Chemistry In Action!

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Celebrating 40 years of chemical education in Ireland

Contents #112

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Editorial #112

A celebration of 40 years in Ireland

I have taken the liberty to use this issue to record the 40th anniversary of my arrival in Ireland in July 1978 to teach chemistry at Thomond College of Education. This marks 40 years of involvement in chemical education in Ireland – *Chemistry in Action!* was launched in May 1980 and the ChemEd-Ireland Conferences started in October 1982. This year was the 12th year of the Chemistry Demonstration Workshops (see cover photo). I hope I'll still be around and active for the 40th anniversary of *Chemistry in Action!* and ChemEd-Ireland.

Is more always a good thing?

In this issue we report two interesting educational developments: the first consortium to get Technological University status in Dublin and the massive expansion of STEM places at Trinity College Dublin with their 3E initiative. They raise the question: *'Is more always a good thing?'* One thing strikes one about Irish education: the lack of long-term planning or coordination. We have heard recently about shortages of teachers of specific subjects – but there has never been any real planning of the number or type of teachers needed (except at primary level), so that the system runs on the principle of uncontrolled competition. Thus we have had more humanities teachers in training than STEM teachers because there is no planning in relation to needs. This summer it was announced that universities would be allowed to take in more students in shortage subjects, including STEM, on both concurrent and consecutive teacher education courses, as a stop-gap measure.

The question *'Does Ireland need more universities?'* is raised by the advent of Technological Universities, a rebranding of the IoTs, formerly the RTCs. The blurring of the distinction also means a confusion of purpose: the RTCs were originally set up to provide vocational training through Certificates and Diplomas, to support Irish industry. Who will do this job when the institutions are chasing parity with universities in offering honours degrees and PhDs? The universities and IoTs are in competition for the same students and so weaker students end up in university courses, filling seats and providing income, while places at IoTs go unfilled. This is evident in the cut-off points published every year for courses.

Ireland has one of the highest percentages of students going on to third level in Europe but quantity is not the same as quality. Taking in more students does not automatically produce better graduates – it often means more drop-outs and lower standards. The concern about the dumbing down of standards and the variation in awards between institutions is something we should take seriously. There is something wrong when we take in more students, going further down the ability spectrum, and yet produce more top grades. Are students so much better today than they were 20 years ago? Why is it easier to get firsts in some institutions than others, even with similar intakes?

Are more STEM places in TCD a good thing? For many reasons TCD is the Oxbridge of Ireland and so attracts many of the best students. TCD's expansion now aims to hoover up more STEM students, who cannot now find places there, to the loss of the other universities. How can this be a good thing overall? Is there any overall planning of the number and type of STEM places in Ireland (or of any other subject)? There would appear not to be any planning. Unrestrained competition seems to be the order of the day and if a course is popular, everyone tries to get into the act e.g. PE teaching and forensic science. The same lack of planning applies to research funding. The healthy thing would be for research funding to be distributed across all institutions and subjects, with centres of excellence in specific areas. Concentrating all research in one or two places, to the loss of others, would not be the best solution for Ireland, even if it were good for international research rankings.

The fall of Irish universities in the international university tables has also made the news this summer, with TCD dropping out of the top 100. The fact that we have 5 in the top 500 is an outstanding achievement for the size of the country and its relatively low investment in third level education, with UL just outside the top 500. We are punching above our weight but our performance is being affected by the drop in funding since the recession (down by 30%) and the increase in the student : staff ratio, and it is clearly in decline. Fewer academic staff are expected to do more world-class research and teach more students but with less resources. This is not a viable plan and again shows the lack of a long-term, overall, integrated plan for higher education.

In October the seven universities launched a campaign to increase funding for universities, which has fallen during the period of austerity.

STOP PRESS:
The University of Limerick is the *Sunday Times* Irish University of the Year 2019, a second win since the previous one in 2015. Congratulations to UL staff and students!

Peter E. Childs
Hon. Editor

In this issue #112:

Countdown to IYPT2019 (p. 16ff)

2019 is the International Year of the Periodic Table (IYPT) and many events are being planned around the world. In this issue we are warming up for IYPT. We have an introduction from the IYPT website (p.11). 2018 is the 200th anniversary of the discovery of selenium by the famous Swedish chemist Berzelius (p.22), and we have an article on this. It is also the 150th anniversary of the discovery of helium (p. 31). We also have an article on Ytterby in Sweden, just named as a European Historical Landmark, where several elements were discovered – to find out how many read the article on p.28. Gordon Woods, a retired UK chemistry teacher, well-known for his impersonations of Mendeleev (which premiered at a ChemEd-Ireland conference), has an article on the history of the Periodic Table (p.16) For an interesting introduction to Mendeleev see http://www.mysteryofmatter.net/Mendeleev.html .

Conference reports (p. 46ff)

We have conference reports from ICCE in Sydney and ECRICE in Warsaw, in both of which there was a symposium honouring the memory of Alex Johnstone. We also have a report of this year's successful ChemEd-Ireland, the first ever held in Trinity College and superbly organised by John O'Donoghue and his team from TCD, and a report on this year's Chemistry Demonstration Workshop. I hope the reports will whet your appetite to attend ChemEd-Ireland and the Chemistry Demonstration Workshop in 2019.

Other items

This issue's feature on 'Chemists you should know' by Adrian Ryder (it really should be Scientists you should know) features Lord Kelvin, who we remember every time we use degrees Kelvin (p.36).

Ever wondered how the gas lighters work that provide a spark when you press a button? Aimee Stapleton tells you how in her article on Piezoelectricity on p.32.

We have been featuring ideas from the TEMI project in past issues – using 'mysteries' to engage students and kick-start inquiry in the classroom. In this issue (p.41) we have one on plastics used in disposable cups, sparked off by putting hot coffee into the wrong sort of cup!

You will also find other bits and pieces, including Chemlingo and CheMiscellany. Every science laboratory should have an up-to-date copy of the Periodic Table (with all 118 elements) and if you have ones which are out-of-date and tatty, make a resolution to replace them to mark the International Year of the Periodic Table. You will find a suggestion on p.21. The RSC have an excellent A4-sized version suitable for student use. There are also many downloadable Periodic Tables so there's no excuse for not giving all your chemistry students and up-to-date one to consult.

Should the Irish sugar industry be revived? When the last sugar factory closed in 2006 it was a great loss to the beet farmers and employees and since then all sugar used in Ireland has been imported. There are moves afoot to revive the industry and on p. 61 we give some information.

Education News and Views

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

New Technological University approved

On July 17th the government approved the awarding of Technological University status to the Dublin consortium of Dublin Institute of Technology, IT Blanchardstown and IT Tallaght. The new institution will be called Technological University Dublin (TUD) and will start in January 2019. It will have three campuses and around 28,500 students. In all, four groupings of Institutes have applied to for the new status and the group comprising Cork Institute of Technology and IT Tralee is thought likely to be the next one approved. The Institute of Technology sector, formerly Regional Colleges of Technology, already award honours degrees, masters and PhDs, in addition to Certificates and Pass degrees (formerly Diplomas). It looks like Ireland is going down the same road as the UK where in 1992 the Polytechnics, set up to provided technical education, were upgraded to universities and since then many third level institutions, including colleges of education and technical colleges, have been upgraded to universities.

"Today is the dawning of new era in Ireland's higher education history. The higher education landscape is changing and the people who will benefit most are the students." Minister of State for higher education Mary Mitchell O'Connor https://www.irishtimes.com/news/education/dublin-colleges-to-merge-into-technological-university-in-january-1.3568350

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LC practical assessment trial report

The trial of practical assessment for the new LC science subjects in 30 schools has been completed and externally evaluated by Sir John Holman. The report and its recommendations were sent in May 2018 to the DES, but have not yet been published. It will be interesting to see what is recommended. We hope to report on this in the next issue. The earliest date for introducing the new courses would be Sept. 2019, following on from the first cycle of the new junior science course, so that the first practical exams would be in 2021 at the earliest. The development groups will reconvene in September. Textbook publishers need a year before a new course is introduced and it doesn't look as though the 2019 target will be reached. The new Agricultural Science course should be implemented in 2019.

For background to the trial see https://www.independent.ie/irish-news/education/exams/sciences-to-become-handson-in-move-away-from-rote-learning-35792620.html

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EuCheMS Division of Chemical Education conferences

1. 14th ECRICE 2018 "Educational innovations and teacher needs"

The 2018 European Conference on Research in Chemistry Education was held in Warsaw, Poland from 2-6 September. http://www.ecrice2018.pl/ (report p. 50)

2. Eurovariety 2019

The next Eurovariety conference will be held in Prato, Italy 17-19 July, hosted by Monash University and organised by Professor Tina Overton. The Website has been just launched https://www.monash.edu/eurovariety-2019/_nocache .

"Papers may be submitted relating to research into chemistry education at tertiary level (undergraduate and/or postgraduate), on innovative practice in teaching chemistry, or interesting approaches to outreach. Papers may be submitted relating to research into chemistry education at tertiary level (undergraduate and/or postgraduate), on innovative practice in teaching chemistry (at 3rd level), or interesting approaches to outreach."

This conference is aimed at university chemistry academics and is an opportunity to share both research and practice in teaching chemistry at university level, including the preparation of chemistry teachers. You are more than welcome to invite colleagues (university lecturers) from your chemical societies to participate in our conference. If you need a flyer, please contact organisers at **eurovariety2019@gmail.com**

3. 15th ECRICE 2020

This will be held in the Weizmann Institute, Rehevot, Israel from 6-8th July 2010, subject to confirmation.

Dr Peter Childs has been the Irish delegate to EuCheMS Division of Chemical Education for many years, representing the Institute of Chemistry of Ireland, including 6 years as the Chair. He has now retired and handed over to Dr Odilla Finlayson (DCU), with Dr Sarah Hayes (UL) as the alternate delegate.

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Trinity unveils plans for E3 Institute

25th May 2018

- ***Single largest donation from Irish philanthropists in the history of the state announced for E3 Institute at Trinity College Dublin***
- ***E3 Institute to provide 1,800 new STEM places for students, addressing skills shortage in Irish economy***
- ***Work to begin on campus in 2018 with completion expected by 2022***

Trinity College Dublin announced plans today [25th May] for a €60 million new E3 Institute in Engineering, Energy and Environment that has been made possible with a major private philanthropic donation by the Naughton family through the Naughton Foundation, established by the founder of the Glen Dimplex Group, Dr Martin Naughton, and his wife, Carmel. This will be combined with Government funding from the Department of Education and Skills.

The Naughton family has made the single largest private philanthropic donation in the history of the state to the new E3 institute by donating €25 million. An additional €15 million is being made available by the Department of Education and Skills. This funding will be provided through the Higher Education Authority (HEA).

In addition to the transformative Naughton gift, significant philanthropic support was also given by Dr Beate Schuler, Dr Paul Johnston with his wife Theresa Johnston, and Mike Peirce.

Central to the vision of the E3 Institute is the construction of the Learning Foundry, a state of the art 6,086 square metre facility based on the main Trinity campus which will deliver new teaching facilities and an innovative interactive learning space for undergraduate and postgraduate students. The Schools of Engineering, Computer Science and Statistics, and Natural Sciences will share the new Learning Foundry which will be a launchpad for a new kind of education experience for students with a focus on collaborative and project work. It will have capacity for 1,800 additional places for students of Science, Technology, Engineering and Mathematics (STEM) which constitutes an increase of 50% STEM places over ten years.

The E3 Institute will introduce a new STEM curriculum, involving a seamless integration of teaching, project work and research in new innovative ways for students, graduates and researchers. From first year, students will engage in project based learning, working in teams across the disciplines of engineering, the natural sciences and computing.

Enterprise, creativity, teamwork and critical thinking will be emphasised as part of the overall education experience. New postgraduate courses will be created in the area of six E3 research themes of Cities; Environment; Data; Resources; Production and Well-being.

New interdisciplinary programmes will be developed in areas such as Technology for Change, Smart Cities, Data Science, Sustainable Energy, Climate Change and Sustainable Development, Spatial Data among many others.

https://www.tcd.ie/news_events/articles/trinity-unveils-plans-for-e3-institute-in-engineering-energy-and-environment/

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Drop in Ireland's QS rankings

The QS university rankings were published at the beginning of June 2018. Table 1 below shows a comparison of the rankings of the 7 Universities for 2018 and 2019. At a national level Ireland no longer has a university ranked in the top 100 and 5 of the 7 universities experienced significant drops from 2018. ULs overall position remained relatively unchanged but is still outside the top 500.

Table 1: QS ranking Irish Universities

HEI	2018	2019
TCD	88	104
UCD	168	193
NUIG	243	260
UCC	283	338
DCU	391	422
UL	501-550	511-520
NUIM	701-750	701-750

Comparing nationally, there were drops in academic reputation, employer reputation, faculty student ratio and citations for TCD, UCD, NUIG, UCC and DCU. UL was the only university to have an increase in citations.

The drop in rankings is clearly linked to the government's funding of third level education, which has dropped 30% since the economic crisis. The high student : staff ratios and lack of investment in infrastructure is impacting performance. The government's own report from 2017 recognised the problem, saying it '*poses a significant threat to our competitiveness rankings*'.

Globally and locally, rankings are an imperfect measurement of what is a very complex environment – multiple factors affect each universities performance and the global rankings tend to simplify this context. Locally, within an Irish context, a decade of severe underfunding is taking its toll, especially against the backdrop of exceptional funding for new universities in the large, emerging economies worldwide.

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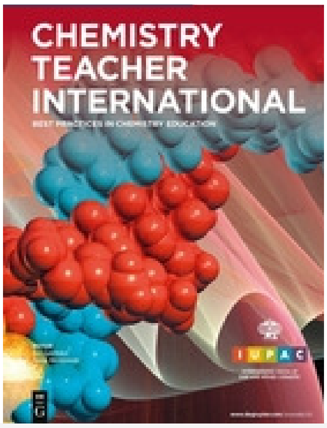
Two new open access science education journals:



Chemistry Teacher International
Best Practices in Chemistry Education

Editor-in-Chief: Apotheker, Jan H. / Maciejowski, Iwona
2 Issues per year
Open access

Aims and Scope

Chemistry Teacher International (CTI) is a peer-reviewed Open Access journal from the Committee on Chemistry Education of IUPAC, in cooperation with the EuCheMS Division of Chemical Education. The journal aims to be a platform for teachers of all levels, focusing on researchers in chemistry education. The objectives of the journal are:

- Bridging the gap between research and education
- Creating a platform for all IUPAC activities in the field of education
- Building an international journal not linked to a specific area or nation

First issue is due July 2018.

URL:
For submission details:
https://www.degruyter.com/view/j/cti

ARISE
Action Research and Innovation in Science Education
Editors: Ingo Eilks and Marika Kapanadze
2 issues per year
Open access
http://www.arisejournal.com
First issue is due October 2018.

ARISE – The Journal of Action Research and Innovation in Science Education is a peer-reviewed international journal. ARISE publishes academic and practitioner research in the field of science education. Papers shall be about action research and related approaches like practitioner research, design research and innovation studies. Papers may comprise theoretical discussions, research studies, or reports on evidence based curriculum innovation. Contributions may focus all the science teaching domains, from early childhood science through the secondary and university level to informal science and environmental education. Manuscripts on science teacher education in

connection to action research, classroom-based research and innovation or research-based learning in teacher education are welcome as well as papers on the methodology of action research for classroom innovation in science education. The journal language is English.
ARISE will publish three types of papers:
- Review and perspectives papers that provide general overviews on any theoretical topic relevant to action research and related approaches with relevance to science education (max. 10.000 words including references)
- Research papers that report action research and related studies form the field of science education (max. 5.000 words including references)
- Short communications raising relevant questions or reporting preliminary works from the field of action research and related approaches in science education (max. 2.000 words including references)
ARISE is a open access electronic journal and does not charge an article publication fee of any sort (i.e. there are neither manuscript processing charges for authors, nor subscription fees for readers). The launch of the ARISE journal is part of the ERASMUS+ CBHE project Action Research to Innovate Science Teaching (ARTIST) and is co-funded by the ERASMUS+ Programme of the European Union.

Founding editors of the journal are Prof. Ingo Eilks and Prof. Marika Kapanadze. An international editorial board is established from among members of the ARTIST project consortium and invited scholars in the field of science education with experience in research methods and action research. Accepted papers will be immediately published after acceptance. The first volume of ARISE will be launched in 2018. ARISE is now open for article submissions.

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EuChemS Historical Landmarks Award

The Liverpool Chemistry Congress in August 2018 also witnessed the very first *EuCheMS Historical Landmarks Award*. The aim of the award is to reinforce a sense of belonging of European chemists, and to demonstrate to the public the vital link that exists between chemistry and our shared cultural heritage.

Following the recommendations of the Landmark Selection Committee and the decision of the EuCheMS Executive Board, two awards have been given out – one focusing on the European-wide level of meaning of the landmark, and the other on its role played at the national or local level.

a) The **Ytterby Mine**, in Sweden, has been awarded the EuCheMS Historical Landmarks Award in recognition of the role it played in the history of chemistry and European sense of belonging between people and ideas. The Ytterby Mine and the important chemical discoveries that were tied to it successfully exemplify the way chemistry is part of the general cultural heritage and history of Nordic, but also all European citizens. (See article on p. 28).

b) The industrial complex of **ABEA** in Crete has been awarded the EuCheMS Historical Landmarks Award in recognition of its role in fostering a deep link between chemistry and local cultural heritage. ABEA and the important chemical discoveries and developments that were tied to it successfully exemplify the manner in which chemistry forms an important element of the regional cultural heritage and history of Crete.

We hope that with these awards, the landmarks will become ever more familiar and well-known, where citizens will better understand and appreciate a significant moment when chemistry and history were forever tied together.
http://www.euchems.eu/newsletters/awards-at-euchems-chemistry-congress-2018/

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Case study of science education in Ireland

The internet can be wonderful. I came across a report written for a Royal Society meeting in 2017 by Tom McCloughlin, DCU, on 'Upper secondary education in Ireland: a case study', with a focus on science education. It was one of six case studies commissioned for the Royal Society's symposium 'Broad and Balanced: What is the future for our post-16 curriculum?' on 17 October, 2017. This is well worth reading. At the end Tom McCloughlin summarises what he sees as the main issues.

In summary, the main issues affecting education policy and practice reform in Ireland are:

1. The examination system at Leaving Certificate level and how students matriculate

2. The resistance to reform in general, and particularly at the Junior Certificate level

3. Financing the education system - "free education"

4. Textbook provision and use and the issue of rote learning

5. Time allocation for the science subjects

6. Resource allocation for the science subjects

7. Participation at third level, and the need for renewal of the vocational sector

8. Practical assessment, and to what purpose is it put, and the lack of technician support.

And finally, since this will determine how to address the previous 8 points:

9. The country needs to come to agreement on what education is for.

Available at: https://royalsociety.org/~/media/policy/topics/education-skills/Broadening%20the%20curriculum/ireland-case-study.pdf Accessed 27/8/18

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Common science entry in UL

Since 2017 there has been a common entry for degrees in chemistry, biochemistry, bioscience and environmental science, which formerly all had direct entry. The first year is common and then students decide which course to follow for the remaining 3 years.

Why Study Biological and Chemical Sciences at UL?

This entry route is designed to provide you with a gateway to better choice if you're unsure which area you'd like to study. You can avail of a broad common first year which will introduce you to various topics in Biological and Chemical Sciences. Having gained a better understanding of each subject area, you then choose your preferred pathway to specialise for the remaining 3 years of your degree programme. At UL, you get to try before you decide.

Science requires a fundamental understanding of the key areas of biology and chemistry and the LM123 Biological and Chemical Sciences at the University of Limerick offers prospective students an opportunity to develop a core competency in both scientific areas in their first year at University. LM123 Biological and Chemical Sciences is a gateway from Year 2 to a degree in either:

BSc Bioscience OR
BSc Environmental Science OR
BSc Industrial Biochemistry OR
BSc Pharmaceutical and Industrial Chemistry

There is still separate entry for Physics and Food Science.
https://www.ul.ie/courses/biological-and-chemical-sciences-common-entry

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Changes to science entry in TCD

Science at Trinity College Dublin is now offered through four different entry routes/streams, leading to an honours degree following four years of study. They have reimagined the science programme and offer students the opportunities to choose from four entry paths/streams:

- Biological and Biomedical Sciences;
- Chemical Sciences;
- Geography and Geoscience;
- Physical Sciences.

Previously TCD had a common science entry.
https://www.tcd.ie/Science/

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Science teacher education

There are several routes to becoming a second-level science teacher in Ireland and it can take 4, 5 or 6 years. The 4 year concurrent courses offered by UL, DCU, UCC and St. Angela's, Sligo produce a qualified teacher in 4 years. The consecutive PDE takes 2 years after a first degree in science and is offered by UCC, NUIG, TCD. NUI Maynooth and UCD now offer a 5 year concurrent course, where the 5^{th} year leads to a Master's qualification. In addition there is a 2 year, part-time, distance learning course offered by Hibernia College. The government, however, onlu supports 4 years of third level education so the 5^{th} year and the PDE students have to pay their own fees.

UCD: Science, Mathematics and Education - DN200 Science

The Common Entry DN200 Science programmes provide students with the option to become Science and Maths teachers at post-primary level via one of 4 Teaching Council approved pathways. Students who opt for one of the 4 pathways complete a 4-year BSc which leads directly into a one-year MSc in Mathematics and Science Education. On completion of both degrees, students are fully qualified to teach their chosen Science subject and Mathematics to Higher Level Leaving Certificate Level as well as Science to Junior Certificate Level.

The four options available are as follows:

- Applied Mathematics, Mathematics & Education

- Biology, Mathematics & Education
- Chemistry, Mathematics & Education
- Physics, Mathematics & Education

For more information
https://www.ucd.ie/science/study/prospectiveundergraduatestudents/sciencemathematicsandeducation/

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CAO points for teacher education courses

Below find collected the entry CAO points for the various concurrent science teacher entry courses on offer in 2018. This does not include the 2 year consecutive PME courses.

Dublin City University	
DC203 Science Education	433
DC205 PE + Biology	511
NUI Maynooth	
MH212 Science with Ed. or Maths with Ed.	434
University of Limerick	
LM092 Science + Teacher Ed. (B+P, AgSc or C)	465
LM096 Science + Teacher Ed. (P+C)	382
University College Dublin	
DN200 Science (teaching option)	520
St. Angela's Sligo	
AS001 Ed., Home Ec.+ Biology	467
University College Cork	
CK402 Biol. & Chem. Sc.	488
CK404 Biol., Earth & Env. Sc.	432
CK406 Chemical Sciences	466
CK408 Physcis & Astrophysics	521

(all with an education Option)

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ChemEd-Ireland conferences

The list of venues for the ChemEd-Ireland Ireland for the next few years is as follows, together with the main organiser.

2018 TCD (John O'Donoghue)
2019 TUD (Claire O'Donnell)
2020 UCC (Declan Kennedy)
2021 DCU (Odilla Finlayson)
2022 LIT (Marie Walsh)
2023 TCD

Next year's conference will be held in Technological University Dublin, Kevin Street on Saturday October 19th and the main theme will be teaching about the Periodic Table, to fit in with the International Year of the Periodic Table.

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Spectoscopy In A Suitcase (SIAS) update

John O'Donoghue, RSC Education Coordinator
John.o'donoghue@tcd.ie

November 2017 - successful extension of Spectroscopy in a Suitcase (SIAS) project by Science Foundation Discover grant to fund the programme until the end of 2019. There are now 6 kits operating in Ireland through 6 host institutions: TCD, UCD, UL, UCC, CIT and the newest addition IT Sligo. Each kit consists of an Infra-red spectrometer and a UV Spectrometer.

The programme is coordinated on a national basis in Ireland by the RSC Education Coordinator based at TCD and regionally by host coordinators at each of the host institutions. Workshops are carried out by staff and PG students of the host institutions in secondary school classrooms, mainly with Leaving Cert Chemistry students.

As of June 2018 we have completed over 450 school visits with over 10,000 students in every county in Ireland since the programme began in 2015. Two rural tours were delivered during 2017, one by TCD in the north midlands (Longford, Cavan and Monaghan, 6 schools, 204 students) and another by UL in the North West (Roscommon, Leitrim, Sligo and Mayo, 5 schools, 113 students). These tours require students to stay overnight in rural locations so we can provide rural schools with this programme as well as schools based in urban centres.

As part of the SFI funding we also got new resources made for teachers, including a poster in Irish for all Irish chemistry teachers based on the 'Not all chemists wear white coats series' (see below). These posters were very well received by teachers nationwide, since Irish is taught is all schools. The 20 GaelColaistes and GaelScoils we visited in particular were hugely appreciative of the posters, since they don't have many resources in Irish for science.

In addition to school workshops, new demos were also developed in 2017/2018 based on Biodiesel/Diesel, which was used at public outreach events such as the Ploughing Championships. A Plastics Recycling Demo was also developed and used at the annual TY Expo in Kildare and at the Dell Junior Achievers events for the first time.

Teacher feedback survey:
100% of teachers thought the workshop furthered their students' understanding of spectroscopy and increased their students' awareness of application of and careers in chemistry.

Teacher comments from open-ended questions:
"Worthwhile and enjoyable"

"Excellent workshop, knowledgeable facilitators, great response from students."

"Really enjoyed the experience...very worthwhile"

"Yes, I learned a few things about university courses that weren't being offered when I was in University."

"Gives opportunity to students to have hands on experience on using IR and UV spectroscopy. Reinforce the theory of the material. Gives a practical view to students on how analytics are used in industry"

"A unique opportunity to work with technology not available in a school setting. It took the abstract into the real for my students who had the aptitude to take it on board."

"The students really enjoyed the day, thank you."

"Please keep the program going."

"Please keep offering this fantastic workshop!"

"It was very informative and my students would not otherwise get to see this equipment and it's every day applications."

"Yes in the sense I have a greater appreciation for the range of applications of spectroscopy."

Comment: SIAS has been very successful and has received a lot of media coverage. Comgratulatiosn to John and his team of academic staff and postgrads in the host institutions. It has proved to be a really worthwhile venture for introducing LC chemistry students to spectroscopy. Ed.

□

A new Minister for Education and Science

I went away in October and Richard Bruton was the Minister of Education and Science. When I came back he had gone and Joe McHugh (a former second-level teacher) was the new Minister. Richard Bruton had overseen a number of initiatives in his two-term in office and it remains to be seen how many will be continued and what new ones the new Minister will introduce.

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8th SMEC 2018

The lates SMEC conference was held this summer on 26th June in DCU on ***'Connecting Research, Policy and Practice in STEM Education'*** and you can consult the book of abstracts at: https://www.dcu.ie/sites/default/files/smec/smec_bookofabstracts2018.pdf

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International Year of the Periodic Table of Chemical Elements IYPT

Countdown to IYPT 2019

(www.iypt2019.org)

Partners

The initiative of the International Year of the Periodic Table of Chemical Elements is supported by the International Union of Pure and Applied Chemistry (IUPAC), International Union of Pure and Applied Physics (IUPAP), European Association for Chemical and Molecular Sciences (EuCheMS), The International Council for Science (ICSU), International Astronomical Union (IAU), The International Union of History and Philosophy of Science and Technology (IUHPS).

Motivation

The Periodic Table of Chemical Elements is one of the most significant achievements in science, capturing the essence not only of chemistry but also of physics and biology. It is a unique tool, enabling scientists to predict the appearance and properties of matter on Earth and in the rest of the Universe.

Great Russian scientist Dmitry Mendeleev is regarded as the father of the Periodic Table. By 1860, only 60 elements had been discovered (we now know 118) and indeed some of the information about these 60 was wrong. It was as if Mendeleev was doing a jigsaw with one third of the pieces missing, and other pieces bent! Mendeleev had written the properties of elements on pieces of card, and tradition has it that after organizing the cards while playing patience, he suddenly realized that, by arranging the element cards in order of increasing atomic weight, certain types of element regularly occurred. The greatness of Mendeleev was that not only did he leave spaces for elements that were not yet discovered but he predicted properties of five of these missing-elements and their compounds. Three of these missing elements were discovered, by others within 15 years (i.e. within his lifetime).

1869 is considered as the year of discovery of the Periodic System by Dmitry Mendeleev. 2019 will be the 150th anniversary of the Periodic Table of Chemical Elements!

The International Year of the Periodic Table of Chemical Elements will be a worldwide initiative to highlight the importance of the Periodic Table in science, technology, and sustainable development of humankind.

History of discovery – Mendeleev and the Periodic Table

The International Year of the Periodic Table of Chemical Elements in 2019 will commemorate a remarkable series of important milestones in the history of the periodic table of chemical elements dating back 2800, 350, 230, 190, 150, and 80 years. Indeed, around 800 BC, an Arab alchemist named Jabir ibn Hayyan first isolated the chemical elements arsenic and antimony. In 1669, phosphorus was the first element to be chemically discovered by Hennig Brandt (German). In 1789, Antoine Lavoisier (French) published a list of 33 chemical elements grouped into gases, metals, nonmetals, and earths. In 1829, Johann Wolfgang Döbereiner (German) observed that when many of the elements were grouped in three (triads) based on their chemical properties and arranged by atomic weight, the second member of each triad was approximately the average of the first and the third (Law of Triads). In 1869, Dmitry Mendeleev (Russian) developed the modern periodic table as it is known today. In 1939, a French woman scientist, Marguerite Perey, discovered element francium based on filling gaps in Mendeleev's periodic table. It is also believed that lead smelting began at least 9,000 years ago in Africa, and the oldest known artifact of lead is a statuette found at the temple of Osiris on the site of Abydos (Egypt) dated circa 3800 BC.

March 1, 1869 is considered as the date of the discovery of the Periodic Law. That day Dmitry Mendeleev completed his work on «The experience of a system of elements based on their atomic weight and chemical similarity.» This event was preceded by a huge body of work by the most outstanding chemists in the world.

By the middle of the 19-th century, 63 chemical elements were already discovered, and attempts to find regularities in this set had been made repeatedly. In 1829, Döbereiner published the «Law of Triads»: the atomic mass of many elements is close to the arithmetic mean of two other elements close to the original one in chemical properties (strontium, calcium and barium; chlorine, bromine and iodine, etc.). The first attempt to arrange the elements in order of increasing atomic weights was undertaken by Alexandre-Émile Béguyer de Chancourtois (1862), who placed the elements along the helix and noted the frequent cyclic recurrence of their chemical properties along the vertical axis. Neither of these models attracted the attention of the scientific community.

In 1866, chemist and musician John Alexander Reina Newlands suggested his version of the periodic system «Law of Octaves» looked a bit like Mendeleev's one. However, it was compromised by the author's persistent attempts to find mystical musical harmony in the table. In the same decade, several more attempts were made to systematize chemical elements. Julius Lothar Meyer was very close to the final version (1864). He published a table containing 28 of the 56 know elements

using valency as the basis for periodicity. Dmitry Mendeleev published his first diagram of the periodic table in 1869 in the article «The Correlation of Properties with the Atomic Weight of Elements» (in the Journal of the Russian Chemical Society). A bit earlier he sent a scientific announcement of the discovery to leading chemists of the world. This table included all the 61 known elements and allowed chemical properties/valency to dominate over atomic weight. He challenged some of the know atomic weights and predicted that there were certain elements still to be discovered.

As has been mentioned, March 1, 1869 is considered as the day of the discovery of the Periodic Law. That day Dmitry Mendeleev completed his work on «The experience of a system of elements based on their atomic weight and chemical similarity.». Meyer published an updated version of his table, which was very similar to that of Mendeleev, in December, 1869.

In the early days, both Mendeleev and Meyer were honored for their discovery of the "periodic relations of the atomic weights", sharing the Davy Medal of the Royal Society in 1882. Nowadays, Mendeleev is almost universally accepted as the originator of the Periodic Table of the Elements, perhaps because he included all known elements and because he used the Table predictively. Subsequently, the unknown elements he had predicted, gallium (1875), scandium (1879) and germanium (1887) were discovered and had the properties he predicted for them.

According to legend, the idea of a system of chemical elements came to Mendeleev in a dream, but it is known that when asked how he discovered the periodic system, the scientist replied: «I've thought about it for twenty years, but you think: he was sitting and suddenly ... it's ready».

From Classification to Law, from Law to System and finally from System to Table

The Periodic Table (System) was discovered in an era when atomic structures and electrons where not known, and equipment to purify and separate elements was still primitive. The discoveries of Mendeleev, Meyer and others are therefore to be seen as immense. After the first International Conference of Chemists in 1860 (Karlsruhe), which both Mendeleev and Meyer attended, it became clear that a number of scientists had noted some regularities between chemical elements. The discoveries published in 1869 by Mendeleev, first in a vertical order, later that year in a horizontal arrangement, were preceded by discoveries of similar "regularities" from Béguyer de Chancourtois, Newlands, Odling, Hinrichs and Lothar Meyer. Only Meyer produced a quite similar tabular arrangement, in fact just after Mendeleev. There is little discussion that Mendeleev published his system noting that there was a periodic classification, i.e. the periodic law and the systematic arrangements of the elements, including some of the not yet discovered elements for which he even predicted chemical properties. Despite the fact that some of these predictions were incorrect and that in his system there was no place for the Noble Gases, he is still generally accepted as the chief architect, since he discovered the "system"; only later it was changed to "Table" as we now use in Periodic Table of Elements. Remarkable, the word "System" is still used as in "Periodic System" in a number of languages, e.g. Danish ("Periodiske system"), Dutch ("Periodiek systeem") and German ("Periodensystem"), just as Mendeleev and Meyer used it in their papers.

Discovery of new elements of the periodic table of elements

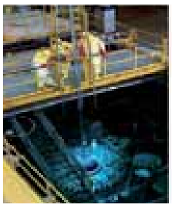
After the discovery in 1940-41 of the first artificial elements – neptunium and plutonium – the problem of the boundaries of the periodic table, the nuclear and chemical properties of the extremely heavy nuclei turned out to be of fundamental interest for natural scientists. Studies have now been carried out for many years in the major research nuclear centres in Germany, the USA, Japan, France, China and in the Flerov Laboratory of nuclear Reactions of the Joint Institute for Nuclear Research in Dubna, Russia.

By the beginning of the 1950 all available cells in the Periodic table of chemical elements had been filled and 8 transuranic elements have been synthesized. New elements were synthesized by the successive capture of neutrons by uranium nuclei in nuclear reactors, or by prompt capture of 15 – 20 neutrons in thermonuclear explosions.

A fundamentally new approach to the synthesis of elements in fusion reactions of heavy nuclei was proposed independently by Professors A. Ghiorso and G. Seaborg at the Berkeley National Laboratory, USA and by Professor G. Flerov in the Laboratory No. 2 of the Academy of Sciences in Moscow, USSR (now it is the National Research Center «Kurchatov Institute»).

On the initiative of Prof. G. Flerov the Laboratory of Nuclear reactions was founded in the Joint Institute for Nuclear Research (JINR), organized at Dubna near Moscow in 1956. The new laboratory was equipped with a heavy-ion accelerator U300. This was the start of a new direction in nuclear physics – heavy ion physics.

The International Unions of Pure and Applied Physics (IUPAP) and Chemistry (IUPAC) recognized the priority of Dubna in the discovery of elements 102-105 and marked the great contribution of JINR in the discovery of elements 106-108. In 1997 at the general Assembly of IUPAC element No 105 was named "Dubnium" as a sign of recognition of the key role of the Laboratory of Nuclear Reactions in the outlining of the scientific strategy and synthesis of superheavy elements. Like Berkelium and Dubnium, the element 110 Darmstadtium honors the city of Darmstadt (Germany) which houses the Helmholtz Centre for Heavy Ion Research GSI where 6 new elements (107 – 112) had been discovered.



By the end of the last century, 20 artificial transuranic elements had been discovered. It was found that the nuclear stability and the probability of formation of transuranic elements decrease dramatically with increasing atomic number. It was thought that even a modest advance into the region of even heavier elements would lead to the limit of their existence.

By the end of the 1990s, the scientists in the Dubna Laboratory of nuclear reactions managed to make a break-through in the synthesis of superheavy elements and in the understanding of the problem of their stability. Due to the achieved high efficiency of heavy ion beams acceleration and the considerable improvement of the experimental methods, the new elements with atomic numbers 113 - 118 were synthesized for the first time.

For the element with atomic number 113 the discoverers at RIKEN Nishina Center for Accelerator-Based Science (Japan) proposed the name Nihonium and the symbol Nh. Nihon is one of the two ways to say "Japan" in Japanese, and literally mean "the Land of Rising Sun".

For the element with atomic number 114 the discoverers proposed the name Flerovium and the symbol Fl. For the element with atomic number 115 the name proposed was

Moscovium with the symbol Mc. These names are in line with tradition of honouring a place or geographical region and are proposed jointly by the discoverers at the Joint Institute for Nuclear Research, Dubna (Russia), Oak Ridge National Laboratory (USA), Vanderbilt University (USA) and Lawrence Livermore National Laboratory (USA). For the element with atomic number 116 the name proposed is Livermorium with the symbol Lv. This is again in line with tradition and honours the Lawrence Livermore National Laboratory (1952).

For the element with atomic number 117 the name Tennessine with the symbol Ts was accepted. Tennessine is in recognition of the contribution of the Tennessee region, including Oak Ridge National Laboratory, Vanderbilt University, and the University of Tennessee at Knoxville, to superheavy element research, including the production and chemical separation of unique actinide target materials for superheavy element synthesis at ORNL's High Flux Isotope Reactor (HFIR) and Radiochemical Engineering Development Center (REDC).

For the element with atomic number 118 the collaborating teams of discoverers at the Joint Institute for Nuclear Research, Dubna (Russia) and Lawrence Livermore National Laboratory (USA) proposed the name Oganesson and symbol Og. The proposal is in line with the tradition of honouring a scientist and recognizes Professor Yuri Oganessian for his pioneering contributions to transactinoid elements research. His many achievements include the discovery of superheavy elements and significant advances in the nuclear physics of superheavy nuclei including experimental evidence for the "island of stability".

The discovery of element 118 completes the 7th row of the periodic table. Scientists associate the further progress in the synthesis of the 8th row elements with the creation in Dubna of the modern accelerator complex - the world's first factory of superheavy elements. The question of the boundaries of the Periodic table of elements remains open.

Some international events planned for 2019

Opening Ceremony, Paris 29/1/19

"Setting their table: women and the Periodic Table of the Elements", 11-12/2/19, University of Murcia, Spain
http://www.iypt2019women.es/scientific_topics.php

Opening ceremony in Russia 8/2/19

"The Periodic Table at 150", Symposium as part of IUPAC World Chemistry Congress, Paris – marking 100th Anniversary of IUPAC

Mendeleev 150: 4th International Conference on the Periodic Table, Russia
www.mendeleev150.ifmo.ru

□

What can you do in your school?

It would be a pity to miss the opportunity of IYPT to promote Chemistry and the Periodic Table in your school.

- If you do something interesting in 2019 send in a report and pictures to *Chemistry in Action!* (peter.childs@ul.ie).
- Make sure every student in yoru school gets an A4 copy of the up-to-date Periodic Table.
- Replace your old wallcharts with new ones with all 118 elements – we will give some ideas for this.
- Get some gift items with the PT on them for prizes – mugs, T shirts, mouse mats etc.
- Set up a noticeboard to profile the elements – over the course of the school year choose 3 elements/week to profile.
- Have a poster competition to illustrate the elements.
- Use Peter Davern's book of Periodic Table limericks to enrich your teaching.

□

Some thoughts on the periodic table, anticipating IYPT 2019

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Introduction

Today's 'man in the street' when asked what chemistry is about will probably say the Periodic Table, whereas 50 years ago perhaps atoms and molecules would have been his answer. He might continue that it was some Russian called Mendeleev, or some such name, who 'discovered' the table. It would be tactless to correct a statement which is mostly correct. However, this article starts by suggesting a more accurate statement.

Dimitri Mendeleev never used the term Periodic *Table!* When writing in English he wrote about the Periodic *Law* and in German (Perioden) System. These two languages were the common languages for scientific writing in the 19th century. Periodic means an event or process which occurs regularly. Related everyday words are the publication of a *periodical* and the sessions or *periods* of a school timetable. (A more specialised scientific word is the *period* of a pendulum.)

Oddly chemistry has another meaning for the word periodic but with different pronunciations, which sound like *pieriodic* table and *pairiodic* acid. The latter is H_5IO_6 in which iodine has the Group 17 (formerly Group VIIB) oxidation number +7. Chlorine, another element in the group, has the analogous perchloric acid $HClO_4$, where chlorine has oxidation number +7.

Much more arguable is whether 'discovered' is appropriate as this suggests finding something which already exists; creation says nothing about a regular layout, which is in rows and columns in most tables. Personally I like formulation since this suggests a human input in a regular pattern, a kind of formula. I say no more!

The United Nations has declared 2019 to be International Year of the Periodic Table (IYPT). Primarily this is to mark the 150th anniversary, or sesquicentenary, of the first recognisable periodic table formulated in 1869 by Mendeleev (Figure 1). This article sketches the changes over these years using 5 examples, arranged chronologically, to illustrate these changes.

1869
When was the first Periodic Table?

The image in Figure 1 is of a miniature sheet* produced in Russia to mark the centenary of the first periodic table.
(* A miniature sheet is aimed at philatelists. Either the whole sheet or merely the stamp with its perforated edges can be postally used.)

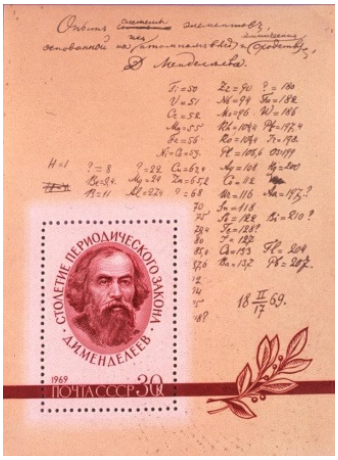


Figure 1: The centenary stamp of the Periodic Table

It shows Mendeleev's jottings of an embryonic table on 17 February 1869 (OS). The most untidy section has been cunningly concealed by the stamp. When giving exact dates it must be remembered that Russia was then using the Julian calendar, which was 12 days behind the Gregorian calendar used in Great Britain and Germany. (This also explains why the Orthodox Christmas is on January 6th, later than the 25th December used in the West.)

An elite group of mainly Russian chemists heard about Mendeleev's new idea on 22 February. So this is the first day when Mendeleev's idea was shared in public. Clearly a German was present because shortly afterwards, the basic 8 points were published in a German journal. (*Zeitung für Chemie* 1869 vol.12 p.405-406) Does the written version in a foreign language for all to read, have a stronger claim to being the first periodic table? Certainly the initial year was 1869, probably March or April, so justifying 2019 being the 150th anniversary.

The sixth point, in translation from the German, reads: *'We must expect the discovery of many yet unknown elements, for example, elements analogous to aluminium and silicon, whose atomic weight should be between 65 and 71'*. Explanations can be disagreed with but prediction is much more risky, since future discoveries can disprove it.

1875
A predicted, but unknown, unknown element discovered

6 years later French chemist Paul Emile Le Coq de Boisbaudran, who was unaware of Mendeleev's work, was studying a small sample of an 'impurity' obtained from a zinc sulphide ore. He was using the relatively recent technique of atomic spectroscopy, hoping to discover a new element which would enhance his scientific status. He observed two previously unobserved spectral lines. He wisely obtained a larger sample with which to examine the element's properties before submitting his results to the French chemical periodical *Comptes Rendus.* He showed national loyalty by naming the supposed element Gallium after Gallia, Latin for France. Some weeks later when Mendeleev read this paper, he identified Gallium as his eka-Aluminium as evidenced by Table 1 below.

Table 1 Mendeleev's prediction of eka-aluminium (gallium)

	Eka-aluminium	**Gallium**
Atomic weight	About 68	69.9
Valency	3	3
Density g/cm^3	**6**	**5***
Formula of oxide	Ea_2O_3	Ga_2O_3
Density of oxide g/cm^3	5.5	5.83
Nature of oxide	Amphoteric	Amphoteric
Melting point ^oC	Quite low	29
Volatility	Volatile	Involatile Bpt > 2000 ^oC

(*Mendeleev had the temerity to query this value for the density so de Boisbaudran obtained a larger purer sample, which yielded a value of 5.9 g/cm^3 for gallium's density! This value was a dramatic support for the discovery of an unknown element, with properties predicted for those of another element.)

The Frenchman de Boisbaudran was thus the first supporter of Mendeleev. Within another decade Lars Frederick Nilsen had discovered Scandium and Clemens Winkler Germanium, both with properties close to Mendeleev's prediction from his periodic law. (Sir) William Crookes, the influential editor and publisher of the weekly *Chemical News*, had spotted Mendeleev's article in the little known French magazine *Moniteur Scientifique* of July 1879, had it translated and published over 19 weeks starting in November 1879, when it mentioned the discovery of Scandium earlier that year. (*Chemical News* Vol XL No.1042 p231) It is an impressive spread of knowledge in one calendar year.

1894 - 1900
Argon and other new gases isolated

Physicist Lord Rayleigh (Sir John Strutt) and chemist William Ramsay were two meticulous scientists who worked together in London. Rayleigh made numerous measurements of the mass of nitrogen, in a glass globe, which had been obtained from dry air by removal of carbon dioxide and oxygen. He also made nitrogen by chemical reaction from urea etc. He then measured the mass of 'chemical nitrogen' in the same globe under the same conditions. The mass of 'air nitrogen' was 2.3102 ± 0.0003g and of 'chemical nitrogen' was 2.2985 ± 0.0005g. With this minute but consistent variation in masses of the nitrogen from 2 sources they reasoned that the sample from air contained some other unknown, heavier gas. This was confirmed by liquefying the 'air nitrogen' which was found to contain just over 1% of a gas with a higher boiling point. Further detailed measurements showed that this gas was totally unreactive, even towards molten alkali, liquid sodium and concentrated acid. They announced these stunning results at the annual meeting of the British Association in 1894, many of whose members refused to believe that an inert element was possible. No wonder that in 1904 Ramsay became the first Briton to win a Nobel Chemistry prize.

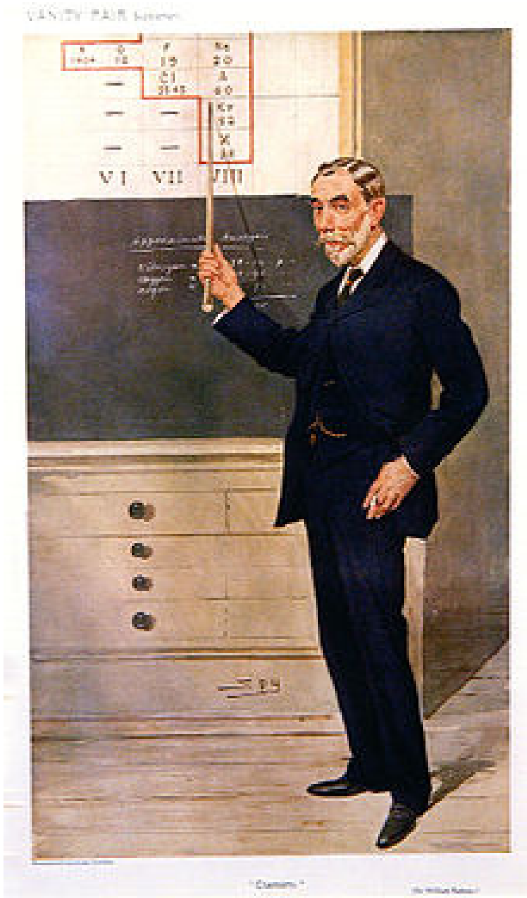


Figure 2: Drawing of William Ramsay and the new group . From Vanity Fair by Leslie Ward. Note the single letter symbols A and X

Further experiments and calculations showed that the *molecular* weight of the gas was 40. More measurements suggested the gas was monatomic hence the *atomic* weight was also 40. Mendeleev rejected this because there was no space in the periodic law for an element between Potassium and Calcium (atomic weights 39 and 40), nor for a new vertical group. Over the next 3 years Ramsay identified minute amounts of other inert gases in air, which he identified by their spectra. Then in 1900 Ramsay suggested that these unreactive gases could form a totally new *group.* Mendeleev then changed from opposition, because there was no space for Argon in his table, to stating that *'the new group is a glorious confirmation of the general application of the periodic law'*. The periodic table had expanded to accommodate the new elements in a new group.

There seemed to be hardly any opposition to argon, with an atomic weight of 40, appearing before the lighter potassium. There seems to be no record of Mendeleev challenging the atomic weight of argon whereas he has earlier disputed the atomic weight of Tellurium.

1914
Periodic Table justified

After initial scepticism in 1870s, chemists had increasingly accepted Mendeleev's periodic law. When elements were listed in rows in order of increasing atomic weight then regularly, that is periodically, elements with similar properties occurred in the columns.

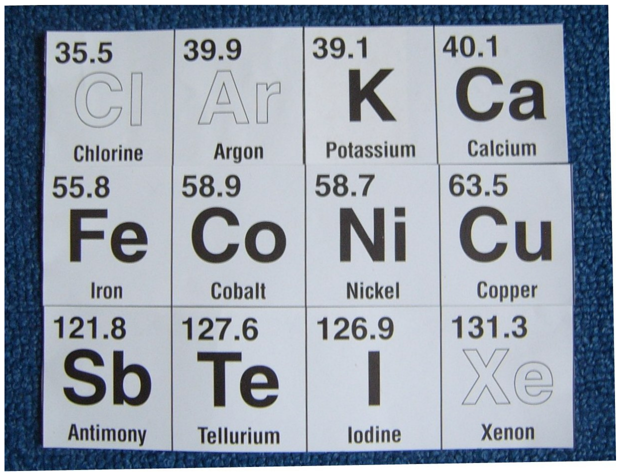


Figure 3: Some of the anomalies based on atomic weight

One difficulty was that the generally accepted atomic weight of Tellurium was more than that of Iodine, yet their chemical properties placed them in reverse order. Mendeleev thought that the atomic weight of Tellurium was wrong, hence his assistant Bohoslav Brauner checked this value, albeit in vain.

Table 2 Atomic weights of a block of 4 elements

Mendeleev (1891) *Principles of Chemistry*	Generally accepted figures by others (1880)
Se 79 Br 80	Se 79 Br 80
Te 125 I 127	Te 128 I 127

The same problem occurred with Cobalt and Nickel but their atomic weights were so similar that these could just be inaccurate values. Chemists merely accepted that an order based on matching chemical properties was more important than atomic weight numbers.

Henry Moseley was an industrious and skilled physicist, who initially worked under Rutherford

(1910-12). Then Moseley, aided mathematically by Charles Galton Darwin, a descendant of Charles, extended the work of an amateur physicist Charles Barkla. They discovered that when high energy electrons bombarded a metal they produced X-Rays, whose frequency was specific for the metal. Moseley working alone, studied the elements from calcium to zinc, omitting scandium. The results were stunning. There was a regular increase in 'property order' of a pair of X-Ray lines as shown in the photograph (Figure 4 from *Phil Mag* 27 (1914) 703-713). Moseley's results were the first measurable physical property which justified the order of the elements, which soon led to the term atomic number.

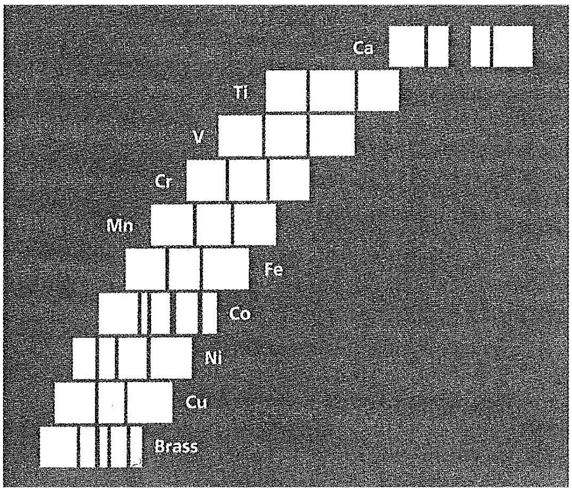


Figure 4: Moseley's results

My graph below (Figure 5) re-plots Moseley's experimental data of wavelength against atomic number and against atomic weight. (See also the *SSR* article Dec 2015 359, p.979) The former is exactly linear whereas the latter is only a best-fit line. Note particularly the point for Nickel, which is on the atomic number line but to the left on the other.

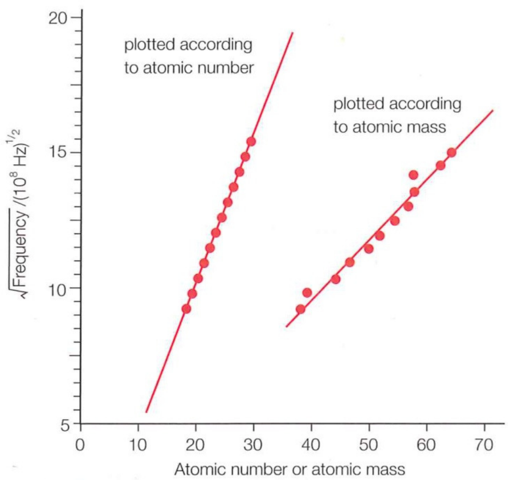


Figure 5: Atomic number versus Atomic mass

Moseley then extended his research for all metals up to atomic number 79 (Gold). This identified the atomic numbers awaiting discovery in the next 20 years and provided a rapid method of testing a claim for a new metal element. It also showed that Uranium had the highest known atomic number. The next two sections show how the discovery of two particular elements, relate to these ideas. Moseley was nominated both for physics and chemistry Nobel prizes but after patriotically volunteering for the army in 1914, he was killed at Gallipoli in 1915 and thus became ineligible. Nobel prizes cannot be awarded posthumously.

1925
Discovery of Rhenium

The link between the element Rhenium and the periodic table is the opposite to that of Gallium, the first element discussed in this article. The discovery of the predicted element Gallium **supported** the existence of the periodic table. The discovery of Rhenium was **driven by 'gap filling' of** the periodic table, the desire to find one of only 5 elements still undiscovered among the 92 elements then regarded as the total number following Moseley's work. Indeed it was later recognised as the last stable, i.e. non-radioactive, element to be found.

In 1920 there were still two gaps, atomic numbers 43 and 75, directly below Manganese. The element atomic number 75 was found by a German couple, Walter and Ida Noddack. They named it Rhenium after the River Rhine close to where they worked. Its symbol is Re, as Rh was already used for Rhodium. The Noddacks also claimed to have isolated element number 43, which they named Masurium, but their discovery was later shown to be incorrect. It was hardly surprising that they had not found it because it is not found in nature. It had to created in 1937 synthetically. This is why it is named Technicium, symbol Tc and it is radioactive.

Rhenium is exceptionally rare, only 0.001 parts per million, meaning that 1 million kg (1000 metric tons) of the earth contain only 1 g Rhenium! 660 kg of the ore molybdenite were needed to make this much Rhenium. No wonder there were hundreds of processing steps needed to obtain the element. It is almost double the price of Gold. This is partly because of its rarity but also because of its exceptional toughness and a very high melting point of 3159 ^{o}C that it has some specific uses, such as the turbine blades of fighter plane engines.

1974
Seaborgium created

During the 1940s the final two missing elements from 1-92, Astatine and Promethium, were synthesised. In the same decade the 'no more than 92 barrier' was broken by the formation of 5 elements of atomic numbers 93-97. All elements with atomic number over 92 are manmade and radioactive. Heavy atoms, starting with Uranium, are bombarded by neutrons and increasingly by heavy ions. It becomes progressively harder to create even heavier atoms. Seaborgium was first made by bombarding Californium-249 with Oxygen-18 ions. Both of these particles are difficult to produce.

For the 'lighter' atoms after Uranium, a visible or weighable amount of product has been made. Production of yet heavier atoms is inferred from other measurements. Only three laboratories in the world have the specialised facilities to make these elements. These are at Berkeley in California in USA, Darmstadt in Hesse, Germany and Dubna in Russia. At element 118 the 6p shell is complete, so this could be the final element in this expansion of the periodic table.

The chemical properties of the Seaborgium were found to those of a transition metal and similar to Tungsten and Molybdenum, the two elements above it in the periodic table. Amazingly this was found using only seven atoms! Now that is microscale chemistry!

Naming the element

I have chosen element 106, Seaborgium (Sg), as the sample element to discuss naming new elements, as it illustrates the stepwise procedure of naming an element. First a new substance must be created and recognised by others as an element. Next the atomic number is determined from its properties. Often the next stage is assigning it a temporary name based on its atomic number, so element 106 would be un-nil-hexium, that is 'one-nil-sixium'. Sometimes agreeing the name is the most controversial stage in its discovery. Some names of these last 20 elements follow an earlier method, as above, in which the name is linked to where the element was created.

As all the elements are manmade it decided to allow them to be named after famous scientists, provided they were dead. Glenn Seaborg, Nobel prize-winner in chemistry, had led a research group at Berkeley responsible for creating 6 elements after uranium. Hence he was an ideal candidate except that he was still alive. Some years after the name Seaborgium had been accepted, opposition was voiced to the name and after contorted arguments the name was ratified, aided by strong American pressure. (Much more detail is given on www.2.lbt.gov.)

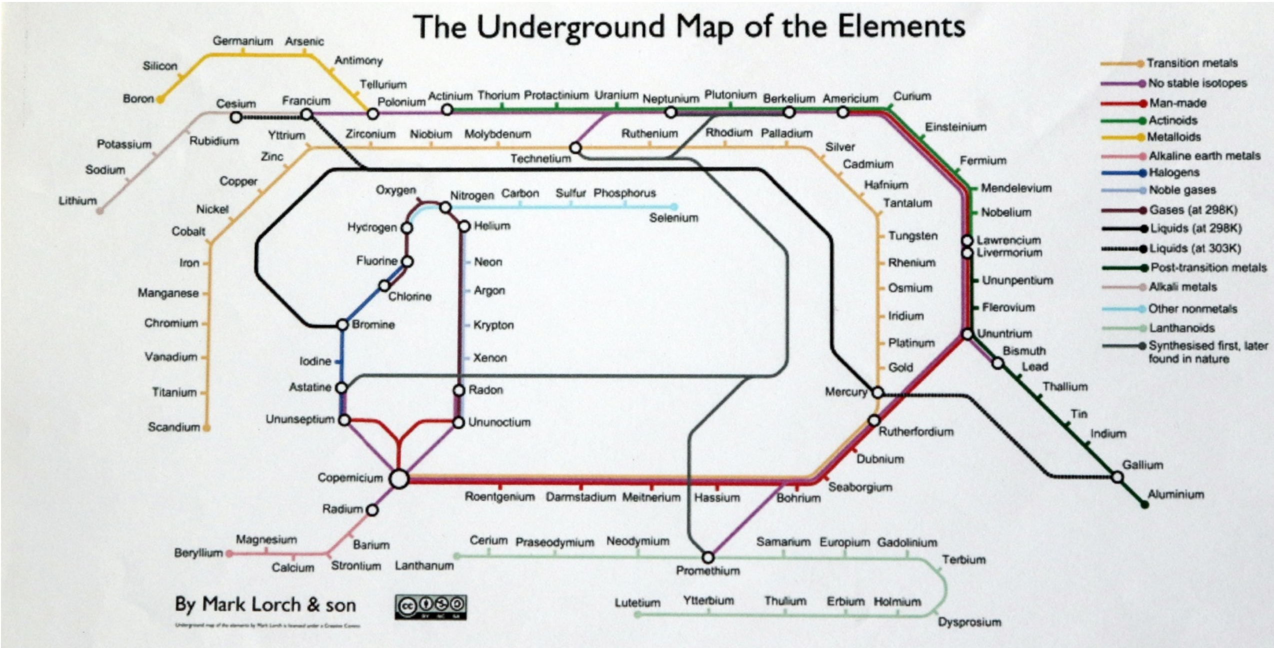
In this periodic table extension we have **sequential** gap filling, which differs from the more **random** appearance of the 1920-1945 gap filling. One could also say that with these last 20 elements less and less is obtained from more and more elements!

2019 Final comment

On reading through this article I noticed that the four elements I had chosen were from Great Britain, France, Germany and the United States, which countries discovered the most elements during the period 1869 – 2019, the first 150 years of the periodic table. Will there be any more elements ... we will see. You might find the unusual Periodic Table below, based on the London tube map, of interest. It is thought-provoking.

Biography:

Gordon Woods is a Fellow of the Royal Society of Chemistry. He was a chemistry teacher for many years ending up as Head of Science at an English independent school. Now retired he has more time to extend his extensive collection of periodic tables, some obtained through contacts made at overseas conferences including a wall-chart in the Irish language.



This version of the Periodic Table is available in 91-61 cm size from allposters.ie for €18.99 plus €6.90 shipping to Ireland (€1 extra for each extra poster). It is often discounted so you may get it for less. This should be supplemented with a Periodic Table showing names and symbols and atomic masses. A nice one available from https://www.fruugo.ie/periodic-table-elements-maxi-poster/p-16713473-36569056?ac=kelkoo&language=en&gclid=Cj0KCQjwsMDeBRDMARIsAKrOP7FDNfFjhkDsx8SK6dOEMxuc94e_kZByl-1pZEihSjNauYw08ZKccc4aApi4EALw_wcB at €5.95 plus €5 shipping for multiple copies.

Berzelius' Discovery of Selenium

“Undersökning af en ny Mineral-kropp, funnen i de orenare sorterna af det vid Fahlun tillverkade svaflet.” [1]

Jan Trofast

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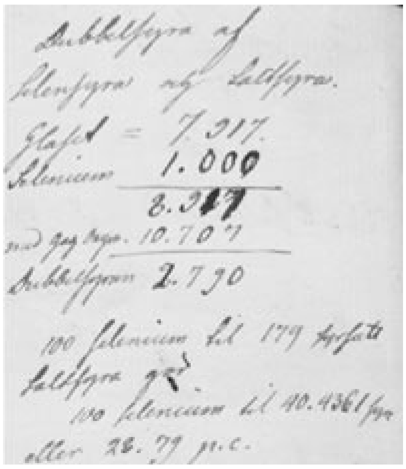
Swedish Discoveries of New Elements

Sweden has a long tradition of mining and assaying. As early as the mid–17th century, Sweden had a chemical laboratory devoted to the study of minerals and ores and the art of mineral analysis. The resulting research was often used to improve mining, iron, and steel production. During the first decades of the 19th century, Jacob Berzelius’ laboratory in Stockholm became the center of these activities. From 1803 to 1843, Berzelius (1779–1848) and his Swedish pupils J.A. Arfvedson, N.G. Sefström, and C.G. Mosander discovered and characterized no less than 10 new elements. Many of these discoveries were made using a simple instrument—the blow pipe.[2]



Determination of the composition of selenic acid. From Berzelius’ laboratory notebooks, Ms. Berzelius, 24:6, Royal Swedish Academy of Sciences, Stockholm.

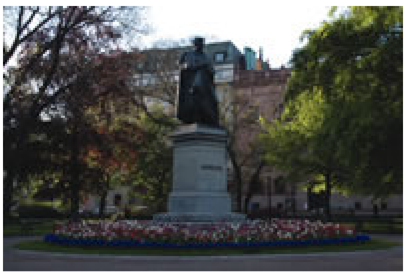
Elements Discovered by Swedish Chemists and Miners

Georg Brandt	cobalt	1735
Axel Fredrik Cronstedt	nickel	1751
Johan Gottlieb Gahn	manganese	1774
Carl Wilhelm Scheele	oxygen	1770s
Peter Jacob Hjelm	molybdenum	1782
Anders Gustaf Ekeberg	tantalum	1802
Jacob Berzelius	cerium	1803/4
	selenium	1818

	zirconium	1824
	silicon	1824
	thorium	1828
Johan August Arfvedsson	lithium	1817
Nils Gabriel Sefström	vanadium	1830
Carl Gustav Mosander	lanthanum	1839
	erbium	1843
	terbium	1843
Lars Fredrik Nilsson	scandium	1879
Per Theodor Cleve	holmium	1879
	thulium	1879

The Gripsholm Chemical Factory

The first major chemical factory in Sweden was established in 1800 in a former distillery adjacent to the Castle of Gripsholm. Following drawn-out negotiations, the factory owners were granted the right to produce alcohol for the manufacture of acetic acid. At that time, one of the major uses of acetic acid was for the production of white lead paint. However, a poor business climate, unfair competition, and incompetent technical management forced the Gripsholm factory into liquidation in 1816. Fortunately, the factory was soon acquired at an auction by some businessmen and the chemists Johan Gottlieb Gahn (1845–1818), H.P. Eggertz, and Jac. Berzelius. Gahn's personal commitment to the business, persuaded Berzelius to join. Thus, three distinguished chemists became linked to the company. Berzelius had been one of the experts in settling disputes concerning the manufacturing rights of white lead. In a long letter to Gahn in late 1816, Berzelius discussed the chemical processes for the production of acetic acid and the improvements he considered necessary.[3]



Statue of Jacob Berzelius in Berzelii Park, Stockholm, Sweden.

As a devoted scientist, Berzelius was in principle disinterested in business, but in this particular case, he saw the potential to use scientific knowledge to establish a robust and profitable industrial business. He participated actively in matters in which he considered himself capable of contributing. A typical example is the isolation of the new element selenium from the bottom sludge of the lead chambers used for sulfuric acid production.[4]

The Discovery of Selenium

Berzelius and Gahn met at Gripsholm in August 1817. Berzelius spent more than one month there, studying, *inter alia*, technical issues related to the production of sulfuric acid and nitric acid (aqua fortis). The former owner of the factory, M. Bjuggren, had noted that a reddish sludge occurred in the lead chamber, only when pyrite (an iron sulfide) from the mine in Falun was used. The sludge was believed to be an arsenic compound and hence the Falun pyrite was avoided. However, Gahn and Eggertz both came from Falun and considered it interesting and important to use Falun pyrite. Therefore, Gahn and Berzelius—being the experts—tried to analyze the reddish sludge. By roasting 200 kg of sulfur they obtained about 3 g of a precipitate. Their subsequent chemical analysis of the sample indicated the possible presence of tellurium (discovered in mines in Transylvania in the 1780s). However, Berzelius doubted this result since tellurium had never been found in minerals from Falun. Nevertheless, he wrote about tellurium in letters to his close friends Alexandre Marcet and H.G. Trolle Wachtmeister in 1817.[5] In early 1818, Berzelius repeated the experiments in his Stockholm laboratory and concluded that the sludge must contain a new element.

The new element had properties of a metal, and was similar to sulfur, initially suggesting it to be a new species of sulfur. In its metallic state, it had a brilliant grayish lustre. When heated by a candle using blowpipe analysis, it burned with an azure-blue flame and emitted a strong odor of horseradish, typical of tellurium. This smell may initially have fooled Berzelius and Gahn.

Klaproth had assigned tellurium (Latin: tellus, earth) to Müller von Rechenstein's new element in 1784. Berzelius chose the name selenium (Greek: selene, moon) for the new element, noting its resemblance to tellurium. The naming was described (in Swedish):
. . . skola beskrifvas vara en egen förut okänd brännbar mineralkropp, hvilken jag har kallat Selenium af ∑εληνη, måna, för at dermed utmerka dess nära slägtskap med Tellurium.[6]

Jacob Berzelius (1779-1848) from a daguerreotype taken by J.W. Bergström 1844. Royal Swedish Academy of Sciences, Stockholm. ©Lennart Nilsson, photography/Scanpix.

Berzelius was able to prove that selenium was indeed a new element after establishing its properties, as well as the properties of the compounds it formed with metals, oxygen, hydrogen, sulfur, phosphorus, and different salts. Due to the similarity between selenium and sulfur and tellurium, Berzelius carefully investigated the properties of these elements (e.g., their ability to form gaseous compounds and their reactivity towards oxygen and metals). In the appendix to the third volume of his *Textbook in Chemistry*, published in 1818, Berzelius gave the formulas of 90 different selenium compounds (58 selenias, 20 selenietum, and 12 hydroselenietum) together with the atomic weight of the element itself. A remarkably high number of compounds!

Berzelius tried to reduce the selenium salts to the pure metal in different ways, but found it difficult to obtain it in a pure enough form for an atomic weight determination. The impurities, mainly mercury, copper, tin, lead, zinc, arsenic, and iron were difficult to remove. Eventually, he managed to obtain beautiful crystals of selenium, still preserved in the Berzelius collection in Stockholm, that he used to determine the atomic weight. These crystals were featured on a stamp commemorating the 200th anniversary of the Karolinska Institutet, the medical school founded by Berzelius and others and where Berzelius was a professor for 25 years.

According to Berzelius, selenium formed two oxides—selenic oxide and selenic acid. His analysis of selenic acid gave the following:

	Content of each element (by mass %)	Content % by mass of oxygen per 100 % selenium
Selenium	71.261	100
Oxygen	28.739	40.33

Selenic acid corresponds to what we today denote as selenious acid (H_2SeO_3). Berzelius reported its anhydride (SeO_2) and assumed the selenic acid contained two oxygen atoms per selenium. Today, this compound theoretically contains 28.84 percent by mass oxygen—a remarkably accurate analysis by Berzelius in 1818![7]Berzelius determined the atomic weight of selenium to be 495.91 (O=100), corresponding to 79.34 (O=16).[8] The value today is 78.96, which again shows the accuracy of his chemical analysis.

His analysis of seleniuretted hydrogen (hydrogen selenide) gave the correct formula:[9]

	Content of each element (by mass %)	Atomic mass	Corresponding formula
Selenium	97.4	495.91	= Se
Hydrogen	2.6	13.27	= 2H

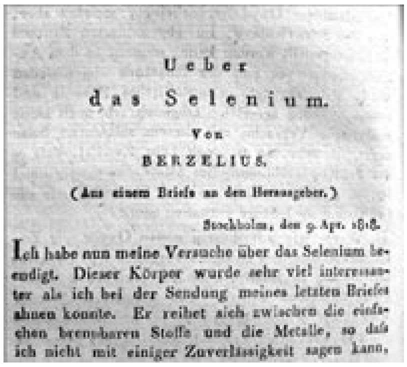
Since selenium possessed a brilliant metallic lustre, Berzelius thought it should be considered a metal. He subdivided the metals into two classes, those that are capable of forming acids, and those that act as bases: ". . . I place selenium among the acidifiable metals near arsenic . . . ."[10]

Berzelius experienced first-hand the toxicity of the gaseous selenium compounds, particularly selenuretted hydrogen (hydrogen selenide). As a medical doctor, Berzelius carefully described the sensation:

The gas has the odour of sulphuretted hydrogen gas [hydrogen sulfide], when it is diluted with air; but if it is breathed less diluted, it produces a painful sensation in the nose and a violent inflammation, ending in a catarrh, which continues for a considerable length of time. I am still suffering from having breathed, some days ago, a bubble of selenuretted hydrogeous gas, no larger than a small pea. Scarcely had I perceived the hepatic taste in the fauces, when I experienced another acute sensation: I was seized with a giddiness, which, however, soon left me, and the sensibility of the schneiderian membrane was so far destroyed that the strongest ammonia produced scarcely any effect upon the nose.[11]

Berzelius' first announced the new element in a letter of 27 January 1818 to J.S.C. Schweigger in Germany, followed by a letter in April for immediate publication in his *Journal für Chemie und Physik*, XXI (1817), 342–344. In February, he sent descriptions to scientific friends including C.L. Berthollet[12] (published in *Annales de Chimie et de Physique*), A. Marcet (published in *Annals of Philosophy*) and H.G. Trolle Wachtmeister.[13] The comprehensive investigation of the discovery of selenium was finalized in April 1818 and published in *Afhandlingar i Fysik, Kemi och Mineralogi*, VI, (1818), 42–144.[14]

These *Afhandlingar* (*Dissertations*) were published in six volumes from 1806 to 1818 by Berzelius and a few of his friends as a practical way of publishing scientific results without being in conflict with other Swedish journals at the time. *Afhandlingar* contain the remarkable scientific achievements made by Berzelius during his most productive years. The discovery of selenium was also included in his *Lärbok i Kemien* (*Textbook in Chemistry*), III (1818), 410–417, although the element had already been described in the second volume of the textbook. The discovery was further reported to the Royal Academy of Sciences in Stockholm by publications in its transactions for 1818.15 Selenium was first isolated from Falun pyrite, but Berzelius also searched for selenium in other minerals. He found 38.5 percent selenium in "selen-copper" or selenite (Cu_2Se, later called Berzelianite) and also in eukairite (AgCuSe) from Skrikerum in Sweden.


Ueber

das Selenium.

Von

BERZELIUS.

(Aus einem Briefe an den Herausgeber.)

Stockholm, den 9. Apr. 1818.

Ich habe nun meine Versuche über das Selenium beendigt. Dieser Körper wurde sehr viel interessanter als ich bei der Sendung meines letzten Briefes ahnen konnte. Er reihet sich zwischen die einfachen brennbaren Stoffe und die Metalle, so daß ich nicht mit einiger Zuverlässigkeit sagen kann,

The letter of 9 April 1818 from Jac. Berzelius to J.S.C. Schweigger was published in Journal für Chemie und Physik, bd XXI (1817), 342.

Selenium was discovered thanks to the curious, analytical, and observant mind of Berzelius at a time when he was also heavily occupied with teaching medical students and overseeing his busy chemical laboratory. Selenium is now known as a trace element, which is essential for important antioxidant systems, thyroid function, and the immune system.

The discovery of selenium—just one example of Berzelius' many accomplishments—further established his reputation as one of the world's leading chemists of the 19th century. He revised the chemical nomenclature and in 1813 introduced the atomic notation system based on the Latin names of the elements, which, in principle, is still in use. He allowed these symbols to design the number of mass units given by the atomic mass of the particular element. Using this formalism, he could construct elegant and simple empirical formulas describing the composition (in mass %) of a given chemical compound. This important innovation finally translated chemistry into the language of atomic theory. For several decades, Berzelius dominated his scientific field more than any other chemist since.

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Acknowledgement: I would like to express my gratitude to Anders Kallner and Lars Ivar Elding for their support and great interest in the work of Berzelius and his contemporaries.

Notes and References

1. "Investigation of a New Mineral, Found in the Impure Varieties of Sulphur, Manufactured at Fahlun"
2. U. Burchard, The History and Apparatus of Blowpipe Analysis, *The Mineralogical Review*, 25 (1994), 251–277.
3. Letter from J. Berzelius to J.G. Gahn 7 Oct. 1816, *Jac. Berzelius Brev*, IV:2 (1922), 140–142.
4. The laboratory notebooks describing the experiments on the discovery of selenium performed by Jac. Berzelius together with drafts to different publications on selenium are kept at the Royal Swedish Academy of Sciences, Stockholm—Ms. Berzelius 24:6; 24:8 and 27:25:1-2.
5. Letter from J. Berzelius to A. Marcet 23 Sept. 1817, *Jac. Berzelius Brev*, I:3 (1914), 155-159.
6. . . . should be described to be a characteristic, not previously known, combustible mineral body, which I have called Selenium, derived from ∑εληνη, moon, in order to indicate its

resemblance with Tellurium." Ms Berzelius 27:25:1, Royal Swedish Academy of Sciences, Stockholm.
7. In his laboratory notebook Berzelius gave the value of the oxygen content as 28.79%!
8. Jac. Berzelius et al., *Afhandlingar i Fysik, Kemi och Mineralogi*, VI, (1818), 42-144, particularly 68-74.
9. Ibid., 79.
10. Letter from J. Berzelius to A. Marcet 6 February 1818, published in *Annals of Philosophy*, XI, (1818), 447–449.
11. Letter from J. Berzelius to A. Marcet 6 February 1818. Marcet wrote on 25 March to John Bostock in order for the information to be published (*Annals of Philosophy*, XI (1818), 291–93).
12. Letter from J. Berzelius to C.L. Berthollet 9 Feb. 1818. The selenium work was published in *Annales de Chimie et de Physique*, 9 (1818), 160-180, 225–267, 337–365.
13. Letter from J. Berzelius to H. G. Trolle Wachtmeister 17 February 1818, published (ed. J. Trofast) in *Brevväxlingen mellan Herr Professoren Jac. Berzelius och Hans Excellens H.G. Trolle Wachtmeister*, part 1 (1998), 40-42.
14. A complete translation into English was published in *Annals of Philosophy*, XIII (1819), 401–412; XIV (1819), 97–106, 257–265; 420–427; XV (1820), 16–27.
15. Jac. Berzelius, *Kongl. Vetenskapsakademiens Handlingar*, (1818), 13–22.

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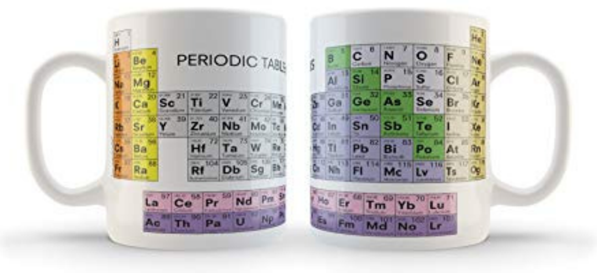
More Periodic Table Resources

The Periodic Table song updated
https://www.youtube.com/watch?time_continue=48&v=VgVQKCcfwnU

https://lyricstranslate.com/en/asapscience-new-periodic-table-song-lyrics.html

Rediscovery of the Elements
A series of 50 articles on the Rediscovery of the elements by James L, Marshall and Virginia R. Marshall in *The Hexagon*, a magazine produced at the University of North Texas. https://digital.library.unt.edu/search/?fq=str_title_serial:%22Rediscovery%20of%20the%20Elements%22

Periodic Table mugs
https://www.cafepress.co.uk/+periodic-table-of-elements+mugs



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Ytterby – the richest single source of elemental discoveries

Peter E. Childs

"The rare earths perplex us in our researches, baffle us in our speculations, and haunt us in our very dreams. They stretch, like an unknown sea before us, mocking., mystifying, and murmuring strange revelations and possibilities."
Sir William Crookes

Ytterby is a small island about 30 minutes drive from Stockholm, where there was a feldspar mine in the 18th century (*Ytterby gruva* in Swedish), which was mined to make porcelain. (https://en.wikipedia.org/wiki/Ytterby) One of the waste products of the mine was a black mineral, which aroused the interest of Carl Axel Arrhenius, a soldier with an interest in geology. He thought it might contain tungsten as it was very dense and so he sent it to his friend Johan Gadolin, a chemistry professor at the Royal Academy in Turku (Finland), to investigate.

Figure 1: A sample of gadolinite – the source of many elements
(By WesternDevil, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2527248)

"Today, a visitor to Ytterby might never realise this island was the Galapagos of the periodic table, a place whose dazzling variety gave chemists crucial insights into their field. The mine shut down years ago, and trees and weeds have since grown over it. But at least the island itself hasn't forgotten its legacy. A small plaque on a rock near the mine commemorates the discoveries made there. And some local streets are named for elements – making it perhaps the only place in the world where knowledge of the periodic table is useful for getting around town."
Sam Kean
http://www.slate.com/articles/health_and_science/elements/features/2010/blogging_the_periodic_table/ytterby_the_tiny_swedish_island_that_gave_the_periodic_table_four_different_elements.html

Figure 2: ASM plaque at the site of the Ytterby mine (By Uwezi - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=7478220)

Figure 3: *Ytterby mine, roughly 1910. Courtesy of Tekniska museet on Flickr*

Johan Gadolin identified it as a new mineral, which he called ytterbite after its source, but later it was named gadolinite in his honour. Gadolin found that the ore contained an oxide of a new element, later named yttria by a Swedish chemist Anders Gustaf Ekeberg. The element yttrium was not isolated until 1843 by H. Rose, although in 1828 Friedrich Wöhler thought he had isolated it. Unknown to them the rocks at Ytterby contained a number of rare earth elements and the black mineral became a rich source of new elements. The rare earths are chemically very similar to each other and so they tend to occur together and due to their chemical similarity, are hard to separate.

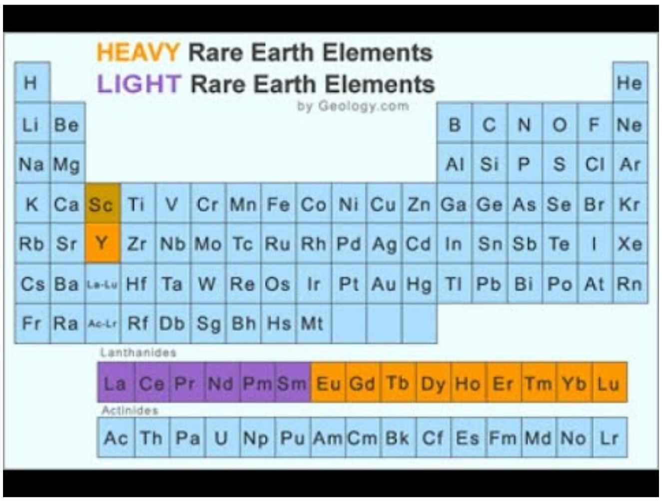

Figure 4: Periodic Table showing the heavy and light rare earth elements

Yttria was found by Gustaf Mosander to contain a mixture of elements (remember that this was before the use of atomic spectroscopy to identify elements) and he was able to separate it into three parts: pure yttria (Y_2O_3), erbia (Er_2O_3) and terbia (Tb_2O_3). Eventually Arrhenius' black mineral was found to contain no less than 9 rare earth metals: Erbium (Er), Terbium (Tb), Ytterbium (Y), Scandium Sc), Thulium (Tm), Holmium (Ho), Dysprosium (Dy), Lutetium (Lu) and Gadolinium (Gd). Four of these names come from the place of discovery, Ytterby – Erbium, Terbium, Yttrium, Ytterbium. Holmium is named after Stockholm; Thulium after an old name for Scandinavia; Scandium also after Scandinavia. The element Gadolinium (Gd) was named after Gadolin. Dysprosium is found in Erbium ores, along with Holmium, and proved difficult to isolate. It was named Dysprosium, meaning hard to get, by French chemist Paul Émile Lecoq de Boisbaudran. You can see from the Periodic Table above that the elements in the black mineral from Ytterby are the heavy rare earth elements.

Table 1 shows the dates when the elements were formally identified. Figure 5 below shows this information more visually.

Table 1: Discovery and isolation of the rare earth elements from Ytterby

Element	Discovery date
Yttrium Y	**1794**
Terbium Tb	**1843**
Ytterbium Yb	**1878**
Holmium Ho	**1878**
Scandium Sc	**1879**
Thulium Tm	**1879**
Gadolinium Gd	**1880**
Dysprosium Dy	**1886**
Erbium Er	**1901**
Lutetium Lu	**1907**

In a similar way the mineral ceria became the source of the light rare earth elements – Cerium (1803), Lanthanum (1839), Samarium (1879), Gadolinium (1880), Praseodymium (1885), Neodymium (1885) and Europium (1901).

This is a fascinating story of discovery and persistence, with many dead-ends and false trails, and makes the small Swedish town of Ytterby a place of chemical pilgrimage. This was recognised this year by EuCheMS by recognising the mine as a European historical landmark.

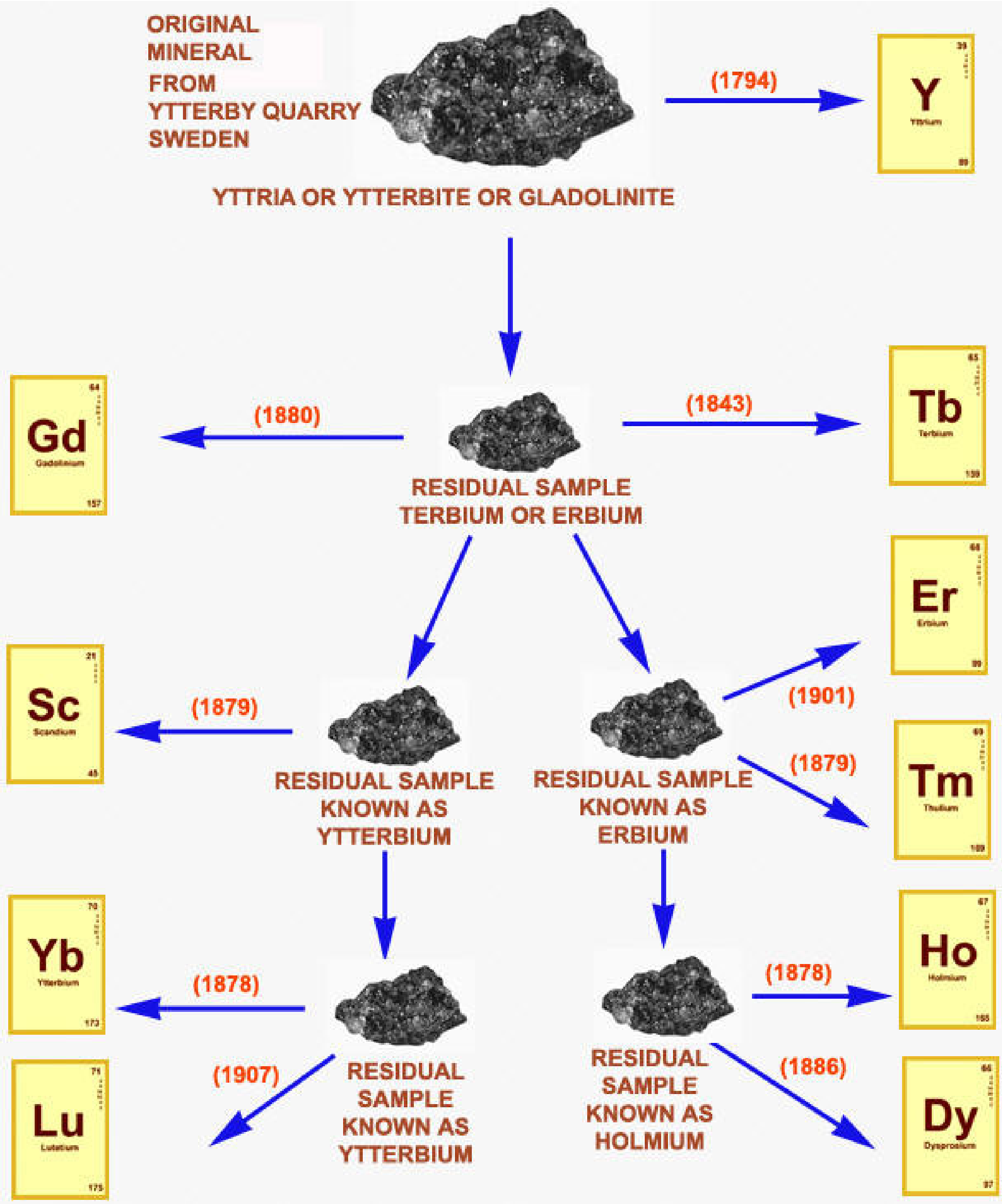

Figure 5: The chronology of the discovery of elements from gadolinite from the Ytterby mine.
Source: The Open Door Website http://www.saburchill.com/chemistry/visual/compounds/004.html
Used with permission.

Sources of more information:

The Discovery and Naming of the Rare Earths
http://elements.vanderkrogt.net/rareearths.php

Yttrium and Johan Gadolin
James L Marshall and Virginia Marshall *The Hexagon* Spring 20088-11
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Rare Earth Element
https://en.wikipedia.org/wiki/Rare-earth_element

Ch. 26 in *Discovery of the Elements* 6th Edition
M. E. Weeks 695-728
https://ia902609.us.archive.org/2/items/discoveryoftheel002045mbp/discoveryoftheel002045mbp.pdf

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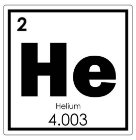
150th anniversary of the discovery of helium



Discovery

Helium, the second most abundant element in the universe, was discovered in the sun before it was found on the earth. Pierre-Jules-César Janssen, a French astronomer, noticed a yellow line in the sun's spectrum while studying a total solar eclipse in 1868. Sir Norman Lockyer, an English astronomer, realized that this line, with a wavelength of 587.49 nm, could not be produced by any element known at the time. It was hypothesized that a new element on the sun was responsible for this mysterious yellow emission. This unknown element was named **Helium** by Lockyer (after *helios* = the sun).

The hunt to find Helium on earth ended in 1895. Sir William Ramsay, a Scottish chemist, conducted an experiment with a mineral containing uranium, called clevite. He exposed the clevite to mineral acids and collected the gases that were produced. He then sent a sample of these gases to two scientists, Lockyer and Sir William Crookes, who were able to identify the Helium within it. Two Swedish chemists, Nils Langlet and Per Theodor Cleve, independently found Helium in clevite at about the same time as Ramsay.

Helium makes up about 0.0005% of the earth's atmosphere. This trace amount of Helium is not gravitationally bound to the earth and is constantly lost to space. The earth's atmospheric Helium is replaced by the decay of radioactive elements in the earth's crust. Alpha decay, one type of radioactive decay, produces particles called alpha particles. An alpha particle can become a Helium atom once it captures two electrons from its surroundings. This newly formed Helium can eventually work its way to the atmosphere through cracks in the crust.

Helium is commercially recovered from natural gas deposits, mostly from Texas, Oklahoma and Kansas. Helium gas is used to inflate blimps, scientific balloons and party balloons. It is used as an inert shield for arc welding, to pressurize the fuel tanks of liquid fuelled rockets and in supersonic wind tunnels. Helium is combined with oxygen to create a nitrogen-free atmosphere for deep sea divers so that they will not suffer from a condition known as nitrogen narcosis. Liquid Helium is an important cryogenic material and is used to study superconductivity and to create superconductive magnets. The Department of Energy's Jefferson Lab uses large amounts of liquid Helium to operate its superconductive electron accelerator.

Helium is an inert gas and does not easily combine with other elements. There are no known compounds that contain Helium, although attempts are being made to produce helium difluoride (HeF2).

(Above sourced from: https://education.jlab.org/itselemental/ele002.html)

The Noble Gases

When Helium was discovered it was the first noble gas to be found and there was no place for it in the Periodic Table. It didn't fit anywhere! Later Lord Rayleigh and William Ramsay liquefied Nitrogen and found a small residue of an unknown substance in nitrogen from the air but not from a chemical source. They found that this residue contained the gases Argon, Neon, Kyrpton and Xenon identified by their unique atomic spectra. They also obtained pure Helium from clevite and by doing so created a new group, group 0 (now group 18) of the Periodic Table. Helium should really be named helion to fit with the other noble gas names. In 1902 Mendeleev had to modify his table to include the new group. Radon was first identified in 1898 by Friedrich Ernst Dorn, and was named *radium emanation*, but was not considered a noble gas until 1904 when its characteristics were found to be similar to those of other noble gases. At the Nobel Prize ceremony in 1904, J. E. Cederblom, then president of the Royal Swedish Academy of Sciences, said *"the discovery of an entirely new group of elements, of which no single representative had been known with any certainty, is something utterly unique in the history of chemistry, being intrinsically an advance in science of peculiar significance"*.
Element 118, Oganesson, completes group 18 of the periodic table.

□

The Power of Piezoelectricity

Aimee Stapleton
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Energy Scavenging

Our lives would be completely unrecognisable without electricity. With the financial and environmental cost of electricity ever increasing, we need to explore all available energy sources. In Ireland, we have become familiar with the sight of wind turbines dotting the countryside generating wind energy. Although less common, solar panels line some rooftops harvesting solar energy. But are we doing enough to scavenge energy from our surroundings?

Salvaging energy means to collect ambient energy around us and use it to power something. There are many examples of ambient energy that are not being tapped into. For example, every time you take a step, you are using mechanical energy. Of course, some of this energy is converted to heat and sound as you take a step and dissipates quickly. If ambient energy like this can be harnessed, it can be used to power low-energy electronics and lessen our demand on non-renewable energy sources.

Piezoelectricity

In the above example, we talked about converting mechanical energy to electrical energy. Piezoelectricity (meaning 'pressure-electricity') is a phenomenon observed in some materials that allows them to convert mechanical energy directly into electrical energy (the direct piezoelectric effect) and from electrical to mechanical energy (the converse piezoelectric effect).

Piezoelectric materials have many everyday applications. While some BBQ lighters use flint to ignite, others have a small piece of a piezoelectric material inside. When you press on the BBQ lighter, you are in effect pressing on the piezoelectric material. It responds to the applied pressure by generating a charge around its surface (the direct piezoelectric effect). One surface of the crystal becomes positively charged and the opposite negatively charged, and thus there is a voltage created across the crystal. The magnitude of this voltage can range from millivolts to tens of volts, depending on the magnitude of the piezoelectric effect in the material. In a BBQ lighter, the electrical voltage across the surface of the crystal then causes a spark that you use to ignite your grill.

The converse piezoelectric effect is also employed extensively across many applications – from the quartz crystal clock to high-precision positioning systems. One common application of the converse piezoelectric effect is ultra-sound. To generate ultrasound, an AC voltage is placed across a piezoelectric material causing it to contract and expand repeatedly. When the material vibrates above a frequency of 20 kHz it is called ultrasound. In medical ultrasound, the ultrasound pulses are directed towards the tissue and are reflected back to the ultrasound probe like an echo. The returning sound wave strike the piezoelectric material again, causing it to deform and via the direct piezoelectric effect generates a detectable voltage.

Crystal structure is key

At the heart of piezoelectricity is the material's crystal structure. There are 32 classes of crystals but only 20 of these are piezoelectric. The pivotal requirement of piezoelectricity is that the crystal must be non-centrosymmetric (i.e. lacks a centre of symmetry). Figure 1(a) shows a non-centrosymmetric crystal such as barium titanate, $BaTiO_3$. With no external forces applied, the positive and negative charges are balanced and there is no net charge. However, applying pressure to piezoelectric materials alters the separation between the positive and negative charges, creating a net charge on the crystal's surface (piezoelectricity).

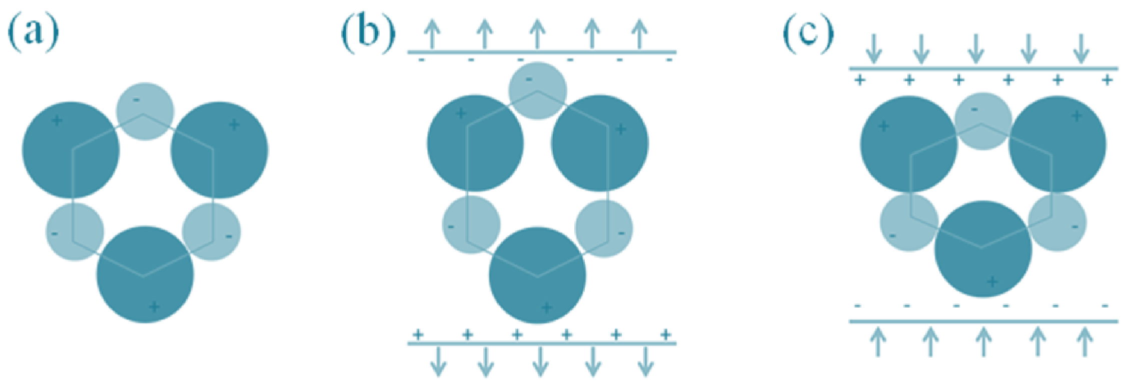


Figure 1: The direct piezoelectric effect. A non-centrosymmetric crystal (a) generates a charge when it is (b) stretched or (c) compressed

However, if the crystal had a centre of symmetry piezoelectricity would not be possible. Figure 2 shows that the average location of the positive and negative charges in a centrosymmetric crystal cancel one another out when no force is applied. Stretching or compressing a centrosymmetric crystal does not change the average position of positive and negative charges. Therefore, mechanical deformation does not induce any net charge.

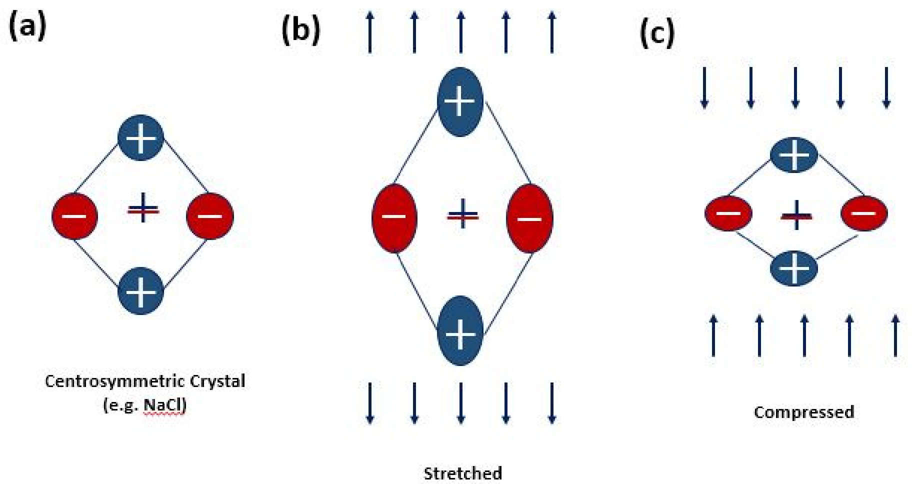


Figure 2: Absence of piezoelectricity in centrosymmetric crystals. (a) A schematic of a centrosymmetric crystal such as NaCl which has a neutral surface charge. When a centrosymmetric crystal is (b) stretched or (c) compressed the average position of the negative and positive charges do not change,

A family discovery

The brothers, Jacques and Pierre Curie (Figure 3), discovered the direct piezoelectric effect in 1880. At the time, Pierre Curie had been studying pyroelectric materials, i.e. materials that produce an electric current in response to a change of temperature, such as tourmaline. An awareness of pyroelectric materials has existed since ancient times when it was known that tourmaline would attract metals when heated or cooled. Pierre Curie's contribution was in studying the relationship between pyroelectricity and crystal symmetry. He appreciated that the structure of crystals and their physical properties are inherently linked. This understanding led him and his brother to investigate the effect of pressure on certain crystal classes and they soon discovered the direct piezoelectric effect. However, they had no idea that the converse piezoelectric effect also existed. This was the contribution of Gabriel Lippman, who in 1881 predicted the converse piezoelectric effect from thermodynamic considerations. Later in the same year, the Curie brothers validated Lippmann's predictions experimentally. Many readers will know that the Curie family's scientific success did not stop there. In 1895, Pierre Curie married a Polish physicist and chemist called Marie Sklodowska. The pair won a Nobel Prize together for their work on radioactivity in 1903. In 1911, a few years after Pierre's death, Marie Sklodowska Curie won a second Nobel Prize for her continued work on radioactivity.

Figure 3: The Curie Brothers, Jacque (left) and Pierre (right), discovered the piezoelectric effect

Biological piezoelectricity

Interesting, many biological materials around us are also piezoelectric. One of the most intriguing bio-piezoelectric materials is bone. A Japanese scientist called Eiichi Fukada discovered piezoelectricity in bone in the 1950s. Bone-piezoelectricity has gathered much interest in the research community because of speculations that bone piezoelectricity might be linked to bone healing. The proposition is simple: when bone is compressed a charge develops on its surface and these charges stimulate cells to grow and heal. There is no concrete proof of this theory. However, anecdotally, we can understand that the bones of an astronaut returning from space are less dense after spending time in low gravity environment. In space, their bones are not experiencing the same load, so the piezoelectric effect would be less and therefore fewer bone cells are stimulated to grow. Conversely, an elite sportsperson such as a tennis player may have greater bone density than an average person. An athlete's bones experience greater loading and therefore the effect of bone piezoelectricity may prompt cells to grow and heal to a greater extent. While we don't have a conclusive answer yet, it is undoubtable that Fukada's discovery sparked a whole new avenue of research. Since the discovery of bone piezoelectricity, many other biological materials have been found to be piezoelectric - from the smallest biological building blocks, amino acids, to more complex structures including wood, proteins and viruses. The occurrence of piezoelectricity in biological samples is so prevalent that some speculate that it may be a universal feature of biology (Figure 4).

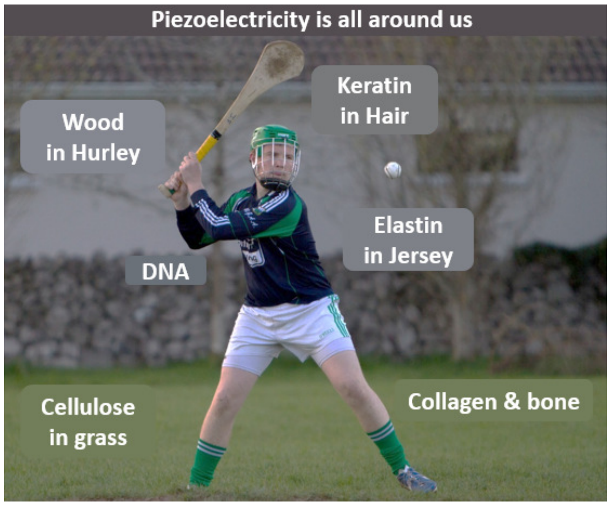


Figure 4: The prevalence of piezoelectricity around us – wood, elastin, DNA, collagen, bone and cellulose are all piezoelectric

In the future biological piezoelectric materials may be employed as energy-harvesters to power medical devices such as pacemakers. At present though, most energy-harvesting applications employ non-biological materials such as barium titanate or lead zirconate titanate (PZT) as energy-harvesters, because their piezoelectric effect is generally stronger than their biological counterparts.

Returning to our example of harvesting the energy of footsteps with piezoelectricity, a company in London called *Pavegen* are commercialising this technology. (www.pavegen.com) *Pavegen* make paving tiles and install them in public locations where footfall is high, such as train station and airports. *Pavegen* tiles are a hybrid system, combining both the piezoelectric effect and electromagnetic induction to generate energy. The electricity produced can then be used to power nearby streetlamps, for example. *Pavegen* tiles were featured recently in a garden at the *Chelsea Flower Show*, which won gold in the '*New Spaces to Grow*' category. Innovative and creative designs like these inspire us to use the power of piezoelectricity to scavenge wasted energy and future-proof our energy needs.

Further Reading

- Lesson plan on piezoelectricity from *Teach Engineering:* https://www.teachengineering.org/lessons/view/uoh_piezo_lesson01
- Jiri Erhart, *Experiments to determine piezoelectric and pyroelectric effects,* Physics Education, Vol 48, No 4 (2013)

http://iopscience.iop.org/article/10.1088/0031-9120/48/4/438

- Simple demonstration of piezoelectricity from *The Creative Science Centre*, http://www.creative-science.org.uk/piezo1.html
- The power of footfall: how cities of the future will harness energy. https://www.theguardian.com/sustainable-business/footfall-cities-future-harness-energy

Dr Aimee Stapleton trained as a physicist in the University of Limerick and holds a BSc. in Applied Physics and a Doctorate in Physics. Her doctoral studies investigated piezoelectricity in lysozyme, a protein found in tears, eggs and milk. She joined the Synthesis and Solid State Pharmaceutical Centre as a Public Engagement Officer in 2017. Her role involves facilitating science outreach activities for the public, providing continuous professional development course for science teachers and training researchers to become science communicators. Aimee is also a team member on an Erasmus+ project called ARTIST, which aims to innovate science teaching through Action Research.

□

Quotes about the Periodic Table

"For the first time I saw a medley of haphazard facts fall into line and order. All the jumbles and recipes and Hotchpotch of the inorganic chemistry of my boyhood seemed to fit into the scheme before my eyes-as though one were standing beside a jungle and it suddenly transformed itself into a Dutch garden. 'But it's true,' I said to myself 'It's very beautiful. And it's true.'"

Baron C.P. Snow
(How the Periodic Table was explained in a first-term university lecture to the central character in the novel by C.P. Snow, *The Search* (1935), 38.)

"Only three of the naturally occurring elements were manufactured in the big bang. The rest were forged in the high-temperature hearts and explosive remains of dying stars, enabling subsequent generations of star systems to incorporate this enrichment, forming planets and, in our case, people.

For many, the Periodic Table of Chemical Elements is a forgotten oddity—a chart of boxes filled with mysterious, cryptic letters last encountered on the wall of high school chemistry class. As the organizing principle for the chemical behaviour of all known and yet-to-be-discovered elements in the universe, the table instead ought to be a cultural icon, a testimony to the enterprise of science as an international human adventure conducted in laboratories, particle accelerators, and on the frontier of the cosmos itself."

Neil deGrasse Tyson, *Astrophysics for People in a Hurry*

"And I often dream of chemistry at night, dreams that conflate the past and the present, the grid of the periodic table transformed to the grid of Manhattan. Sometimes, too, I dream of the indecipherable language of tin (a confused memory, perhaps, of its plaintive "cry"). But my favourite dream is of going to the opera (I am Hafnium), sharing a box at the Met with the other heavy transition metals my old and valued friends Tantalum, Rhenium, Osmium, Iridium, Platinum, Gold, and Tungsten."

Oliver Sacks

"As a second year high school chemistry student, I still have a vivid memory of my excitement when I first saw a chart of the periodic table of elements. The order in the universe seemed miraculous, and I wanted to study and learn as much as possible about the natural sciences."

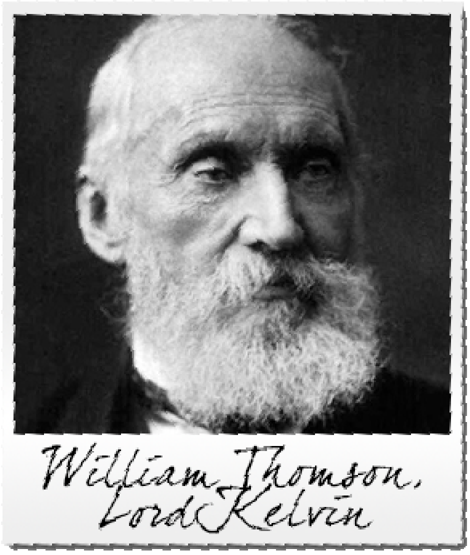
Joseph E. Murray
(In Tore Frängsmyr and Jan E. Lindsten (eds.), *Nobel Lectures: Physiology Or Medicine: 1981-1990* (1993), 555)

Chemists you should know: #4

William Thomson (Lord Kelvin)

26th June 1824 – 17th December 1907

Adrian Ryder tutorajr@gmail.com



Lord Kelvin in later life

Degrees Kelvin

In 1848 based on Carnot's theory of the motive power of heat and on Regnault's observations of the gas thermometer, William Thomson showed, in the *Philosophical Magazine* of October 1848, a need for an "Absolute Thermometric Scale", where the zero would be the absolute zero, the temperature at which all thermal motion stops and as a consequence chemical action ceases. It had been shown that the rate of reaction for two particle reactions is proportional to the square root of the temperature Kelvin. Thus at 0° K no chemical reaction is possible. The scale was set with the two fixed points, being this zero and the triple point of water set at 273.15° K, a degree on this scale being exactly equal to a degree on the Celsius scale. This scale, now known as the Kelvin Scale, following William's elevation to the Peerage in 1892, as Lord Kelvin, is the primary scale of temperature. This essay now describes William's life.

Early life and education

William's father was James born in Annaghmore near Ballynahinch, Co. Down, on the 13 /11/1786, the fourth son of a small farmer also named James. Financial constrictions delayed his matriculation in Scotland in 1810 and following his graduation he was appointed the Professor of Mathematics at the Royal Academical Institute of Belfast in 1815, a position he maintained until 1832 when he took the Chair of Mathematics in Glasgow. William's mother was Margaret Gardner, the daughter of William Gardner, a merchant in Glasgow, who died when William was just six years old in 1830. The children were then taken care of by Margaret's sister Mrs. Gall. The children were Elizabeth (1818-1896) who married the Rev. David King, Anna (1820-1857) who married William Bottomley, James (1822-1892), William (26 /06/1824 – 17 /12/1907), John (1826-1847), Margaret (1827-1831) and Robert (1829-1905).

The two eldest boys were supervised by their father in their early education but in 1834 they were allowed to attend the lectures given by their father in the University. On holiday in Germany William wrote his first paper, which was published in Frankfurt in that year and in Glasgow the following one. In October 1841 William went up to St Peter's College, Cambridge and in the years 1841-1843 published some ten papers in the Mathematical Journal of the University. Thus began what was to be a prodigious output of papers lasting his lifetime. While in Cambridge, William won the Colquhoun

Sculls and played cornet and trumpet with the musical society. He also developed his lifelong love of sailing in Cambridge.

In 1845 William took his BA degree and shortly after was elected a Fellow of St. Peter's College. He now went to London where he did research work under Michael Faraday in the Royal Institution and onward to Paris for more under Regnault.

In 1846 Dr. Meckleham, the Professor of Natural Philosophy in Glasgow died, and William applied for the post. On the 11th of September 1846 William was elected as Professor, a position he was to hold until 1899.

William Thomson as a young man

Scientific work

His first paper written as Professor was on the possible age of the earth as determined by cooling, when he estimated an age of 20 million years. This extended the age of the earth considerably and was contentious, although in time William was shown to have the correct idea, although he underestimated the age. William always had a deep interest in geology and served as the President of the Geological Society of Glasgow from 1872 to 1893. He used his students to work on experimental results, checking ideas coming from notable scientists from all over the world, from which he made published conclusions in various fields. This allowed him to work on many more aspects of science than he could possibly have done on his own. One of these cases was when his brother James predicted in 1849 that increase of pressure would lower the freezing point of water. William at once took up the idea and following extensive experimental work with his students was able to verify the suggestion. With Professor P.G. Tait of Edinburgh he produced text books for use by his students, a novel idea for the time.

His research, with the experimental aid of his students, into the nature of heat helped him formulate the second law of thermodynamics in 1857, which states that heat will not flow from a colder body to a hotter body. Kelvin's statement of the law says that some of the heat from a high-temperature energy source will be downgraded to low-quality energy.

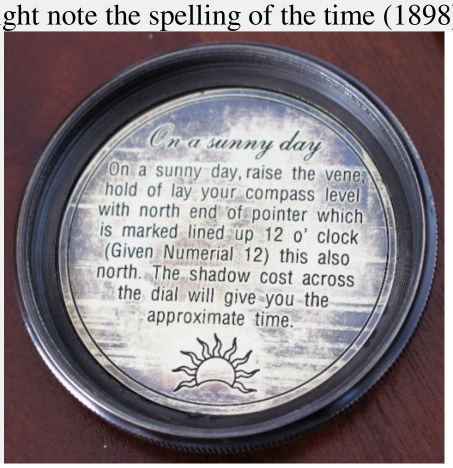
Following a third and final rejection of his proposal of marriage to Sabina Smith, whom he had been courting for years much against the will of her father and brother, and indeed his own father and brother James, William married Margaret Pattison Crum, a distant cousin on his father's side, who he had known most of his life, on the 14th of September 1852. She became seriously ill on their honeymoon and never fully recovered. William vacated his Peterhouse Fellowship to care for her until she died in 1870. William went on to marry Frances Anna Blandy (1837-1916), daughter of Charles R. Blandy of Madeira, after a short courtship there in 1874. Neither marriage produced children.

Among William's interests was the passage of electricity through wires and he made many practical suggestions about the transmission of electricity through the proposed Atlantic telegraph cable. 1857 saw the first attempt to run a cable across the Atlantic by the US frigate Niagara. The cable broke some 300 miles off Valencia. After adopting precautions suggested by William, in 1858 the first successful cable was laid from the US Niagara and HMS Agamemnon, working from each side of the Atlantic, meeting in mid-ocean where the two parts were spliced together. William was the engineer in charge. The cable operated from that date, August 6th only to September 6th, when it failed. Following further modification by William, the next attempt was in 1865 by the SS Great Eastern. However, the cable broke in mid ocean. This cable was recovered in 1866 and a fresh cable was successfully brought across, which functioned without mishap, William was again the engineer in charge. For his efforts William was knighted as Lord Kelvin and received the freedom of the city of Glasgow. During the period 1882 – 1884 William was the engineer in charge for the laying of the French Atlantic cable and that of the Commercial Company.

Signals, in Morse code, passed along the cable in 1858 were received by the mirror galvanometer, an invention of William's. This was later replaced by the siphon recorder. Also arising from his maritime experiences, William perfected a marine compass which was unaffected by the iron of the ship itself. He devised a new depth sounder, initially a continuous spool of fine piano wire, later replaced by a more robust braided wire, which allowed for depths to be found without the ship to come to a halt. He also produced a pocket compass-chronometer which on a sunny day could give a close approximation of the time, thus allowing a ship to closely work out its longitude by comparison to a clock kept to Greenwich time. (Every four minutes difference between local time and Greenwich time, equating to one degree of longitude.)

Photo of author's Kelvin chronometer Photo 23rd Jan 2017

Kelvin's pocket compass consisted of two sections which screwed together. The lower part (left) is a compass which is set due North-South. The upper part (right) which has a hinged rod is set with the rod and the 12 mark in line with the compass needle. The shadow cast by the sun and rod gives the time. Above the shadow indicates a local time of about 11.15am. The standard time is 11.54am and since Galway lies 9 degrees west of Greenwich, a difference of 36 minutes, one can at once see the accuracy of the instrument. Underneath the top section, instructions for the use are given (below). One might note the spelling of the time (1898).



William was President of the Royal Society from 1890 to 1895 and in 1892 was created Baron Kelvin of Netherhall, Largs in the County of Ayr, and became the Chancellor of Glasgow University in 1904, a position he held to his death in 1907. His fame was such that he was given formal burial in Westminster Abbey on the 23rd of December 1907. Lord Kelvin was hugely influential in defining and shaping the world in which we live today. But he wasn't always right. Among the statements he made that were proved wrong were: "Heavier-than-air flying machines are impossible" in 1895; "Radio has no future" in 1897; "X-rays will prove to be a hoax" and *"There is nothing new to be discovered in physics now. All that remains is more and more precise measurement,"* in 1900.

References:

Lord Kelvin: An Account of his Scientific Life and Work, by Andrew Grey

In Memoriam by Unknown Author. Forgotten Books: www.Forgotten Books.com

https://en.wikipedia.org/wiki/James_Thomson_(mathematician)

http://www-history.mcs.st-and.ac.uk/Biographies/Thomson_James.html

http://memento-mori-scotland.blogspot.ie/2014/07/the-thomson-family-ireland-and-glasgow.html

https://en.wikipedia.org/wiki/William_Thomson,_1st_Baron_Kelvin

Some anecdotes about Lord Kelvin:

Lord Kelvin was noted for his dry wit as these anecdotes show.

Kelvin worked out an improved method for measuring the depth of the sea, using piano wire and a narrow-bore glass tube, stoppered at the upper end. While experimenting with this invention, he was interrupted one day by his colleague James Prescott Joule. Looking with astonishment at the lengths of piano wire, Joule asked him what he was doing, "Sounding," said Thomson. "What note?" asked Joule. "The deep C," returned Thomson.

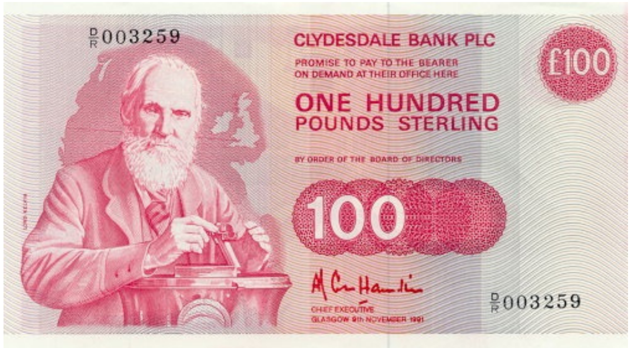
*****

The famed physicist William Thomson (later Lord Kelvin) was a professor of natural philosophy at Glasgow University for some fifty years. Unable to meet his class one day, he

posted a note on the door of his lecture room: "Professor Thomson," it said, "will not meet his classes today." As a joke, some of his mischievous students erased the "c," leaving a message reading: "Professor Thomson will not meet his lasses today." The following day when the pranksters assembled in anticipation of the effect of their joke, they were chagrined to find that the professor had outwitted them. The note was now found to read: "Professor Thomson will not meet his asses today."
[Cyrus Northrup, University of Washington Address, November 2, 1908]

*****

At Glasgow University one day, Lord Kelvin found himself delivering a lecture in a room directly beneath another colleague whose students, at the end of the lecture, showed their appreciation in the customary manner—by stamping vigorously on the floor. "Ah," Lord Kelvin remarked, as chucks of plaster fell from the ceiling, "I see Dr. Campbell's conclusions don't agree with my premises."



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Diary

2018

ChemEd-Ireland
20 October
Trinity College, Dublin
John.o'donoghue@tcd.ie

ISTA Senior Science Quizzes
Regional Rounds:
Thursday 15th November
National Final:
Saturday 24th November

SciFest National Final
9 November
Dublin

Science Week Ireland
11-18 November
www.science.ie

2019

ASE Annual Conference
9-12 January
University of Birmingham
https://www.ase.org.uk/annual-conference

New Perspectives in Science Education
21-22 March
Florence, Italy,
https://conference.pixel-online.net/NPSE/

ISTA Conference
12-14 April
DCU, Dublin
www.ista.ie

Using Education to Foster Meaningful Chemistry Learning
Gordon Research Conference
16-21 June
Lewiston, ME, USA
https://www.grc.org/chemistry-education-research-and-practice-conference/2019/

Eurovariety 2019
17-19 July
Prato, Tuscany, Italy
https://shop.monash.edu/eurovariety-in-chemistry-education-2019.html

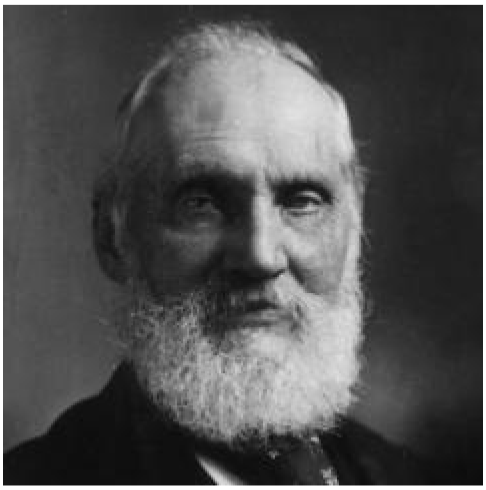
ChemEd 2019
21-25 July
North Central College, Naperville, USA
https://www.chemed2019.com/

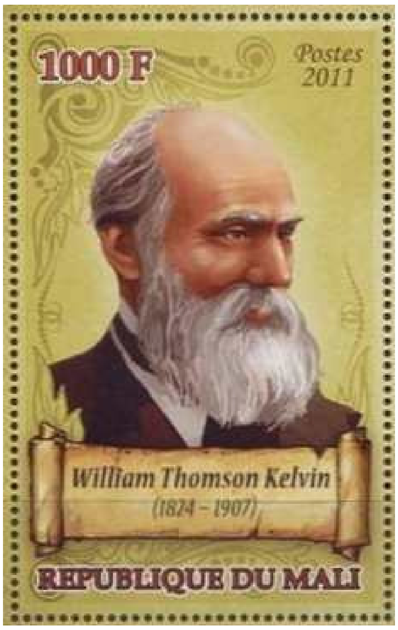
ChemEd-Ireland
19 October
DIT, Kevin Street
Claire.O'Donnell@dit.ie

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

Famous Chemical Quotations: #9

Lord Kelvin (1824-1907)





"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."

Lord Kelvin

What happened to the cup?

Grade level: Can be done at age 15-16 (JC) without going into glass transition temperatures and structures; age 17-18 (LC) with a more detailed look at polymer structure and properties
Subject-matter targets: Chemistry/polymers
Inquiry-based targets: Structure and properties of polymers; recycling logos for polymers
Duration: 2-3 lessons

ENGAGEMENT

Scenario:
I was making a cup of coffee and there were no clean cups. So I grabbed a transparent disposable plastic cup from the shelf and put in the coffee powder and then poured the hot water into the cup. It was a good job I did it over the sink because the cup 'collapsed' and shrank, spilling all the liquid. The cup had collapsed and changed its shape. That doesn't happen when I use cold water or when I use a more rigid plastic beaker. Why did that happen? What is the difference between these two plastic cups? How can I use hot liquids in one sort of cup rather than another, even if they look similar? How hot does the water have to be to make it happen? Does it happen with all disposable plastic cups?

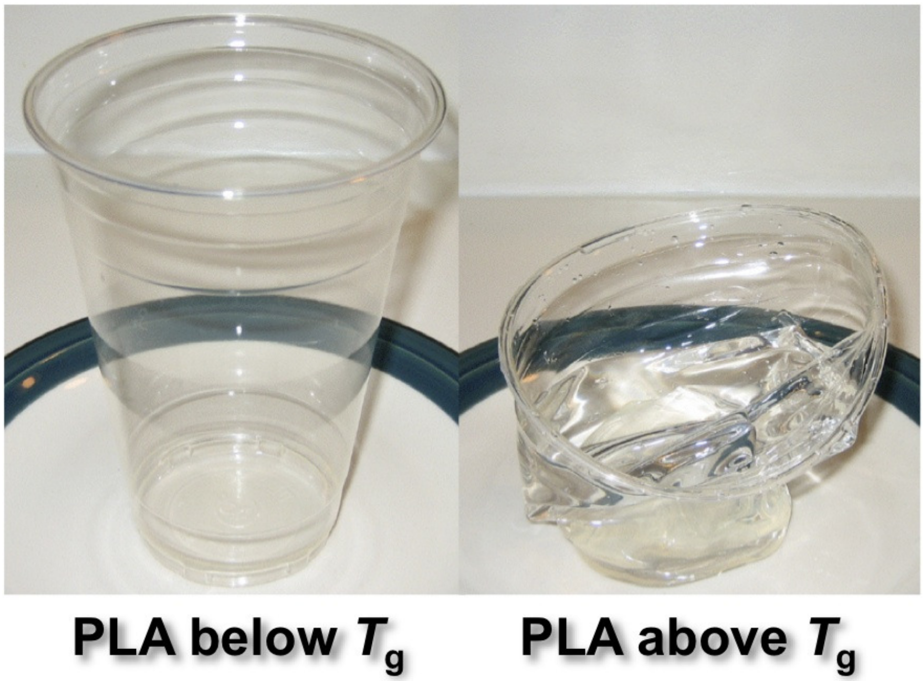


Figure 1: The effect of hot water on PLA cups – Tg is the glass transition temperature, above which the polymer becomes plastic and returns to its original size.

EXPLORE

How hot does the water have to be for this to happen? Set up an investigation using hot water from a kettle and a thermometer to test this out. Does it happen with other makes of disposable cups? Get some different transparent cups and try it out. Does it work with all or only some? Is it reversible – does cold water restore the shape or not? How can you check what sort of polymer the cups are made from?

(Hint: check the symbol on the bottom and look up the name and symbol to identify the plastic. See the table of polymer symbols provided.)

Are the cups that collapse made from particular polymers? Is the way they are produced of relevance? What about cups that don't collapse? The cups change shape but do they lose mass or stay the same? Is it to do with whether the polymer is biodegradable or not?

Preparation: you need to source some transparent, disposable plastic cups made from different plastics. Several types are available: polystyrene (PS), polyethyleneterephthalate (PET), polylactic acid (PLA), polypropylene (PP). There are also coloured, opaque cups available and white, expanded polystyrene cups. The initial mistake was made with PLA cups, which are also biodegradable. The cups are cheap and easily available and so after the initial teacher demonstration, the students can work in groups with a set of different cups. Each group should have access to hot water e.g. from an electric kettle, thermometer and a plastic bowl or container to contain the cups and water. This should avoid water being spilled over the classroom. Caution: care is needed if using boiling or nearly boiling water. The cups should be filled inside a bowl to collect any spills.

EXPLAIN

The cups are made from various types of polymers and are meant for one use only. They are made from very little plastic and are thin-walled and are usually used for cold drinks. However, some types can be used for hot drinks. Why do some cups collapse when hot water is used and others don't? What do you think is happening when hot water is added? Can you think of other examples where this sort of thing happens? You should identify the plastics used for each make of cup (look on the bottom for the recycling code) and look up its properties e.g. whether it is biodegradable or not, its melting point (Tm)and its glass transition temperature (Tg), a property special to polymers.

Clarification of the subject-matter

Different polymers have different melting points (Tm), when they turn into a viscous liquid, but at a lower temperature (known as the glass transition temperature, Tg) they become plastic or rubbery and shrink back to their original size, much like a balloon when the air is let out. On cooling they set solid again. A table of values for common plastics is given below. Plastic cups are often made by blowing air into a blob of hot, molten polymer in a mould. It expands to fill the mould and when it is cooled it has the shape of the mould. When the plastic is hot it can be shaped and blown like a balloon, but on cooling it sets into the new shape. [You can find some plastic bubbles in toy shops which can be used to blow permanent bubbles.] If the Tg is low then the cup will collapses when hot water is added.

Table 1: Properties of common polymers

Name	Abbreviation	Tm/°C	Tg/°C
Polylactic acid	PLA	163	60
Polystyrene	PS	240	95
Polyethyleneterephthalate	PET	260	70
Polypropylene	PP	130-171	0
Polyvinylchloride	PVC	160	87

EXTEND/ELABORATE

Take a 500 mL or 2 L drinks bottle, used to contain fizzy drinks. If you check the bottom they may see that they are made from PET polymer (PolyEthyleneTerephthalate). They are transparent like glass and they are made by blowing the polymer in a bottle-shaped mould. What do you think might happen if you put a bottle into boiling water? Is this behaviour the same or different to the cup? Try filling a 500 mL bottle half full of hot water and then screwing on the top. What do you think will happen?

Figure 2: PET bottle and perform (https://upload.wikimedia.org/wikipedia/commons/d/d4/Plastic_bottle.jpg)

What do you think the effect of cold will have on a plastic cup? Plastics have two temperatures similar to melting and freezing points. At the lower point, the glass transition temperature, a flexible plastic becomes rigid like a glass. Check this temperature for the polymer you have identified during the exploration phase and then see if you can cool it below that temperature.

[Hint: You may need to think how to get that cold – will a freezer do it? Or a salt-ice cooling mixture? Or dry ice? Or liquid nitrogen? If you have access to a suitable way of cooling the cup, try and see what effect cooling has on its physical properties. Your teacher might show you the effect of liquid nitrogen on a flexible polymer.]

Make a model of a thermoplastic polymer and use this to explain why it can change its shape.

You can buy a plastic bubble kit, which can be used to blow up permanent bubbles, which don't burst like soap bubbles. What is the connection between these bubbles and a balloon on the one hand, and a plastic cup or bottle on the other?

EVALUATE

Can the students explain in terms of the structure and properties of the polymer, why some plastic cups collapse when hot water is poured into them and others don't do this? Can they explain how soft drinks bottles are made from a former (a test-tube like shape) and why they retain their shape when they have been produced by heat and blowing with gas? Can they then explain why the bottle will collapse back to nearly its original size if heated?

Figure 3: Recycling symbols for common polymers (learn.eartheasy.com)

Some resources

Unbreakable bubbles
http://chemistry.about.com/od/bubbles/a/Bubbles-That-Dont-Pop.htm (access date)

Magic plastic bubbles – around £4 per tube (available in toy shops)
http://www.hawkin.com/magic-plastic (date)

PET Bottles
Making PET bottles from a former.
https://www.youtube.com/watch?v=v89ezOA0oNE
Using PET to make bottles and its properties
http://www.kenplas.com/project/pet/
See also:
https://en.wikipedia.org/wiki/Polyethylene_terephthalate

Slideshow on the development of plastic cups to make them more heat resistant:
http://www.slideshare.net/Atkinderek/innobioplast-2013-presentation-dwa-coffee-cup-development

This idea was also published in the Austrian science teacher's journal *PLUS LUCIS* 1/2016 30-33. Available at: https://www.univie.ac.at/pluslucis/PlusLucis/161/S30.pdf

Student worksheet

What happened to the cup?

Transparent plastic cups are available in vending machines for drinks but are usually used for cold drinks. They are disposable and have thin walls. Is this the only reason they are used for cold drinks?

Engage

By mistake your teacher poured hot coffee into a transparent plastic cup and it collapsed, spilling the drink, as shown in the picture below.

Before After

When the teacher repeated this with a different make of cup, the cup didn't collapse. Why was the behaviour different?

Elaborate

Was there a difference between the two types of transparent cup? How could you identify what they were made from?
Hint: think about recycling and how we know what polymer something is made from.
Does the temperature of the water have an effect on the collapse of the cup? Devise an experiment using both sorts of cup to see what effect temperature has on the shape of the cups.
Caution: you will need to use boiling water, which can be dilute with cold to get different temperatures.
Can you find any other makes of transparent cups made from different polymers? See if they are affected by hot water or not?
Look up the properties of the different polymers you have identified and whether they are biodegradable or not.

Explain

Most solids have a definite melting point when they change from a solid to a liquid. Polymers have two temperatures: one where they turn from a rigid, glassy state to a rubbery, plastic state (the glass transition temperature, Tg) and one when they turn into a viscous liquid (the melting point, Tm.) Draw up a table for the polymers used in the cups giving the melting point and glass transition temperature, Compare this with the behaviour that you have investigated and come up with an explanation of why some polymers change their shape in hot water and others don't. Make models or look at pictures of polymer chains and explain how they can be both plastic (rubbery) and rigid (glassy) depending on the temperature. Why do they behave differently from other organic molecules, like paraffin wax or benzoic acid, which have a definite melting point?

Extend

Look up and research how soft drinks bottles are made from PET, starting with something that looks like a test-tube. Explain in terms of Tm and Tg how the test-tube can be made into a 500 mL or 2 L plastic bottle. Will the mass change when this is done or not? Explain now what happens when you put the 500 mL or 2 L bottle into a beaker of boiling water.

Find out how PET bottles are recycled, and whether or not they can be turned back into new bottles.

If available, investigate the properties of plastic bubbles and try to explain why they don't collapse like soap bubbles.

Evaluate

Can you explain why polymers don't behave like other organic molecules in terms of their structure? How do the special properties of polymers allow us to make cups or bottles by blowing molten polymer inside a mould? Why is it important to check what polymer is used before using a plastic cup for liquids?

Recycling symbols for common polymers (learn.eartheasy.com)

Conference reports 2018

ICCE 18
SYDNEY | JULY 10-14, 2018

25th ICCE, Sydney 10-14 July 2018

1. Chemistry education takes place upside down!

ICCE in full flow (Photo: Bob Worley)

In the last issue of *Chemistry In Action!*, my eulogy on the Alex Johnstone's triangle, explaining why chemistry is difficult to understand and teach, was published alongside a moving tribute from Tina Overton. Alex had died in December 2017 and his valuable contribution to chemistry and education was celebrated at the International Conference of Chemical Education (ICCE2018). This event is held every two years in exotic locations and this time it was Sydney. I also went to the CONASTA meeting (CONference of the Australian Science Teachers (and technicians) Association). This is very much like the UK ASE meeting but with better food! As one merged into the other in the week of July 9th 2018, I was able to do two microscale chemistry workshops, one in each conference.

After temperatures of 32°C in the UK, it was wonderful to walk around Sydney at 20°C with a fresh breeze off the Pacific and wonder at the sights of the city and its many natural harbours. However, as a nerd, one day of sightseeing and I have to concentrate back on my conferences. The worries and concerns of teachers and technicians are very much the same in Australia as in the UK and Ireland. Funding, job retention, recognition etc are all there. It is not helped by, although seeming to have a national Curriculum in Australia, that the publishers have to provide different textbook for each State.

The microchemistry workshop in action (Photo: Bob Worley)

Helped by Andrew Shelley of Canberra Grammar School, who had invited me several years ago to a CONASTA meeting in Oz, the workshop went ahead in a room in the main exhibition building very successfully. *"How did you manage that?"* asked the convenor of the ICCE conference. *"Well the organiser had seen my workshop in England and said Bob can do this in on flat tables, he does not need a wet lab"*. For the ICCE I had to fill in a giant Risk Assessment Form and I took great delight in stating the mass of solid used in one experiment was 0.00005 Kg and I was using 0.0005 L of solution. Yes, I had to state amounts used in those units. I always think just how far removed many University academics are from what happens in schools now. None of workshop presenters were there to set fire to hydrogen balloons, start thermite reaction etc.. It was a chemical EDUCATION conference.

Aishling Flaherty's talk on how students find organic reaction mechanisms difficult was extremely interesting but *"Wait a minute!"*. I was doing this in 1967. People found them difficult then, are they still difficult? Well yes. Chemists may well be able to make a hydrogen fuel economy, make plastics which decompose in 1 year to monomers, be able to transport drugs by molecular robots to sites of special interest in our bodies, but budding chemists will still need educating and they will still find reaction mechanisms and all the other areas of chemistry difficult. In a wonderful tribute from Tina Overton, Bob Bucat and Roy Tasker to Alex Johnstone, we saw how he had researched the issues confronting the young mind when learning chemistry, at the University of Glasgow. I was given the privilege of adding to how this had happened. He had been a high school teacher for 13 years and knew at first-hand, the problems we teachers have.

Bob Worley bobworley4@gmail.com

The iconic view of Sydney (Photo: Bob Worley)

2. From Limerick to Sydney

The beginning of 2018 brought exciting news. I was to receive an '*Activating Chemistry Education Research*' travel bursary from the Royal Society of Chemistry to attend the International Conference on Chemistry Education (ICCE) that was taking place in July in Sydney, Australia. Hosted by the University of Sydney, the ICCE kicked off with an opening welcome by Adam Bridgeman, originally from the University of Hull, and who is now the Director of Educational Innovation at the University of Sydney. Preceding Adam's welcome, we were soon made aware of what singles out Sydney as one of the most special and profound cities in the world - not including the majestic Opera House or the iconic Harbour Bridge!

A Spine-Tingling Tribal Warrior Welcome

The city has a rich aboriginal heritage that acknowledges the Gadigal of the Eora Nation as the traditional custodians of the city of Sydney. As a mark of respect to the Eora Nation, City of Sydney events, official meetings, functions and other special occasions begin with a 'Welcome to Country' ceremony. The ICCE conference was to prove no different and we were treated to a spine-tingling 'Welcome to Country' performance by three tribal warriors who introduced themselves as Terry, Lisa and Dave. Terry led the performance of a series of dances from Lisa's country in Far Northern Queensland, while Lisa provided the vocals and Dave played the Didgeridoo. The welcome dance, kangaroo dance and farewell dance transfixed the audience, which had been commanded to attention by the tribal warriors, their actions, movements and sounds. In just a few minutes, my entire attitude towards the city had changed following this performance. It raised my consciousness of the land I found myself in, its significance and preciousness to those who roamed it over 40,000 years ago and indeed, those who roam it today. The message of '*travel the land in peace*' by Terry at the end of the performance was to linger in my mind for days.

ICCE 2018: Thinking Critically, Thoroughly and Holistically

The ICCE symposia were themed in just eight categories; ranging from translating assessment into the next dimension, linking to secondary education research, to joining the dots in laboratory learning. Compared to other chemistry education conferences, which feature hundreds of symposia, having a limited number of sessions to attend at the ICCE in a relatively small space, proved successful in its efficiency for all involved.

A main trend throughout the conference talks focused on empowering and developing the mind of the student to address global challenges. It's not about collating chemistry content to regurgitate in exams anymore but rather, chemistry education is striving to identify the questions we will need students to answer in the future, as citizens responsible for sustaining the world. It is about identifying the ways of thinking they will need to engage in to answer these questions and developing skills, which are not typically assessable using pencil and paper tests.

This trend was most evidenced by the level of interest in the topic of 'systems thinking' in chemistry education, that was delivered throughout a joint plenary talk by Peter Mahaffy and Stephen Matlin, as well through a series of symposia talks by Thomas Holme, Felix Ho, Daniel Southam, Jan Apotheker, Djafer Bernachour, Elena Volkova and Jennifer MacKellar. The systems thinking approach takes into consideration various societal issues which are central to the progression of chemistry. It is defined as an approach that *"…enables those who learn and practice chemistry to be aware of and respond to the interconnectedness of chemistry and related chemical sciences with local and global systems. This interconnectedness, including with the biosphere, the environment, human and animal health, economics, politics, psychology and the law, is summed up in the concept of one-world chemistry"* (Matlin, Mehta, Hopf, & Krief, 2016, p. 398). The systems thinking approach is echoed by the recent proposal of an over-arching learning outcome for American Chemical Society courses, which states that "*Chemicals have benefits and hazards, and these must be considered together* (Holme & Hutchison, 2018, p. 499). Here, the positive and negative impacts of the practice of chemistry are dually considered together, with the priority of maximising the positive impacts.

Peter Mahaffy and Stephen Matlin's joint plenary talk opened with the question: "*What is the most important technological invention of the 20th century?*" While some may have been quick to leap to answers that had something to do with the invention of nuclear energy, space exploration or the humble World Wide Web, it was soon argued that the manufacture of ammonia from nitrogen and hydrogen, known as the Haber-Bosch process, is in fact, the most important technological intervention of the 20th century. Producing ammonia is essential for the promotion of plant growth through the use of nitrogen-based fertilisers and without the Haber-Bosch process, the world's population could not have grown from 1.6 billion in 1900 to today's 7.4 billion. The systems thinking approach to chemistry education would encourage the student to take into consideration, not just the conceptual knowledge associated with the Haber-Bosch process, but also the repercussions of the development and emergence of this process.

This plenary talk was attended by both ICCE delegates and delegates from the CONASTA conference (the annual science education conference of the Australian Science Teachers Association). During the discussion of the systems thinking plenary, a CONASTA delegate, who was a secondary school teacher, raised an important issue associated with the process that ultimately encapsulated what it means to think critically and systematically. While the Haber-Bosch process may have sustained the growth of earth's human population, it also prolonged World War 1 and fuelled the onset of World War 2, as it provided munitions in the form of nitrates for gunpowder and explosives (Travis, 2015).

The systems thinking approach to chemistry education highlights the responsibility which teachers have of not just developing students' conceptual understanding of chemistry as a body of knowledge, but also guiding them to critically identify and assess the implications and impacts which chemistry has for our environment and society.

I do believe that there are some limitations to this approach, which could ultimately stifle the integration of the fundamental tenets of this approach. It is inherently difficult and complex for students to develop the skills to think and critique chemistry on several different levels and in a number of different ways. Any pedagogical approach that seeks to foster cross-curricular linkages will always be a taxing pursuit for teachers, who have to invest a great deal of effort to contextualise the many facets of chemistry.

I think that for this approach to be nurtured and embraced for the progression of the field and society as we know it, both students and teachers need to hold as a profound value, the development of chemistry thinking in a manner that is critical, thorough and holistic. They need to believe in their ability to nurture this manner of thinking and its ability to transform the world, as well as developing the attitudes that guarantee the achievement of its aims.

I was on hand to speak twice at the ICCE: firstly on a project I carried out with Tina Overton in Monash University last year which was about developing Teaching Assistants' transformational leadership behaviours, as a means of catalysing them in their lab teaching roles. My second talk was by invitation as part of a symposium dedicated to celebrating the life and career of Alex Johnstone. Here, I introduced my Post-Doctoral work, which I will commence next month with Melanie Cooper at Michigan State University, seeking to further Transformative Chemistry Education theory.

In concluding this report, I think it's appropriate to mention the final part of the Tribal Warrior performance at the ICCE, which was a farewell dance. Before the warriors commenced the dance, it was explained that of all of the languages across the country, 600 different languages and 250 dialects of those languages, there is no word or direct translation for goodbye. Instead, they bid farewell, "*Guwayu*" by acknowledging their next meeting whenever that may be, be it down the track, at the next water hole, next hunting trip or indeed, the next life.

To those I shared time with at the ICCE and in particular, the members of the Monash University Chemistry Education research group, see ya next time!

References:

Holme, T. A., & Hutchison, J. E. (2018). A Central Learning Outcome for the Central Science. *J. Chem. Educ., 95*(4), 499 - 501.

Matlin, S. A., Mehta, G., Hopf, H., & Krief, A. (2016). One-world chemistry and systems thinking. *Nature chemistry, 8*(5), 393.

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Finished her PhD at the University of Limerick in August 2018, where she was member of the Chemistry Education Research Group, and is a now a Post-Doc in Melanie Cooper's group at Michigan State University, USA.

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14th ECRICE, Warsaw, 2-6th July 2018

(http://www.ecrice2018.pl/)

The Soviet era Palace of Science and Culture in Warsaw, a major landmark in the city

The 14th European Conference on Research in Chemistry Education was held in the University of Warsaw, Warsaw, Poland from 2-6th July. The conference had about 100 participants, with 4 plenary talks, 33 oral papers, 38 posters and 4 workshops. This meant it was quite a small conference but it also meant that there was plenty of opportunity for interaction outside the lectures, over meals and at the poster sessions. The venue was very convenient and the organisation was very good, with good time-keeping and excellent food! Warsaw was a good venue with its strong scientific tradition, the home of both Marie Curie and Copernicus. Not only that, but the weather was lovely – warm and sunny.

Reproduction of Marie Curie's laboratory in Paris in the Marie Curie Museum, Warsaw

There is a Marie Curie museum in the house where she was born and a statue, featuring the element she discovered and named, polonium, on a site overlooking the Vistula River (see below)

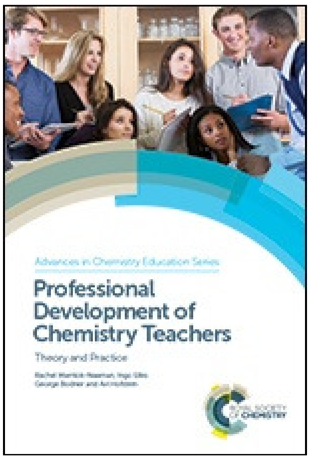
A bronze status of Marie Curie holding a model of polonium, overlooking the Vistula River

A statue of Copernicus has pride of place in front of the National Academy of Science and in the centre of a solar system. Warsaw has excellent public transport and this makes it easy to get around.

Statue of Nicolas Copernicus in Warsaw

Interaction over coffee at the 14th ECRICE

ECRICE focuses on chemical education research at all levels from primary to tertiary level. A special feature of this conference was a symposium in honour of Alex Johnstone, who died in November 2017, organised by Georgios Tsaparlis. Norman Reid, Alex's ex-student, colleague and successor at the Centre for Science Education in Glasgow, was not able to attend but sent an excellent video tribute, outlining Alex's contributions to chemical education over nearly 40 years. Several speakers highlighted 'Johnstone's triangle' and Tina Overton, Monash University, spoke about her work on problem solving inspired by Alex's work. (The recent ICCE in Sydney. Australia, also featured a symposium in honour of Alex Johnstone.)



Another symposium was on the 'Professional Development of Chemistry Teachers' and featured the authors of a new book from the new RSC Advances in Chemical Education series (https://pubs.rsc.org/en/content/ebook/978-1-78262-706-7) The 203 pp hardback costs £99 and much of the material has already been covered in other books. Such as *Teaching Chemistry: A study Book*, Eilks and Hostein, eds., Sense Publishers, 2013 and *Chemistry Education: best practices, opportunities and trends*, Javier García-Martínez and Elena Serrano-Torregrosa, eds., Wiley, 2015.


The poster session at ECRICE

Given the location, most of the participants and speakers seemed to come from Eastern Europe, and unusually this year, there were only two people from Ireland – myself and Sarah Hayes (UL). There was also a handful of people from outside Europe – from America, New Zealand and Australia.

Chemistry Teacher International is a new journal sponsored by EuCheMS DivChemEd and IUPAC CCE. It is a free-access electronic journal, at least for the first 2 years, and the first issue is due soon in late 2018 with two issues a year. (https://www.degruyter.com/view/j/cti) It was launched at the conference and one of the workshops was run by the joint editors, Jan Apoteker (CCE) and Iwona Maciejowska (DivChemEd).

The first plenary lecture was given by Ingo Eilks, Bremen, Germany, on the development of teaching materials related to phosphate recovery and its use and potential future shortage. The importance and use of phosphate in agriculture seems to be largely unknown to teachers and rarely features in the curriculum. The second plenary was given by Maija Aksela, Helsinki, on the impressive science outreach activities from and at the Finnish Luma Centre. The third plenary was given by Jan Lundell, Jyväskylä, Finland, on the 'Reform of First Year Chemistry' in his university. This has taken several years and has been very successful in revitalising the course and in attracting and motivating students. There were many lessons to be learnt here about how to apply the findings of chemical education research in practice. The final plenary talk was given by Ron Blonder, Weizmann, Israel on 'Lessons that chemistry educators can take from nanotechnology.' This described the work of her group at the Weizmann Institute over many years in developing teaching materials on nanotechnology and training teachers in their use. This was an excellent and inspiring talk and it was worth coming to the conference just to hear this. She and her group will be organising the next ECRICE in 2020 at the Weizmann Institute, Rehevot, Israel in early July.

Extra events included a Chopin recital (this is also the city of Chopin) and a conference banquet. It was a full programme running over 3 ½ days, although like every conference, the quality of the presentations was variable, with some excellent ones and some like the curate's egg – good in parts. Suzanne Boniface from New Zealand talked about the special scholarship exams in chemistry for the cream of the high school crop, used to select the very best students for university entry. These questions were very challenging even for university students. Like in many countries, the majority of these high-achieving students opt to take medicine. Shirley Simon, UCL, UK, talked about an RSC 'Chemistry for All' project on widening access to chemistry for disadvantaged and low achieving students, by providing extra practical activities in school and out-of-school in universities. This is a project running over 5 years with the same schools in order to assess the effectiveness of the interventions used over the long-term. (This has been reported in the ASE journal *Education in Science*, May 2018). The attendance at ECRICE was a little disappointing and I think it was too late in the year, overlapping with the start of schools and universities in many countries. Early to mid July seems to be a time for conferences that suits most people and can easily be combined with a holiday. Keeping the conference fee down is another way to make conferences like ECRICE more attractive and it would be nice to see more teachers attend and present their work.

The next Eurovariety will be held in Prato, Italy, 17-19th July 2019, jointly organised by Tona Overton, Monash University, Australia and the Italian Chemical Society. The 15th ECRICE will be held in Israel at the Weizmann Institute, Rehevot from 6-8th July 2020, organised by Ron Blonder and her team. The dates may change as the next ICCE is only a few days later (13-17th July) in Cape Town, Israel.

Peter E. Childs, peter.childs@ul.ie

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12th Chemistry Demonstration Workshop

4-6 July 2018

Dept. Of Chemical Sciences, University of Limerick
Peter E. Childs, Martin McHugh & Aimee Stapleton
Info: martin.mchugh@ul.ie or aimee.stapleton@ul.ie



Overview

The highly successful Chemistry Demonstration Workshop for science teachers and science education students ran again this summer from July 4th to 6th in the University of Limerick. This year, the workshop hosted 14 teachers, who are currently teaching in Cork, Clare, Limerick, Tipperary and Dublin. The workshop also welcomed two pre-service teachers (studying in University College Dublin and Dublin City University). who worked alongside experienced educators throughout the workshop, sharing their experiences and knowledge.

The objective of the workshop was to offer exemplary professional development for secondary school science teachers, particularly in the area of chemistry. The course placed strong emphasis on safety, relevance to the curriculum in the junior and senior cycles, and on peer learning with high levels of interactivity. All participants had the opportunity to watch experienced demonstrators, to access printed materials and internet resources, to try out demonstrations themselves and to leave with materials and tested demonstrations for use in schools, as well as increased enthusiasm, confidence and competence is using demonstrations in teaching science.

Key Stakeholders

The success of the workshop was possible only because of the ongoing support from several key stakeholders. The Synthesis and Solid State Pharmaceutical Centre (SSPC) and BioPharmaChem Ireland jointly sponsored the workshop. Both the Faculty of Science and Engineering, and the Department of Chemical Sciences in the University of Limerick gave invaluable support, in terms of providing both laboratory space and technical staff time. The Institute of Physics in Ireland and the Royal Society of Chemistry and IOP Physics Busking facilitated hands-on, creative activities during the workshop. Biopharmachem Ireland through the auspices of Siobhan Dean, provided financial support for the week.

In raising awareness of the workshop, both the '*Chemistry in Action!*' magazine and ISTA *Science* journal publicized the workshop. Information about the workshop was also shared on the *Sharing Science* teachers' forum as well on relevant Social Media platforms. If you've attended one of these workshops and benefited from it, please help us to publicise the 2019 workshop.

New features to the workshop

This year's workshop was structured as a three-day residential workshop, compared to previous years where the workshop had been structured as a four-day workshop, split over five days. Another new addition to the workshop was a session on 'Microscale Chemistry' delivered by Dr Ahmad Basheer of the Academic Arab College for Education in Haifa, Israel, who was visiting UL on an Erasmus staff mobility exchange.

Building on the success of previous years, many of the sessions remained unchanged. Laurie Ryan (SSPC) opened the workshop with the SSPC Science Show, exemplifying how creative science demonstrations can capture and engage an audience. Peter Davern (CS Department) shared an informative presentation on the essential safety aspects of science demonstrations. Special guest presenters included John O'Donoghue from the

Royal Society of Chemistry and Sarah Brady from IOP Physics Busking. John provided a dynamic workshop on spectroscopy and UV-light. Sarah introduced many creative demonstrations from the Physics Busking toolkit, useful for engaging an audience.

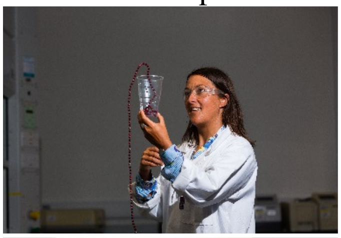
An important aspect of any workshop is the networking opportunities they provide. As part of the social programme, a competitive science quiz was held on campus in the Pavilion Bar and Lounge. To mark the last day of the workshop, Leo Kirby (CS Department) whetted the teachers' appetites by making ice-cream with liquid nitrogen.

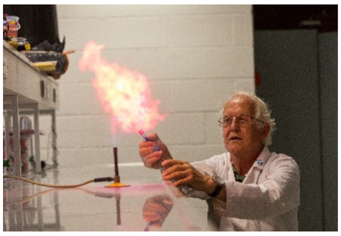
Teachers' Science Shows

The last day of the workshop saw the culmination of the three days of learning, sharing and hands-on practice. The workshops would not be the same without the science magic shows. The teachers, working in groups, eprepared and performed a short science show to their peers, showcasing their new skills. The teachers' science shows were video-recorded and shared with them after the workshop for further self-reflection and improvement.

Feedback from teachers

Did the workshop fulfil its aims and motivate and equip science teachers to do more demonstrations? The overall feedback from teachers was overwhelmingly positive. From the exit survey responses, 100% of teachers said that the workshop exceeded their expectations and that they are now feel better equipped to integrate chemical demonstrations in to their regular teaching.

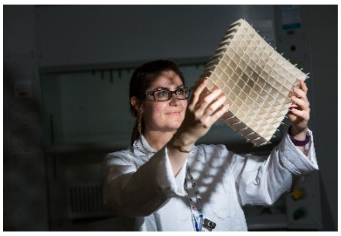




"I feel much more confident to put on a chemical magic show, also have widened the range of experiments I could do"

"Science behind demonstrations explanations helped bring me back to simplicity of science"

"It definitely exceeded expectations – as a biology & maths teacher I wasn't sure how applicable this course would be for me but it was really useful for junior cycle science and a great way to network with other teachers"



Special thanks to: Peter Davern, Sarah Brady, Brian O'Shaughnessy, Sinead Walsh, Maria Munroe, Leo Kirby, SSPC researchers, John O'Donoghue, Ahmad Basheer, Sarah Brady, Siobhan Dean

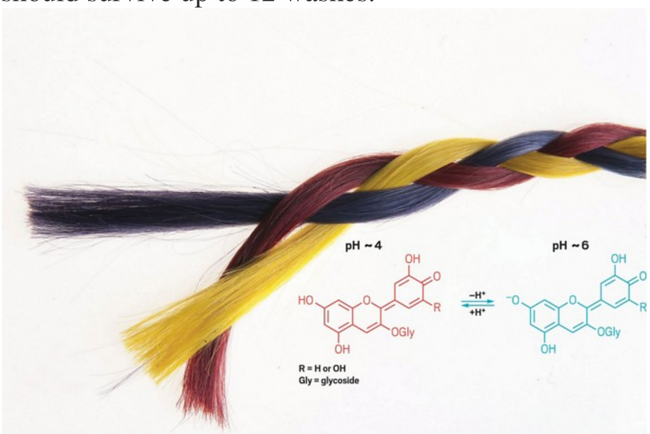
Hair dyes from blackcurrant skins

The vitamin C-rich drink Ribena is made from the juice of blackcurrants, as everyone knows. In the UK 12,000 tonnes of blackcurrants are harvested each year and this generates thousands of tonnes of waste, mainly the skins. The process produces a large amount of waste but the skins also contain large amounts of pH-sensitive anthocyanins, which are natural dyes. Researchers in the University of Leeds have managed to extract the pigments for use as a hair dye. Dr Richard Blackburn, a colour chemist, said:

"Anthocyanins are pigments that provide colour to most berries, flowers, and many other fruits and vegetables. They are non-toxic, water-soluble and responsible for pink, red, purple, violet and blue … and are widely used as natural food colorants all over the world. We knew they bound strongly with proteins – hair is a protein – so we thought if we could find an appropriate source of these natural colours, we might be able to dye hair."

http://www.thejournal.ie/blackcurrant-hair-dye-4042326-Jun2018/

The new dyes will be available this summer from the spin-off company Keracol and sold under the Dr. Craft brand and should survive up to 12 washes.



Credit: Keracol The colour of anthocyanins depends on pH.

Women and the Periodic Table:

As part of IYPT a new book *In her element*, featuring contributions of women to the Periodic Table is being produced and will be launched in 2019.
Also in 11-12 Feb. 2019 a conference will be held in Murcia Spain on *Setting their Table: Women and the Periodic Table.*
(file:///C:/Users/User/Documents/Downloads/CfP%20Setting%20their%20Table.pdf)

37th ChemEd-Ireland

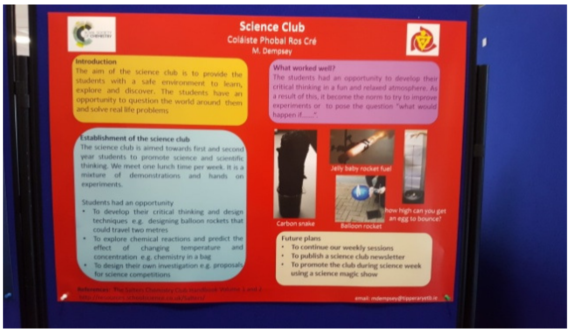
20th October 2018
Trinity College, University of Dublin

The programme:

Chemistry has a long history at TCD – the first chemistry courses were given in 1711 as part of medical courses. ChemEd-Ireland came to TCD for the first time this year and there was a great turn-out – 100 teachers registered from all over Ireland, plus speakers and helpers. As usual when you get teachers together there was a great buzz – over coffee and lunch and before and between talks. Bringing teachers together to talk about teaching their subject is one of the main benefits of conferences and one of the reasons the ChemEd-Ireland conferences were started in 1982. The conference started with coffee, tea and pastries – an essential start for any conference where people have travelled the length and breadth of the country to get there. The conference was very well organised by John O'Donoghue and his team and I am sure the conference will return to TCD in future.

Part of the audience at ChemEd-Ireland

Professor Mike Lyons, Head of TVD Chemistry, welcomed teachers and mentioned the changes in science at TCD with TR061, with 4 different streams and a quota of 72 students. (See p. 8) He extolled the enthusiasm and eagerness to learn of the teachers at the conference and their willingness to give up a Saturday to develop professionally. In the coffee/lunch area there was also a small display of posters done by teachers on RSC Education grants – this was a new feature and worth repeating to highlight teacher's research or development activities in schools.



One of the science posters

The morning saw three plenary talks: one on nanoscience from Professor Valeria Nicolosi (TCD), whose group is doing cutting-edge research on layered solids; Dr Michael Seery (Edinburgh, formerly DIT) spoke on ways to use chemical education research to improve teaching and learning; and Professor Sir Martin Poliakoff (Nottingham) gave an amusing, stimulating and inspiring talk on the YouTube channel on the chemical elements, which he started in 2008, and which is now one of the top science sites on the web.

You can watch an interview with him at https://www.youtube.com/watch?v=zvcaXM2hMgA)
The Periodic Table videos and others can be accessed at:
https://www.youtube.com/user/periodicvideos

Teachers were then offered a choice of 4 workshops, given before and after lunch, from which they could choose to do 2. One was given by the JCT science team on teaching chemistry across the strands; the second was on safe and simple chemistry classroom activities using homemade colorimeters; the third was on simple experiments and demonstrations for visualising rates of reaction; the fourth was on managing risk in the laboratory.

Visualising rates of reaction workshop

These were all hands-on and relevant to teaching second-level chemistry and teachers got stuck into them with enthusiasm. The resources were provided on a USB in the conference bag.

After the second workshop session, Professor Sylvia Draper (TCD) gave a personal account of her career and enthusiasm for doing, teaching and spreading the message about chemistry. Three chemists from industry then spoke about their career progression and the jobs they do. Finally, Dr Fiona Desmond, Chief Examiner for Chemistry for SEC, brought us up-to-date on the pilot assessment of practical work for the new LC science subjects, although the report still has to be published, and reviewed the 2018 LC Chemistry papers, with advice from teachers on preparing students for the exam. This is always a popular feature at ChemEd-Ireland.

Teachers at the JCT workshop on chemistry across the strands

This was a full day from 10 to 5 and most teachers stayed to the end. The organisation, catering, speakers and venue were all excellent and I am sure everyone attending took away some new ideas. Well done to John and your team of staff and students – you did ChemEd-Ireland proud! John will be the guest editor in preparing the Proceedings of the conference, which as usual will be published in the Spring issue of Chemistry in Action! (#113). Hard copies of the magazine are now given out at ChemEd-Ireland and the ISTA conferences, and participants got either issue 110 or 111 in their conference bags. Current and back issues, as well as TY science modules, can now be accessed at the website www.cheminaction.com, whose web editor is Maria Sheehan.

A montage of photos from the conference is given on the next page.

I can safely say that I am the only person who has been to all 37 ChemEd-Ireland conferences and I hope to be at many more.

Peter Childs

Chemistry in action at ChemEd-Ireland 2018

Coffee is vital first thing in the morning

Teachers in the rates of reaction workshop

Teachers busy at the JCT workshop

Teachers studying the poster display

Sir Martin Poliakoff chatting to teachers at lunch

The CRANN nanoscience stand in the exhibition

The workshop using homemade colorimeters

The great CO_2 shortage of 2018

We are always hearing about too much CO_2 in the atmosphere and global warming, but this summer there was a crisis over a shortage of CO_2 gas. Demand for it was increased by the hot summer and the World Cup, with an increased consumption of beer and soft drinks. Surprisingly CO_2 is used by many industries, especially the food industry, for a variety of purposes:

- Putting the fizz in carbonated drinks.
- Pressurising beer kegs.
- Creating an inert atmosphere for food packaging.
- Stunning pigs for slaughter.
- Dry ice is used in refrigeration especially in transit.
- Used in greenhouses to stimulate growth.
- Used to decaffeinate coffee.
- Enhanced oil recovery during fracking (especially in the USA).
- Chemical production e.g. urea
- etc.

"The CO_2 shortage has highlighted the invisible ubiquity of a gas used almost everywhere in the food and drinks industry, from stunning poultry and pigs in abattoirs to extending the shelf life of products through "modified atmosphere packaging", seen in puffed up salad bags and taut fresh meat packs."
Financial Times 30/6/18
https://www.ft.com/content/36183d1e-7b73-11e8-bc55-50daf11b720d

The interesting thing about these varied uses of CO_2 is that all of it will end up in the atmosphere after use. Since most of it comes from fossil methane, it is a net contributor to global CO_2 levels. If CO_2 were sourced from renewable sources e.g. brewing, bioethanol, then it would be CO_2 neutral.

Why was there a shortage in the summer?

CO_2 is a by-product of other industries, especially the production of ammonia for fertilisers by reforming natural gas. The hydrogen is extracted leaving behind CO_2 as a valuable waste product. Fertiliser use peaks in the Spring and so manufacturers use the summer for maintenance and shut down their plants. This summer several large ammonia plants in the UK were shut down and so CO_2 supplies were short. The CO_2 from ammonia plants is sold to gas suppliers like Praxair, Linde, Messer and Air Liquide, who clean it to food grade quality and supply it in tankers under pressure in liquid form to the various end users.

Ireland used to have its own source of industrial CO_2 from the NET ammonia plant in Cork, now closed. Brewing also produces CO_2 as a by-product and it can be recovered, purified and re-used in the industry. I am not sure if any Irish brewers do recover and reuse their CO_2. Most of Ireland's industrial CO_2 comes from Europe via the UK so we are at the end of a long supply chain, without mentioning BREXIT!

□

Chemlingo: Odd and old names for elements

Peter E. Childs

The word for calcium in Greek is *asbestos*, which means inextinguishable, which is used in English for the group of minerals which resist heat. Why do the Greeks use this name? It comes from their word for lime. Our word calcium comes from *calx*, the old name for calcium oxide (and by extension any metal oxide produced by heating), produced from limestone by strong heating. It was coined by Humphrey Davy for the new element he extracted in 1808 from lime.

In German nitrogen is *Stickstoff* (the choking gas) and in French it is *Azote*. Oxygen in German is *Sauerstoff* (acid gas) and in French *Oxygène***.** In German iodine is *Jod* and the symbol J is often used for it, whereas in Franch it is *Iode*.

Most of the elements now have symbols clearly connected to their name in English, but several elements known from antiquity, have symbols at odds with their English names. This is because their symbols come from their old Latin names as the table below shows. Students are often confused by this and it is worth a historical diversion to talk about the origins of the names.

Some Americans still refer to Niobium (Nb) as Columbium (Cb) and of course, they persist in calling Aluminium, Aluminum, despite international agreement to call it aluminium!

Element Name	Element Symbol	Old Name
Silver	Ag	Argentum
Gold	Au	Aurum
Copper	Cu	Cuprum
Iron	Fe	Ferrum
Mercury	Hg	Hydrargyrum
Potassium	K	Kalium
Sodium	Na	Natrium
Lead	Pb	Plumbum
Antimony	Sb	Stibium
Tin	Sn	Stannum
Tungsten	W	Wolfram

The naming of the new, transuranic elements, has also not been without controversy as there has been competition between the American, German and Russian labs over priority and thus the right to name the elements. At the end of the day IUPAC has the final say on element names and symbols.

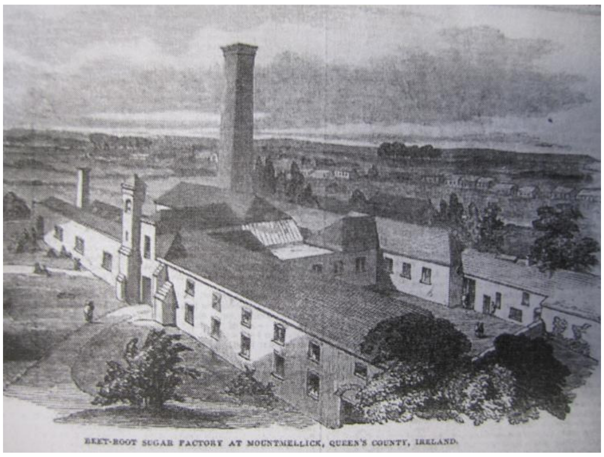
Element 105 (Dubnium. Db) was claimed by the Russian lab in Dubna, who wanted to call it Nielsbohrium (Ns) after Niels Bohr. The Americans at the University of California, Berkeley suggested Hahnium (Ha) after Otto Hahn. Eventually IUPAC recommended that element 105 be named Dubnium, Db after Dubna. All was not lost to fans of Niels Bohr and element 107 later became Bohrium, Bh.

(see https://en.wikipedia.org/wiki/List_of_chemical_elements_naming_controversies)

□

Reviving the Irish sugar industry?

One thing is certain, the sugar you put in your tea or coffee or sprinkle on your cornflakes was not produced in Ireland, even if it says Suicre on the packet. Ireland's last sugar beet factory closed in 2006, the sad end of an industry which started in 1851 in Mountmellick, Co. Laois, with the Royal Irish Beet-root Sugar Company (closed 1862).



The first sugar beet factory in Ireland in Mountmellick (1851-1862) (leinsterexpress.ie)

The last two factories – in Carlow and Mallow – were closed due to a change in the EU subsidy programme, putting 300 people out of work and making 3,500 growers diversify into other crops. The sugar industry was one of Ireland's economic success stories post-independence. When the factories closed there was a lot of controversy regarding whether they should have closed at all. It later turned out that they need not have closed after all. Sugar quotas in the EU have now been removed and there is pressure to restore beet cultivation and sugar production, although this would mean the construction of new factories. All sugar used in Ireland now has to be imported. Making our own sugar again would create jobs and income both in farming, transport and processing and replace imports.

A sugar factory was opened in Carlow in 1926. Irish Sugar (Comhlucht Siúicre Éireann) was formed in 1933 and by 1934 also had factories in Tuam, Mallow and Thurles. (https://www.irishtimes.com/news/many-sweet-years-before-all-turned-sour-1.1028700)

The Tuam and Thurles factories were closed following a 1982-83 rationalisation plan, Tuam in 1986 and Thurles in 1989; the Carlow plant closed in 2005 and the Mallow plant in 2006. At its peak the industry produced 200,000 t of sugar each year.

Ireland currently spends €300 million importing sugar and an indigenous industry could replace most of this.

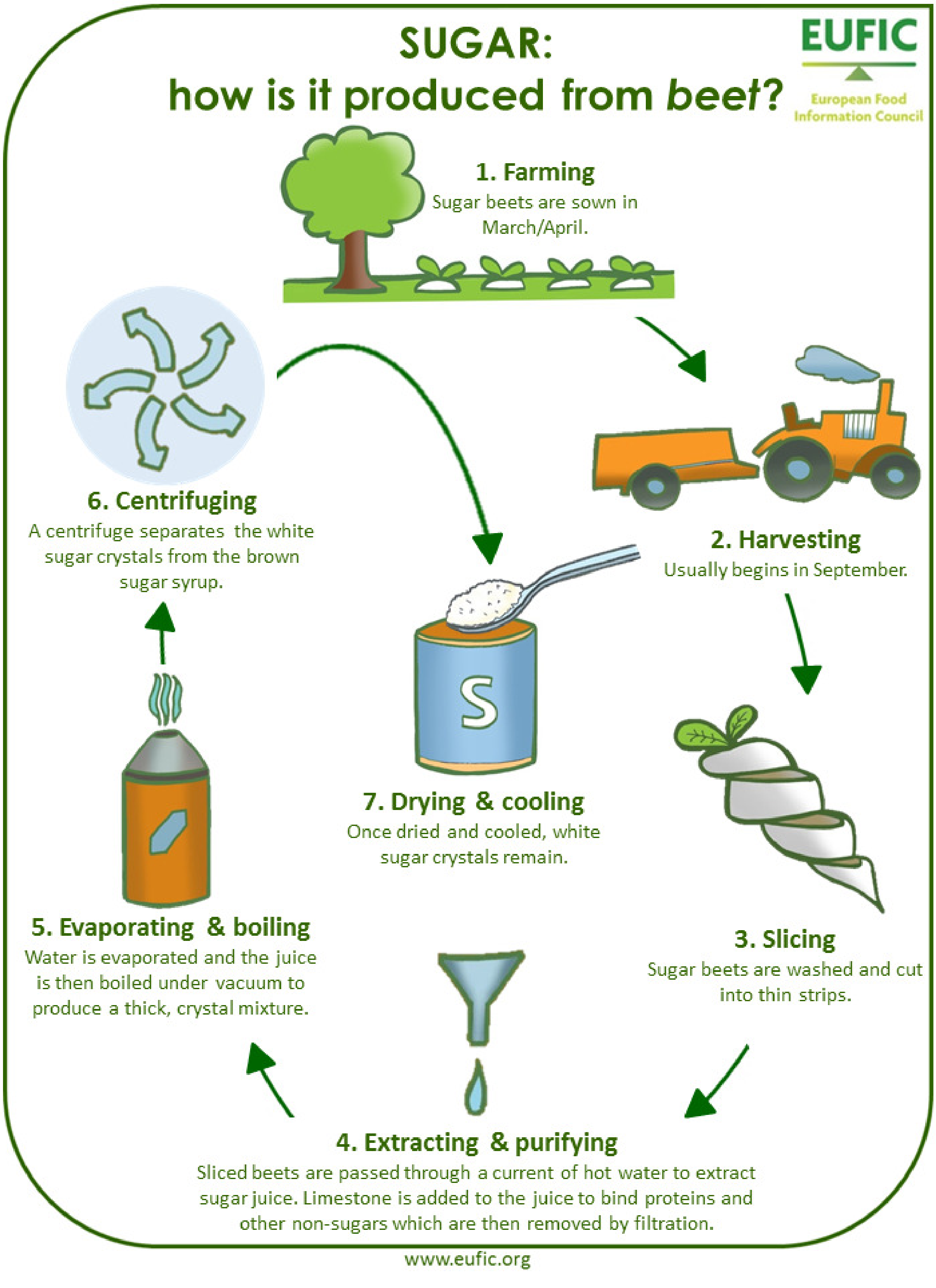
Carlow sugar factory, 1900s. (See http://sites.rootsweb.com/~irlcar2/sugar_factory_1.htm)

Charles Spillane (Ryan Institute, NUIG) has suggested reviving the sugar industry but not just for food use. He suggests that sugar refineries could act as 'innovation platforms' to encourage the use of sugar as a source of bio-derived, low carbon chemicals. He said: *"We need to consider sugar not only as ingredients for sweetening foods but also as the molecules upon which a more sustainable sugar-based bioeconomy can be developed that produces multiple products from sugar."* (*The Times*, 25/8/18)

Brazil is the world's largest producer of sugar and it also has a large bioethanol industry based on sugar. In 2015/16 Brazil produced 30.23 billion L of ethanol and 42% of its transport fuel was replaced by ethanol. Ethanol can also be converted to ethane and this leads into polymer synthesis such as polyethene. World sugar production in 2015/16 was 191.81 Mt, of which Brazil produced 38.87 Mt, India 32.45 Mt and the EU 21.15 Mt. Around 80% of world sugar comes from sugar cane in tropical countries.

A recent article on the history of the Irish sugar industry:

Muiris O'Sullivan and Liam Downey, (2017), 'Sugar Refining', *Archaeology Ireland*, 31(4), 49-52



The production of sugar from beet is a relatively simple process (see diagram above) and produces pure sugar (sucrose) crystals. The processes involve common laboratory processes. Sugar is the organic chemical produced on the largest scale worldwide and one of the purest. Its production would be a good way to illustrate the relevance of some common lab techniques.

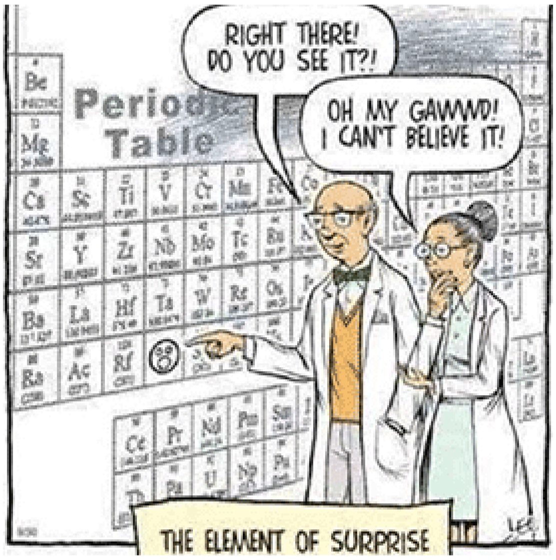
CheMiscellany

Some elementary jokes to make your students groan.

I would tell you some good chemistry jokes but all the best argon.

I heard that oxygen and magnesium were going out and I said "O Mg".

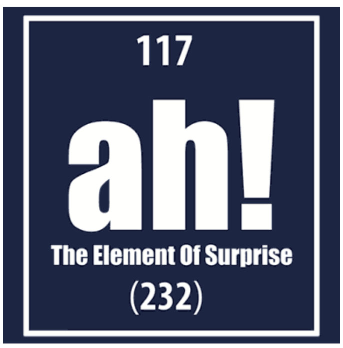
Q. What do you do with a dead chemist?
A. Barium.



Did you know that oxygen went for a second date with potassium?
How did it go?
It went OK2!

Q. What is the show caesium and iodine love watching together?
A: **CSI**

Q: Anyone know any jokes about sodium?
A: Na



Q: Why was the mole of oxygen molecules excited when he walked out of the singles bar?
A: He got Avogadro's number!

Q: Why did the chemist sole and heel his shoes with silicone rubber?
A: To reduce his carbon footprint.

A small piece of sodium that lived in a test tube fell in love with a Bunsen burner. "Oh Bunsen, my flame," the sodium pined. "I melt whenever I see you," The Bunsen burner replied, "It's just a phase you're going through."

Q: When one physicist asks another, "What's new?" what's the typical response?
A: C over lambda

Q: **What happened to the man who was stopped for having sodium chloride and a nine-volt battery in his car?**
A: He was booked for a salt and battery.

Q: What emotional disorder does a gas chromatograph suffer from?
A: Separation anxiety.

Q: What did the Mass Spectrometer say to the Gas Chromatograph?
A: Breaking up is hard to do.

More like this at https://www.inorganicventures.com/fun-chemists

See if you or your students can come up with some new jokes for CheMiscellany.

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Send it as a word document, single spaced. Times New Roman 12 pt., with any diagrams, figures, tables inserted between paragraphs (not embedded in the text). Include a short biography at the end.

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Web editor: Maria Sheehan

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In the next issue:

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