high road to Oughterard from Clifden, in the townland of Glengowla East and in metamorphic rocks. The gangue is calcite and barytes ; blende and fluorspar occur. The mine is described, with a plan and section, in Mem. 95, p. 65 (1870). Min. Stat. give it as worked in 1851 and 1852. Thirty-nine and one-quarter tons of lead from it yielded 140 oz. of silver, or 3' 57 oz. per ton. The Lists of Mines give it as a mine of lead ore and pyrites under Mr. G. F. O'Flahertie (O'Fflahertie) from 1860 to 1865. It was reported on by Mr. H. J. Daly to the Department for the development of Mineral Resources in 1917.
(from Cole, 1922, p. 102-103)

Further reading

Historic mine sites: inventory and risk classification – a report on the risks from the EPA (2009)
https://www.epa.ie/pubs/reports/land/mines/Non-Technical%20Summary.pdf
G. J. A. Cole (1922) *Memoir and Map of Localities of Minerals of Economic Importance and Mefalliferous Mines in Ireland.* Dublin: The Stationery Office
http://www.geologicalmaps.net/IrishHistMapsDownload/B02138.pdf
A video tour of the mine is available from I.A Recordings
http://www.iarecordings.org/features/glengowla.html

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Diary

2017

ChemEd-Ireland
21 October
University of Limerick
Sarah.hayes@ul.ie

ISTA Senior Science Quizzes
Regional Rounds: Thursday 16th November
National Final: Saturday 25th November in Trinity College Dublin.

Science Week Ireland
12-19 November
www.science.ie

2018

ISTA Annual Conference
23-25 March
Athlone I.T.
www.ista.ie

New Perspectives in Science Education
22-23 March
Florence. Italy
https://conference.pixel-online.net/NPSE/

1.

24th Bremen Symposium
"Building bridges across disciplines for transformative education and a sustainable future"
31 May – 2 June
University of Bremen, Germany

ICCE 2018
'Bridging the gap'
10-14 July
Sydney, Australia
www.ICCE2018.org

ChemEd-Ireland 2018
20 October
Department of Chemistry, Trinity College, Dublin

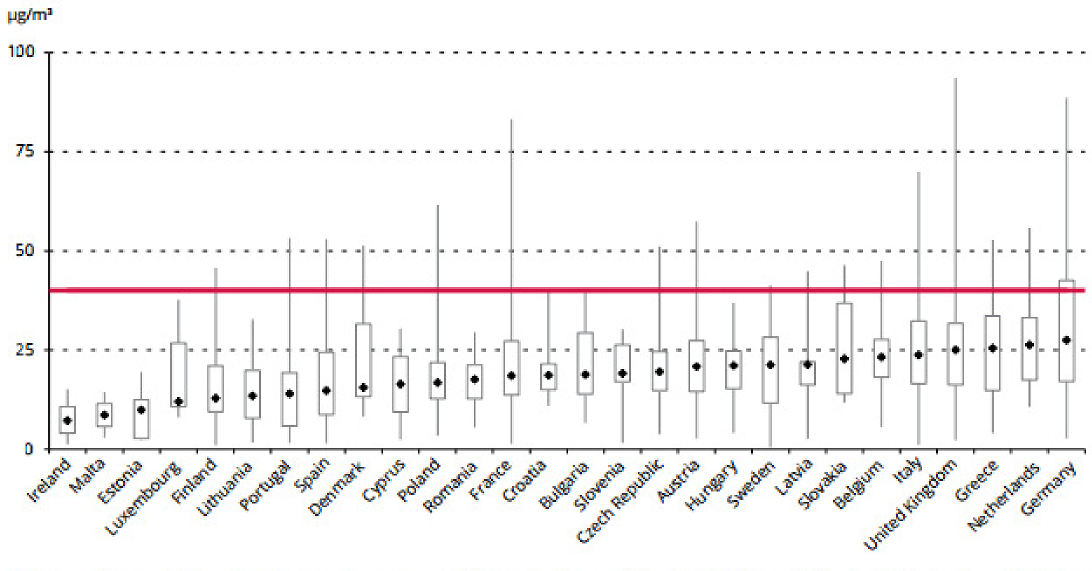
If you know of any relevant conferences or events of interest to chemistry teachers, please send in details to:peter.childs@ul.ie

Air quality in Europe 2016: Report from the European Environment Agency

http://www.eea.europa.eu/publications/air-quality-in-europe-2016

If you're interested in the quality of air in Europe and how Ireland fares compares to other countries, then you should read this report. An example of the information it contains is shown in the graph below. NO_2 levels are in the news in relation to diesel cars, along with $PM_{2.5}$ emissions of particulate matter.

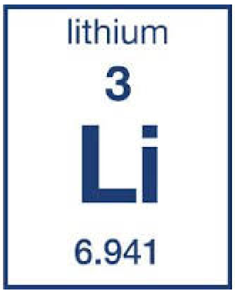
Figure 6.1 NO_2 **concentrations in relation to the annual limit value in 2014 in the EU-28**

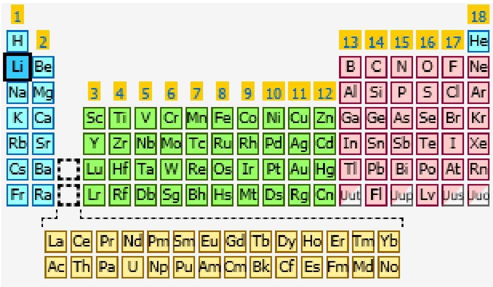


Notes: The graph is based on the annual mean concentration values for each Member State. For each Member State, the lowest, highest and median values (in µg/m³) at the stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The limit value set by EU legislation (equal to the WHO AQ guideline) is marked by the red line.

Source: EEA, 2016a.

Lithium the light metal powering the future – from brines to batteries






History and discovery

The credit of discovering lithium goes to the Swede Johan August Arfwedson in 1817, working in Berzelius' laboratory, when he was analysing a sample of petalite ore ($LiAl(Si_2O_5)_2$). Berzelius named the metal in the ore lithium, from the Greek *lithos* = stone, as it was found in a rock. The metal was first extracted by William Thomas Brande in 1821 by the electrolysis of molten lithium oxide at the Royal Institution in London. In 1818 Arfwedson showed that the element gave a red colour to a flame. Robert Bunsen and Augusts Matthiessen made larger quantities of the metal in 1855 by the electrolysis of molten lithium chloride and in 1923 commercial production was started by the German company Metallgesellshaft, using a mixture of lithium chloride and potassium chloride. In 2016 36,000 t of lithium were produced.

Sources

There are two main sources of lithium: brines and pegmatites (spodumene, lepidolite and petalite). In the brines, mainly from S. America, lithium salts are mixed with potassium and magnesium salts, and separation is relatively easy, though time consuming. Lithium is much harder to obtain from the pegmatites, which are hard minerals. The main producers are Australia and Chile. Due to the increased demand for lithium batteries, the production of lithium has increased and so has the price. The price of lithium as gone from \$2,320/t in 2006 to \$7,475/t in 2016, and it is still increasing (Figure 2). In 2015 world production was ~32,500 t, with world reserves of 14,000,000 t, and in 2016 36,000 t were produced (https://minerals.usgs.gov/minerals/pubs/commodity/lithium/mcs-2016-lithi.pdf). Over 80% of production was due to Australia and Chile. There is no shortage of lithium but the increased demand has meant that production continues to be increased and there is great interest in new sources of lithium e.g. oil well brines (see later).

Table 1 Main sources of lithium in 2015

Rank	Country	Production/t
1	Australia	13,400
2	Chile	12,900
3	Argentina	3,800
4	China	2,200
5	Zimbabwe	900
6	Portugal	300
7	Brazil	160

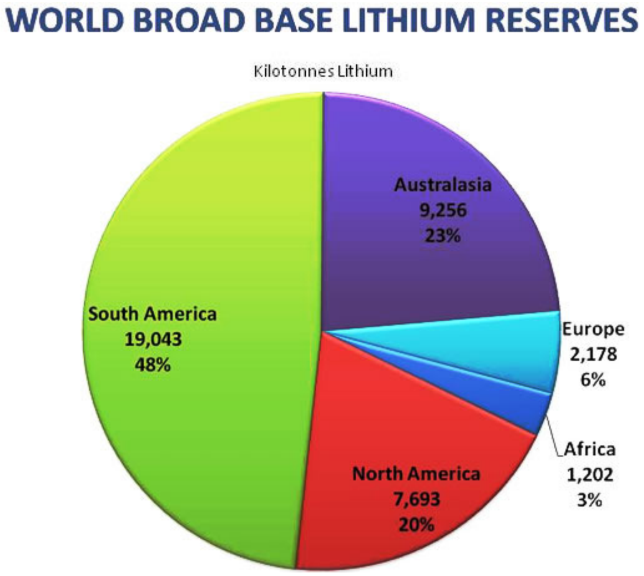


Figure 1: Global lithium reserves

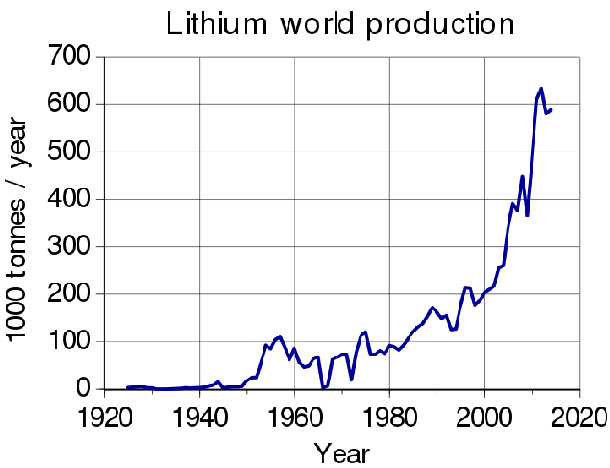


Figure 2: World production of lithium
(By Con-struct - U.S. Geological SurveySearch USGS publicationUSGS–2010 Minerals Yearbook LITHIUM (ADVANCE RELEASE)USGS–2012 Minerals Yearbook LITHIUM (ADVANCE RELEASE)USGS–2013 Minerals Yearbook LITHIUM (ADVANCE RELEASE)U.S. Geological Survey Data Series 140, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27876962)

Extraction of the metal

a) From brines

The salt lakes and salt deposits in Chile and Argentina are a mixture of group I and gp II metal salts, produced by the evaporation of salt lakes.

Figure 3: Salar de Atacame, Chile Photo: © Francesco Modelin Creative Commons License https://commons.wikimedia.org/wiki/File:Salar_de_Atacama.jpg

A recent description of salt mining in Chile can be found in the *Financial Times* article (8/7/16) at https://www.ft.com/content/cde8f984-43c7-11e6-b22f-79eb4891c97d.

The extraction of the various components of the brines is similar to that used in the Dead Sea.

The underground brine is pumped to the surface and allowed to evaporate in solar ponds. This can take from months to a year. This concentrates the salts. This is a lengthy but low energy route and only about 50% of the lithium is recovered.

The process has the following stages.

1. Pumping underground brines into ponds.
2. Solar evaporation (12-18 months)
3. Removal of potassium and then magnesium salts by crystallisation
4. Removal of boron by solvent extraction#
5. Precipitation of lithium carbonate by sodium carbonate
6. Filtering and drying.
7. Conversion into LiOH or LiCl if needed.

b) From pegmatites

Lithium is strongly bound in hard rock in the pegmatites and the lithium-bearing minerals have to be separated out. 50% of the energy costs of extraction are due to the grinding of the hard ore into powder. The lithium-rich mineral is then separated out by froth flotation. The concentrate then has to be roasted to break up the crystal structure and leached with sulphuric acid to get lithium sulphate. Processing involves the following stages.

1. Grinding into powder.
2. Calcination at temperatures > 800 °C
3. Leaching
4. Purification
5. Precipitation of lithium carbonate or lithium hydroxide

Figure 4: The Greenbushes lithium, tin and tantalum mine, Australia (Photo: Hilary Falconer https://www.travelblog.org/Photos/4705750)

c) Metal production

Lithium is mostly produced in the form of lithium carbonate or lithium chloride, whether from brines or pegmatites, and the metal is then obtained by the electrolysis of a molten mixture of lithium and potassium chlorides at 450°C in a Down's cell. The eutectic salt mixture is used to reduce the mpt and hence the energy consumption. The molten lithium is cooled and stored under oil or wax.

d) Main lithium producing companies:

Sociedad Química y Minera de Chile (Chile), Chemetall (Germany), FMC (USA) and Talison (Australia).

Properties

a) **Physical**

Lithium is the first element in Group I, the alkali metals. The small size of lithium atoms means that the metallic bonding in solid lithium is the strongest in the group, and it is thus the least reactive and the least metallic of the group I metals. It has the highest mpt and bpt, and the longest liquid range. Lithium metal does not need to be stored under oil, although it often is. It reacts much more slowly with water than sodium or potassium. The small atomic size means that lithium has the highest energy density of the alkali metals, hence its use in batteries. The charge/size ratio for Li^+ is similar to Mg^{2+} and thus there are similarities between the two elements in their compounds (the diagonal relationship).

Table 2: Properties of the alkali metals

Property	**Lithium**	**Sodium**	**Potassium**	**Rubidium**	**Caesium**
Atomic no., Z	**3**	11	19	37	55
Atomic mass	**6.94**	22.99	39.10	85.47	132.91
Density g/cm^3	**0.534**	0.968	0.89	1.532	1.93
Atomic radius/pm	**152**	186	227	248	265
Ionic radius/pm	**76**	102	138	152	265
Mpt/°C	**180.54**	97.72	63.38	39.31	28.44
Bpt/°C	**1342**	883	759	688	671
E°/V	**-3.04**	-2.71	-2.92	-2.92	-2.92

When alkali metal ions are excited in a flame, they emit visible light as the excited electrons fall back to a lower energy level. Each element has a different spacing of energy levels and thus has a different colour in a flame. These characteristic flame colours can be used to identify the elements and are the basis of flame photometry. The flame colours are shown below.

Lithium	Sodium	Potassium	Rubidium	Caesium
Crimson	Yellow	Violet	Red-violet	Red

b) Chemical

The group I metals show clearly the group (family) resemblance and the change in properties down the group, and these are easily demonstrated at school for the first three elements, which are readily available.

All the metals react with water to give hydrogen gas and a soluble metal hydroxide (alkali). This can be shown using beakers, and water with a little phenolphthalein added. They all react in the same way giving off gas, and the phenolphthalein indicator turns pink indicating an alkali is formed. Heat is generated in the reaction and causes the irregular pieces of metal to melt and form globules, which scoot around on the water surface as they are jet-propelled. The rate of reaction increases from lithium to potassium (linked to atomic size and the strength of metallic bonding), and with potassium the energy is given out so quickly that it catches fire. (The same will happen with sodium if hot water is used as it is due to the speed of the reaction.)

$M(s) + H_2O \rightarrow MOH(aq) + H_2(g)$

This is conveniently demonstrated on an OHP using flat-bottomed beakers or glass petri dishes.

The alkali metals form ionic compounds with the group 17 elements (F, Cl, Br). However, the lithium compounds of Cl, Br and I have considerable covalent character. The halides are chemically stable and thus the elements are commonly found as salts in the oceans, brines and salt deposits. The halides have relatively low mpts and thus the metals are extracted by the electrolysis of molten salts.

Uses

Today the demand for lithium (see below) is dominated by the lithium battery industry, and this will increase, although lithium's main use in 2014 was ceramics and glass. The share used up by batteries will increase in the future with a shift to electric cars and the use of lithium batteries as back-up storage for renewable energy sources like wind.

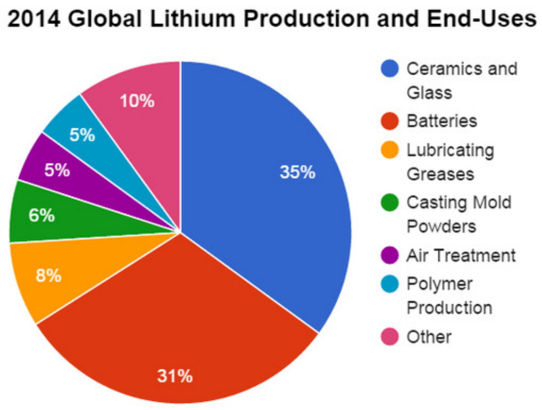


Figure 4: End uses of lithium in 2014

New sources of lithium

The heavy demand for lithium from battery makers has increased its cost and has stimulated the exploration of new resources and the opening of new mines. In addition to the South American brines and the pegmatites, several companies are looking at alternative and potentially disruptive sources of lithium. The two main sources have disadvantages: the extraction from S. American brines is slow and inefficient; the extraction from hard rock is shorter but more expensive and energy intensive.

a) **Hot brines in Cornwall:** Cornwall has a long history of mining, mainly tin and copper, but has also produced large amounts of granite for building. Granites contain lithium and this is leached from the rock by hot water deep in the earth, producing hot brines. Cornish Lithium (www.cornishlithium.com) has raised funds this year to look into the feasibility of extracting lithium from hot brines found in

Cornwall. Lithium was first identified in these brines in 1864. This has the potential to be a valuable new industry in Cornwall, providing a domestic source of lithium in the UK.

b) **Oil well brines:** When oil is produced, mineral-bearing brines are also extracted as waste water, which must be disposed of carefully. These oil well brines contain lithium and MGX Minerals of Vancouver, Canada (www.mgxminerals.com) is developing a process to recover Mg and then Li from the brines. This process would have the side-benefit of cleaning up the waste water ad extracting useful minerals from it.

c) **Lithium micas:** Lithium Australia (lithium-au.com) has developed a process for extracting lithium from Li-silicates (micas) using a leaching process based on sulphuric acid and halides, and avoiding the expensive roasting stage used with pegmatites.

Recycling lithium batteries

One of the major challenges of the lithium battery industry is recycling spent batteries. Only 5% of Li batteries are currently recycled. By 2020 11 million t ot lithium batteries will have been discarded. The process is complex but possible (see https://www.li-cycle.com/news) and will recover the other valuable metals (Ni, Co, Al) as well.

Sources

https://en.wikipedia.org/wiki/Lithium

https://www.thebalance.com/lithium-production-2340123

Recycling Li batteries:
https://www.li-cycle.com/news
http://pmr.umicore.com/en/batteries/our-recycling-process

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Conference Reports

10th IViCE, Irish Variety in Chemistry Education

21st April 2017, Dublin Institute of Technology, Kevin Street, Dublin 4

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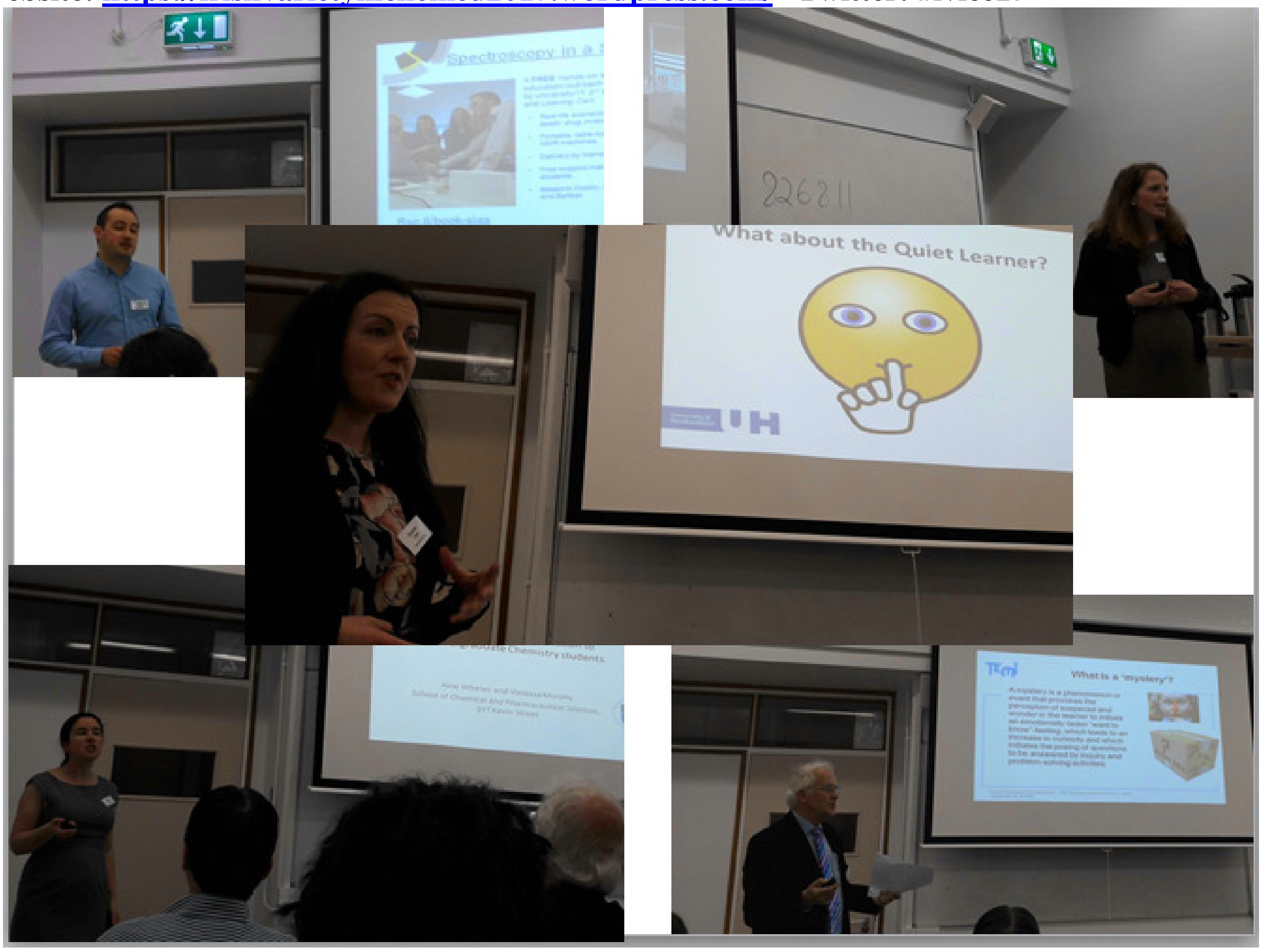
Website: https://irishvarietyinchemed2017.wordpress.com/ Twitter: #ivice17



Speakers at the 2017 Irish Variety in Chemistry Education meeting at DIT – centre, Dr Suzanne Fergus (keynote); top right, Dr Orla Kelly (DCU); bottom right, Dr Peter Childs (UL); bottom left, Dr Aine Whelan (DIT); top left, Dr John O'Donoghue (RSC & Trinity College).

The 10th Irish Variety in Chemistry Education (IViCE) meeting took place earlier this year in Dublin Institute of Technology on Friday 21st April. We welcomed about 30 participants from 9 different higher education institutions and from the Royal Society of Chemistry (RSC), to the Kevin St campus in Dublin city centre. These included a sizable proportion of first-time attendees. The meeting is held every two to three years and aims to share good practice in chemistry teaching at third level in Ireland and beyond. The meeting was sponsored by the Royal Society of Chemistry Republic of Ireland Local Section and the School of Chemical & Pharmaceutical Sciences, DIT.

The programme included inputs from 10 speakers and the keynote talk was given by Dr Suzanne Fergus. Suzanne is based in the University of Hertfordshire and received the 2016 RSC Higher Education Teaching Award. The programme and some of the presentations from the event can be found at the website:

https://irishvarietyinchemed2017.wordpress.com/. We had some active twitter users in attendance and tweets from the event can be found using the hashtag #ivice17.

A context-based approach

A common theme that emerged from many of the presentations was the emphasis on a 'real world' context and the application of theory to motivate and engage learners, and to make teaching a topic more interesting. Dr Sarah Rawe and Dr Aine Whelan (both from DIT) provided examples of how they implemented this approach. Sarah used the context of side-effects and effectiveness of some common pharmaceuticals, as well as related ethical issues, as a framework to develop transferable skills such as information retrieval, communication and group work among first years. Aine described how third year students were provided with a context-based team scenario (based on the pharmaceutical or brewing industry or a forensic or environmental testing laboratory) that required the preparation of quality management and validation documentation. Dr Peter Childs (University of Limerick) gave a thought-provoking and interactive presentation which had the audience guessing throughout. It included demonstrations of several of the chemical conundrums that have been incorporated as part of a European project, Teaching Enquiry with Mysteries. The importance of context as a driver for learning was also one of the messages that Dr Suzanne Fergus highlighted in her excellent keynote and she has published some examples of her work in this area on 'recreational' psychoactive drugs, that demonstrate the link between chemistry and social and legal issues involving patient safety (Fergus, Kellet & Gerhard, 2015).

There were two other main examples of effective practice that Suzanne shared. One was the process she has implemented to improve practical skills using Structured Chemistry Examinations – see Kirton, Al-Ahmad and Fergus (2014) for further details. This has developed further into a student partnership project, as supporting videos have been prepared in a project driven by undergraduates.

Technology and Chemistry Education

The other aspect of Suzanne's practice, which was highlighted, was the role technology can play in enhancing the learning experience and encouraging engagement. Examples included the use of Mentimeter to encourage less vocal students to contribute and to check student understanding as well as the implementation of Peerwise to get learners involved in preparing, answering and evaluating multiple choice questions on a relevant topic. Suzanne embedded the use of Mentimeter as part of her presentation on the day to get participant input and this allowed us to experience the interactive tool first hand.

The incorporation of technology was considered from a more holistic perspective by Dr Mike Kinsella from Waterford Institute of Technology. The modification of a traditional module to a blended version that incorporates technology and is designed to engage learners was discussed and included the use of online discussion forums, podcasts, quizzes, wikis and a blog. Dr Barry Ryan (DIT) later posed the question, 'How can embedding technology enhance the Final Year Project experience for students and staff?' He discussed how he has addressed this by developing an online resource to support students during their final year project and has used Mentimeter to gather thoughts from participants on best practice in this area.

Links to Secondary and Primary Science Education

Dr Barry Ryan (DIT) also reported on the Science Bridge project that he has developed and evaluated with his colleague, Dr Christine O'Connor. It is an open access interactive web site that gives students in second level and further education an opportunity to engage with Science learning and teaching resources. It would also be useful to first year undergraduates. The web site can be viewed at https://goo.gl/3Vpgv7 and attendees were invited to contribute science learning resources they may have developed or that they are aware of. Dr John O'Donoghue (RSC education coordinator based in Trinity College) discussed the RSC Spectroscopy in a Suitcase resources, which are designed to show secondary school students how spectroscopy can be applied to forensic and other contexts, in relation to the LC Chemistry course. He brought along the portable instruments used and they were on display during the meeting. John also examined the associated opportunities for undergraduate and postgraduate students who work on delivering these spectroscopy activities in schools to develop their teaching and science communication skills. Dr Vanessa Murphy (DIT) presented on a community-based learning project in which 2nd year students from DIT prepared and delivered hands-on science activities to young people (10 to 12 years) from a local youth project. On completion of activities in three sessions, the participants achieved a DIT Junior Scientist badge. Dr Orla Kelly (DCU) discussed an interactive and collaborative activity that she implemented with primary education students, in which a student developed timeline can be used to explore the history of climate science. A similar timeline activity could be implemented on varied topics and across a range of education levels.

The organising committee for the event were Dr Claire McDonnell, Dr Vanessa Murphy, Dr Gavin Sewell and Dr Aine Whelan, all of whom are based at Dublin Institute of Technology and are members of the DIT Chemical Education Research Team. It is hoped to hold the next Irish Variety in Chemistry Teaching meeting in April 2019.

References

Fergus S., Kellett, K. and Gerhard, U. (2015). The Khat and Meow Meow Tale: Teaching the Relevance of Chemistry through Novel Recreational Drugs. *Journal of Chemical Education*, 92, (5), 843-848.

Kirton, S.B., Al-Ahmad, A. and Fergus, S. (2014). Using Structured Chemistry Examinations (SChemEs) As an Assessment Method To Improve Undergraduate Students' Generic, Practical, and Laboratory-Based Skills. *Journal of Chemical Education*, 91 (5), 648-654

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Science on Stage Europe

June 29th – July 2nd, Debrecen, Hungary

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The Irish SonS team 2017 of (l-r): Paul Nugent, Robert Clarke, Sean Fogarty, Máire Duffy, Nicola Sheehan, David O'Connell, David Keenahan, Enda Carr, Declan Cathcart.

The 10th biennial jubilee of Science on Stage (SonS) provided a platform for exhibition and teacher exchange for over 450 teachers of primary and second-level Science from over 30 countries. The theme of the festival was 'Inventing the Future of Science Education'. Ireland sent a team of 9 delegates including 5 competitors, each with their individual project.

Criteria for the projects were as follows:

- promotes students interest in science,
- refers to everyday life,
- has a sustainable effect,
- is feasible in everyday school life and can be financed with reasonable expenses,
- promotes inquiry-based learning.

Innovative teaching concepts were shared at individual stands in the fair, at workshops and on-stage performances on the stage of the Kölcsey

Conference Centre. It felt in many respects like a Scifest or BT Young Scientists for teachers. The public were invited to engage with the various projects at their stands at an Open Day on July 1st which resulted in a large number of visitors.

The experience is rewarding for all participant teachers and provides:

- A network of and for STEM teachers at all levels (nationally and internationally).
- A European platform for the exchange of teaching ideas.
- An awareness of the importance of STEM in schools among the public.
- The opportunity to develop a joint project at a future festival with a teacher from another country.

Ireland enjoyed success at the festival with the projects:

'Green Greens?' by Robert Clarke (Confey Community College, Leixlip, Co. Kildare) and 'The Wonderful World of Woodlice' by Declan Cathcart (Temple Carrig School, Greystones), winning highly commended awards.

Also, Paul Nugent of the Irish Science on Stage National Steering Committee was elected to the 7-person European Executive Board during the festival which represents a huge honour for Irish Science teachers.

Further details of the 2017 festival may be obtained at: www.sons2017.eu. The next festival will take place in Lisbon in 2019. If you are interested in partaking, please contact a member of the Irish National Steering Committee at:
paulnugent@gmail.com or
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On p. ** you can read Enda's own entry for Science on Stage.

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11th Chemistry Demonstration Workshop 2017

3-7 July 2017, University of Limerick

Martin McHugh, Aimee Stapleton, Sarah Hayes, Laurie Ryan and Peter E. Childs

This year the 11th annual Chemistry Demonstration Workshop for teachers took place at the University of Limerick in July. The highly successful and exciting 4-day residential course allows teachers to explore the biggest and best chemistry demonstrations and engaging experiments.

Figure 1: The Chemistry Demonstration Workshop cohort from 2017 enjoying experimenting outdoors (Photo: True Media)

By working collaboratively, the course places an emphasis on peer learning with high levels of interactivity. Teachers were asked to bring their favourite or "go to" chemistry demonstration to perform, while they were also taught the tips and tricks behind developing engaging ideas for chemistry 'magic' shows. The workshop focuses on the coolest chemistry experiments and demonstrations guaranteed to inspire interest among students.

Figure 2: The "Methane Mamba" performed by James Holden and James O'Connor (Photo: True Media)

Furthermore, teachers work on physics demos for a half-day, run by Dr Sarah Brady for IOP, which can be incorporated into their teaching. There was also an opportunity to examine outreach activities such as ‘Spectroscopy in a Suitcase’ by Royal Society of Chemistry, and their teaching resources, presented by Dr John O’Donoghue.

Figure 3: Thomas McMahon demonstrates centrifugal force by swinging a plate and a cup of water in a circular motion

With an emphasis on injury and design, the teachers developed confidence in the chemistry lab with skilled tuition from teaching, pharmaceutical, physics and chemistry experts. Teachers worked in pairs to research, devise, test and present their own 10-20 minute chemical magic show at the end of the week.

The workshop offers many advantages to teachers, including the future active engagement of students in chemistry projects. Moreover, teachers can see the benefits of the workshop as chemistry plays an important role both in our lives today and in our future.

This year’s participants included Rebecca Kenneally, James Frawley, Vanessa Whelan, James Holden, James O’Connor, Thomas McMahon, Hannah Campbell, Marium Kamal, Mary Connolly, Michael O’Connor, Gemma Buckie, Alan Boal, Alana Carolan and Aimee Stapleton. The workshop proved to be a great success with teachers creating and performing their own chemistry magic shows by the end of the week.

Some comments from participants:
Hannah Campbell said:
“It absolutely exceeded all expectations. It was amazing!”
Mary Connolly noted:
“It made me feel comfortable doing the experiments and gave me the confidence to show how wonderful science is.”
Some of the most popular demonstrations included the “Methane Mamba”, “Water to Wine” and “Money to Burn”. A highlight of the first day is liquid nitrogen ice-cream made in situ, and teachers get a chance to play with liquid nitrogen. Most teachers went away with dozens of new, tested demonstrations to use in school.

Figure 4: Rebecca Kenneally demonstrates the “Cornflower Bomb” (Photo: True Media)

Figure 5: James O'Connor shows off bubbling liquid nitrogen (Photo: True Media)

The course is residential to allow for a longer exposure of teachers to each other and the atmosphere of the course. The courses is subsidised and costs only €150 for 4 days B&B a, full board and tuition. Scholarships are also provided to one final year concurrent science education student or PDE science education student from Irish higher education institutions.

The workshop was supported by SSPC, The Dept. of Chemical Sciences, Biopharmachemical Ireland, IOP and the PDST. If you are interested in attending next year's Chemistry Demonstration Workshop, contact Peter Childs at peter.childs@ul.ie

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6th Annual BASF Summer School for Chemistry Teachers

27 – 28 June 2017, Eureka Centre, University College Cork

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Figure 1: The group of chemistry teachers who attended the first day of the BASF Summer School. (Photo: Dr Trevor Carey)

BASF recognises the crucial importance of having highly trained chemistry teachers in our schools and for the past six years has funded the BASF Summer Schools for Chemistry Teachers in Ireland. The sixth annual BASF Summer School for Chemistry Teachers was held on 27 – 28 June 2017 in the Eureka Centre, University College Cork (UCC). This summer school is organised by Dr Declan Kennedy in collaboration with UCC, the Professional Development Service for Teachers (PDST) and the Cork branch of the Irish Science Teachers' Association.

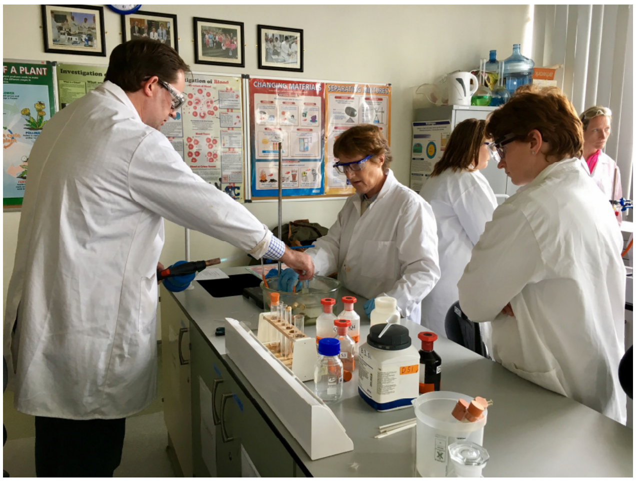

Figure 2: Some teachers preparing ethene gas during the BASF Summer School for Chemistry teachers. (Photo: Jeff Jamias)

The BASF Summer School arose out a request made to University College Cork (UCC) from chemistry teachers for assistance to help them to update their knowledge and skills to teach chemistry - particularly the newer aspects of the chemistry syllabus in Ireland. As BASF has an excellent track record in promoting chemical education through the sponsorship of various activities at local level, the BASF plant in Little Island near Cork was contacted by Dr Declan Kennedy, Senior Lecturer in Science Education, UCC for sponsorship to provide assistance to the chemistry teachers. After discussions held with Frank McDonnell, Dr Dan McSweeney and Paul

O'Driscoll, the BASF Summer School was born in 2012 and has continued since that time. Initially, it was planned that the BASF Summer School would be a one-day event but so many teachers apply for places each year that it is always run over two days. Due to the heavy emphasis on practical work, the numbers attending each day are limited to 35 teachers so over the two-day period a total of 70 teachers attend the BASF Summer School each year. This year proved very popular and there was a waiting list of 20 teachers on each day.
The themes that have been studied each year in the BASF Chemistry Summer Schools are summarised in Table 1.

Table 1: Themes of BASF Chemistry Summer Schools 2012 - 2017

Year	Theme of BASF Chemistry Summer School
2012	Assessment of Practical Work in the revised Leaving Certificate Chemistry Syllabus
2013	Key Practical Skills in Chemistry.
2014	Instrumentation in the Leaving Certificate Chemistry Syllabus
2015	Industrial Chemistry and Atmospheric Chemistry in the Leaving Certificate Chemistry Syllabus.
2016	Teaching the Organic Chemistry section of the Leaving Certificate Chemistry Syllabus.
2017	Great ideas and teaching resources for teachers of Leaving Certificate Chemistry.

Figure 3: Dr Ian O'Connor demonstrating how to use carry out datalogging experiments using wireless sensors and mobile phones. (Photo: Jeff Jamias)

Figure 4: Dr John O'Donoghue, Royal Society of Chemistry, demonstrating the *Spectroscopy in a Suitcase* teaching package to Dr Dan McSweeney BASF and Dr Declan Kennedy UCC. (Photo: Jeff Jamias)

The BASF Summer School is based each year in the laboratories and teaching rooms of the Eureka Centre, UCC. It is an ideal centre for providing inservice training to science teachers, as it consists of two state-of-the art science education laboratories, a Science Education Resource Centre, offices and a seminar room fully equipped with the latest audio visual communication facilities. Funding for the Eureka Centre was provided by government sources, by the pharmaceutical industry and by the College of Science, Engineering and Food Science UCC. The laboratories are fully equipped with all the apparatus and chemicals needed to teach the syllabi in Chemistry, Biology and Physics to Leaving Certificate standard.

Figure 5: Dr Dan McSweeney BASF (far left) visiting one of the experiments being carried out by teachers attending the BASF Summer school (Photo: Jeff Jamias)

The timetable that was followed on both days for the 2017 BASF Summer School is summarised in Table 2.

Table 2: **Programme for Fifth Annual BASF Summer School**

PROGRAMME
9.00 – 9.30 Registration. Tea / Coffee in Room G2 Kane Building, UCC.
9.30 – 10.15 *The answering of Atomic Structure questions on the Leaving Certificate exam paper.* - Ms Hilary Lynch, Clonakilty Community College, Co. Cork.
10.15 – 11.00 *Resources for teaching Leaving Certificate Chemistry available from the Royal Society of Chemistry* - Dr John O'Donoghue, Royal Society of Chemistry.
11.00 – 11.15 Tea / Coffee.
11.15 – 12.00. *Teaching Stoichiometry and Volumetric Analysis on the Leaving Certificate syllabus* – Brendan Duane , PDST.
12.00 – 1.00 *Laboratory practical session*. – Dr Declan Kennedy, Dr Ian O'Connor, Dr Trevor Carey
1.00 – 2.00 Lunch in UCC staff dining room.
2 p.m. Bus departs from UCC for industrial visit.
2.30 – 4.00 Visit to Glaxo SmithKline pharmaceutical plant in Currabinny, Co. Cork.
4 p.m. Presentation of Certificates of Attendance.

BASF was represented at the BASF Summer School by Dr Dan McSweeney, who spoke of his delight that the BASF Summer School had proved so attractive to chemistry teachers each year and that the demand for places has exceeded the number of places available. He congratulated the teachers present on taking time out of their summer holidays to update themselves on new methodologies for teaching chemistry.

In bringing the seminar to a close, Dr Declan Kennedy thanked BASF for making the BASF Summer School a reality, as without their support it would not have been possible to hold the seminar. He also thanked the PDST for recognising the course as a formal inservice training course for teachers and his colleagues in the Cork branch ISTA for their assistance in running the event. He described this initiative as an excellent example of an Industry-Education partnership and expressed the wish that the BASF Summer School would become an annual event in the calendar of chemistry education in Ireland.

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7th Eurovariety in University Chemistry Teaching

University of Belgrade, Belgrade, Serbia 28-30th June 2017

Peter E. Childs

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The conference building, University of Belgrade, Serbia

The Eurovariety conferences are sponsored by the EuCheMS Division of Chemical Education and alternate with the ECRICE conferences. The Eurovariety conferences (EViCE) started in 2005 and were a spin-off from the successful Variety in Chemistry Education (ViCE) conferences held in the UK and are aimed at university chemistry lecturers. The emphasis is on both research and practice with the aim of improving the teaching and learning of chemistry at tertiary (university) level, including the training of chemistry teachers. An Irish version, IViCE, was held in DIT in April this year for academics based in Irish institutions (see report p.**).

The challenge for such events is to get university academics to attend such conferences as they are not about chemistry research and teaching is often seen as a peripheral and less important activity than research. Often only 1 or 2 people in a Chemistry Department are interested in chemical education unless they are involved in training chemistry teachers and in many European countries this takes place within the chemistry departments, rather than in an education department. However, the increased emphasis on teaching quality in UK universities is evidenced by the greater emphasis on chemical education within UK chemistry departments. It was notable at this year's Eurovariety that both the University of Reading and University of Keele were strongly represented and each has a group of academics focused on chemical education. The University of Reading has two professors of Chemical Education, and several UK universities now have Professors of Chemical Education, or academics focusing on teaching and learning, like Michael Seery in Edinburgh.

Around 60 people attended this conference and there were 2 plenary lectures, 4 keynotes, 40 oral papers, 3 workshops and 18 posters.

Michael Seery giving his plenary lecture

The first plenary lecture was given by Michael Seery, formerly of DIT, and now a Reader in Chemical Education at the University of Edinburgh, which has a strong focus on chemical education in order to improve its undergraduate teaching. Michael presented an interesting range of ideas being tried out in Edinburgh to improve the undergraduate practical experience, by improving their practical skills, integrating theory and practice better and developing scientific process skills. One idea to improve practical techniques was to get students working in pairs, videoing each other's performance using smart phones, with commentary, and uploading these for evaluation. (http/bit.ly/skillstitrating). Another interesting idea was to award digital badges of competence, using the Open Badge idea (openbadges.org), so that students build up a portfolio of lab skills that they have mastered.(See badginglabskills.wordpress.com for more details).

The second plenary lecture was given by Silvija Markic, now at the University of Ludwigsberg, Germany and formerly at the University of Bremen, dealing with the challenges of heterogeneity in classes. She stressed the importance of cooperation between teachers, science education researchers and language teachers, for dealing with the special needs of second language learners.

Natasha Brouwer from Holland reported on an interesting project from ECTN to produce an online course to help university lecturers develop best practice in running undergraduate practical classes. This will be offered in six modules over 6 weeks and involve 2 hours study per week.

Matthew Almond from Reading talked about ideas being developed in the University of Reading to improve students' transferable skills, for example through a course called 'Chemical Concepts in Context' in year 1 and in year 2 through a collaborative case study, the Titan Project. Also from Reading, Philippa Cranwell described a first year course to develop inquiry skills, often lacking in school leavers, by using a series of guided investigations to develop independent investigatory skills. The course has had a positive effect on students' understanding and generic skills.

Odilla Finlayson (DCU) giving her talk

Unusually, Ireland was not well represented this year, with only Odilla Finlayson (DCU) and Peter Childs (UL) in attendance, if we don't count Michael Seery (ex DIT).

The poster session

The three workshops were useful in involving participants in the topics: team teaching, redesigning first year labs using student inputs, and careers in chemistry.

The EuCheMS Division of Chemical Education also holds its annual council meeting in conjunction with the Eurovariety and ECRICE conferences. Peter Childs (UL) is the national delegate, representing the Institute of Chemistry of Ireland, and a past chairman of the Division. The meeting's main activity is to decide the venues of future conferences. Some items from the meeting are given below.

International Year of the Periodic Table: An International Year of the Periodic Table (PT) has been proposed to UNESCO by IUPAC in 2019 to mark 150 years of the Periodic Table. It was suggested that countries could try and get Mendeleev and the PT on a stamp in that year and have a focus on the PT in conferences.

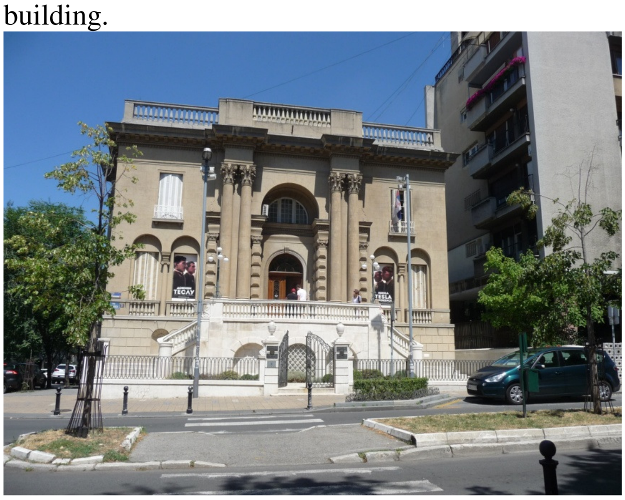
Decisions on future conferences: These conferences must be sponsored by the national chemical society and are hosted by a university in that country.

ECRICE – the next ECRICE was due to be in Greece in 2018 but the offer to host it has been withdrawn. Three offers were on the table: Warsaw and Lodz in Poland and Antalya in Turkey, The Council agreed to accept the bid from Warsaw, with the exact dates in 2018 to be confirmed.
Offers were received for 2020 from Germany and Israel and for 2022 from Sweden. It was decided to go to Israel, to the Weizmann Institute, for 2020. The Council is to liaise with the IUPAC Committee of Chemical Education (CCE) to see whether the 2022 ECRICE could be a joint meeting with ICCE (as in the successful 2012 Rome conference). This was due to happen in 2018 in Berlin but this proposal fell through and the 2018 ICCE is in Sydney, Australia.

Eurovariety: a proposal was received from Professor Tina Overton, Monash University, Australia formerly from the University of Hull, UK) to hold a joint European-Australian Eurovariety in 2019 at Monash's campus in Italy. This proposal was received with enthusiasm and was agreed in principle, subject to agreement from the Italian Chemical Society to support and co-host the conference. No proposal has yet been received for 2021.

The River Danube from the castle

Belgrade was an excellent city to hold the conference and the conference hotel was only a 5 minute walk from the conference venue, though the 35 degrees plus temperature was a challenge. The conference was well organised, except for the lack of time to move between sessions. However, all the rooms were conveniently located within one building.



The Tesla Museum, Belgrade

Serbia is the birthplace of the inventor Nicolas Tesla and the Tesla Museum (above) in Belgrade is a key tourist attraction. Tesla invented the induction motor amongst many other significant inventions. This small museum is well worth a visit.

It is a pity that more chemistry academics don't take the opportunity to attend such conferences, or those at a national level, in order to share their experience and ideas and use evidence from research to improve the teaching and learning experience of students. The RSC open access journal *Chemistry Education Research and Practice* provides a platform for such research and is now the highest ranked journal in chemical education. An increasing amount of research from third level institutions is being published in this journal, as well as papers on second level chemical education. CERP was a spin-off from an ECRICE conference held in Ioannina, Greece in 1998.

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ESERA 2017, the conference of the European Science Education Research Association

August 21-25, Dublin City University

http://www.esera2017.org/

Peter E. Childs

The opening ceremony of ESERA 2017 (Photo: P.E. Childs)

ESERA 2017, the largest gathering of science educators and researchers in Ireland was held in DCU 21-25 August. This was also the largest ESERA ever with over 1,500 people registered. It was jointly organised by Ireland's two leading science education centres, CasTeL from DCU and EPI-STEM from UL, and the organising committee was composed of Eilish McLoughlin (chair), Odilla Finlayson, Sibel Erduran and Peter Childs. Handling so many people and over 20 parallel sessions over 5 days is a major logistical challenge but it went off very well. Even the weather turned out well despite a wet start on the Monday. Many participants stayed on campus, which was very convenient and the city was still very accessible. The conference venues were all within walking distance and this made it easy to mover between sessions.

Here are some impressive statistics for the conference:

- **1529** total registrations

- **453** student registrations
- **293** reviewers
- **51** fellowships (€25,000)
- **48** local organising team
- **36** strand chairs
- **16** invited symposia

1246 total presentations
- **683** oral
- **344** symposium (86 symp)
- **203** poster
- **12** workshop
- **4** keynote
- **75** countries

If you were assiduous is being at every possible session then you could only be at 5% of the programme offerings. This is always a problem with large conferences – you inevitably miss more than you see. To fit everything in the days were very intensive, running from 9 to 6.15 Tuesday to Thursday, with half-days on Monday and Friday. The conference hub was the Helix and there were groups of people talking in this venue and in other buildings all through the day, the sign of a good conference.

Earnest conversations in the Helix (Photo: P.E. Childs)

The conference topics covered all levels of education from primary to tertiary, formal and informal learning, together with a number of symposia on specific topics and EU projects, and most sessions were well attended. There really was something to interest everyone on the programme. The conference banquet took place in the Helix and was an Irish Ceile, with group participation.

There were four excellent keynote talks, including an excellent one by Professor Paul Conway from UL. Each of them was quite different in scope but all had a practical emphasis and were well presented. The keynotes were:

1. <u>Equity in science education: Science as a tool rather than a destination</u>
   Angela Calabrese Barton*[1] and Emily Dawson[1]
   [1]Michigan State University in East Lansing, USA, [2]University College London, UK
2. <u>Science education: a balancing act between research in university, daily instruction in schools, and politics in education ministries</u>
   Peter Labudde
   University of Applied Sciences and Arts Northwestern Switzerland, Switzerland
3. <u>The good science teaching quest(ion): constructions and contestations</u>
   Paul Conway
   University of Limerick, Ireland
4. <u>Broadening our understanding of transformative science learning contexts: The role of design, collaboration and digital technologies</u>
   Eleni A. Kyza
   Cyprus University of Technology, Cyprus

Many of the talks will be published after the conference in an e-Proceedings, which will be available on the ESERA website. Around a third of the participants were postgraduate students, many of whom would be science teachers, but there was a noticeable absence of science teachers (surely the target audience for much science education research), and it would be good to see future ESERA conferences trying to reach out and communicate with local teachers. The other disappointing thing about ESERA 2017, surely a flagship event for STEM education in Ireland, was that no government minister was willing to come and open the conference, a major international event. Another plan to have a forum to discuss STEM education in Ireland had to be cancelled because of lack of interest from stakeholders. This is not way to promote STEM education or to indicate its importance to the Irish economy. **What a missed opportunity!**

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Science at the National Ploughing Championships 2017

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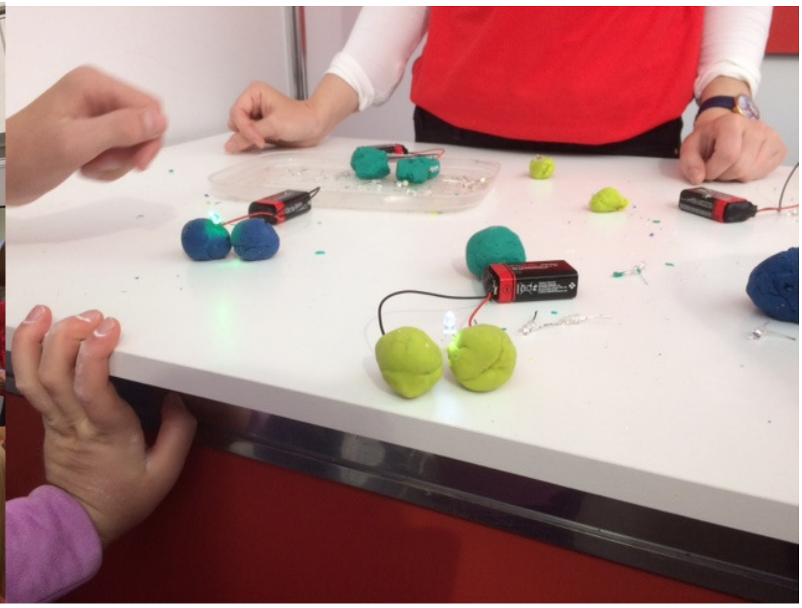
The annual National Ploughing Championships were held in Screggan, Tullamore, Co. Offaly from 19th to 21st of September this year. Globally, the agricultural sector is becoming more scientific and technical in its approach. In New Zealand, drones are used to watch livestock in large farms. Closer to home, Irish farmers are using genomics to select the most profitable animals for their herds. To learn more, we visited the Science Foundation Ireland (SFI) tent to meet researchers, scientists and technologists from many of the Irish research institutions.

Researchers from the Synthesis and Solid State Pharmaceutical Centre (SSPC) were there on the day to demonstrate the principles of crystallisation using hand warmers. The hand warmer is a pouch contains a super-saturated solution of sodium acetate. Saturated sodium acetate solution is very stable and easily stays in its liquid form below its crystallisation temperature of 54 °C – we call this a super-saturated solution. It is in a metastable state.

Also inside the hand warmer is a small stainless steel disc. Bending or clicking the steel disc triggers a few crystals to move into solution – these are called ‘seed crystals’. These seed crystals then encourage the sodium acetate solution in their vicinity to crystallise, spreading almost instantly throughout the pouch. During crystallisation, heat is released, and the temperature of the sodium acetate increases rapidly to its ‘freezing’ temperature – a comfortable 54 °C. The heat pack remains at this temperature until all the sodium acetate has crystallised and then slowly loses heat and returns to room temperature.

The hand warmers are reusable; by heating the pouch in boiling water for ten minutes or so, the sodium acetate crystals will dissolve and return to a liquid state. The hand-warmers can be used and reused several times. The plastic pouch may wear out eventually causing the sodium acetate to leak. This is not dangerous as sodium acetate is non-toxic. A sheep farmer we met on the day told us that he uses sodium acetate heat packs to keep newborn lambs warm.

The Physics buskers we met from Dublin City University and the University of Limerick fascinated everyone with their carrot pianos, non-Newtonian fluids (made from cornstarch) and play-dough electric circuits. The latter was my favourite – incredibly, a small LED connected to a battery using play-dough wires will light up! The reason is simple: play-dough is a good electrical conductor. Armed with this knowledge, what other things could be made from these squishy circuits?



One of the biggest attractions to the SFI tent were the live science shows from Sue McGrath (aka Scientific Sue) and James Soper, the juggling physicist! Scientific Sue welcomed us to her *Bubble Laboratory* where we questioned why bubbles float, asked why bubbles are round and designed an experiment to make the biggest bubbles. The Guinness world record juggler, James Soper, told us about the *REAL Science of the Circus*. Combining his scientific knowledge and circus skills, he presented the laws of physics (gravity, in particular!) as you have never seen them before.

Also at the ploughing championships were the National Biodiversity Centre, aiming to get Ireland buzzing with the All-Ireland Pollinators Plan. In Ireland, 30% of our 97 wild bee species are at risk of extinction. With our bee species under threat, the All-Ireland Pollinator Plan aims to address this by working together with schools, local communities, farmers, businesses and local authorities to reverse this trend.

Finally, we met Brendan O'Flynn, head of Wireless Sensor Networks in the CONNECT Centre in Tyndall National Institute. Brendan showed us how the Internet of Things applies to farming – remote wireless sensors can be used to measure and monitor important information such as soil temperature, giving farmers the information they need to make grass-management decisions.

From soil sensors to hand-warmers, science plays an important role on Irish farms; we look forward to seeing even more next year at the National Ploughing Championship 2018.

□

Chemlingo: what's in a name - nitre or natron?

Peter E. Childs

When I was growing up and first studying chemistry at school, I always thought the name Chile saltpetre (saltpeter in American) was a funny name. Saltpetre is the old name for potassium nitrate, KNO_3, also known as nitre (niter). Chile saltpetre is sodium nitrate, $NaNO_3$, and is also known as soda nitre or nitratine. The crude mixture of salts from which sodium nitrate is obtained is known in Chile, where there are large deposits, as *caliche*.

Where does the name saltpetre come from? One derivation is from the Latin *sal petrae*, meaning the salt of rock. (1) An alternative etymology is the salt of Petra, the *"rose-red city, half as old as time"*(2) in the Jordan desert.(3) Petra was a major trading centre on the camel trains across the Arabian desert into the Roman Empire and accumulated heaps of camel dung, which in turn yielded on fermentation an efflorescence of potassium nitrate. Potassium nitrate was often found as an encrustation of soluble salt on rock. It was important because it was a key constituent of gunpowder, the first explosive. The men who went around collecting saltpetre from dunghills and cattle sheds were known as saltpetre men (in 1643 known as salt-petre-men) and were authorised to collect human and animal wastes from wherever they could be found (4).

Confusingly in much earlier times sodium carbonate was known as natron (also as nitre), from which we get the symbol Na for sodium. In the Old Testament in Proverbs 25:20 we read:

> *Like one who takes away a garment on a cold day,*
> *or like vinegar poured on soda,*
> *is one who sings songs to a heavy heart.*

The word soda here is translated from the Hebrew *neter* (in older English translations nitre). However, the chemical context tells us that the biblical nitre is in fact soda, sodium carbonate. Both potassium and sodium carbonates were known as nitre or natron. Natron became restricted to sodium carbonate and thus became the etymological origin of Berzelius' *natrium* (sodium), symbol Na. Humphrey Davy called the new element he found in soda by electrolysis, sodium. Nitre came much later to be used for both sodium and potassium nitrates, and then just for potassium nitrate, which then gives us both nitrogen and nitric acid.

Imagine how confusing chemistry was before the names of elements and compounds were standardised and its nomenclature systematised. As you can see above, the same name was used for different substances and the same substance had different names. It is interesting that the name saltpetre is still in use commercially.

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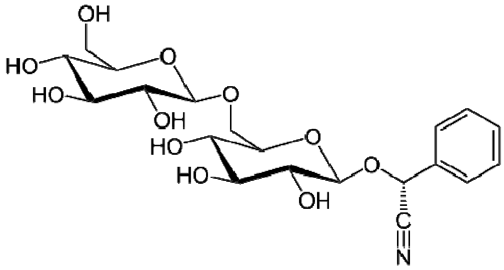
(1) J.F. Partington, 1998, 'Saltpetre', ch. VII in *A History of Greek Fire and Gunpowder*, John Hopkins University Press

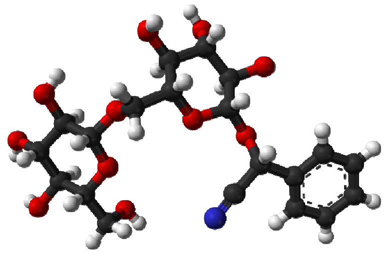
(2) From the poem "Petra", John William Burgon, 1845 (see http://en.wikipedia.org/wiki/John_William_Burgon, accessed 10/7/09)

(3) David Bloch, origin of saltpetre at http://www.salt.org.il/frame_saltpet.html, accessed 10/7/09

(4) For the 1646 ordinance authorising the collection of saltpetre see http://www.british-history.ac.uk/report.aspx?compid=56118, accessed 10/7/09

The danger of cherry stones





[(6-*O*-β-D-Glucopyranosyl-β-D-glucopyranosyl)oxy](phenyl)acetonitrile or amygdalin (https://en.wikipedia.org/wiki/Amygdalin)

The name amygdalin comes from the Greek for almond (*amygdale*) and is found in the stones of almonds, apricots, cherries, plums and other fruits. I came across a newspaper report in the summer, of man in England who was rushed to hospital with cherry stone poisoning! The headline was: 'Man nearly dies after eating cherry stones'. (http://www.independent.co.uk/life-style/man-cherry-stones-nearly-dies-eating-fruit-blackpool-matthew-creme-a7864261.html)

Now many people, including me, have swallowed cherry stones and come to no harm. So what was the difference? Most nuts have within the hard shell a softer kernel. It is the kernel that can grow into a new plant under suitable conditions. The problem is that cherry kernels contain the chemical amygdalin, which when broken down in the stomach releases hydrogen cyanide. As everyone knows, hydrogen cyanide is a highly toxic poison. The man concerned opened the cherry stone to find the kernel, ate it and enjoyed it. So he ate two more! In 10 minutes he started to feel unwell and his partner called an ambulance.

"Symptoms of cyanide poisoning can include stomach cramps, headache, nausea and vomiting. If untreated, it can lead to cardiac arrest, respiratory failure and death. A fatal dose can be as little as 1.5 mg per kg of a person's bodyweight.

A recent study showed that the amygdalin content of apple seeds was 3mg per gram of seeds, with one seed weighing roughly 0.7 g.*

Whilst red cherries contain 3.9 mg/g of seeds, apricots contain a staggering 14.4 mg/g but greengage plums are the biggest offenders, with 17.5 mg/g."

Amygdalin is also found in apple pits and small amounts can be found in apple juice (see https://pdfs.semanticscholar.org/8830/3a551945a77579a517aadb5e5e5f1d1757e0.pdf).

How does it turn into poison?

From the structure above, you can see that amygdalin contains a -CN (nitrile) group. Enzymes from bacteria in the stomach break amygdalin down in stages to give hydrogen cyanide. *"The body handles small amounts of cyanide differently than large amounts. In small doses, cyanide in the body can be changed into thiocyanate, which is less harmful and is excreted in urine. In the body, cyanide in small amounts can also combine with another chemical to form vitamin B_{12}, which helps maintain healthy nerve and red blood cells. In large doses, the body's ability to change cyanide into thiocyanate is overwhelmed. Large doses of cyanide prevent cells from using oxygen and eventually these cells die. The heart, respiratory system and central nervous system are most susceptible to cyanide poisoning."* (https://www.health.ny.gov/environmental/emergency/chemical_terrorism/cyanide_general.htm)

The laetrile health scam

Semi-synthetic Amygdalin was marketed as a health food in the 1970s known as laetrile or vitamin B17 (it is **not** a vitamin) and promoted as a cure for cancer. There is no clinical evidence for this and it is banned in many countries. Apricot kernels have been marked as ant-cancer agents on the basis that they contain amygdalin. Their sale has been banned in some countries as health risk. This means that people are being conned into deliberately eating something that can poison them, without any proven health benefits. It gives some real meaning to the colloquial phrase: it's the pits, meaning something bad or unpleasant.

"Apricot kernels are often marketed as alternative cancer treatment due to the presence of

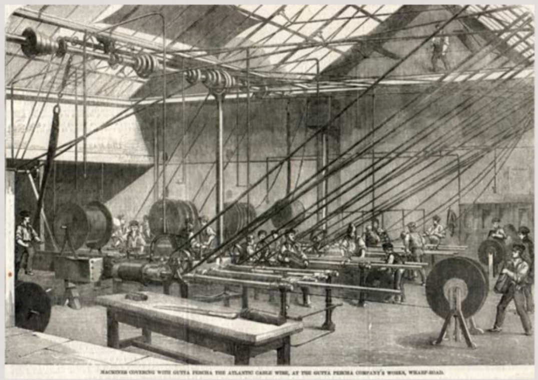
amygdalin, which converts to cyanide in the body. Branded as Laetrile or "vitamin B-17" (despite not being a vitamin), amygdalin has been sold as a miracle cancer cure since the 1950s, under the misguided premise that the cyanide targets only cancerous cells, leaving healthy cells alone."
https://www.quackwatch.org/01QuackeryRelatedTopics/Cancer/laetrile.html

The two faces of rubber

Two forms of rubber

Reading a book recently on the history of the 19th century and the crucial period from 1851-1862 when the modern world was born (Ben Wilson, (2016). *Heyday*, London Weidenfield and Nicholson), I came across a eulogy for Gutta-Percha, a form of natural rubber. It had been known for centuries but until 1832 its unusual and useful properties were unknown in the West. Dr William Montgomerie, a surgeon in Singapore, was shown how gutta-percha could be moulded into shape when hot, and then set into a hard solid. He was awarded the gold medal of the Royal Society of Arts for this 'discovery', which he brought back to England.

Ben Wilson writes (p.xxiv): *"Soon gutta-percha became ubiquitous in daily life. You could have gutta-percha raincoats, shoelaces, boot soles and walking sticks. .. The material was everywhere and anyone who has handled a Victorian knick-knack has undoubtedly and probably unwittingly touched gutta-percha. Resistant to acids, saline and chemicals, it was invaluable in industry. The use of the material in golf balls transformed the sport ...."* But the transformative use that changed society was its use as an insulator in the first undersea, telegraph cables. It was used for the first cable to the continent from England in 1851 and then later for the transatlantic cables. The telegraph (and later the telephone) was the internet of the 19th century, which connected countries and continents together in a way that had been impossible before. The telegraph was made possible by the special properties of gutta-percha and the cables shrank the world. The transatlantic cable was successfully laid in 1858 and came ashore in Valentia, Co. Kerry. The cable soon broke down and the technical problems of laying a 2,000 mile cable under the ocean took years to solve. Today gutta-percha has been replaced in cable insulation by polyethene, a synthetic material discovered in the 1930s.


Machines covering with gutta percha the Atlantic Cable wire, at the Gutta Percha Company's works, Wharf Road

Gutta percha was a wonder material and was widely used to make mouldable and waterproof items. It is still used today in dentistry. It was also used in 1845 to make the first mass-produced gold balls, known as 'guttys', which were in use to the end of the 19th century.
The first gutta percha golf ball, known as a "gutty" was hand moulded by J Patterson in Scotland in 1845 and was just a smooth ball. Previous balls had been made of wood, then leather stuffed with feathers and these took a couple of hours or so to make. The rapid introduction of metal moulds meant that one person could turn out 10 or more per hour which drastically reduced their cost and was a significant factor in the expansion of the game's popularity. In the 1860's it was discovered that cutting groves in the ball improved its flight. Again, this was originally done by hand but by the 1890's the pattern was built into the moulds. Early in the 1900's a new ball was introduced which had a core of stretched natural rubber thread and the era of the gutty was over.
http://plastiquarian.com/?page_id=14211

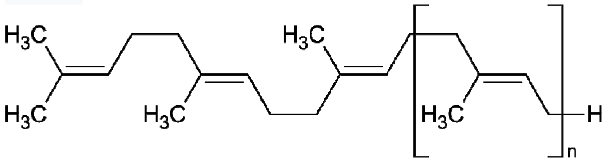
The other form of rubber is quite different. It is flexible and stretchy, and when vulcanisation with sulphur was invented by Charles Goodyear in the USA in 1839, to harden and stabilise the natural rubber chains, rubber became a vital raw material for many uses such as tyres, conveyor belts and

waterproofs. Charles Hancock in the UK was the first to patent the process. Natural rubber still has important uses, although a range of synthetic rubbers are now available.
Why do gutta-percha and rubber have such different properties? Gutta-percha is the sap of the palaquium fruit tree, also known as the gutta percha tree, and rubber is the sap of the rubber palm (*hevea brasiliensis*), so they are both natural products. They are both milky liquids, which harden in air, but their chemistry is quite different. The different properties of gutta-percha and rubber are a good illustration of the effect of structure, and geometrical isomerism, on physical and chemical properties.

Chemistry and structure

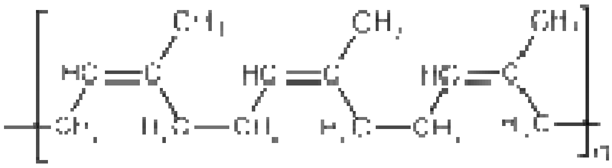
Gutta-percha

Gutta-percha is trans-polyisoprene, a polymer of isoprene. Isoprene is $CH_2{=}C(CH_3){-}CH{=}CH_2$ (2-Methylbuta-1,3-diene). The double bonds allow it to be polymerised by breaking one of the double bonds.

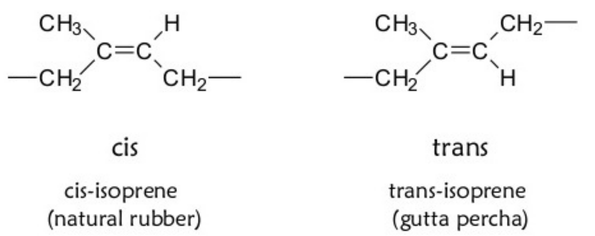


Natural rubber

Natural rubber is cis-polyisoprene, a polymer of isoprene.



This is a good example of cis-trans (geometrical) isomerism.



The straighter, more rigid and symmetrical chains of gutta-percha fit together to form a hard crystalline solid, but one which is thermoplastic (i.e. it softens on heating and goes hard again on cooling).

Items made from gutta percha
(http://atlantic-cable.com/Article/GuttaPercha/)

Rubber has a more flexible and less symmetrical structure due to the shape of the chains, so that it is rubbery rather than rigid. Heating natural rubber with sulfur produces cross-links between the polymer chains, which makes it more rigid but still flexible. This process is known as vulcanisation and was discovered by the American inventor Charles Goodyear in 1839. The flexibility of rubber is determined by the degree of vulcanisation and it is possible to make hard rubber, known as vulcanite or ebonite.

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At the same site you will also find the University of Limerick's science and technology magazine for schools, *ELEMENTS* and also information on SICICI, ChemEd-Ireland and other chemical education activities.

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