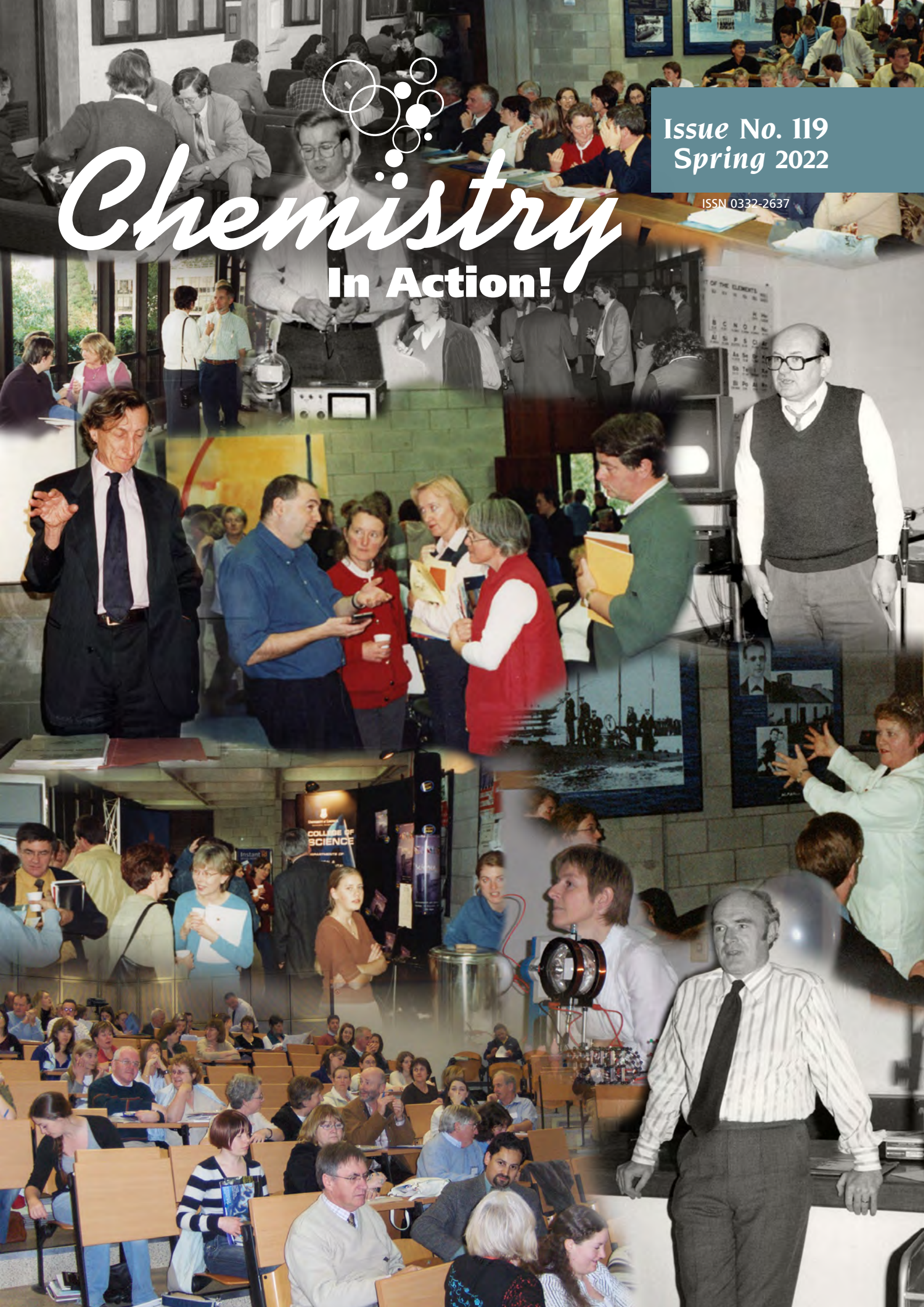


Issue No. 119
Spring 2022

ISSN 0332-2637

Chemistry

In Action!



Contents

1.	Contents	
2.	Editorial #119	
4.	In this issue #119	
5.	Education News and Views	
6.	Senior Cycle Reform	
9.	Vale: A tribute to Professor Peter Fensham	
10.	Current Chemistry Investigators (CCI)	John O'Donoghue
13.	Revising the LC sciences (B,C and P) – a proposal	
16.	Chemistry and Science Education at DCU	Odilla Finlayson
19.	Proceedings ChemEd-Ireland 2021	
20.	40 years of ChemEd-Ireland: a retrospective	Peter E. Childs
26.	PCR in the school laboratory	Declan Cathcart
34.	Getting More from your CO ₂ Monitor	John O'Donoghue
37.	Representations & visualisations – interesting experiments for chemical change and rates of reaction	Odilla Finlayson
43.	Transition Year Autumnal Chemistry - STEAM - Wellbeing - Connecting with Community	Michelle Dunne
48.	First principles calculations for titrations	Seán Kelleher
51.	Organisation Tips for a Safer Laboratory – An introduction to 5S for Schools	Michele Somers
55.	Elementary Chemistry	
58.	Quirky Elemental Rhyming Facts	Peter Davern
60.	Chemical Myths Exploded! #4 What is a molecule?	
65.	Chemists you should know: #10 Jean-Baptiste André Dumas	Adrian J. Ryder
69.	Chemlingo: Chemistry is a load of Twaddle	Peter E. Childs
70.	Diary/ Information Page	

Disclaimer

The views expressed in *Chemistry in Action!* are those of the authors and the Editor is not responsible for any views expressed. *Chemistry in Action!* does not represent the official views of any institution, organisation or body. Any unsigned articles or items are the responsibility of the Editor and if reprinted the Editor should be credited. If any errors of fact are published, or anyone's views are misrepresented, then the Editor will be glad to publish either a correction or a reply.

The Editor is not responsible for any actions taken as a result of material published in *Chemistry in Action!*. Any experiments or demonstrations are done at your own risk and you should take all necessary safety precautions, including wearing eye protection. Teachers may copy materials from *Chemistry in Action!* freely, without prior permission, for use in their schools. Articles and other material in *Chemistry in Action!*, except those originating in other publications, may be used freely in other educational publications without prior permission. Please acknowledge the source and author and send a copy of the publication to the Editor. Prior permission is needed if material is being used in commercial publications.

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

Cover design: George Fitzgerald, Mobius Design, Limerick

Cover photo: Montage of photos from ChemEd-Ireland conferences (P. E. Childs)

Editor: Peter E. Childs peter.childs@ul.ie

Assistant editors: Marie Walsh, Maria Sheehan, Sarah Hayes, Anne O'Dwyer

Editorial #115

The curse of grade inflation

There has been a lot of discussion over the last few months about whether the Leaving Certificate 2022 should be by exam only, the traditional model, or be a hybrid again of exam and accredited grades. The result of the hybrid model was massive grade inflation in 2021, greater than that in 2020 with only accredited grades. Students and parents have pushed for the hybrid model again, as it worked in the student's favour, but as I write this (1/2/22) the Minister of Education, Norma Foley, has announced that it will be by exam only in 2022. One reason given is that one quarter of the LC cohort have no junior certificate results for comparison and standardisation.

The official decision now is that the exams will run as usual but with more choice for students, and details of topics to be examined, to allow for their interrupted education and variation between schools and students relating to the periods of online tuition. There is also a promise that the 2022 results will be no lower than the 2021 results, i.e. grade inflation is being reinforced and maintained, and built into the examination system. In 2021 on average, the CAO points were 60 points higher than previously. This amounts to one grade extra per subject for all students. A quarter of this year's cohort will not have done a public exam, as they missed the JC in 2020 and didn't do the TYO. Keeping the grades high this year will make it even harder for the SEC to reduce grade inflation in future and go back to a 'normal' system. In my opinion it would have been better to go back to the slightly lower 2020 grades, as a mover towards restoring normal grades.

There is never a level playing field in Irish education due to the range of educational opportunity available to students: compare for example the experience in a DEIS school and a fee-paying school. Progression rates into higher education are higher for non-DEIS than DEIS schools, and especially high for the 50 fee-paying schools. 'A rising tide lifts all boats' is true of the grade inflation in 2020 and 2021. All schools have benefited as historical school performance was not taken into account. This had the effect of increasing grades for DEIS school students so that more students entered third level education. At the top end of the CAO scale, good students were bunched together so that good points were not

enough to get their first choices and a lottery was used. This left many students disappointed. At the lower end, more students would have enough points to enter third level due to the grade inflation. This is not always a good thing as there will be students who are now qualified on paper but do not do well in third level. I would predict lower rates of progression for students who have just managed to get into third level due to the increased grades. There is evidence that drop-out rates are lower the higher the CAO points a student has. Artificially increasing the grades doesn't alter a student's ability, but it will give more students an opportunity to prove themselves at third level.

Grade inflation actually does nobody any good. It takes away from the achievement and discrimination at the top, as many more students are given the top grades, so removing any differences between students. This makes it harder for third level institutions to select students for high-points courses and in 2021 they had to resort to a lottery to fill in-demand courses – too many students were qualified for the number of places. This will continue in 2022 if grades remain high. Students will also have too high an expectation of their ability, as will their lecturers, and this can create problems at third level and even drop-outs. Just as with grade inflation at degree level, LC grade inflation means that employers cannot properly assess a person's ability and the marks or degree class may end up meaning nothing. Giving everyone a prize means that all prizes are devalued, and they tell you little about the student's ability.

The LC grade inflation in 2021 made it more difficult for students to get the courses they wanted, but it also seriously disadvantaged students from previous years applying in 2021, who had to compete against inflated grades. Continuing the same system in 2022 would give LC students an unjustified expectation of an easier ride and higher grades than before the pandemic. Restoring the credibility and reliability of the exams as a valid measure of student achievement is going to be a major challenge. Three years' worth of inflated grades will be hard to roll back. I fear that the Minister's decision will be fiercely contested, despite its rationale, and there will be a massive protest from parents, students and opposition parties, a perfect media storm, and if

past history is anything to go by, the decision will be reversed under pressure.

A relevant quote from *Alice in Wonderland*. *First it marked out a race-course, in a sort of circle, ('the exact shape doesn't matter,' it said,) and then all the party were placed along the course, here and there. There was no 'One, two, three, and away,' but they began running when they liked, and left off when they liked, so that it was not easy to know when the race was over. However, when they had been running half an hour or so, and were quite dry again, the Dodo suddenly called out 'The race is over!' and they all crowded round it, panting, and asking, 'But who has won?'*

This question the Dodo could not answer without a great deal of thought, and it sat for a long time with one finger pressed upon its forehead (the position in which you usually see Shakespeare, in the pictures of him), while the rest waited in silence. At last the Dodo said, 'EVERYBODY has won, and all must have prizes.'

The effects of the new JC Science course

The revised JC Science course was introduced in 2015 and was examined for the first time in 2018 and 2019. The JC exams in 2020 and 2021 were cancelled because of the pandemic, although they are set to resume in 2022. In October 2020 the ISTA submitted a letter to the NCCA based on a survey of members, voicing serious concerns about the new course and its implications for LC sciences, and also about the proposals for outcomes-based specifications for the new LC sciences – Biology, Chemistry and Physics. Agricultural Science is already running in the new format, see the discussion by Humphry Jones and Aine Hyland in *CinA!* Issue 118. What we haven't had yet is any feedback from teachers as to the real impact of the new JC Science course on the LC sciences. The majority opinion of teachers in the ISTA survey was that students would be more poorly prepared to start the LC courses. **Was this in fact so?** Did students and teachers struggle to make up the larger gap between junior and senior cycles? Did the topics omitted in the JC impinge on the unchanged LC science syllabi? A quarter of JC students go straight into the senior cycle and 75% take the TYO; thus a quarter of the 2018 cohort would have been due to take their LC in 2020, which was cancelled and replaced by

teacher accredited grades. Three-quarters of the 2018 cohort and a quarter of the 2019 cohort would have taken their LC in 2021, when the hybrid model was used. This means that none of the students taking the new JC Science course will have had a normal LC experience (due to lockdowns) or a normal LC assessment. It will be very hard then to assess what effect, if any, the new JC Science course has had on students' experience of the LC sciences, which apart from Ag. Science are still in their traditional format. Too many variables have changed in the last two years to draw any meaningful conclusions, which is a pity as they would have relevance to the debate about the revised LC science courses, and the suitability of an outcomes-based specification.

Any revision of the LC sciences needs to take account of the new JC Science course, which ideally should have been revised to follow on from the first cohort finishing the new JC Science course. The revision would need to take account of several things: topics which have been omitted but were previously taught; the introduction of the nature of science; changes in teaching methodology; the amount and nature of practical work done in the new course; changes in the terminal assessment. There was already a large gap between JC Science and the LC science courses in content, pedagogy and cognitive demand, and this has increased massively with the new course. The danger is that topics will have to be added to LC sciences to make up for topics not covered, and this means that either the course will become overcrowded or existing topics will have to be cut down or dropped to fit the time available. This may lead to dumbing down of the LC courses, with implications for third level entry. JC Science is perhaps more important than any other single JC subject, although it is not a core subject, because it feeds into and supports **five** LC science courses. Weaknesses in the new course will thus have major effects on subsequent science courses. This has not been taken into account at the moment, and it remains to be seen what the effects of the mismatch are on students and teachers, and eventually on third level courses.

Peter E. Childs

Hon. Editor

In this issue

Proceedings ChemEd-Ireland 2021

The main focus of this issue is the Proceedings of the 40th ChemEd-Ireland, held online by DCU in October 2021.

There is always a problem in getting presenters to turn their talks from a ppt into an article, and thanks to those who did this. In the end we managed to get 7 out of 13 talks for the Proceedings. Thanks also to James Lovatt who organised the conference and chased up articles and Odilla Finlayson for her introduction and profile of Chemistry and Chemical Education at DCU (p. 16)

The papers are presented in the order on the programme (p. 19) except that the Proceedings are starting with Peter Childs' retrospective looking back over 40 years, even though this was given at the end of the conference. Declan Cathcart describes how PCR can be used in the school laboratory (p. 26). John O'Donoghue (p. 34) describes a nice way of using a CO₂ monitor, which were provided to monitor classroom CO₂ levels to ensure good ventilation. Odilla Finlayson also described some interesting classroom experiments, one using a mobile phone as a colorimeter to follow kinetics. (p. 37) Michelle Dunne has some good ideas on integrating science and arts (STEAM) in looking at the chemistry of Autumn (p. 43). Titration calculations should always be done from first principles, not using a magic equation, and Seán Kelleher describes resources to help teachers use this approach (p. 48). Lab safety and organisation is always an important topic and Michele Somers explains how to sue the 5S approach to create a safer laboratory (p. 51.) This is an interesting collection of articles with some good teaching ideas.

Vale Peter Fensham

In August 2021 the well-known Australian chemical educator, Professor Peter Fensham, died and we reprint an appreciation which appeared on the website of Monash University (p. 9). In the Spring issue of the ISTA's magazine *Science* you will find a longer article by Peter Childs on Peter

Fensham, in the *Pioneers of Science Education* series, #14.

Other items

Adrian Ryder continues his historical series on famous chemists with an article on Jean-Baptiste Dumas (p. 65).

We continue the series on Chemical Myths, looking at some common chemical misconceptions, by looking at molecules (p. 60).

Peter Davern (UL), known for his book of Periodic Table limericks, contributes two pieces of Quirky Elemental Rhyming Facts (p. 58).

In the Elementary Chemistry feature we look at some applications of iodine (p. 55).

If you've never heard of degrees Twaddle read p. 69.

The reality of practical chemistry

In high school and in undergraduate courses in college, one learns from textbooks. One learns what is known with considerable certainty, in compressed form, so that one can remain quite ignorant of the fits and starts and false trails and silly beliefs that were amply displayed when that textbook knowledge was first being gained by human beings. Only when one tries to do something oneself — even if it is only the repetition of some standard experiment — does one begin to get a glimpse of what those equations in the texts actually stand for. Thus, having learned from lectures and books a host of chemical reactions involving organic substances, that oxidation of an alcohol yields an aldehyde and then an acid, for example, I discovered in the laboratory that when organic chemists talk about the product of a reaction they do not mean that the reaction proceeds cleanly, that the product is all that is produced. Far from it. Some reactions yield only a small percentage; and the product is the substance that interests the chemist, not necessarily the one that is produced in the most copious amounts. (Beginners usually find that tars are produced in the most copious amounts.)

Henry H. Bauer, *Scientific Literacy and the Myth of the Scientific Method* (1992)

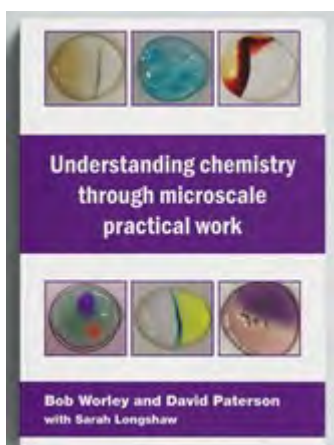
Education News and Views

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

Microchemistry update

Bob Worley

I have finally downloaded some of my brain. Writing is a slow process to me, so I was grateful for Sarah Longshaw of the Association for Science Education and David Paterson to get me to cowrite this little book of big ideas in small-scale practical chemistry, challenging the huge problem of misconceptions in learning the subject.



Go to <https://www.millgatehouse.co.uk/product/understanding-chemistry-through-microscale-practical-work/>, for details. It is available both as a book (which will have to be delivered to you) or an interactive PDF. In either case you will also gain access to a website. Nothing there at the moment but soon, extra items will be added.

I have also found it on Amazon which might help with delivery overseas.

https://www.amazon.co.uk/Understanding-Chemistry-Through-Microscale-Practical/dp/0863574785/ref=sr_1_1?qid=1643538008&refinements=p_27%3ABob+Worley&s=books&sr=1-1&text=Bob+Worley

Obviously, safety is important, so teachers and technicians need to carry out risk assessments following their country's laws and guidelines. Microscale is also green in many ways and any risk assessment should cover disposal.

We sometimes refer to CLEAPSS documents. These are behind a subscriber paywall, but we think there is enough information for a competent teacher to carry out the procedures and then introduce them to the class.

The methods are not based on a kit as these need continual maintenance and parts-replacement, but it does make use of easily obtained materials and technical guidance is provided. However, it does make use of equipment which is sometimes found in biological sciences, plastic Petri dishes, plastic transfer pipettes and dropper bottles and even plastic folders from the school office. It also makes use of advances in technology such as the small digital balances weighing to 100g to two decimal places and cost less than £10.

Improvisation is also necessary; the crown bottle tops (with the plastic insert burned out) make excellent crucibles.

The sudden interest in the UK using these methods have been brought about by the pandemic but teachers and technicians have found there are many other advantages including widening the variety in presentation, classroom control and explaining chemistry. Practical work is there to provide evidence for the teaching.

2022 ISTA Conference

8-9 April

University College Cork

"Senior Cycle Science Reform: Issues and Challenges."

www.ista.ie

Booking through Eventbrite.

[ISTA Annual Conference 2022 Tickets, Fri 8 Apr 2022 at 18:00 | Eventbrite](#)

CASTeL 9th STEM Education Research Conference (SMEC)

24-25 June 2022

"Regenerating STEM Education – Growing back better"

Dublin City University's Centre for the Advancement of STEM Teaching and Learning (CASTeL) invites researchers, teachers, policymakers, students, industry representatives, new and emerging researchers and interested others to Dublin City University (public health guidelines permitting) on **24-25 June 2022**. Here we aim to help debate, discuss and share visions for how we can "Regenerate STEM education" such that we can "grow back better" in the service of improving environments and outcomes for learners and teachers. Join us to see how you can

grow, develop and interrogate your practice in the community of your peers.

41st ChemEd-Ireland

15 October

TUS, Limerick, Moylish, Limerick

Marie.walsh@tus.ie

Senior Cycle Reform

From [Department of Education](#)

Published on 29 March 2022

Last updated on 29 March 2022

A Vision for Senior Cycle Reform

The Minister for Education has announced a vision for the reform of Senior Cycle education in Ireland.

Full details of the Minister's announcement are available here: [Minister Foley announces plan for reform of Senior Cycle education - Equity and Excellence for All](#)

The changes to Senior Cycle education are informed by the work of the National Council for Curriculum and Assessment (NCCA) and its review report on Senior Cycle. [Senior Cycle Review Advisory Report](#)

The broad-based Senior Cycle experience will be maintained. To deliver the Minister's vision, key actions include:

- a Senior Cycle Reform Programme Delivery Board will be established to oversee and drive the changes
- the department is establishing a dedicated implementation group to implement the actions set out in the programme of work. This group will also include the Inspectorate, the NCCA, State Examinations Commission (SEC) and the teacher support services

Key changes to Senior Cycle

Developing the Curriculum and Managing the assessment burden

- new and revised subjects will be developed.
- from September 2023, students will take Leaving Certificate Irish and English Paper 1's at the end of 5th year
- the marks for paper 1 will be added to the marks awarded for paper 2 which students will take in June of 6th year
- the experience of running Orals and Practical Music Examinations at Easter in the

last 2 years will be reviewed. It is hoped to run the examinations in this way in the future

New subjects and new ways of assessing students

- new subjects will be developed and new subject curricula, which outline what material is taught and assessed in a subject, will be devised
- the process of doing this will involve teachers, students and school communities as well as other education experts
- the NCCA will publish a curriculum review by September 2023. This will set out a plan for new and revised subject curricula to be delivered in annual blocks
- 2 new subjects will be available for students in network schools from September 2024: Drama, Film and Theatre Studies, and Climate Action and Sustainable Development
- 3 science subject curricula (Biology, Chemistry and Physics) as well as a curriculum for Business will be ready for introduction to the network schools by September 2024
- revised curricula in Latin, Ancient Greek and Arabic will be introduced for all schools in September 2024

Network Schools

- new and revised subjects will be introduced firstly in network schools
- working with network schools provides a real-time opportunity to learn from experience (learn by doing) especially in relation to assessment. That learning can then be applied when subjects are rolled out to all schools and other subject curricula are revised or developed
- 5th year students starting in September 2024 in network schools will be able to take these new and revised subjects in their Leaving Certificate
- as teachers are key to implementing curriculum change, particular attention will be paid to the design of the curriculum documents and the professional development that is required. The department has learnings from the experience of curriculum change and the NCCA is being asked to conduct further research and a consultation process with teachers to inform what is needed

How changes will be supported

- an extensive programme of work will be put in place to implement the changes that are being announced

- a Senior Cycle Reform Programme Delivery Board will be established to oversee and drive the changes
- the department is establishing a dedicated implementation group to implement the actions set out in the programme of work. This group will also include the Inspectorate, the NCCA, State Examinations Commission (SEC) and the teacher support services
- the changes will need to be supported by resources, particularly resources that support the professional learning of teachers, the development of the curriculum and assessment modes and support schools in implementing the changes

Leaving Certificate Applied and Leaving Certificate Vocational Programmes

- from September 2022, students who take the LCA programme will have the opportunity to take Leaving Certificate Mathematics and, where possible, a Leaving Certificate Modern Language
- the changes will mean that should a student need access to LC Mathematics for certain further education options, then they will be facilitated while also continuing their LCA programme
- the department will work with employers and other interests to explore improved progression routes for those taking the LCA programme
- in schools providing the LCVP, students starting 5th year in 2022 will be able to take the Link Modules without having to meet the subject-specific criteria
- further work on Pathways and Flexibilities for LCAS students are being undertaken

Transition Year

- Transition Year will remain as a standalone programme in Senior Cycle
- a revised Transition Year programme statement will be developed and available for schools from early 2024

All students will have the opportunity to take the Transition Year programme. Therefore, schools that have not previously provided TY will be encouraged to do so.

gov.ie - Senior Cycle Reform (www.gov.ie)

□

Another new university

April 4th saw the launch of the Atlantic Technological University (ATU.) This is a merger of Galway-Mayo IT, Sligo IT and Letterkenny IT, together with St. Angela's College, Sligo. The new President is Dr Orla Flynn, formerly President Galway-Mayo IT. The new university will have over 20,000 students and 2,215 staff spread over eight campuses in Sligo, Galway city, Castlebar, Letterfrack, Mountbellew, Letterkenny and Killybegs. Galway joins Limerick and Cork in now having two universities. Waiting in the wings for university status are Waterford IT and Carlow IT.

Elemental quotes

Inert, noble and rare

There are the so-called inert gases in the air we breathe. They bear curious Greek names of erudite derivation which mean "the New," "the Hidden," "the Inactive," and "the Alien." They are indeed so inert, so satisfied with their condition, that they do not interfere in any chemical reaction, do not combine with any other element, and for precisely this reason have gone undetected for centuries. As late as 1962 a diligent chemist after long and ingenious efforts succeeded in forcing the Alien (xenon) to combine fleetingly with extremely avid and lively fluorine, and the feat seemed so extraordinary that he was given a Nobel prize. They are also called the noble gases — and here there's room for discussion as to whether all noble gases are really inert and all inert gases are noble. And, finally, they are also called rare gases, even though one of them, argon (the Inactive), is present in the air in the considerable proportion of 1 percent, that is, twenty or thirty times more abundant than carbon dioxide, without which there would not be a trace of on this planet.

Primo Levi, "Argon" *The Periodic Table* (1975)

Centenary of the ACS Division of the History of Chemistry

The Division of the History of Chemistry of the American Chemical Society (HIST) is 100 years old in 2022. For this anniversary year, we have prepared an extra issue of the *Bulletin for the History of Chemistry*, available electronically to anyone (open access). Prominent chemist historians and historians of chemistry were invited to contribute essays on the theme "Novel Insights in the History of Chemistry: Looking Back Yet Mostly Looking Forward." This theme led to a wide variety of responses, which we have collected together into the following six topics:

Expansive Approaches to the History of Chemistry

Foci on Specific Topics

Multidisciplinary Approaches and Tools

Thriving, Inclusivity, Diversity, and Equity and the History of Chemistry

Relationships of Historians and Chemist-Historians

The Past, Present and Future of History of Chemistry

We invite you to peruse this commemorative issue online at:

http://acshist.scs.illinois.edu/bulletin_open_access/bull22-vol47-1.php

While you are there, check out 30 years of open-access issues of the

Bulletin, which are free to all after a three-year window of access

exclusively by HIST members and subscribers.

http://acshist.scs.illinois.edu/bulletin_open_access/bull-index.php

Finally, join HIST as a member or affiliate. HIST is the home within ACS for chemists interested in the history of their discipline. Among our activities are publication of a peer-reviewed

journal in history of chemistry, the *Bulletin for the History of Chemistry*, and holding symposia on historical topics at national and regional meetings of the ACS. Both of these activities involve chemists and historians from around the world. All members and affiliates of HIST receive two issues of the Bulletin each year as part of their membership: hard copies delivered by mail as well as electronic access. More information about HIST is available at:

<http://acshist.scs.illinois.edu/index.php>

and a membership form can be found at:

[http://acshist.scs.illinois.edu/HIST%20Brochure\(ACS\)rv2020.pdf](http://acshist.scs.illinois.edu/HIST%20Brochure(ACS)rv2020.pdf)

Carmen Giunta

giunta@lemoyne.edu

Department of Chemistry, Le Moyne College

<http://web.lemoyne.edu/giunta/>

The importance of chemical language

Although their trade is more recent than that of theologians, vintners, or fishermen, chemists too, since their origins, have felt the need to equip themselves with a specialized language of their own. Nevertheless, unlike all other trade languages, that of chemists has had to adapt itself to rendering a service which I believe is unique in the panorama of the numerous specialized jargons: it must be able to indicate with precision, and if possible describe, more than a million distinct objects, because that is the number (and it grows every year) of the chemical compounds found in nature or constructed by synthesis.

Primo Levi, "The Language of Chemists (I)", *Other People's Trades* (1989)

Vale Emeritus Professor Peter Fensham

26 October 1927 – 23 August 2021

[Vale Emeritus Professor Peter Fensham - Vale \(monash.edu\)](https://monash.edu)

A Tribute



Image courtesy of photographer Tony Miller with permission from the Monash University Archives.

Emeritus Professor Peter Fensham, who has died aged 93, was one of Australia's foremost science educators and Australia's first Professor of Science Education.

Peter's academic background in both chemistry and the social sciences gave him insight into two very different worlds. It imbued him with the belief that science was not only a subject, but a tool for social change. His contributions over a long and distinguished career led to the integration of social justice into science education's operational equation. His best-known seminal paper, *Science for All* (1985) was a plea for access to science for all students as opposed to a small minority of future scientists, in the hope that they would use it as a force for good in the wider world.

Peter came to Monash in 1967. His appointment as the Ian Clunies Ross Chair of Education and Foundation Professor of Science Education was considered a daring move by the University, as he had neither the school-teaching experience nor the post-graduate qualifications in education that were customary at that time in departments and faculties of education. This lack of a formal background in education raised considerable suspicion among some of the existing staff. But it was a gamble that paid off; ten of the first 20 PhDs to be completed at Monash were in science education.

During his tenure, Peter and his colleagues brought outstanding international educators to Monash, positioning the University as a leader in educational research, particularly in science education, whilst creating international research opportunities for existing staff. His publications were testament to his inexhaustible energy and included more than 20 books and 150 research papers on topics ranging from chemistry to science education's social impact. According to the American science educator James Wandersee, while other researchers frantically chopped away at science education's multiple problems, Peter took time to reflect before proceeding to sharpen his investigative axe "and thus made every swing count."

Peter was a self-effacing, modest individual, with exceptional warmth. Like so many high achievers, his curiosity and drive had its roots in childhood. Throughout his career he was preoccupied by the question; why was he the only one out of the fifty students in his primary school who decided to study and practice chemistry? Why could his contemporaries not see the vast possibilities that science offered? Peter realized the current structure of science education needed a drastic shake-up. Young minds ached for real-world challenges; they needed to be able to apply their knowledge in order to understand the discipline's relevance. His Christian faith and Methodist upbringing also greatly influenced his beliefs, namely that science should be used as a tool for social justice and that education was about enabling everyone to reach their fullest potential as moral, intelligent beings who can contribute to the well-being of society.

Peter James Fensham was born in Melbourne in October 1927. He completed a Bachelor of Science (1948) and an M.Sc. in Chemistry at the University of Melbourne (1950); a PhD on heterogeneous catalysis at Bristol University in the UK (1952); and a Postdoctoral Fellowship in Chemistry at Princeton University (1953).

In Princeton, Fensham met Professor Hadley Cantril, who, along with another notable psychologist, Sir Frederic Bartlett, sparked his curiosity for social psychology. In 1953 he returned to England courtesy of a Nuffield scholarship to study for a PhD in social psychology and social anthropology at Cambridge University. Not without trepidation, he left the familiar world of atoms, molecules and ions to undertake an ethnographic study of a textile factory community experiencing rapid technological change.

The job he was offered after graduating with his second PhD (1956), however, was not in the field of social sciences, but in chemistry at the University of Melbourne. After a decade of research, Peter became a reader in physical chemistry. To maintain a focus on the social sciences, he conducted a study on chemistry learning at university level which was an under-researched area at the time. He also analysed the outcomes of a national scholarship scheme for senior secondary students and found it failed its alleged equity intention, leading to its cessation.

On moving to Monash, Peter seized the opportunity to start a new academic research field in Australia drawing on both of his academic backgrounds. On his appointment, the then Dean of Education said to him, “I don’t know anything about your field and I don’t think you know much about it, but find out what you need and you’ll have full rein to make it a successful academic field.”

A series of high-profile public lectures led to Peter’s book, *Rights and Inequality in Australian Education* (1970), which became a foundation for the 1972 reformist federal Whitlam government’s school education policies. He also organized the first conference of the Australasian Science Education Research Association (ASERA) in 1970 - a critical step in putting Australia at the forefront of international scholarship about science education.

In the 1970s Peter was heavily involved in the emergence of environmental education in Australia and became the first National President of the Australian Association for Environmental Education (1981) – a role he had earlier played in the Australian Science Teachers Association (1972-1974). In 1985 he recommended curriculum reforms to the State Government in the Blackburn Report which led to the creation of the Victorian Certificate of Education (VCE). In the late 1980s, Peter, along with his distinguished colleagues, Richard White and Dick Gunstone, enjoyed one final breakthrough for science education research when the Australian Research Council awarded the trio the first continuing research grant in education.

On an international level, Peter worked in many overseas countries, and developed a close relationship with UNESCO and the International Organization for Science and Technology Education (IOSTE). He was a member of the Science Expert Group of the OECD’s Programme for International Student Achievement (PISA) project (1998-2009) and helped to shape its emphasis on public scientific literacy. His numerous prestigious posts included memberships of the Universities Council (1977-1981); the State Board of Education (1982-1986); and appointment as Dean of Monash’s Faculty of Education (1982-1988).

Not surprisingly, Peter was awarded many honours and distinctions. He was elected Fellow of the Australian Academy for Social Sciences (1985); appointed a Member of the Order of Australia (AM) (1986); granted the Distinguished Service Award from the International Council of Associations for Science Education (1988); and was awarded the National Association for Research in Science Education’s Distinguished Contribution Award (1999). In 2010, the Royal Australian Chemical Institute (RACI) introduced the Fensham Medal for Outstanding Contribution to Chemical Education in his honour. In 2015 the Education Faculty at Monash established a PhD scholarship in his name, in recognition of his outstanding contribution.

Upon retirement from Monash, Peter was appointed Emeritus Professor in 1993. His active career, however, was far from over. He served as Adjunct Professor at Queensland University of Technology and was appointed Patron of the Science Teachers Association of Victoria (1998-

2002), and Science Education Ambassador for Queensland (2003-2010).

Science education was only one component of Peter's kaleidoscopic life. Outside the University, he was also involved in the Pugwash Movement for Nuclear Disarmament, and appointed National Chair of the Australian Student Christian Movement (1972-1976). As a Christian he was active in social justice issues, including opposing government state aid to non-government schools. He was also an avid walker who loved hiking in the Tasmanian wilderness and played croquet regularly well into old age.

As well as his passion for science, Peter had the knack of bringing people together and translating

ideas into action and service. He was, as his colleagues noted, a fountain of ideas, generous with support and always enthusiastic. He challenged science teachers and students alike to open their eyes to the potential impact of their work that stretched far beyond the classroom and into the wider world. His legacy lives on in the students he inspired to gather wisdom as well as knowledge.

□

Reprinted by permission of Monash University. A longer article on Peter Fensham by Peter Childs will appear as PoSE#14 in the Spring 2022 issue of the ISTA magazine *Science*.

Current Chemistry Investigators (CCI)

John O'Donoghue

School of Chemistry, Trinity College, Dublin

John.ODonoghue@tcd.ie

Electrochemistry is a relatively small section on the Leaving Cert Chemistry course and doesn't really feature on the Junior Cycle Science course or at primary level. But as the world becomes ever more reliant on energy storage technology and rapid analytical techniques, we need more electrochemists to match the rising demand for these technologies. We know from research that electrochemistry is one of the most difficult topics for students to grasp. We also know that it is one of the least answered questions on both the Leaving Cert chemistry exam and the Chemistry Olympiad Ireland entrance exam, and those who do attempt electrochemistry questions do very badly. In fact, it is one of the worst answered topics across the entire Leaving Cert. As a result, we may be drifting towards a potentially huge problem for our future energy and analytical demands.

The 2019 Nobel Prize in Chemistry was awarded for the "development of lithium-ion batteries", a breakthrough that has revolutionised society. The Irish Government and the European Union have committed to a carbon neutral climate no later than 2030. To meet this, while increasing the use of renewables, the next decade will see a generational change in how we create, store and use energy. Recently, the illumination of the Eiffel Tower in France was powered by a hydrogen electrolysis system and new hydrogen buses have started in Dublin. A similar system is currently

planned for Moneypoint in Co. Clare, to convert wind power into hydrogen for storage. Battery storage facilities are also under construction in Ireland and the Irish Government plan to have 1 million electric vehicles on Irish roads by 2030.

The Chemistry Education team at Trinity College Dublin, in partnership with the Faculty of Science at the Atlantic Technological University (ATU) Sligo (formerly IT Sligo), have been awarded funding by Science Foundation Ireland (SFI) for a new 2-year project called "Current Chemistry Investigators (CCI)". CCI will provide students, teachers and the public with new activities based on simple electrochemistry activities. CCI will provide hands-on activities, equipment and resources to demonstrate the real-world applications for electrochemistry. Using an Irish context, this will create an appreciation for the role of electrochemistry research in everyday life, increasing interest in this vital area.

There is a long tradition of electrochemistry innovation in Ireland, with some of the world's first batteries created in the 19th century by Nicolas Callan at St. Patricks College in Maynooth. Irish Chemist Dr James J. Drumm also created one of the world's first battery powered trains in 1931. It carried passengers on the Dublin-Bray route until 1949 and the batteries were recharged at stations using electricity generated from the newly built Arnacrusha Hydroelectric

trains in 1931. it carried passengers on the Dublin-Bray route until 1949 and the batteries were recharged at stations using electricity generated from the newly built Arnacrusha Hydroelectric Dam (1929). It was one of the world's first fully green public transport services.



The official opening of the Drumm Battery train which ran between Dublin and Bray in December 1931

Electrochemistry is now an important part of our modern lives with many life changing applications e.g. hydrogen production, batteries, touchscreens, cardiac deliberators, glucose sensors, alcohol breath testers and gel electrophoresis for COVID19 testing. The CCI project will help schools and the public rediscover our forgotten Irish electrochemistry heritage, explore new research by Irish scientists and provide links with regional industry in Ireland like Abbott Diabetes Care and Randox Teoranta who manufacture electroanalytical devices.



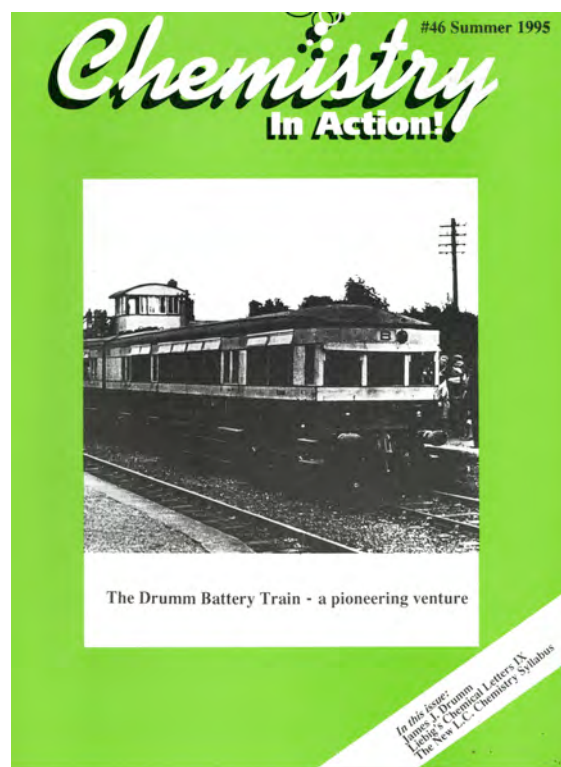
A focus group run by John O'Donoghue and Natalia Garcia Domenech with the Galway branch of the Irish Science Teachers Association (ISTA) for Current Chemistry Investigators (CCI) in February 2022.

CCI will provide the necessary equipment and guidance to carry out hands-on electrochemistry

investigations. Activities will be designed for specific audiences like Transition Year (TY), Leaving Cert (LC) and public engagement. Activities include making batteries, investigating hydrogen fuel cells and using conductometers to investigate chemical reactions that tie into the curriculum. The new secondary school workshops are currently in development and will be piloted in May 2022 before their roll out to all schools in Sept 2022. We will also be running our first public engagement event at the Cork Carnival of Science on the 11th and 12th of June. More information will be available on our website soon www.currentchemistryinvestigators.com

□

More on electrochemistry



Interestingly in the Summer 1995 issue (#46) of *Chemistry in Action!* (cover above) we published an article on the Drumm Battery Train. The article was about James J. Drumm (1897-1974) by Rev. Professor Michael J. Carey of Maynooth. In the next *CinA!* the Chemical Myths feature will look at some of the problems and misconceptions in electrochemistry.

□

Revising the LC sciences (B,C and P) – a proposal

Everyone agrees, I think, that science syllabi need regular revision. It took over 40 years for Ag. Science to be revised, which is far too long. The current LC Biology, Chemistry and Physics courses have now been running for over 20 years and so are overdue for revision. Ideally all courses should be revised at least every 10 years (5 student cohorts), although this will usually mean only minor modifications and updating.

The current revision has now been going on for ten years, without an end in sight, and with serious disquiet expressed by teachers. The problem is that the proposed new specifications (not now called syllabi) have not been well received by science teachers and others in the science and science education community, with their over-reliance on learning outcomes and their lack of detail in depth of treatment. This was brought out clearly in the 2014 Hyland Report from the ISTA, which showed that the new proposals did not match up with best international practice. (See [The Hyland Report – Irish Science Teachers' Association \(ista.ie\)](http://www.ista.ie)) So far it appears that the NCCA has been unwilling to listen to teachers and their valid concerns. The new Ag. Science specification, the first test case of the new approach, has not been well received by teachers, and this does not bode well for the other sciences. (See the comments in *CinA!* #118 by Humphry Jones and Áine Hyland, after the first full cycle of the new Ag. Science course.) If this is allowed to come to fruition in the other three LC science courses, this will be a disaster for the subjects with serious implications for third level courses.

The majority of teachers seemed to be happy with the content, presentation, mandatory practical work and assessment of the old science syllabi, disregarding Ag. Science, which were seen as a good preparation for third level courses or for entering the workplace. The issue as to whether there should be an assessed practical component is a separate issue, apart from the content and presentation of the course content.

Here is a suggestion for **revising** the current science syllabi.

1. Keep the same basic four column format, differentiated between ordinary and higher level, which has worked well.
2. Add appropriate learning outcomes, differentiated into ordinary and higher level, in a fifth column. These must be clearly stated in the proper form for learning outcomes and closely linked to the course content.
3. Revise the science content to take account of new developments in science since the 1990s when they were produced, e.g. in chemistry – nanoscience, green chemistry, sustainability, climate change, etc. (This should be more than a token mention, i.e. ‘an appreciation of nanotechnology’.)
4. Revise and update the social and applied aspects, emphasising the relevance and connections of science to 21st century society and providing for a broadly-based scientific literacy. This might include introducing elements of a context-based approach into the way traditional topics are taught, e.g. combining the course content with STS aspects.
5. Revisit and revise the mandatory practical work (which should be retained) and allow more flexibility in how it is delivered, e.g. using microchemistry, alternative procedures, project work. Possibly introduce an element of practical assessment, at least on acquiring basic lab skills on a pass/fail basis.
6. Integrate and build on the nature of science (NoS) from JC Science throughout the theory and practical elements of the course, but not as a separate topic.
7. Build in more opportunities for students to develop communication skills (written, oral and IT), and other soft skills.
8. Revise the examination to discourage rote learning, test a wider range of skills, and discourage question spotting. This and point 7 would answer the demands from industry and third level for more soft skills, like critical thinking, problem solving, inquiry, communication skills etc.

Such changes could be brought in without a major upheaval, although changing the format and nature of the assessment would require CPD and examples of sample papers from the very start. It would have implications for

pedagogy but if the assessment was changed, then teachers and students would soon adapt to the different demands and teach accordingly.

One important aspect of curriculum development, and the rock on which most new

curricula fail, is a failure to listen to and bring teachers along with you, and provide the necessary training, preparation and resources to deliver the new course.

How to do curriculum change

The EC has a useful document and guide to managing curriculum development and is worth reading.

(<https://europa.eu/capacity4dev/file/23136/download?token=cJar8YvT>)

I include two items: a diagram showing the stages and timescales for curriculum development (Figure 1).

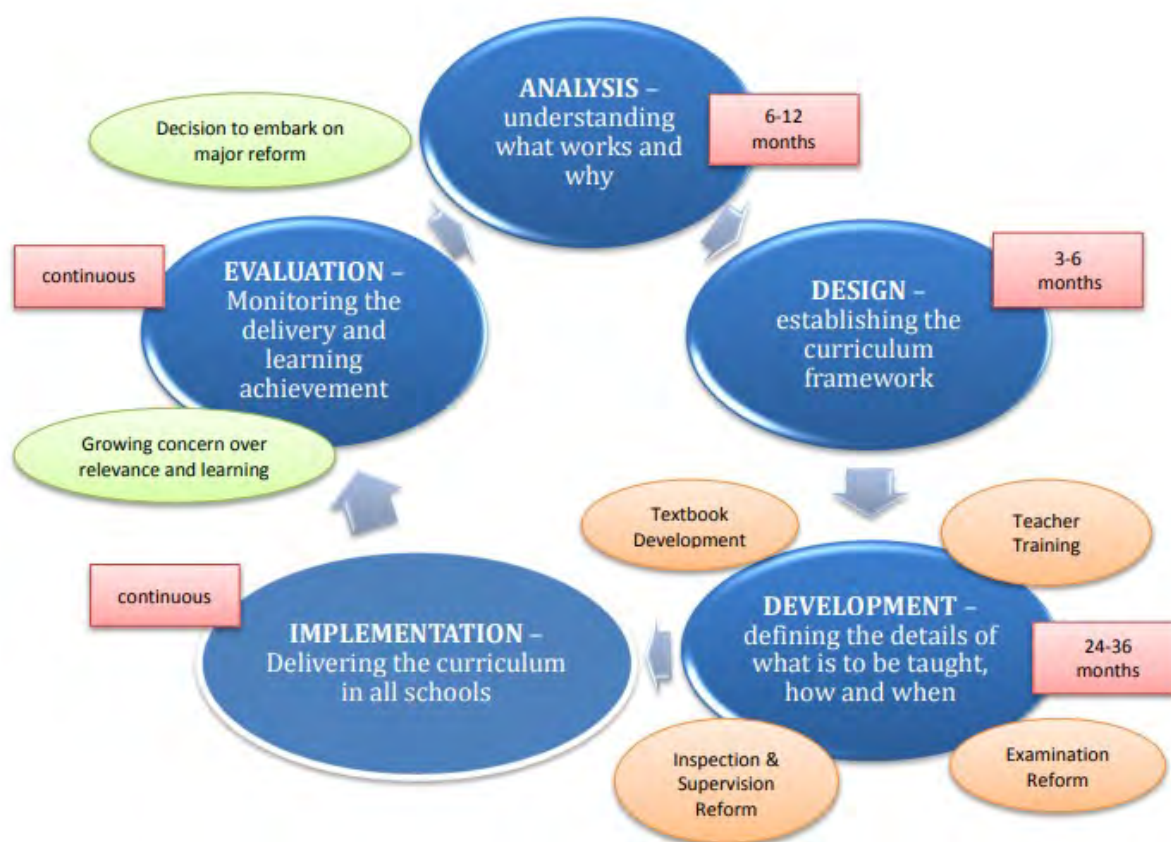


Figure 1: The five stages of curriculum change (EU, 2014)

The second item below is a table comparing good and bad practice in curriculum development. It is of interest to compare this table with the NCCA's development of the junior cycle science specification and the proposed LC science specifications.

Table 1: Good and bad practice in curriculum development (EU, 2014)

Good practice	Bad practice
Developed in an open and participatory way, extensive consultation.	Developed behind closed doors in the curriculum department.
Piloted and tested for validity	Too rushed to be able to pre-test.
New curriculum well communicated and distributed prior to launch.	Reform is poorly communicated and not understood by majority.
Serving teachers oriented and trained before, curriculum guides developed and distributed.	Teachers unaware and untrained, continue to teach to old curriculum.
Teacher training college curriculum aligned, and staff trained.	Teacher colleges not involved and courses continue to prepare for old curriculum.
New textbooks and learning resources printed and in schools.	No support materials available to teachers, Books still being developed, now new books in schools,
New assessment and examination system launched at same time.	Examinations unchanged, so assesses on old curriculum.
Inspectors and supervisors oriented and trained, able to monitor and promote new curriculum	School support and supervision remains based on old curriculum.

It is better not to change the curriculum if it is not done properly.

□

The importance of inquiry

Children are born true scientists. They spontaneously experiment and experience and reexperience again. They select, combine, and test, seeking to find order in their experiences - "which is the mostest? which is the leastest?" They smell, taste, bite, and touch-test for hardness, softness, springiness, roughness, smoothness, coldness, warmness: the heft, shake, punch, squeeze, push, crush, rub, and try to pull things apart.

R. Buckminster Fuller

The first key to wisdom is assiduous and frequent questioning...for by doubting we come to inquiry, and by inquiry we arrive at truth.

Peter Abelard

When you make the finding yourself - even if you're the last person on Earth to see the light - you'll never forget it.

Carl Sagan

The strongest arguments prove nothing so long as the conclusions are not verified by experience. Experimental science is the queen of sciences and the goal of all speculation.

Roger Bacon

Elementary school science should not be measuring out teaspoons of trivia like measured doses of castor oil. Rather, to learn science, children must do science.

Ken Mechling

When learning is active, the learner is seeking something in answer to a question, information to solve a problem, or a way to do a job. Learning can't be swallowed whole. To retain what has been taught, students must chew on it.

Mel Silberman

□

Chemistry and Science Education at DCU

Odilla Finlayson

odilla.finlayson@dcu.ie



CASTeL at DCU

CASTeL at Dublin City University were delighted to organise and host the 40th ChemEd Ireland conference in October 2021. The ChemEd conference provides a great opportunity for chemists and chemistry educators at all levels to come together and share their ideas and research in chemistry teaching and learning.

CASTeL is the university-designated research centre in DCU which aims to advance the teaching and learning of STEM subjects, through research and practice, at all curriculum levels, from early years to postgraduate education. Its members – consisting of 27 academics - are from two Faculties in DCU, namely the DCU Institute of Education and the Faculty of Science & Health. For almost two decades, CASTeL has made significant contributions in the field of STEM education both nationally and internationally. Through evidence-based research, CASTeL is leading and advising on the development and implementation of innovative and effective curricula, teaching and learning in STEM education across the continuum from early childhood to postgraduate level. Members of CASTeL are actively involved in teacher education, pre-service teacher education, as well as in many national and internationally funded research projects. Keep an eye on castel.ie for updates.

CASTeL provides professional development programmes for teachers. A major event has been the SMEC conferences and the 9th STEM Education Research Conference (SMEC) “Regenerating STEM Education – Growing back better” will be held in DCU on 24-25th June 2022. ([SMEC - Science and Maths Education Conference 2022 \(dcu.ie\)](http://SMEC - Science and Maths Education Conference 2022 (dcu.ie)))

Science and Maths Teacher Education at DCU

Pre-service second-level teacher science/maths education programmes offered by DCU include the (a) [B.Sc. in Science Education](#) and (b) the Professional Master of Education ([PME](#)) for those who already have undergraduate degree in their discipline. The BSc in Science Education provides students with a Teaching Council accredited concurrent degree qualification in post-primary initial teacher education, which combines the study of three curricular subjects with teacher education studies. On successful completion of the programme, graduates can directly register with the Teaching Council as qualified to teach two subjects chosen from Physics, Mathematics and Chemistry, to Leaving Certificate Level. Throughout the programme, students engage in microteaching as well as two extended periods of placement in schools, teaching mainly at Junior Cycle (1st placement) and Junior and Senior Cycle (2nd placement). Students can also participate in the STEM Teacher Internship Programme - an initiative developed by DCU, Accenture and 30% Club that facilitates DCU STEM teachers in completing a 12 week paid internship in industry during summer of third year.

Note for students with interests in P.E., there are also the concurrent programmes B.Sc. in Physical Education with Biology and B.Sc. in Physical Education with Mathematics.

Much of the science/maths components of the teacher education programmes are delivered through the Schools of Chemical Sciences, Physical Sciences and Mathematical Sciences within the Faculty of Science & Health.

Chemistry Programmes at DCU

Within the School of Chemical Sciences, there is a new degree programme (Chemistry with Artificial Intelligence) in addition to the three undergraduate programmes previously offered focusing on specific aspects of Chemistry, i.e.

- B.Sc. Analytical Sciences ([AS](#))
Analytical science graduates can detect and quantify substances in a sample of material, using appropriate analytical techniques, within the biological, forensic and pharmaceutical environments.
- B.Sc. Chemical and Pharmaceutical Sciences ([AC](#))
Graduates understand design, synthesis, formulation and characterisation of active pharmaceutical ingredients (and other molecules and materials).
- B.Sc. Environmental Sciences and Technology ([EST](#))
Graduates have skills that enable them to understand and address environmental issues, such as climate change, biodiversity and waste (generation and management).
- B.Sc. Chemistry with Artificial Intelligence ([Chem with AI](#))
Graduates will use the power of AI to identify novel, useful molecules, e.g. new medicines and new sustainable materials, revolutionising discovery, development and production of new molecules.

There is also an option for students who wish to delay their choice of programme until the end of 1st year; students can follow the Chemical Sciences General Entry ([CGE](#)) and then choose between AS, AC, and Chem with AI at the end of first year. Two points to note, however: firstly, if you wish to pursue the Chem with AI degree, then you must join the Chemical Sciences General Entry in year 1. Secondly, while every effort is made to offer all CGE students their first choice at the end of year 1, however, if the level of interest exceeds year 2 places available, then they may be

offered their second or third choice. Students can apply directly through CAO for AS or AC in year 1.

While these four programmes all follow a common first year, they follow specific specialist modules from second year onwards. Additionally, a period of industrial/research placement is taken by all students in their third year (INTRA), providing valuable experience within the chemical/pharmaceutical industry or research laboratory.

The School of Chemical Sciences strives for teaching and research excellence by helping students to develop critical thinking and problem solving. We prepare our students to meet the challenges of modern industry and cutting-edge research environments. Our courses cover the fundamental principles and practice of chemical, pharmaceutical, analytical and environmental sciences, built to create an outstanding and stimulating educational experience. Our students experience lab-based environments, while enjoying the engagement with research-active staff members. Our degree programmes offer the skills and knowledge sought after by many industries. Our graduates are nationally and internationally regarded by prospective employers and research bodies. We offer a supportive and innovative learning environment for students, researchers, staff and collaborators.

Research in the School of Chemical Sciences

The School of Chemical Sciences is a research-intensive department with three primary research themes, which span key areas of research of national and international significance. These include climate and environmental research, nanomaterials and devices, and therapeutics and diagnostics. Underpinning these three themes lies core academic expertise in the areas of synthetic, medicinal, physical, nanomaterials, bioinorganic, and analytical chemistry.

Brief aspects of these areas are summarised in the diagram below.



T1: Climate Action: Energy, Water & Sustainability

Includes expertise in the following areas, for example: environmental research relating to climate, water, soil, atmospheric science, chemical ecology, green technology and pollution; analytical method development and the development of intelligent analysis tools to monitor and improve our environment. Study of marine and terrestrial ecosystem health; study of the atmosphere through aerosol characterisation and investigations of the contents of the air we breathe. Ongoing research seeks to breakdown greenhouse gases such as CO₂ for other uses and developing green technology that enables industry to be more sustainable. Studies of carbon in soil, water and coastal sediments and the investigation of subjects such as past environments on Earth, the recycling of waste and the search for extra-terrestrial life.

T2: Advanced Materials & Devices

Includes expertise in the following areas, for example: diverse materials science as applied for example to design responsive biointerfaces for sensor and drug delivery platforms, catalytic materials for energy production and luminescent probes for high precision cellular targeting and imaging; integration of sensing interfaces with functions such as fluidic handling, engineering architectures and properties in novel materials for biosensor and bioelectronic applications, as well

as meeting device sensitivity challenges related to analyte detection in marine water for example and early detection of disease biomarkers in blood.

Engineering of nano- and micro-patterns of soft polymers with responsive properties, the synthesis and photochemistry of materials with antimicrobial properties, conjugated polymers as hydrogen evolution catalysts, the design of carbon nano-onions for catalytic and sensing applications, and electrode material design for wireless electrochemiluminescence and cell stimulation.

T3: Therapeutics & Diagnostics

Includes expertise in the following areas, for example: developing precision-targeted probes for sensing of proteins, metabolites, structure and (super resolution) imaging in live cells and tissues; synthesis of imaging probes for cancer cells and bio-inspired functionalization of nano-onions for drug delivery; photocatalytic materials to target antimicrobial resistance and in the generation of renewable fuels; computational chemistry that focuses on modelling the stability and properties of pharmaceutical solid forms and the development and application of new DFT approaches.

Keep informed at: [School of Chemical Sciences](#)



Proceedings 40th ChemEd-Ireland

Saturday 16th October 2021, Dublin City University

The 40th ChemEd-Ireland was successfully held online, with a good attendance and a good range and number of talks (see programme below). Some of these talks are given in the Proceedings and others can be accessed as ppt presentations.

ChemEd-Ireland 2021 40th Annual Conference

A Celebration of Chemistry Teaching and Learning

Programme

- 9:30 Zoom Webinar Log-In and Welcome
09:40 Dr Mary Pryce, School of Chemical Sciences, Dublin City University
Renewable energy and climate change mitigation
10:00 Prof. Wesley Browne,
Professor and Chair of Molecular Inorganic Chemistry, University of Groningen, NL
Electrochemistry in energy storage: seeing inside the battery pack
10:50 Break
11:00 Susan Hammond, Head of Chemistry, Woking College, UK
Embedding microscale approaches in the classroom
11:30 **Celebrating Classroom Practice 1**
11:30 Dr Declan Cathcart, Temple Carrig School, Greystones (1)
PCR in the School Laboratory - DNA analysis to detect pathogenic E.coli
11:45 Dr Lisa Darley, Loreto Navan (2)
Inspiring future chemists - Ideas for transition year
12:00 Seán McMahon, Stepside, ETSS (3)
The use of digital learning in Leaving Cycle Chemistry
12:15 Michelle Bolger, Knockbeg College, Carlow (4)
The mechanism of monochlorination of methane - An active approach
12:30 Breakout Room discussion with presenters from Classroom Practice 1
12:45 Lunch
13:15 Dr John O' Donoghue, Trinity College Dublin / Royal Society of Chemistry
CO₂ Monitor Research and RSC Updates
13:45 Dr Brian Murphy, Technological University of the Shannon Midlands Midwest
2021 - The Year like no other! & IrEOES
14:00 Dr Odilla Finlayson, CASTeL, Dublin City University
Visualisations, Representations and Kinetics
14:30 **Celebrating Classroom Practice 2**
14:30 Michelle Dunne, St. Joseph's College, Lucan (1)
Transition Year Autumnal Chemistry - STEAM - Wellbeing - Connecting with Community
14:45 Seán Kelleher, Colaiste Choilm, Swords (2)
Notes from the far side of first principles
15:00 Dr Michele Somers, Dublin City University (3)
Simple but effective organisation strategies to improve Lab Safety
15:15 Breakout Room discussion with presenters from Classroom Practice 2
15:30 Dr Peter Childs, University of Limerick
Looking back: 40 years of ChemEd-Ireland

Several of the presentations are available at [ChemEd PP Presentations - Google Drive](#)
Talks in blue above are in the Proceedings.



40 Years of ChemEd-Ireland: A retrospective

Peter E. Childs
peter.childs@ul.ie



The background

I came to Ireland in July 1978 to teach chemistry to degree level at Thomond College of Education (TCE), initially to students of PE with Chemistry. Later from 1980 I taught chemistry to students of General & Rural Science (later Science Education), Woodwork and Metalwork. In May 1980 I started *Chemistry in Action!*, a chemistry teacher's newsletter, supported by donations from industry and launched at the Institute of Chemistry of Ireland's (ICI) Annual Congress in Sligo. In Uganda I had started a similar newsletter, *A Modern Approach to Chemistry*, and was also involved in running a conference for A level chemistry teachers. These gave me the idea to start a newsletter (sparked by a conversation with a teacher at the 5th ICCE in Dublin) and later a dedicated conference to fill a gap in the school year. The ISTA conference was held in March/April each year and the ICI ran a teacher's refresher course in January, as well as Department of Education in-service courses. I decided to run a conference at the start of the school year in October and to focus on developments in chemical education, research and practice, rather than just supporting the existing curriculum. It was to be a chemical education conference not an in-service course.

The basic idea

The conference was launched in 1982 and in the original design there was to be an invited speaker, usually from overseas, and a well-known chemical educator. The conference started on Friday night with the Thomond Lecture in Science Education, by the invited speaker, an open lecture. The conference followed on the Saturday, which required registration, and included another talk from the invited speaker. The first Thomond Lecture was given by Professor Malcolm Frazer from the University of East Anglia. The theme of the first conference was 'Chemical Education in Ireland', Table 1, and various speakers looked at the state of chemical education in Ireland, North and South.

Table 1: 1st ChemEd-Ireland conference 1982 *Chemical Education in Ireland*

Thomond Lecture in Science Education
Solving Chemical problems M.J. Frazer
Introduction P. E Childs
Chemical Education in the South H. J. Lyons
Chemical Education in the North B. McGarvey
Chemical Education in East Anglia M.J. Frazer
The proposed new LC Chemistry Syllabus D. Nash
The ISTA chemistry sub-committee P. Hogan

There was a small fee to cover lunch and materials, and the cost of the speaker's expenses was raised from various sources. One aim was to

keep the fee as low as possible to make the conference attractive – it was £15 for many years. I was assisted in the early years by Mary Smith, and later by Marie Walsh (now teaching in TUS, formerly LIT). It stayed in Limerick for 25 years, moving to the University of Limerick when TCE merged with it in 1991. In Limerick it was organised by two people – I looked after the programme, speakers and donors, and Mary, then Marie, were co-organisers and looked after registration and general organisation. Students were recruited to run the tea and coffee breaks.

I wanted it to be a conference that would encourage, inspire and stimulate teachers at the start of a new school year; giving them new ideas and insights into the teaching and learning of chemistry, and giving them an opportunity to meet and talk to other chemistry teachers. This was an important aspect of the conference, which was small enough to allow people to meet, as often teachers were the only chemistry teacher in their school. Attendances were typically 30 to 70. I hoped that the teachers would go away energised and enthused about chemistry for a new school year. Amazingly this worked and it drew teachers from all corners of Ireland – from Dundalk to Donegal, Cork to Waterford, and all places in between, and a few from Limerick! I soon learned that you can't run a conference, in-service course or industry study tour, and depend on local teachers to attend. The conference was timed to meet the early trains from Dublin and Cork, and many teachers came long distances and attended year after year. Familiar faces appeared each year, although I am the only person to have been to all 40 conferences. Most of the teachers who came to the first ones have now retired.

I decided that the conferences would have a single theme or topic, so that one day would give a substantial introduction, rather than having several unrelated topics. You can see this in the titles of the first 25 conferences (Table 2). I wanted to expose teachers to chemical educators from outside Ireland and the latest chemical education research (CER) and new ideas for teaching chemistry.

Table 2: The topics for the first 25 conferences

1982	#1	Chemical Education in Ireland*
1983	#2	Practical Work in School Chemistry*
1984	#3	Mixed Ability Teaching in Science*
1985	#4	Teaching about Industrial Chemistry at School*
1986	#5	Everyday Chemistry*
1987	#6	Environmental Chemistry ⁺
1988	#7	The History of Chemistry ^x
1989	#8	Chemistry and Materials*
1990	#9	Chemistry in the Junior Science Course ⁺
1991	#10	Improving The Image of Chemistry ⁺
1992	#11	Health and Safety in School Chemistry ⁺
1993	#12	Chemistry in the Transition Year ⁺
1994	#13	The New L. C. Chemistry Syllabus ⁺
1995	#14	Environmental Chemistry II ⁺
1996	#15	Analytical Chemistry ⁺
1997	#16	Industrial Chemistry II ⁺
1998	#17	Practical Work in Chemistry II ⁺
1999	#18	Information Technology and Chemistry ^x
2000	#19	Chemistry for a New Millennium ⁺
2001	#20	Real-life Chemistry: teaching from issues ⁺
2002	#21	Laboratory management and organisation ⁺
2003	#22	Transition Year Chemistry II ⁺
2004	#23	Chemical Education Research and the Teacher ⁺
2005	#24	Teaching about STS ⁺
2006	#25	Twenty-five years of chemical education in Ireland ⁺

* Proceedings published as separate volumes

^x Proceedings not published

⁺ Proceedings published in *Chemistry in Action!*

Distinguished chemical educators

I wanted to expose Irish chemistry teachers to well-known chemical educators from outside Ireland, given that most teachers were not able to attend overseas conferences. Over the years we have had some leading chemical educators, some of whom are given in Table 3. Later some of these also spoke at the ISTA conferences.

Table 3: Some overseas ChemEd-Ireland plenary speakers (#1-25)

*** From the University of York**

Malcolm Frazer
Alex Johnstone
Rosalind Driver
*David Waddington
*John Holman
*Judith Bennett
Vanessa Kind
John Emsley
*Francesca Garforth
Ilka Parchmann
Stuart Bennett
Ruth Jarman

I had a previous connection with the University of York and Professor David Waddington. The Science Education Group at York (UYSEG) was responsible for the world-famous context-based Salters' courses, and the Chemical Industry Education centre (CIEC) was also based there in the Chemistry Department. (For more details about David Waddington's contributions to chemical education see Childs, 2021). Over the years a several of the plenary speakers have come from York (see Table 3). Figure 1 shows speakers from the 1983 conference on Practical Work, featuring the late Alex Johnstone, including Roy Brown then TCD and a young Declan Kennedy, then a chemistry teacher in Cobh.



Figure 1: Some of the speakers from the 2nd ChemEd-Ireland, 1983. L to R: Roy Brown, Lex Johnstone, Declan Kennedy

After a few years we dropped the Friday night open lecture as it was poorly attended and made it the opening lecture on Saturday.

But one speaker doesn't make a programme, and I always tried to invite a mix of speakers on the topic, teachers and third level lecturers, men and women, and tried to get someone each year from Northern Ireland to give an all-Ireland flavour. I tried not to have the same speakers too often and to encourage young teachers and postgrad students to take part. The early conferences were mostly lectures with some demonstrations, but later workshops were introduced to break up the programme, and this proved very successful. We also had a bookstall and a few other exhibitors, like Gordon Woods' Science Shirts.

Publishing the Proceedings

One of the weaknesses of conferences is that they're one-off, ephemeral events – they're great on the day for those who come, but then their message is forgotten, the impact weakens, and the majority of teachers who don't come, miss out. From the beginning I decided to publish the Proceedings as a permanent record of the event, and also to make the talks more widely available. Several Proceedings were published (Figure 2) containing the plenary talk(s) and other talks. Always assuming I could get the speakers to prepare written versions of their talks, which thankfully many did.

However, I soon found that this didn't do the job. We had to sell them at cost and couldn't afford to post them to every participant. Not enough were sold to make it worthwhile and it wasn't reaching

enough the target audience. These published Proceedings still contain useful material. I thus decided from 1987 onwards that the proceedings would be published in the Spring issue of *Chemistry in Action!* in the year after the conference. At its peak this reached about 600 Irish teachers and up to 1,000 in the UK through the RSC.

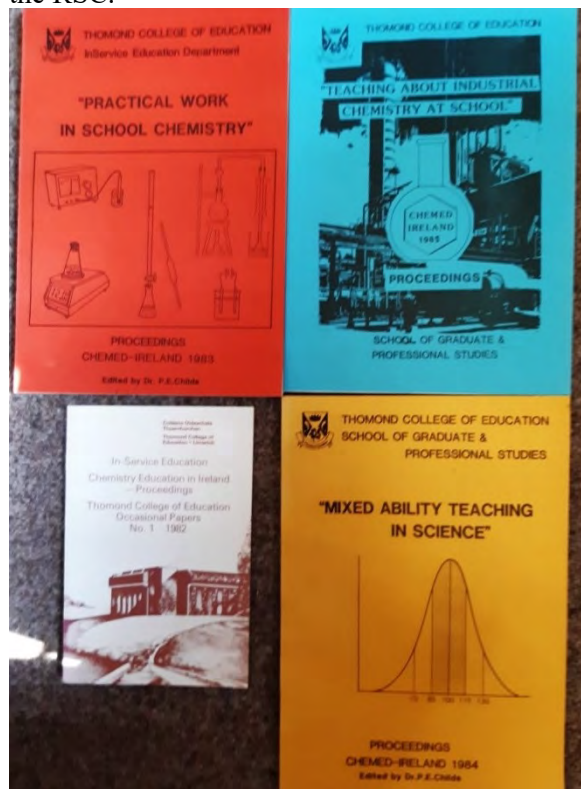


Figure 2: Four titles from the Proceedings of ChemEd-Ireland

This was much more effective and reached far more teachers and this has continued until today, apart from a couple of years when it proved impossible to get the written talks. *Chemistry in Action!* is now distributed mainly electronically, due to high postage and printing costs, and the most recent back issues are available free at www.chemistryaction.com (thanks to Maria Sheehan, the web editor).

The future secured

Having run ChemEd-Ireland for 25 years (most with Marie Walsh) in Limerick and as I was approaching retirement, I decided that to ensure its future it should move around the country. I contacted my friends in chemical education in other Irish institutions to see if they were willing to take it on. The idea was that it would rotate around various institutions, alternating between the east and west coast, and including Limerick (UL or LIT) as a venue. The 26th conference was

hosted by Declan Kennedy and his team in UCC and was the best-attended ChemEd-Ireland ever (until the 2020 online event, also in UCC.) The list of venues from the 26th onwards is given in Table 4. On the East coast we have DCU, TUD (formerly DIT) and recently TCD, and on the West coast UCC, TÚS (LIT) and UL. Thus each institution hosts the conference every 5 years or so. This has proved to be a very successful model.

Table 4: Venues for ChemEd-Ireland from #26

2007 26 th	UCC
2008 27 th	DCU
2009 28 th	UL
2010 29 th	DIT
2011 30 th	UCC
2012 31 st	DCU
2013 32 nd	LIT
2014 33 rd	DIT
2015 34 th	UCC
2016 35 th	DCU
2017 36 th	UL
2018 37 th	TCD
2019 38 th	TU Dublin (DIT)
2020 39 th	UCC online
2021 40 th	DCU online
Future conferences	
2022 41 st	TÚS (LIT)
2023 42 nd	TCD
2024 43 rd	UCC
2025 44 th	TU Dublin
2026 45 th	UL

Some conference highlights

The conferences have proved to be great opportunity for teachers to meet, chat and share ideas over coffee, lunch and at the bookstalls and workshops. There is always a great buzz and it is very hard to get a room of teachers quiet for the next session! I have been at every one and a generation of chemistry teachers has come and gone since the conferences started. Due to Covid-19 the last two conferences have been online and this has worked amazingly well. The 2020 conference in UCC had the largest attendance ever (over 200). Hopefully in 2022 the conference will be back to face-to-face, but I think it is likely to be offered as blended conference in future – part in person and part online, with two fee levels. It is easier and cheaper to attend online, although it's not the same, and will suit many teachers. Figure 3 shows two speakers from the 2001 conference on Real Life Chemistry, David Waddington and Stuart Bennett.



Figure 3: Two visiting speakers at the 20th ChemEd-Ireland 2001. L to R: Professor David Waddington (York) and Dr Stuart Bennett (Open University)

I can remember some highlights of past conferences. The model blast furnace throwing off sparks in a classroom in TCE, as part of the conference on Teaching the History of Chemistry (very interesting but one of the poorest attended.) Demonstration lectures by Roy Brown, Randal Henly and the tour de force by the late Viktor Obendrauf (from Austria), Figure 4, as well as Kitchen Chemistry from Gordon Woods dressed as Mendeleev giving the premiere of his lecture about Mendeleev and the Periodic Table (Figure 5), which he went on to give in many places. John Emsley, chemist turned author, on 'Elements of surprise', Annie Hodgson from York using a

Geiger counter to show us that Low Salt (KCl) was more radioactive than a smoke detector (containing americium). We have had some excellent talks over the years from local speakers, including teachers and postgrad students speaking about their own research.



Figure 4: The late Viktor Obendrauf (Austria)



Figure 5: Gordon Woods as Mendeleev
[Gordon Woods: Mendeleev and the Periodic Table - Marlborough College](#)

The importance of bonding

One important aspect of the conferences has been the opportunity for chemistry teachers to meet, talk and share ideas with other teachers. (Figure 6)



Figure 6: Scenes from past conferences

There was always a great buzz of conversation before and after talks, over coffee and lunch, and in workshops. Teachers love to talk to each other!

The conferences bring everyone together for a day away from school and home responsibilities, with a common purpose, and this makes it easy to share experiences, ask advice, meet old friends, and make new ones. I usually had a bookstall with lots of freebies and teachers always went away with more than they came with. My plan with *Chemistry in Action!* going mostly electronic, was to give away printed copies at ChemEd-Ireland and at the ISTA annual conference, but this was disrupted by the pandemic.

Main themes from 40 years

Chemistry teachers:

1. need and value opportunities to meet each other and discuss teaching their subject, and share ideas.
2. need to be aware of the findings of chemical education/science education research and its relevance and use in the classroom.
3. need to emphasise teaching for understanding rather than just recall of facts - focus on deep rather than shallow learning.
4. need to include hands-on experience of chemicals and chemical reactions to bring theory to life – through demos and practical work.
$$\text{Na(s)} + \frac{1}{2}\text{Cl}_2\text{(g)} \rightarrow \text{NaCl(s)}$$
 versus demo or video
“A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.” Albert Einstein (1879-1955)
5. need to be better informed about Ireland’s chemical industry and careers in chemistry so as to make their subject attractive and relevant to their students.
6. need to keep up-to-date with their subject – a lot has changed in chemistry/science in 40 years!
7. need to adapt to and be prepared for new curricula and new types of assessment (as with the 1983 and 2000 syllabi.).

Conclusion

When I started the ChemEd-Ireland conferences in 1982 I didn’t think they’d still be going and that I’d be still around 40 years down the road. The conference now has an established place in the Irish chemistry teacher’s calendar and I hope

it will outlast me. I would like to thank the many people who have helped to organise the conferences over the years (too many to name) and who have spoken at the conferences or run workshops. I would also like to thank the 100s of teachers who have attended over the years. I hope the conferences will continue to run and develop over the coming years. I hope that those of you who have been to one or more ChemEd-Ireland conferences have profited from the experience and have learnt as much as I have from attending.

In 2022 it is due to return to Limerick hosted by the new Technological University of the Shannon in Limerick, and organised by Marie Walsh, no stranger to ChemEd-Ireland.

References

Childs, P.E., (2021), PoSE#13 ‘Professor David Waddington: chemistry in context’, *Science*, Nov. 2021

□

PCR in the school laboratory

Declan Cathcart

Declan.Cathcart@ucd.ie

Introduction to PCR

The polymerase chain reaction (PCR) is a technique used to synthesise millions of copies of a specific DNA sequence from a tiny number of original DNA molecules. It has arguably been the most important tool in the history of molecular biology, making possible many of the advances in biomedical research as well as applications in genetic testing, the detection and identification of pathogens, analysing ancient DNA, and criminal forensics.

Since 2020, PCR has become an everyday household term, but even before that, there was a case for including PCR as an element of the secondary science curriculum. An understanding of PCR is dependent on having a clear idea of the structure of DNA, the process of DNA replication, and an appreciation of the relative size of genes and genomes. PCR provides us with a relevant real-world context for the teaching and learning of these core concepts.

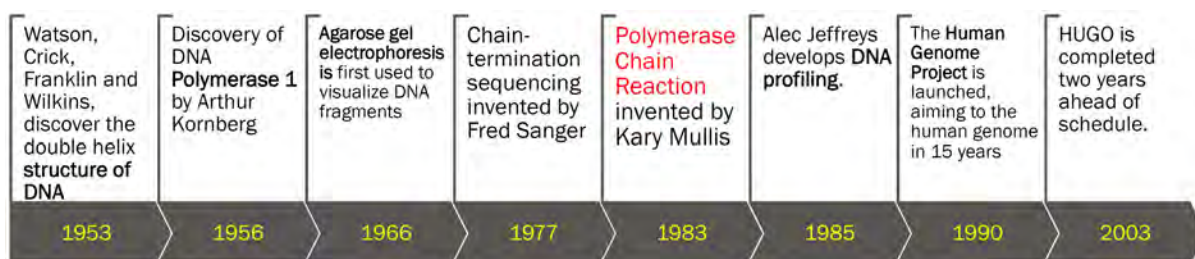


Figure 1. Timeline of some key events in the development of PCR and related DNA technology.

PCR was invented by Kary Mullis, a scientist working at the biotech company Cetus in California since the late seventies, developing techniques to synthesise oligonucleotides (short DNA molecules). According to Mullis, the idea came to him one Friday evening in 1983, as he drove to a chalet in the hills where he was going to spend the weekend with his girlfriend. He was planning a DNA sequencing experiment, when it occurred to him that the DNA polymerase enzyme used in sequencing reactions could be harnessed to copy specific DNA sequences in enormous quantities, even if the target DNA was only present in tiny amounts in the original sample. The story goes that he had to stop the car twice so that he could scribble down some notes, and that when he finally got to his getaway destination, he couldn't stop talking about it. "It was difficult for me to sleep that night," he said, "with deoxyribonuclear bombs exploding in my brain."

Mullis was awarded the Nobel Prize for Chemistry in 1993 for his invention of the polymerase chain reaction. In doing so, he solved two major challenges in detecting and identifying specific DNA sequences.

The first problem is one of specificity – the sequence we are looking for is buried in a lot of DNA that we don't want to detect. The human genome is 3,400,000,000 nucleotide base pairs long. If this was written on a tape measure, then the tape would be about 8000 km long. Looking for a 500 base-pair sequence in a human genome is like trying to find a one-meter section on that 8000 km tape.

The second issue relates to the quantity of DNA we are trying to find – the total amount of target DNA in most samples is very, very small. In order to visualise a specific 500bp fragment of DNA on an agarose gel, we need about 10-20 nanograms of it. A 500 bp DNA fragment has a MW of about 660g/mol. Since Avogadro's number is 6.02×10^{23} , we need 1.8×10^{10} copies of that 500 bp DNA fragment so that we can see it on a gel.

Mullis' polymerase chain reaction not only solves the problem of trying to detect a gene (or any section of DNA) among a mind-boggling number of other genes, it also provides the user with billions of copies of that gene. The idea of PCR is relatively simple, prompting Mullis to think that the idea was too simple for someone not to have thought of it first. After doing some asking around, he was satisfied that nobody had heard of anything like it. Mullis then spent many months planning his first PCR reaction. His experiment turned out to be an immediate success.

DNA Polymerase

Mullis' experiment involved using an enzyme that was being widely used for DNA sequencing since its invention by Fred Sanger in 1977. DNA polymerase, discovered in 1956 by Arthur Kornberg (see Figure 1), plays a central role in the function of a cell. It is the key enzyme in DNA replication, a process that is essential for cell division, growth and repair, and of course for reproduction.

DNA molecules consists of two complementary strands that are anti-parallel – the two strands run in opposite directions. During DNA replication, the two strands of the double helix are separated, and the DNA polymerase enzyme catalyses the addition of nucleotides using the separated DNA strands as templates. The enzyme adds nucleotides to the growing DNA strand, with each addition being complementary to the template strand. In this way, DNA synthesises a new complementary strand on each of the original strands. The resulting two double-stranded DNA molecules are half-old, half new, which is why we refer to DNA replication as *semi-conservative*.

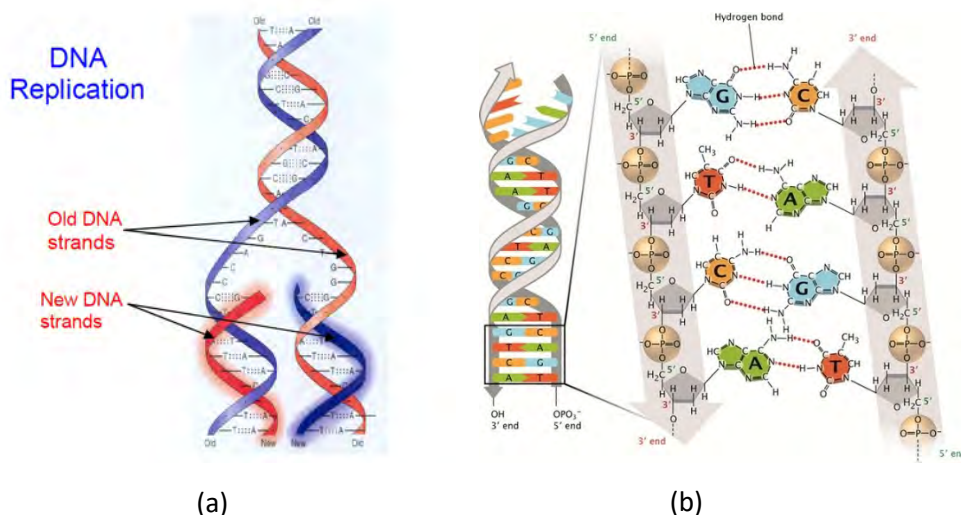


Figure 2: (a) semiconservative DNA replication. (b) the structure of DNA. Each nucleotide subunit consists of a deoxyribose sugar, a phosphate and a nitrogenous base, with a 5'-phosphate on one end, and a 3'-OH on the other. The strands are thus anti-parallel.

One of the characteristics of DNA polymerase is that it can only catalyse the addition of nucleotides in one direction. DNA is always synthesized in the 5'-to-3' direction (see Fig 2b), meaning that nucleotides are added

only to the 3'-end of the growing strand. During DNA replication, the 5'-phosphate group of the new nucleotide binds to the 3'-OH group of the last nucleotide of the growing strand.

This characteristic of the enzyme necessitates the involvement of a primer oligonucleotide primers to initiate the activity of DNA polymerase. Short RNA primers bind to the DNA stand that is to be copied, giving the polymerase the 5'-end it needs to begin adding the free nucleotides (see Figure 3). Note that DNA replication in cells is complicated by the fact that DNA molecules on the lagging strand must be synthesised in fragments as the fork of the double helix is opened up. These Okazaki fragments are then stitched together by another enzyme DNA ligase.

The Chemistry of PCR

The polymerase chain reaction invented by Mullis borrows from the playbook of DNA replication.

A PCR reaction consists of the following components:

- **Target DNA**
 - or a sample of DNA that is being tested for the presence of the target DNA)
- **Primers**
 - two DNA oligonucleotides that are complementary to sequences that flank the DNA of interest, one primer for each strand
- **DNA polymerase**
 - Catalyses the synthesis of new DNA strands complementary to existing template sequences
- **Nucleotides**
 - individual dATP, dCTP, dGTP, dTTP molecules, collectively known as dNTPs
- **Buffer**
 - containing salts and ions to provide the optimal conditions for polymerase activity

The PCR reaction mix is then incubated at a series of different temperatures in order to achieve the following steps:

- **Denaturation**
 - typically 90-95 °C for 30-60 seconds, which separates the double-stranded DNA to single-stranded DNA, by disrupting the hydrogen bonds between the strands of the double helix.
- **Annealing**
 - typically 42-60 °C, which allows the primers to attach to the target DNA at the complementary regions.
- **Extension**
 - carried out at the optimal temperature for DNA polymerase activity, allowing the addition of nucleotides to the strand that is complementary to the single-stranded DNA template.

These three steps are then repeated many times (typically 25-30 times). The result is an exponentially increasing number of copies of the target DNA fragment.

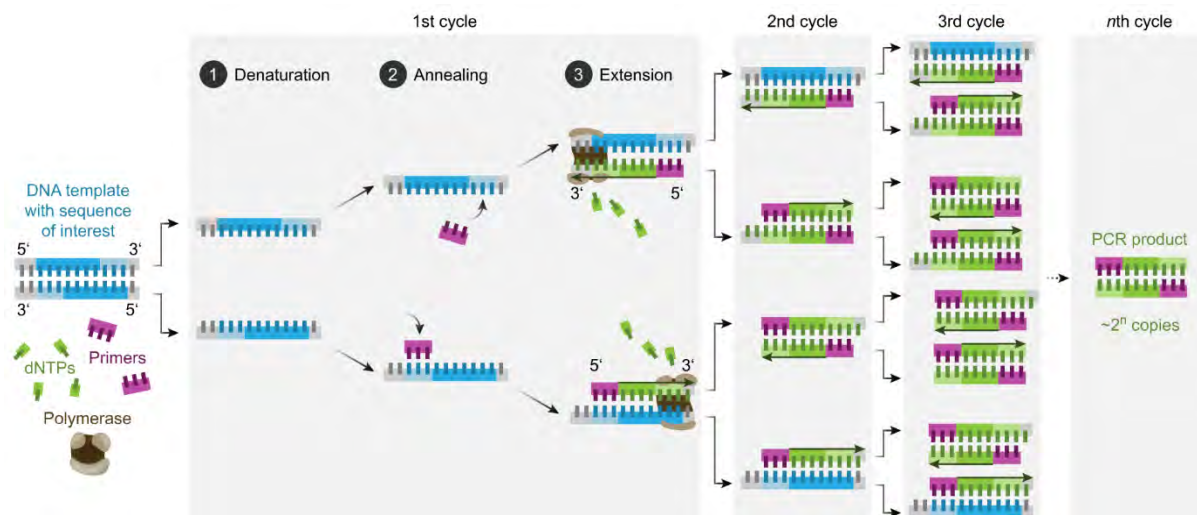


Figure 3: The Polymerase Chain Reaction

When Mullis carried out those original pioneering PCR experiments, he used Kornberg's DNA Polymerase 1, which had been isolated from the bacterium *E.coli*, the model organism for much early molecular biology research. The optimal temperature for DNA Pol 1 activity is 37°C. Since each round of the PCR reaction required a high denaturation temperature to separate the two strands of the double helix, enzyme had to be added manually at the end of each round. For researchers using PCR in the very early days, this meant resetting the PCR reaction as many as 40 times over a four- or five-hour period, adding fresh enzyme each time. It also required standing by three water baths set at different temperatures, patiently moving tubes from one water bath to another, restarting timers every minute or two, over the course of the reaction see (Figure 4).

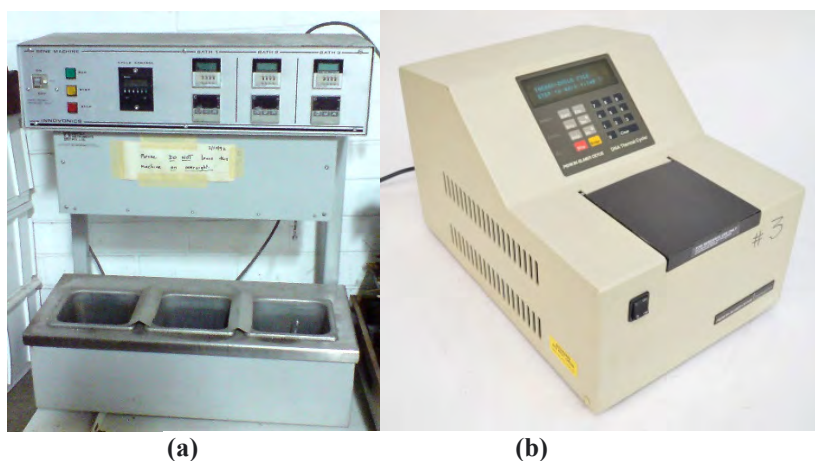


Figure 4: (a) An early, three temperature water bath thermal cyclers for PCR. (b) the Perkin Elmer DNA Thermocycler

Taq polymerase and the Perkin Elmer TC1

Two major advances allowed PCR to become the widespread practical tool that has been used in labs the world over ever since. In 1986, Mullis and his colleagues at Cetus isolated a DNA polymerase from a thermophilic bacterium by the name of *Thermus aquaticus*. This bacterium had been known since the late 1960's having been discovered by Thomas Brock, who isolated the strain from the volcanic hot springs of the Lower Geyser Basin at Yellowstone National Park.



Figure 5: The Lower Geyser Basin at Yellowstone National Park, where Thomas D. Brock and Hudson Freeze discovered the thermophilic bacterium *Thermus aquaticus*, in 1969.

T. aquaticus grows best at around 70°C. Mullis and his team figured that if they could isolate the DNA polymerase from this bacterium, it might be heat-stable enough to withstand the denaturation temperatures of the PCR reaction. In 1986, they succeeded in isolating what became known as *Taq* polymerase, versions of which have been used in PCR reactions ever since. The commercialisation of *Taq* removed the need for the researcher to manually add the polymerase after each round of PCR.

Within a year, advances in computer programming and automation also allowed the US biotech company Perkin Elmer to produce an instrument they named the TC1 DNA Thermal Cycler (Fig. 4b). This was essentially a programmable heating and cooling block which allowed the automated regulation of the temperatures and times needed for PCR. The invention of this all-in-one machine automated PCR. This altered the course of molecular biology research across the world, as PCR became a reliable, portable, practical, and efficient laboratory procedure with endless applications in biotechnology research and industry.

Shiga toxin-producing *E.coli* (STEC)

Escherichia coli (abbreviated as *E. coli*) is a bacterium found in the environment, foods, and intestines of people and animals. There are many different strains or types of *E.coli*, some harmless, some harmful and some useful. The harmless strains are commonly found in the intestines of humans and other animals and are an important part of normal gut microflora. It is easy to grow in the laboratory and is the most widely studied prokaryote. It has been used as a model organism for many decades in microbiology and biotechnology. Many of the great discoveries and advancements in molecular biology and genetic engineering were made through the lens of the biology of *E.coli*.

Although most *E.coli* strains are harmless, and some are very useful, others are pathogenic. Some can cause diarrhoea, while others cause urinary tract infections, pneumonia, and other illnesses.

There are some *E. coli* strains that cause disease by making a toxin called Shiga toxin. We call these “Shiga toxin-producing” *E. coli*, or STEC for short. They are sometimes also called verocytotoxic *E. coli* (VTEC) or enterohemorrhagic *E. coli* (EHEC).

The most commonly identified STEC in Ireland and in many other countries has been *E. coli* O157:H7 (often shortened to *E. coli* O157 or even just “O157”). News reports that talk about “an outbreak of *E. coli*” are often referring to O157. However, there are other *E. coli* strains that are of concern. In 2011 there was a large outbreak in Europe caused by a Shiga toxin-producing *E. coli* O104:H4.

The Irish Environmental Protection Agency estimates that 30% of household wells in Ireland are contaminated by *E. coli* arising from animal or human waste. It also points to a growing number of STEC cases, and that these patients are up to four times more likely to have consumed untreated drinking water from household wells (EPA, 2017).

Ireland has the highest incidence of STEC in Europe. Cattle are the main source, and infection is spread either through animal contact or through contaminated food and water. Person to person spread is also common. In other countries the most common source of infections is through food outbreaks (EPA, 2017). In Ireland, rural families are often affected through contaminated household wells. Consumers of water from household wells are at a much greater risk of STEC infection than those who drink water from either public or private mains supplies (EPA, 2017).

Using PCR to detect STEC in the school laboratory

Methods used to detect STEC in food, water and clinical samples previously relied on culture-based methods and detection of indicator proteins using antibody methods (e.g. ELISA).

In recent years PCR technology is being used to screen samples for certain the presence of particular DNA sequences associated with STEC. The PCR detection is then followed by confirmation and further strain identification using culture-based methods.

There are genes that, if detected by PCR, have been shown to be indicators of the presence of STEC. One such gene codes for the production of the **Shiga toxin**. Another example is a gene for the production of the **Intimin** adhesin protein.

These genes are **virulence** factors. The virulence of a pathogen is its ability to cause disease. The proteins produced by these virulence genes play key roles in the development of the disease in the host.

1. Shiga toxins - *stx* genes:

This is a family of related molecules produced by STEC and a few other related bacteria such as *Shigella*. Shiga toxins cause damage to cells by inhibiting protein synthesis, in a similar way to the plant toxin ricin, made famous by the Soviet KGB.

There are two groups of Shiga toxins - **Stx1** and **Stx2**. The *stx2* gene shares a 60% sequence identity with the *stx1* gene.

2. Intimin protein - *eaeA* gene:

Intimin is a protein present on the cell wall of some bacteria that allows it to attach to and disrupt the cell membrane of host cells such as the cells of the lining of the human intestine. This causes lesions in the intestinal lining resulting in diarrhoea, and sometimes bleeding.

The intimin protein is needed by the bacterium so that it can adhere to the human host cells. The protein is encoded by the *eaeA* gene, and some mutations in the *eaeA* gene have been shown to make the bacterium unable to invade the host cell.

Table 1: Primers used in this PCR protocol for the detection of *stx* and *eaeA* genes

Name	DNA sequence	Function	PCR Product size (bp)
stxForwa	GAACAAAATAATTTATATGT	Forward <i>stx1</i> and <i>stx2</i>	526 (<i>stx1</i>) 523 (<i>stx2</i>)
stxForwb	GAACGAAATAATTTATATGT	Forward <i>stx1</i> and <i>stx2</i>	
stxForwc	GAGCAAAAATAATTTATATGT	Forward <i>stx1</i> and <i>stx2</i>	
stxForwd	GAGCGAAAATAATTTATATGT	Forward <i>stx1</i> and <i>stx2</i>	
stxReva	ATGATGATGACAATTCAGTAT	Reverse <i>stx1</i> and <i>stx2</i>	
stxRevb	ATGATGATGGCAATTCAGTAT	Reverse <i>stx1</i> and <i>stx2</i>	
stxRevc	CTGATGATGACAATTCAGTAT	Reverse <i>stx1</i> and <i>stx2</i>	
stxRevd	CTGATGATGGCAATTCAGTAT	Reverse <i>stx1</i> and <i>stx2</i>	
eaeForw	ACCCGGCACAAGCATAAG	Forward <i>eaeA</i>	741
eaeAReva	CGTAAAGCGAGAGTCAATATA	Reverse <i>eaeA</i>	
eaeARevb	CGTAAAGCGAGAGTCAATGTA	Reverse <i>eaeA</i>	
eaeARevc	CGTAAAGCGGGAGTCAATATA	Reverse <i>eaeA</i>	
eaeARevd	CGTAAAGCGGGAGTCAATGTA	Reverse <i>eaeA</i>	

Single and duplex PCR protocol

The primer pairs described above in Table 1 can be used in separate PCR reactions to detect a specific gene (either *stx* or *eae*) but the two primer pairs can also be combined in a single **duplex** PCR protocol.

This duplex PCR allows for the detection of both the *stx* and *eaeA* genes simultaneously. In addition, this PCR protocol is designed to detect *all* STEC variants that have been described to date (or at least until 2019).

These genes are the two most important virulence factors associated with *E. coli* outbreaks. Notice that this PCR test does not set out to identify the strain of *E. coli* that is present in the sample, but rather the presence of (either or both of) these two virulence genes, including any known versions of them. This is important because more than 50% of STEC infections may be caused by non-O157:H7 strains, of which there are many.

The inclusion of both primers pairs results in a PCR diagnostic tool that should detect any and all known variants of STEC.

PCR in School

In the school lab, students are presented with a number of water samples for testing. A background story tells them of an outbreak of *E. coli* O157 in the south-east, and their task is to test a variety of drinking water sources to see if they can find the source of the outbreak.

One of the samples contains a small quantity of genomic DNA from *E. coli* O157. This is harmless but will provide a “positive” sample. Students are given the primer sets for the *stx* and *eaeA* genes, a PCR mix containing *Taq*, dNTPs and buffer. They use micropipettes to prepare the PCR reaction by mixing the samples in tiny 25µl tubes with the other PCR reagents (including positive and negative control tubes). They then place their sets of tubes in the PCR machine, and press start.

After the PCR reaction has finished, students analyse their tubes for the presence of DNA fragments using agarose gel electrophoresis. The presence of either of two DNA fragments of the expected sizes indicate the presence of Shiga-toxin producing *E. coli* in that water sample.

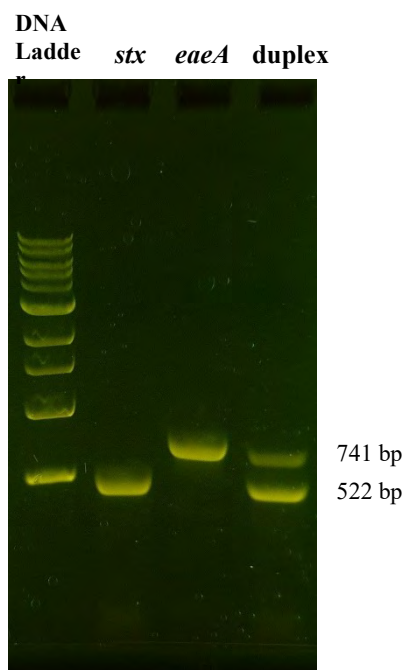


Figure 6: Agarose gel electrophoresis of the PCR products of the STEC detection protocol, showing the DNA fragments of the *stx* and *eaeA* genes, virulence factors associated with STEC.

Acknowledgements

This project was carried out with support from the Amgen Biotech Experience (ABE), Ireland and the ABE Master Teacher Fellowship Program. ABE provided materials and equipment which otherwise I could not

have hoped to bring into my school laboratory. ABE supports teachers worldwide by enabling teachers and students to access the equipment and consumables needed to engage with cutting-edge science and technology in schools.

Science on Stage also provided me with a grant to travel to the Netherlands to pilot these and other biotechnology and bioinformatics activities with secondary school students, as part of a Science on Stage Joint Project with fellow science teacher and partner Andrea van Bruggen in Utrecht. I am also grateful to ABE Netherlands, and U-talent at the University of Utrecht for their support. Finally, I would like to thank my TY Biotech students at Temple Carrig School, Greystones for their patience with, and enthusiasm for, trying new things.

Biography

Dr Declan Cathcart teaches Science, Biology and Mathematics at Temple Carrig School, Greystones, where he runs a 10-week TY Biotechnology module. Declan is also a part-time lecturer at the School of Education at UCD and the School of Mathematics and Statistics, where he works with BSc, MSc and PME students. He is also a member of the Irish Science on Stage team since 2017 and will present a workshop on PCR at the European Science on Stage Festival in Prague in March. Declan has been collaborating with Amgen Biotechnology Experience, Ireland since 2015, developing and piloting biotechnology practical activities for secondary students.

Declan ran his first PCR in 1990, at the Department of Protein Engineering in the University of Reading, having never heard of this new-fangled thing until he started working there.

References

- Angles d'Auriac, M.B., and Sirevag, R. (2018) Multiplex PCR for the simultaneous detection of the Enterobacterial gene *wecA*, the Shiga Toxin genes (*stx1* and *stx2*) and the Intimin gene (*eae*). *BMC Res Notes* 11: 360
- European Food Safety Authority (2019) The European Union One Health 2019 Zoonoses Report. European Centre for Disease Prevention and Control
- Fagerquist, C. K., Zaragoza, W. J., Sultan, O., Woo, N., Quiñones, B., Cooley, M. B., & Mandrell, R. E. (2014). Top-down proteomic identification of shiga toxin 2 subtypes from Shiga toxin-producing *Escherichia coli* by matrix-assisted laser desorption ionization-tandem time of flight mass spectrometry. *Applied and Environmental Microbiology*, 80(9), 2928–2940. <https://doi.org/10.1128/AEM.04058-13>
- Gunstone, R. F., & Champagne, A. B. (1990). Promoting conceptual change in the laboratory. In E. Hegarty-Hazel (Ed.), *The student laboratory and the science curriculum* (pp. 159–182). London: Routledge
- Kimata, K., Shima, T., Shimizu, M., Tanaka, D., Isobe, J., Gyobu, Y., Watahiki, M., and Nagai, Y. (2005). Rapid Categorization of Pathogenic *Escherichia coli* by Multiplex PCR. *Microbiol. Immunol.*, 49(6), 485–492
- Moon, G., Kim, W.J., and Shin, W. (2004). Optimization of Rapid Detection of *Escherichia coli* O157:H7 and *Listeria monocytogenes* by PCR and Application to Field Test. *Journal of Food Protection*, Vol. 67, No. 8, 2004, pp. 1634–1640
- Report of the Scientific Committee of the Food Safety Authority of Ireland (2020). Advice on Shiga toxin-producing *Escherichia coli* (STEC) detection in food. FSAI, Ireland.
- Zhang, L., Zhang, L., Du, Y., Li, X., Unger, M., Davlut, D., Sloan, A., Armstrong, G. D., Wang, G., & Cheng, K. (2019). Mass spectrometry-based Shiga toxin identification: A clinical validation. *Journal of Proteomics*, 198 (January), 145–150. <https://doi.org/10.1016/j.jprot.2019.01.020>

□

Getting More from your CO₂ Monitor

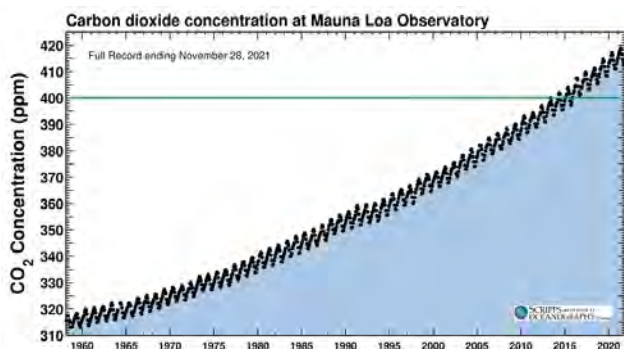
John O'Donoghue

School of chemistry, Trinity College Dublin and the Royal Society of Chemistry (RSC) Ireland
john.odonoghue@tcd.ie

In the early days of the pandemic, the World Health Organisation (WHO) mistakenly claimed that COVID19 disease was not contractable through airborne transmission. Unfortunately, this was based on out of date science since we now have extensive evidence from hundreds of scientific experts from all over the world that the SARS-CoV-2 pathogen that causes COVID19 is in fact airborne and can hang in the air for long periods of time. Some reports even claim that without ventilation, it can “*retain infectivity for up to 16 hours in respirable-sized aerosols*”. [1][2] Because of this, the demand for Carbon Dioxide (CO₂) monitors from all sectors of society increased substantially near the end of 2020 and throughout 2021.

But what do these monitors actually tell you, how do they work, and is there a possibility of doing some experimental investigations with them?

Firstly, CO₂ monitors are not a proxy for measuring the level of exposure to the SARS-CoV-2 virus. They only allow you to measure the level of ventilation in a room through quantifying the build-up of CO₂. The theory is that the monitor will let you know when you need to increase ventilation, which should then reduce the risk of airborne SARS-CoV-2 virus remaining in a room.



Credit: “The Keeling Curve” of atmospheric CO₂ levels, from the SCRIPPS Institution of Oceanography, Nov 2021.

The Keeling Curve is a graph of the CO₂ accumulation in the Earth’s atmosphere from 1958 to the present day, with readings taken at the

Mauna Loa Observatory in Hawaii. It was started and monitored by Charles David Keeling until his death in 2005. In 2017, the average level of CO₂ in the atmosphere stayed above 400 parts-per-million (ppm) for the first time in recorded history and has increased even further since.[3] This is why CO₂ monitors do not start at 0 and should normally not go below 400 ppm. This serves as a great jumping off point with students to discuss the climate crisis, the greenhouse effect and atmospheric chemistry. It is estimated that at the current rate of build-up, the level of CO₂ in the atmosphere will reach 500 ppm in less than 50 years. In 2021 the world’s largest CO₂ scrubbing facility opened in Iceland called Orca. It can remove 4,000 tons of CO₂ from the atmosphere annually, but this is only equivalent to about 790 fossil fuel cars and it uses enormous amounts of energy.



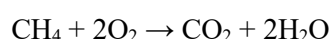
Credit: The Orca direct air capture and storage facility from The Verge, Sept 2021

In general, over 800 ppm is a feeling of stuffiness (yellow), while over 1000 ppm is associated with a reduction in concentration and cognitive performance (orange). Even higher values can make people feel unwell with some reports of headaches, nausea and respiratory symptoms (red).[4] The most accurate CO₂ monitors use a Non-Dispersive Infra-Red (NDIR) sensor like the ones delivered to Irish schools. These operate on the exact same principle as colorimetry or spectroscopy (and the beer-lambert law), but instead of measuring the concentration of liquids, it measures the concentration of specific gases.

CO₂ absorbs IR light with a wavelength of 4260 nm, so the detector in these sensors calculates the amount of IR light hitting it which is inversely proportional to the light absorbed by CO₂ molecules.

Interestingly, your school's Vision branded CO₂ monitor also records up to 30 days' worth of data and stores it on the device. You can connect your CO₂ monitor to your computer using a USB cable. Through the use of a free app, it will then allow you to see a continuous graph of CO₂ readings every 15 minutes. You can also download the data for further manipulation with Excel. The app for your computer can be found at: <https://www.flamefast-gas-safety.co.uk/vision.html>

This means you can also use your CO₂ monitor for some experiments and investigations. In fact, I would go so far as to say that the current delivery of CO₂ monitors to schools represents one of the largest investments in lab equipment ever by the Department of Education! In theory, these CO₂ monitors can be employed to measure any change in CO₂ such as when methane is burned in Bunsen Burners to produce CO₂ and water.



There are plenty of opportunities for Biology and Agricultural Science investigations to measure CO₂ production. For instance, the respiration and fermentation of yeast in sugary water produces CO₂ and this process is temperature dependent. At lower temperatures (25° C), the CO₂ production from the yeast is very slow. However, at higher temperatures (35° C), the CO₂ production increases quite rapidly.

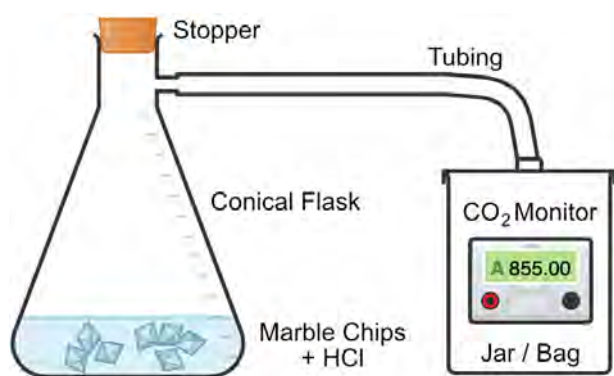
You can also measure the rate of photosynthesis in plants by placing a bag over the plant with the CO₂ monitor inside. In direct sunlight the CO₂ levels should drop and this can then be compared to when a plant is away from direct sunlight, like in a cupboard for example. Germinating seeds also give off CO₂ which can be measured over time using your CO₂ monitor in a sealed jar or plastic bag. This can then be compared to dried seeds in another jar over the same period of time which will not give off any CO₂.



Credit: from @AdamWteach on Twitter, Nov 2021

Finally, there are also some opportunities for Chemistry investigations by using your CO₂ monitor to measure the rate of CO₂ production from the reaction of acetic/ethanoic acid (vinegar) with sodium bicarbonate (baking soda) or the reaction of Hydrochloric acid (HCl) and marble

chips (calcium carbonate). Using a test-tube or a conical flask with a bung and some tubing connected to a sealed bag containing the CO₂ monitor will allow you to measure the increase in CO₂ levels. This setup is only a slight variation on the well-known experiment that normally uses a measuring cylinder or a gas syringe to measure the volume of CO₂ produced. Changing the concentration of the reactants will also influence the rate of reaction and hence the amount of CO₂ produced. Details about these reactions and their accompanying resources are freely available on the Royal Society of Chemistry's (RSC) Education website at <https://edu.rsc.org>, just search for "carbon dioxide".



Credit: John O'Donoghue using Chemix Online Editor

However, there is one important thing that you need to keep in mind before you start using your CO₂ monitors for experimental investigations. Most CO₂ monitors automatically recalibrate every 24 hours, which is known as "auto baseline correction" or "ABC". This means that it will assume that the lowest reading from the previous 24 hours corresponds to 400 ppm, i.e the average outside CO₂ level. In general, with nobody in the room for long periods (like overnight), it will return to this level at some stage over a 24 hour period. However, from my own investigations, it can take quite a bit of time for high levels of CO₂

to disperse even with a window open. So, if you confine the monitor to a sealed jar or plastic bag to measure CO₂ as an experiment over a few days, the ABC may affect your readings. The CO₂ monitor needs to be exposed to 400 ppm at least once in a 24 hour period so maybe keep your experimental investigation length to a few minutes or few hours only.

Acknowledgements:

Special thanks to Prof. John Wenger at the School of Chemistry at University College Cork (UCC) for sharing so much valuable information on Twitter about CO₂ monitors and ventilation. You can follow his work on twitter here @johnwenger9. Well done and thanks also to the many people who shared ideas about using the CO₂ monitors for experiments on various forums and social media platforms.

References:

1. A. C. Fears *et al*, *Persistence of Severe Acute Respiratory Syndrome Coronavirus 2 in Aerosol Suspensions*, **Emerging Infectious Diseases**, Centres for Disease Control and Protection, 26, 9, 2020.
2. T. Greenhalgh *et al*, *Ten scientific reasons in support of airborne transmission of SARS-CoV-2*, **The Lancet**, 297, 10285, P1603-1605, May 01, 2021
3. The Keeling Curve, **Scripps Institution of Oceanography**, University of California San Diego, 2021: <https://keelingcurve.ucsd.edu>
4. K. Azuma, *Effects of low-level inhalation exposure to carbon dioxide in indoor environments: A short review on human health and psychomotor performance*, **Environment International**, 121, 2018, 51-56.
5. Vision Support Website: <https://www.flamefast-gas-safety.co.uk/vision.html>

□

Representations & visualisations – interesting experiments for chemical change and rates of reaction

Odilla Finlayson

School of Chemical Sciences, Dublin City University, Glasnevin, Dublin 9

Odilla.finlayson@dcu.ie

Introduction: developing observation

In chemistry teaching, the laboratory work is often carried out to support the teaching and learning that has already taken place, i.e. the outcome of the experiment is already known to the student and so the observations made can be limited to those that 'are expected'. For example, if the student knows that a particular colour change is to be expected, then that is what is focused on, maybe ignoring any temperature change that may occur in the reaction flask or even gas evolution!

If the above is the case, then we are removing the excitement of the experiment, removing the power of observation and also students' ability to engage with all that is happening within a chemical process.

A nice experiment to encourage observation, by eye (but also by touch and feel), is the 'Baggy Experiment', adapted from the Exploratorium of Inquiry (adapted from Institute for Inquiry, www.exploratorium.edu). In this experiment, students are given the following instructions and asked to suggest signs of a chemical reaction (Figure 1.)

Add the following to the plastic bag (no not mix):
1/4 teaspoon sodium bicarbonate
1/2 teaspoon calcium chloride
5 mL phenol red
Seal the bag – taking as much air from it as possible
Mix the contents of the bag
Observe and note your observations

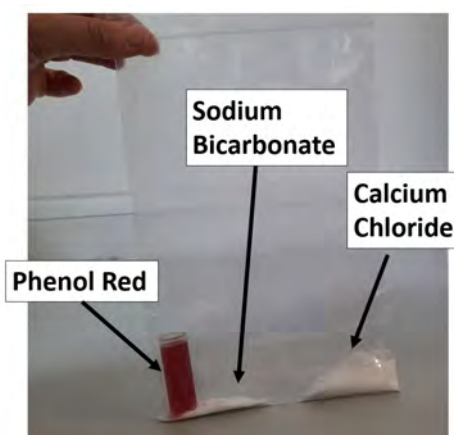


Figure 1: Student instructions to carry out the 'Baggy Experiment'

Students can note many changes (the extent of which depends on the relative amounts added), (see Figure 2a) including those listed in column 1

in Table 1. An interpretation of the observations suggests, for example, the data shown in Table 1, column 2.



Figure 2: Baggy experiment investigations. (a) showing colour change and inflation of bag; (b) measuring temperature change of CaCl_2 with water.

Table 1: Possible student observations and inferences following ‘Baggy Experiment’

Possible student Observations	Inference
Bubbles forming	formation of a gas
Bag ‘inflating’	formation of new compound which is gas – possibly CO_2 ?
Colour change	suggests change in pH (phenol red is yellow at $\text{pH} < 6$, and red at $\text{pH} > 8$), mixture changing from basic to acidic
Feeling hotter and / or colder	reactions occurring where heat is evolved and also where heat is taken in
Feeling a ‘grainy deposit’ in the bag	possibly a new compound formed that is not soluble

These observations lead directly to a determination of ‘what is causing them’? So what combination(s) are responsible for these observations? This gives rise to a systematic testing of any 2 reagents at a time, or varying the relative quantities of the 3 reagents. It should be noted that phenol red is an aqueous solution and so water can be substituted in some investigations if required.

Students should find out the following for example:

- Adding two solids together (Na_2CO_3 and CaCl_2) does not give rise to any observable change;
- Replacing phenol red with water gives rise to the same observations (bag

expanding, temperature changes etc) – but not to the colour change;

- Addition of CaCl_2 to water (or phenol red) gives rise to a temperature increase;
- Addition of NaHCO_3 to water (or phenol red) gives rise to a temperature drop (these temperature changes can be felt by hand feeling the outside of the bag, or by inserting a temperature probe inside the bag).

This experiment can be useful at both Junior Cycle and Senior Cycle – at Junior Cycle for students to determine evidence of a chemical reaction and to develop systematic testing skills. At senior cycle, the students, as well as developing observational skills and interpretative skills, should also be able to write the appropriate

chemical reactions involved, confirming that CO_2 is produced, and possibly identifying the ‘grainy precipitate’ that may be produced (CaCO_3). The discussion around the species present in solution when, e.g. CaCl_2 is added to water (temperature rise, $\Delta H_{\text{soln}} \text{CaCl}_2 = -81 \text{ kJ/mol}$), or when NaHCO_3 is added (temperature drop, $\Delta H_{\text{soln}} \text{NaHCO}_3 = +17 \text{ kJ/mol}$) leads on nicely to a discussion of ions in solution and the reaction, e.g. $\text{CaCl}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$ and the realisation that the behaviour of ions in solution is different from ions in an ionic solid.

Allowing students to show their representations of these ideas on paper is extremely valuable as a way of identifying any alternative conceptions that students may have in this regard.

Rate of reaction

There is a really nice experiment that is visual and straightforward to carry out – the rate of the oxidation reaction between blue dye and bleach (or peroxide). The product of this reaction is colourless and so you can visually follow the progress of the reaction by the decrease in the blue colour (i.e. the loss of the blue dye reactant) with time.

Blue dye (aq) + NaOCl (aq) $\rightarrow$ colourless products (aq)

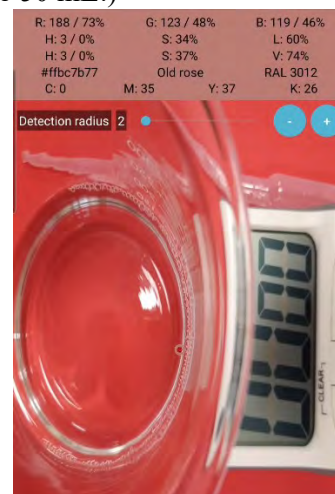


Figure 3: Set up for experiment; (a) materials required; (b) set up of camera, reaction flask and times; (c) camera view with RGB app.

Record the red (R) value on the smart phone – this is the R_0 value.

Then add the blue dye, start the timer and mix the solution quickly. Record the R values at say 30 s intervals. You can continue to record for say 5 min or until the solution becomes colourless. You do not need to wait for the reaction to go to completion.

This reaction has been described in detail in the RSC resources Spectroscopy in a Suitcase (<https://edu.rsc.org/resources/spectroscopy-in-a-suitcase-uv-vis-teacher-resources/941.article>), where the loss of colour is followed using a colorimeter or a spectrophotometer. However, it is also possible to follow this reaction using the RGB app on a smartphone (as described in detail here (<https://www.saltise.ca/wp-content/uploads/2020/07/SALTISE-Chem-Protocol-The-Rate-Law-in-Chemical-Kinetics-Using-Blue-Dye-v2.pdf>)).

We have trialled this experiment both in a classroom setting and ‘at home’ and it works very well. Brief details will be given here (including some of the underlying concepts that may be suitable for extension work).

To set up the experiment:

Download an RGB app to your smartphone. Place a sheet of red paper underneath the reaction beaker containing the bleach solution (Figure 3). Keep shadows around the apparatus to a minimum and it is helpful to have the timer within the view of the camera on the smart phone.

Requirements: RGB Colour app, **Blue Dye** (e.g. (Homestore & More E133 – gel) (0.5 g/50 mL – use 1 mL of the solution) and **Bleach** (use 5 mL bleach diluted to 50 mL.)

You can then repeat this experiment using different starting concentrations of blue dye (e.g. 0.5 mL, 1 mL, 1.5 mL) or at different temperatures (e.g. 4 °C, 15 °C, 25 °C).

Explanation:

The blue solution (when the dye is added) absorbs red light, so only some of the red light will pass

through the solution and be detected by the camera app placed above the solution. As the amount of light absorbed is proportional to the concentration of the absorbing species (from Beer Lambert Law, $Abs = \epsilon bc$ or $Abs \propto \text{concentration}$, as ϵb is a constant for the system), the change in concentration of the blue dye can be monitored by the change in the absorbance values. The amount of red light that passes through the blue solution is represented by the red value in the app (R). So the amount of light absorbed by the blue solution

at any particular time is $Abs = -\log(R/R_0)$, where R_0 is the red value when no dye is present, while R is the red value recorded at that time.

Data handling and explanation

The data collected from one such experiment is given in Table 2 – columns 1 and 2. The Absorbance (or concentration) of the blue dye is calculated from the red (R) values and is given in column 3.

Table 2: Data collected for Reaction of blue dye, using 1ml blue dye

	Initial Red (R_0) 150			
Time (s)	Red Reading R	$Abs = -\log(R/R_0)$	Ln Abs	1/Abs
5	5	1.48	0.39	0.68
30	20	0.88	-0.13	1.14
60	37	0.61	-0.50	1.65
90	47	0.50	-0.69	1.98
120	58	0.41	-0.89	2.42
150	71	0.32	-1.12	3.08
180	87	0.24	-1.44	4.23
210	90	0.22	-1.51	4.51
240	102	0.17	-1.79	5.97
270	115	0.12	-2.16	8.67
300	127	0.07	-2.63	13.83

Columns 1 and 2 are the raw data

A typical graph of absorbance versus time (Figure 4(a)) shows the decrease in the reactant (i.e. blue dye) concentration with time, and the rate at different times can be measured from this graph (initial, instantaneous and average). Taking the instantaneous rate (i.e. the rate at a particular

concentration) and plotting it against Abs (or concentration) gives a reasonable straight line, the slope of which gives the rate constant, k (Figure 4(b).)

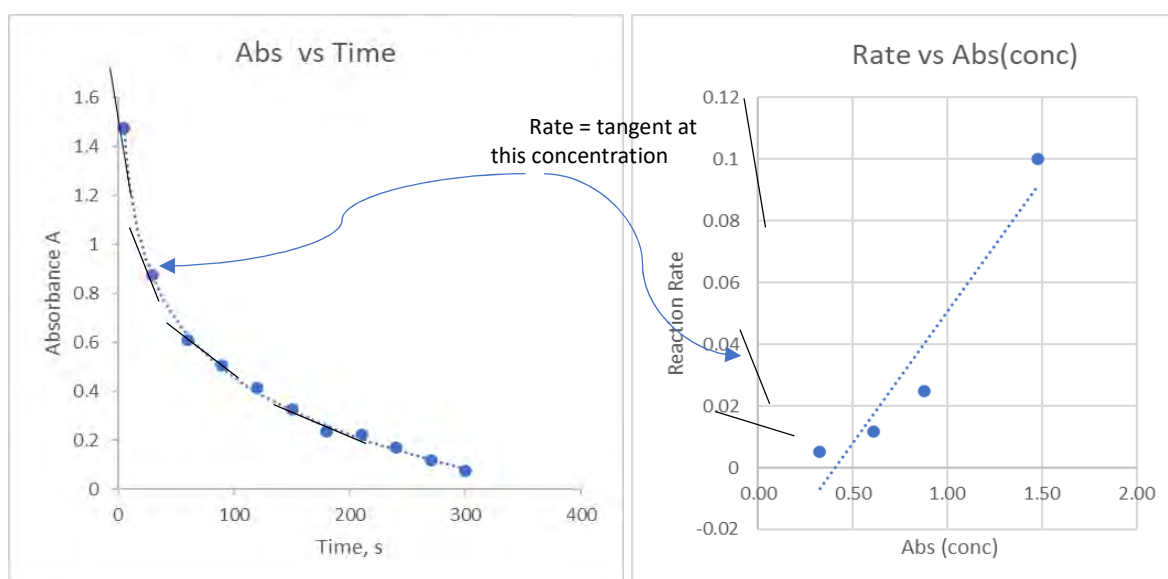


Figure 4: (a) Graph of Absorbance value against time, showing the changing rate with concentration; (b) Graph of reaction rate (determined from (a) at particular times) against Abs, showing linear relationship.

For any reaction, we generally define the rate of reaction as the rate of change in concentration of reactant (or product) with time e.g. $A + B \rightarrow P$, the rate of reaction $\propto [A]^x[B]^y$, where $[]$ denote concentration, and where x and y are called the order of reaction and give us information about the mechanism of the reaction and rate determining steps. The rate equation must be determined experimentally for any reaction.

For the blue dye reaction,

$$\text{Rate} \propto [\text{dye}]^x[\text{NaOCl}]^y$$

$\text{Rate} = k [\text{dye}]^x[\text{NaOCl}]^y$, where k is called the rate constant

We can make an approximation if $[\text{NaOCl}] \gg [\text{dye}]$, then the change in the concentration of the NaOCl throughout the reaction will be small in comparison to the change in concentration of the

Table 3. Integrated rate equations for first ($x=1$) and second ($x=2$) order reactions.

Value of x	Rate equation	Integrated rate equation*	Plot
If $x=1$	$\text{Rate} = k'[\text{dye}]^1$	$\ln[\text{dye}]_t = -k't + \ln[\text{dye}]_0$	Plot $\ln[\text{dye}]_t$ vs t should be linear with slope $= -k'$
If $x=2$	$\text{Rate} = k'[\text{dye}]^2$	$\frac{1}{[\text{dye}]_t} = k't + \frac{1}{[\text{dye}]_0}$	Plot of $1/[\text{dye}]_t$ vs t should be linear with slope $= k'$

* $[\text{dye}]_0$ and $[\text{dye}]_t$ are the dye concentration at times 0 (start of reaction) and at time t , resp.

Using the data in Table 2, the following graphs were obtained for first ($x=1$) and second ($x=2$) order plots (Figure 5.) As the data agrees with the linear relationship in Figure 5(a) rather than that

blue dye; hence allowing the following simplification:

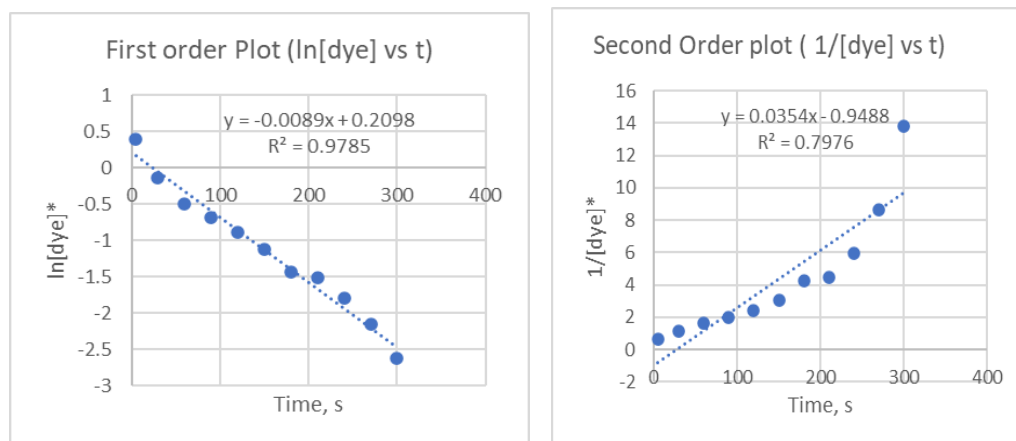
$$\text{Rate} = k' [\text{dye}]^x, \text{ where } k' = k[\text{NaOCl}]^y$$

In Figure 4b above, we assume $x=1$, so $\text{Rate} = k'[\text{dye}]$; hence the slope is a measure of the rate constant k' . Generally, it is the rate constant that is reported when considering the kinetics of a reaction. Note that the units of k , in this example (when $x=1$), are $\text{rate}/\text{conc} = \text{abs}/t/\text{abs} = 1/t$.

Further mathematical treatment:

While the rate equations and orders of reaction are not on the current Leaving Certificate syllabus, it is a nice extension of this activity to determine the order of the reaction with respect to the dye i.e. the value of x , using the integrated rate equations, shown in Table 3.

in Figure 5(b), this indicates that this reaction may be first order in dye i.e. $x=1$, rather than second order ($x=2$).



*ln[dye] is plotted as lnAbs, 1/[dye] is plotted as 1/Abs as $\text{Abs} \propto [\text{dye}]$

Figure 5: Graphs of integrated rate equations (a) first order ($x=1$), (b) second order ($x=2$).

Effect of Temperature:

This experiment can be conducted at different temperatures – and the initial rates can be compared. Generating data for a few mins at say three different temperatures allows one to determine the value of the initial rate. The higher rate with temperature is clear from the initial slopes. If the value of k is determined (as above) at say two or three different temperatures, then it is possible to determine the activation energy using the Arrhenius Equation:

$$k = A \cdot \exp\left(\frac{-E_a}{RT}\right)$$

$$\ln(k) = \ln(A) - \frac{E_a}{R} \cdot \frac{1}{T}$$

Where A represents factors that can affect the rate including collision frequency and orientation factors, E_a is the activation energy, while R is the gas constant and T is temperature of the reaction (in Kelvin). So determining k (as shown earlier), and plotting $\ln(k)$ vs $1/T$, the slope $= -E_a/R$ and intercept is $\ln(A)$. Hence, the value of E_a can be determined.

Note it is easier to carry out this experiment at temperatures less than room temperature.

Why I like this experiment!

There are a number of advantages to this experiment in teaching the topic of kinetics, including, briefly:

- directly follows the progress of the reaction, i.e. following the loss of one reactant with time
- quick and easy to set up and to generate usable data
- reactants and products are easy to access and waste is minimal
- it uses technology appropriately

- allows discussion on differences between rate, rate constant, how rate constant is used to report 'one value' (note in radioactive decays, the value of k (rate constant) is given)
- easy to vary concentration and to vary temperature; hence opening up further activities
- both the concentration of dye and bleach can be varied
- can be extended for students to determine if the reaction is first order or second order (particularly suitable for those with an interest in maths as well)
- reactions can be repeated easily, as only small quantities of solutions required
- avoids any confusion between rate and $1/t$
- students enjoy using their phones!

I hope you will try these investigations, allowing your students to generate hypotheses and then to conduct suitable experiments in order to investigate them.

Acknowledgements

These experiments were first trialled by Christopher Burke – a third year Science Education student in DCU - during lockdown at his home, as part of his project work. They were further trialled in DCU by Michele Somers, technician, Institute of Education, whose results are presented here.

Biography

Dr Odilla Finlayson, Associate Professor (Emeritus) Science Education, School of Chemical Sciences, DCU. Research interests include curriculum development, assessment and pre-service teacher education in chemistry. Involved in Science Olympiads, post-graduate research supervision and pre-service teacher education.

□

Transition Year Autumnal Chemistry - STEAM - Wellbeing - Connecting with Community

Michelle Dunne

St. Joseph's College, Lucan, Co. Dublin.

mdunne@stjosephslucan.com

Introduction

September 2020 saw the return of students and teachers to the classroom with our transition year students having not completed their Junior Cycle Examinations due to the Covid-19 pandemic. Our school body had employed Google Workspace as its primary learning management system and I as a chemistry teacher had to deliver teaching for a double class period meeting the requirement of one metre physical distancing while teaching simultaneously to students located elsewhere in the school building using Google Meet. Laboratory practical work is an essential element of any chemistry teaching period serving to stimulate both student interest and student inquiry. Student progression from Junior Cycle Science to Leaving Certificate Chemistry allows transition year to the act as the bridge building on key skills acquired during Junior Cycle, developing core competences to gather, record, analyse and evaluate data working with others while refining their literacy and understanding of chemistry, to progress their study of Chemistry at Leaving Certificate. As a chemistry teacher I was challenged to build knowledge, innovation, creativity, wellbeing and experimental work into my transition year chemistry classes, whilst employing technology, in a hybrid teaching environment. Some students were in the chemistry lab with other students joining from the satellite station.

Chemistry Plan Centered on Season of Autumn for Term One

My chemistry plan focused on reading and balancing of chemical equations, revision of atomic structure, paper chromatography and the carbon cycle all found in the Chemical World of the Junior Cycle Science Specification moving to mathematically determine the mass of carbon in a tree by extrapolation from a standard curve, extract, separate, analyse and identify plant pigments from different tree fallen autumnal coloured leaves using thin layer chromatography, calculate the retention factor (R_f) values for separated leaf pigments, determine the number of

moles of carbon contained in selected trees, examine the benefits of trees in urban spaces, promote sustainable practices germinating a horse chestnut and create an individual piece of art using autumnal coloured leaves gathered in the park. Thin layer chromatography and the mole concept are found on the Leaving Certificate Chemistry Syllabus (Department of Education, 2002). Chemists employ technology sharing information using technology and my chemistry plan for term one ended with students presenting their work to the school, the residential committee and Lucan Tidy Towns through the medium of a poster display and Twitter, highlighting the role of trees in the capture of carbon in their leaves and trunk using chemistry to quantify the amount of carbon stored in trees.

Learning Intentions Completed Over a Number of Classes with Subject Curricular Links

- Promote chemical literacy by reading in advance a CompoundChem article “The Chemistry Behind The Colour of Autumn Leaves (2014) and “I’ve heard several different answers to this seemingly simple question: what causes the leaves on trees to change color in the fall?” (American, 2022)
- Download the Period Table – Royal Society of Chemistry, 2022.
- Revise The Carbon Cycle, 2022.
- Study in advance of class the video -Thin Layer Chromatography, 2022
- Perform thin layer chromatography to identify the different pigments found in leaves using spinach leaves and red coloured leaves collected in the neighbouring park. Reading guidance from “Student Sheet 10 – Using Thin Layer Chromatography for Photosynthetic Pigments” – Science and Plants for Schools.
- Identify trees from their leaves with the aid of the Opal Tree Health Survey Tree

ID Guide (Imperial College, 2022).
(Biology)

- Increase student awareness of nature in residential community in close proximity to our school, employing Google Maps to see an aerial view of the school. (Geography)
- Enhance student wellbeing walking to the park while having a practical class outside the lab where students could investigate, communicate and collaborate being positive with each other, enjoying their study of chemistry. (Wellbeing)
- Examine how trees mitigate climate change by viewing a TedEd video “What happens if you cut down all of a city's trees?” (2020) with students presenting five advantages of the presence of trees in an urban community. (Geography and Environmental Science and Society)
- Employ technology to promote collaboration between individuals using Google Jamboard and Google Classroom with students completing a poster display at the end of the Autumnal Chemistry module.
- Collect, plant and germinate horse chestnuts focusing on sustainability and

recycling using spent coffee grounds and a peat free compost mixture as a planting medium. Empty milk cartons used as planting containers. (Environmental Science and Society)

- Determine the amount of carbon stored in trees, plotting a standard curve of tree circumference (cm) against tree dry weight (kg) as outlined in “How to measure the carbon content of trees”, 2022. Half of the tree’s dry weight is attributed to the mass of carbon. (Mathematics)
- Create an individual leaf art piece using autumnal leaves gathered in the neighbouring tree lined park. (Art and Wellbeing)
- Connect and forge positive relationship between the school and neighbouring housing estate committee that has a mature tree lined park discussing the importance of their trees as carbon sinks. (Wellbeing and Community)
- Promote student work in school and on the school Twitter account.
- Extension: Construct a clinometer and determine the height of a selected tree. (Mathematics)

Instructions for measuring the tree and carbon stored

- 1 Measure the circumference of the tree at the standard chest height (1.3m) with a tape measure. Record the result in centimetres. Repeat at least 3 times, at the same height, and calculate the average measure.
- 2 When you've got your average circumference, look at the table to convert this to dry weight. Use the nearest value in the table to your value.
- 3 Because half the dry weight of the tree is carbon, you then need to divide your answer by 2. This tells you how much carbon is stored in the tree.
- 4 You can also calculate how much carbon dioxide was absorbed to create this carbon store, by multiplying your figure for carbon by 3.67.



Circumference (cm)	Tree dry weight (kg)
50	106
100	668
150	1,964
200	4,221
225	5,771
250	7,641
275	9,842
300	12,410
325	15,350
350	18,700
400	26,674

These values, provided by Forest Research, are for an individual hardwood tree in Westonbirt Arboretum. They can be used as an example. Trees will grow at different rates across the UK depending on, for example, the species, soil, drainage, slope aspect and climate conditions.

Image courtesy of gsgeography.wordpress.com which allows the drawing of a standard curve of circumference of tree (cm) against tree dry weight. The values were obtained from Forest Research in the UK.

Further Investigation - Making of a Clinometer

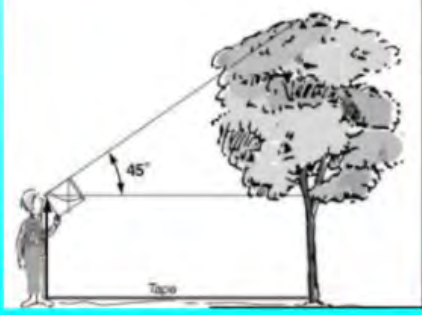
Click to add text



NCE-MSTL
National Centre for Excellence
in Mathematics and Science Teaching and Learning

Junior Certificate
Trigonometry

Student learning task 2:
All groups are given one object to measure somewhere around the school (e.g. prefab, pole, tree, handball alley etc). Two groups are sent to measure the same object but are not given a specified distance to measure it from. They are provided with a clinometer and measuring tape.





Extension Work: Using a self-constructed clinometer as viewed on the right to determine the height of a tree.

Leaf Art Samples - STEAM



Selection of Leaf Art pictures created by transition year chemistry students in St. Joseph's College, Lucan, Co. Dublin

Conclusion

As with all good lesson plans they need review and refinement. The students are key stakeholders and I am delighted to say that the presentations at the end were excellent, noting how students managed their work and continued their study of chemistry electing to study Chemistry in fifth year

for their Leaving Certificate. Google classroom was central to the teaching over a number of weeks since work could be posted and space created for Google Jamboard to facilitate student collaboration. Students and teachers of chemistry love experimental work and it is amazing to remember that we collectively learned wearing

masks, using the medium of technology to support student learning maintaining the physical distancing requirements in our efforts to encourage the study of chemistry acutely aware that considered caution was needed to mitigate the spread of Covid-19 in the Chemistry laboratory of the school.

Bibliography

What happens if you cut down all of a city's trees?. 2022. [video] Directed by S. Al. Ted-Ed.

American, S., 2022. *I've heard several different answers to this seemingly simple question: what causes the leaves on trees to change color in the fall?*. [online] Scientific American. Available at: <<https://www.scientificamerican.com/article/ive-heard-several-differe/>> [Accessed 29 January 2022].

Jct.ie. 2022. [online] Available at: <<https://www.jct.ie/perch/resources/science/science-lo-poster.pdf>> [Accessed 30 January 2022].

Department of Education, 2002. *Leaving Certificate Chemistry (Higher and Ordinary Level)*. Dublin: The Stationary Office, p.60.

geogy. 2022. *How to measure the carbon content of trees*. [online] Available at: <<https://rgsgeogy.wordpress.com/mrcs-tree-carbon-content-calculator/>> [Accessed 1 February 2022].

Imperial College, London, 2022. [ebook] London: Imperial College. Available at: <<https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/opal/Tree-Health-Survey-Tree-ID-guide-WEB.pdf>> [Accessed 31 January 2022].

Rsc.org. 2022. *Periodic Table – Royal Society of Chemistry*. [online] Available at:

<<https://www.rsc.org/periodic-table/>> [Accessed 1 February 2022].

Saps.org.uk. 2022. *Student Sheet 10 - Thin Layer Chromatography for Photosynthetic Pigments*. [online] Available at: <<https://www.saps.org.uk/secondary/teaching-resources/181-student-sheet-10-thin-layer-chromatography-for-photosynthetic-pigments>> [Accessed 29 January 2022].

Earthobservatory.nasa.gov. 2022. *The Carbon Cycle*. [online] Available at: <<https://earthobservatory.nasa.gov/features/CarbonCycle>> [Accessed 29 January 2022].

Compound Interest. 2022. *The Chemicals Behind the Colours of Autumn Leaves*. [online] Available at: <<https://www.compoundchem.com/2014/09/11/autumnleaves/>> [Accessed 29 January 2022].

Youtube.com. 2022. *Thin Layer Chromatography*. [online] Available at: <<https://www.youtube.com/watch?v=lj5OWzhZS ac&t=76s>> [Accessed 1 February 2022].

Biography

Michelle Dunne is a Chemistry, Science, Environmental Science and Biology teacher at St. Joseph's College, Lucan, Co. Dublin. She is the Transition Year Coordinator with a keen interest in getting students growing vegetables in small green spaces. She is a professional support teacher with NIPT and a former Chemistry methodology tutor to PME students at Maynooth University. Also a former physics busker and Open Schools for Open Societies Champion. She tweets from @ChemLab99 and @scientixeu_ie when time permits.

□

First principles calculations for titrations

Seán Kelleher

skelleher@colaistechoilmswords.ie

A response to an emerging trend

Based on original work by my PDST colleagues, Brendan Duane and Yvonne Higgins-Vallely, I have developed an integrated suite of resources on First Principles calculations for titrations. Brendan Duane rewrote LC Chemistry titration calculations from 2006 to 2014 in the First Principles style, while Yvonne Higgins-Vallely created a grid format as a method of scaffolding students when attempting these types of calculations. Combining these has allowed the development of a presentation of exam questions from 2006 to 2021 and associated teacher and student handouts.

These resources are a practical response to the emergence of First Principles calculations as a permanent feature of Higher Level LC Chemistry exams, from 2015. The formula method continues to be examined at Ordinary Level.

As chemistry teachers, in addition to all our day-to-day duties, keeping up with emerging trends in the State Examinations is something that we don't always have sufficient time to discuss with other chemistry colleagues. The siloed nature of teaching, and the solo-flyer nature of chemistry teaching in Irish post-primary schools, compounded by the Covid-19 lockdowns, are discouragements to discussion that we all battle with in our professional lives. Inspired by the collective reflection of several teachers, this suite of resources is an attempt to bridge that gap in a practical manner that is relevant to teacher practice in Irish post primary schools (see Figure 1.) (N.B. the weblinks associated with the QR codes are given in the references at the end.)



Figure 1: PDST Chemistry First Principles Resources

Moving from plug-and-play to First Principles

At Higher Level a deeper and more quantitative treatment of chemistry is required (NCCA, 1999). While titration calculations by First Principles have always been permitted, for a number of possible reasons, many of us will have tended to use the titration formula method. The “plug-and-play” aspects of this approach are obvious: many students develop fluency with its algorithmic simplicity and are successful in finding an “answer”. However, in discussions with other chemistry teachers, I have often heard praise for this but concern at the actual level of student understanding. In my mind it raises the question that the formula method may be reinforcing the procedural similarities of all titrations at LC Chemistry, but not an appreciation of the fundamental nature of volumetric analysis.

The phrase “First Principles” implies calculations from basic (fundamental) and known quantities. If this fundamental approach can be embedded in how we present titration calculations, with the hope is that a deeper and more systematic understanding of titration calculations may develop. In my experience it also links explicitly to the following concepts: the mole, molarity, reaction ratios, A_r and M_r . In the formula method the understanding of these can be vague and hidden behind symbols and place position within the formula. What a purely mathematical and utilitarian approach gains in speed and calculation accuracy may be offset by a lack of chemical understanding.

Responding to circumstances

The second Covid-19 lockdown and the social distancing requirements prior to it, created a backlog of experimentation for my 5th Year class group at that time. I had used the RSC Learn Titration Simulation (see Figure 2) and several videos from Witwatersrand University (see Figure 3) to help prepare students for the block of practical work that followed reopening. This block of concentrated practice combined with

student enthusiasm to return to practical activities in the classroom lead to the polished development of the required practical skills. The next step was to develop a similar level of skill and understanding in titration calculations.

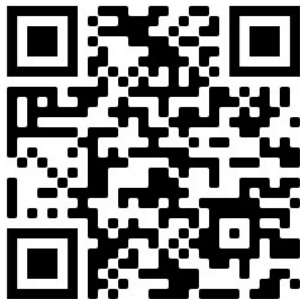


Figure 2: RSC Learn Titration Simulation



Figure 3: Witwatersrand University Chemistry Videos

Grid organisation

As not all titration calculations have the same format, a First Principles Calculation Grid needs to have standardisation but also room for variations. Conforming to A4 size was also an important practical consideration. The grid was consisted of three columns. The first column listed a number of steps that the students would complete during the calculations. The second and third columns were labelled Reagent #1 and Reagent #2 (see Figure 4.)

For each calculation, students were asked to name the reagents, and not to always think of them as only acids or bases. Each named reagent was also matched with their respective vessels.

The next step involved students identifying the given information for each reagent, noting that the concentration for one of these would be absent, by underlining or highlighting with their pens. This information was transferred to the grid along with

the reaction ratio from the given balanced equation.

Students then calculated the number of moles for the reagent with the most information, and then the number of moles for the second reagent, based on the reaction ratio. The concentration of the second reagent was then calculated and depending on whether this reagent had been used in dilution, the concentration was scaled up to $\text{g}/1000\text{cm}^3$.

While not required for all titration calculations the grid is easily extended to include p.p.m., %w/v and waters of hydration calculations also.

A Powerpoint presentation guides students through each calculation from 2006 to 2021, linked to a complete handout for teachers and a fill-in-the-blanks version for students.

Reflections

Context is often king in many situations, so while a focused run of titration activities allowed the development of consistent and accurate lab skills and lent itself to a consistent and systematic approach to calculations, it may not work in all contexts. However, the resources available through the QR codes above can be used as concentrated practice or interleaved as teachers see fit for their teaching context.

In my context I felt that students of all abilities had developed and mastered a set of pertinent skills. How these skills are maintained may also be the slave of context.

References

NCCA (1999), *Leaving Certificate Chemistry Syllabus (Ordinary and Higher Level)*, Dublin: The Stationary Office.

PDST Chemistry First Principles Resources
<https://bit.ly/3qZ6W3N> [accessed 3 April 2022]

RSC Learn Titration Simulation
<https://rsc.li/3qYAn65> [accessed 3 April 2022]

Witwatersrand University Chemistry Videos
<https://bit.ly/3NJfXrq> [accessed 3 April 2022]

Biography

Seán Kelleher is a teacher of Chemistry, Science and Maths, at Coláiste Choilm Swords. He is also a PDST Chemistry Associate and won the inaugural High Impact Award 2019 as a member of the Irish team at the international science fair for teachers, Science on Stage.

YEAR/QUESTION NUMBER	First Principles Calculation Grid	
	REAGENT #1	REAGENT #2
Name the reagents		
Vessel (burette/conical)		
Information given for each reagent (molarity & actual volume used in cm ³)		
Ratio from balanced equation		
Find the number of moles of reagent for which you know the concentration/ have the most information on for the volume given in the question $\text{molarity} = \frac{\text{mass used in } 1000\text{cm}^3}{M_r}$ $\text{no. of moles} = \text{molarity} \times \frac{\text{volume}}{1000}$		
Use the ratio in balanced equation find the number of moles of the other reagent that this will react with		
Using the volume of this reagent given in the question, find the concentration of this solution (moles per 1000 cm ³) $\text{conc.} = \text{molarity} \times \frac{1000}{\text{volume}}$		
Concentration in g/1000 cm ³ - Find the Relative Molecular Mass (RMM) of substance $\text{g}/1000 \text{ cm}^3 = \text{RMM} \times \text{conc.}$		
$\text{p.p.m.} = \text{g}/1000 \text{ cm}^3 \times 1000$		
$\% \text{ w/v} = \frac{\text{g}/1000 \text{ cm}^3}{1000} \times 100$		

Figure 4: First Principles calculation grid

NOTE: The calculation from first principles has been covered in past issues of *CinA!* And I always insisted my students in UL used this method rather than a ‘magic formula’ that they didn’t

understand and could only apply in certain standard titrations, but not, for example, if a solid was involved. It is good to see it more widely used and recommended. PEC

□

Organisation Tips for a Safer Laboratory – An introduction to 5S for Schools

Michele Somers

School of STEM Education, Innovation and Global Studies, Dublin City University

Email: michele.somers@dcu.ie

Spring Cleaning your Lab with 5S, a Lab Organisation Strategy

Spring is in the air, so it's the perfect time of year to consider a Lab Spring Clean! We are all familiar with the age old sayings "A place for everything and everything in its place" and "A tidy desk is a tidy mind" and it is generally accepted that cluttered, messy spaces can actually adversely affect our mental health (Roster et al., 2016; Rogers & Hart, 2021). Clutter can also lead to accidents such as items falling down, slips & trips, lacerations and spills to name a few.

Lean Six Sigma (LSS) is a business management strategy commonly used in production industries to improve process efficiency and quality and reduce waste. Lean manufacturing, was developed by Toyota, and Six Sigma originated at Motorola.

One tool from Lean Manufacturing that will fit nicely into your day to day work as a teacher is an organisation strategy known as **5S (Sort, Set, Shine, Standardise, Sustain)**. (Sari et al., 2017). More recent interpretations of this 5S system go up as far as 6S (ensuring compliance with **Safety** legislation) and 7S (**Social** Responsibility) (Fernández Carrera et al., 2021).

The aim of 5S is simply to give you an organised space, minimal clutter, what you need when and where you need it, which in turn improves safety, efficiency, ergonomics, stress levels and productivity. While the corporate jargon and formality of the process may make this seem a somewhat daunting undertaking, this strategy is not just applicable to industry, and is actually very similar to some common home organisation strategies.

Thanks to professional home organisers and influencers such as Marie Kondo and the Home Edit, you may have tidied up, edited and cleaned your home and the powerful influence of Social Media may even have made you feel compelled to clean up and clear out to keep up with the Hinch's. (Shearer & Teplin, 2019 & 2020, Kondo, 2014) Taking away the novelty aspects of these approaches, such as rainbow colour schemes or keeping only items that "spark joy", these home

organisation approaches broadly align with those of 5Ss. So let's look at how we can approach this in the laboratory.

1. Sort (Seiri)

This is the part where we pull out everything, go through it and you guessed it - sort it out. When it comes to lab equipment, the sort phase will identify what we **need**, what **works**, what is **fit for purpose**, discarding what is no longer needed. These criteria do not necessarily "spark joy" (Kondo, 2014), however, if there is some old equipment or instrumentation that perhaps **sparks curiosity**, but has been sitting in a drawer for 20 years or is not fit for purpose, you could create a display of old science equipment, like we have done in DCU, see Figure 1. (McCloughlin, 2021)



Figure 1: Science Education Archive, DCU IoE

Always remember when you are getting rid of waste to ensure it is disposed of correctly. WEEE recycling should be used for all electrical goods and batteries. Hazardous chemicals should be disposed of via a licenced disposal company, who specialise in disposal of hazardous materials.

2. Set (Seiton)

When you have everything you need, decide what you need it for and when, and set it in order:

group items based on intended use in a box or tray and place it where you want it to go. This phase groups tools and equipment in place, so that you can figure out where items will be stored, so they are near to where they will be used. You could group your items by subject, the type of

equipment, its use, its size etc. At this phase you can also think about designating specific areas for specific functions, such as a designated handwashing sink, hot plate cool-down area, or trolley/tray storage (Figure 2).



Figure 2: Designated Spaces

Certain more specific items can be grouped by subject and even by experiment, but some items such as glassware will be used across all subjects, so be careful what you do put into “kits” and what needs to be left out for general use.

I like to have my “general lab equipment” grouped where possible by subject and if its for general use, it remains available in a central

location across the laboratory, e.g. open shelving for glassware and drawers for smaller equipment.

Where some items are only used for one particular experiment, you might consider putting a kit together for that experiment and keeping everything for that experiment together for ease of taking out and tidying (Figure 3).



Figure 3: Centralised Storage for General Use Items & Student Kit using a take-away box

3. Shine (Seiso)

Clean and tidy the workspaces, storage areas and the equipment and glassware itself so that everything is ready to use. Organise the space the way you want it, making it easy to take out or put back items where you need them.

Ergonomic Safety is how we fit our workspaces around us, rather than trying to adapt, work around and over-stretch. So, think about the flow of the work, and have things close by to where

you need them (e.g. spatulas near the balance). Looking at how we store things, and setting our workspaces around us and our work ultimately reduces the chance of injury by improper manual handling or repetitive strain. Storing heavier items lower down on shelves reduces the risk of injury when trying to retrieve them, with higher use items at eye level. Storing bottle carriers near the chemical store will reduce the chance of someone carrying too much.

Where possible don't mix up different types of items and store by size (e.g. for glassware) in lines or in sections so they are easily accessible. As well as presses and storage looking more appealing, they also become more accessible compared to a drawer full of random bits and bobs. Utilise drawer dividers or compartmentalised storage to avoid this.

4. Standardise (Seiketsu)

Here we “promote visible and modest rules” (Sari *et al.*, 2017) – i.e. finalise spaces, write procedures (where necessary) but most importantly, LABEL EVERYTHING!! When it comes to storage, once you have decided where everything should go and are happy that it works for you, make a rule, and the simplest way to do this is using a clear and concise label. Utilising signage and labelling means that everyone knows what items are and where they should go, and this brings in the added bonus of accountability in cleaning up after yourself.



Figure 4: Colour-Coding for Chemical Storage in Action

By labelling both the shelf/location AND the container, when something is not put back in its place there will be a very visible gap, so it is easier to spot if there is something missing. The use of Shadowboards or shape marking can be incorporated in some areas, also to highlight if tools are in use, e.g. if you have a tool board.

5. Sustain (Shitsuke)

Follow your new rules and see how it goes. Of course, you will need buy-in from colleagues for it to be successful but remember if you keep in a mindset of “Kaizen” or continuous change for the better, it is ok to go back to re-evaluate and re-organise to make it work for you.

Once you find the right balance, the 5S system will result in a simple, effective storage system in place, which makes it easier to hold colleagues

When it comes to chemical storage, there are real safety implications due to improper segregation or long-term storage of expired chemicals, so one area this is particularly useful is in the safe storage of chemicals.

Hazard pictograms are very important in highlighting the type of hazard presented by a particular substance, but having multiple hazards associated with a material can make storage confusing. A simple “hack” for ensuring that chemicals are returned to the correct spot is through the use of a very clear and concise colour labelling system, as per the PDST guidelines for safe storage of chemicals (https://www.pdst.ie/sites/default/files/ch_sd_safetyandstorage.pdf). The most appropriate storage location is determined through a risk assessment by using the chemical Safety Data Sheet (SDS). This way students and colleagues who are not chemists will understand exactly where something needs to go. The colourful label is on the press/shelf and on the bottle/container, which reduces confusion (Figure 4).

and students accountable for their tidy up, improves safety and reduces stress.

References:

- Fernández Carrera, J.; Amor del Olmo, A.; Romero Cuadrado, M.; Espinosa Escudero, M.d.M.; Romero Cuadrado, L., (2021), ‘From Lean 5S to 7S Methodology Implementing Corporate Social Responsibility Concept’. *Sustainability*, 13, 10810. (<https://doi.org/10.3390/su131910810>)
- Kondo, M., (2014), *The Life-Changing Magic of Tidying Up: The Japanese Art of Decluttering and Organizing*, (ISBN: 978-1607747307)
- McCloughlin. T. (2021) 'Lost and found: The Nooth apparatus'. *Endeavour*, 45 (1-2).100763 (<https://doi.org/10.1016/j.endeavour.2021.100763>)

Rogers, C.J. & Hart, R., (2021), *Journal of Environmental Psychology*, 73, 101553

(<https://doi.org/10.1016/j.jenvp.2021.101553>)

Roster, C.A., Ferrari, J.R., Jurkata M.P., (2016), *Journal of Environmental Psychology*, Volume 46, pp. 32-41

Sari, A. D. *et al* (2017) IOP Conf. Ser.: Mater. Sci. Eng. 215, 012032

(<https://doi.org/10.1088/1757-899X/215/1/012032>)

Shearer, C. & Teplin, J., (2019), *The Home Edit: A Guide to Organizing and Realizing Your House Goals*, (ISBN: 978-0525572657)

Shearer, C. & Teplin, J., (2020), *The Home Edit Life: The Complete Guide to Organizing*

Absolutely Everything at Work, at Home and On the Go, (ISBN: 978-1784727161)

Biography

Michele Somers is the Senior Technical Officer at Dublin City University's School of STEM Education, Innovation and Global Studies. She completed her PhD in Chemistry in DCU in 2008, after which she spent some time working in the Pharmaceutical industry as an Analytical Chemist and Quality Specialist. She has been supporting primary and post primary Science Education for the last 4 years in DCU, where she is also member of a number of Health and Safety committees.

□

The start of the chemical industry



Charles Tennant's St. Rollox Chemical Works, Glasgow in 1831, then the biggest chemical enterprise in the world.

[Chemical industry - Wikipedia](#)

Elementary Chemistry

In this feature we look at interesting items about the chemical elements. Peter Davern starts a new series on **Quirky Elemental Rhyming Facts**.

Iodine applications I

Iodine is one of my favourite elements and one which used to be extracted in Ireland in the 19th century (see below), when Irish seaweed was a major source of the world's iodine.

Heavyweight element

Iodine is a heavy element with an atomic mass of 126.9 amu. Two applications make use of this property.

Contrast agents

[Iodinated contrast - Wikipedia](#)

Iodine-containing organic molecular ions in aqueous solution are used as X-ray contrast media. They are injected into the bloodstream and travel through the blood system. As iodine is a heavy element it shows up well in X-ray images and allows the blood system in the brain or heart to be imaged. It can be used to show up problems like blockages, which can cause strokes. The iodine is filtered out by the kidneys and excreted. Another heavy element, barium (at. m 137.3 amu) is used in medicine in the form of insoluble barium sulfate, BaSO₄ (s), as a 'barium meal' to allow the stomach and intestines to be imaged. Heavy elements absorb X-rays well and thus show up in the X-ray photos. Thus the element lead is used in X-ray screening to absorb X-rays.

Rocket propulsion

Rockets work on the principle of action and reaction and the heavier the gases being produced, the more propulsion they will produce. The rare gas xenon has been used to make ion engines for space propulsion systems. Xenon atoms are ionised and then accelerated using an electric field, producing a steady, continuous thrust. Xenon is a rare element and is expensive. The first iodine ion engine has been announced, as iodine is cheaper and more available than xenon. It is also a solid and is thus easier to store, and takes up less volume. The disadvantage is that it is more corrosive than xenon. Iodine is vaporised and then ionised by bombarding with electrons. The ions are accelerated by an electric field and ejected from the engine, propelling the spacecraft forward (action and reaction.) For this purpose, mass matters and a constant thrust produces a steady acceleration. Such ion engines can run a long time

with little fuel usage, the opposite of chemical rockets, and are thus more suited to long space journeys or to power small satellites.

[New Electric Propulsion Engine For Spacecraft Test-Fired in Orbit For First Time \(sciencealert.com\)](#)

□

Iodine from seaweed

Iodine is much less abundant in the oceans than bromine, which is obtained from seawater, but is concentrated in seaweed. Iodine was discovered by accident in 1811 by a French chemical manufacturer, Bernard Courtois, in the residues from seaweed extraction. It was quickly confirmed to be a new element similar to chlorine, the only halogen then known. Seaweed was the main source of iodine and an industry quickly developed as new uses for iodine were found in medicine, photography and chemical synthesis. From the 1840s this led to an iodine boom and the ash from burning seaweed, known as kelp, was in great demand. Previously kelp had been used as a source of alkali, for the soap, glass, alum and textile industries, but was displaced by synthetic soda from salt from 1823 onwards. The demand for iodine revived the kelp industry but a cheaper source was found in the Chilean nitrate deposits from 1874 onwards, and this undermined the iodine from seaweed industry. It struggled on into the mid-20th century and kelp was still being produced in Ireland until around 1950. Irish seaweed was rich in iodine and in the mid-19th century 60% of the kelp imported into Glasgow came from Ireland. Iodine manufactories were established in Ramelton and in Galway, although they closed before the end of the 19th century. An attempt was made to revive the industry in Galway in 1929-30, but it was too late and cheap iodine from Chile made it unviable.

My interest was sparked by reading about the factory in Ramelton and I included the iodine from seaweed industry in an article in 1998 on the 'The early chemical industry in Ireland'. I have recently been starting to publish some articles on the history of the industry, with a special focus on Ireland, and details are given below. The most accessible one is the 2021 article in *Irish Chemical News*. I have also produced articles on the local industry in Galway, Clare and Donegal. I'd be interested to hear of any local knowledge on the Irish kelp industry, especially any physical remains, and in the last 20 years there been an

increased interest in the archaeology of the industry.

References

- Childs, P.E., (1998), 'The early chemical industry and industrialists in Ireland', *Irish Chemical News*, XII(1), 18-25, Summer 1998 (also published in *Chemistry in Action!*)
- Childs, P.E., (2021a), 'From soap to ice-cream: the Irish seaweed industry 18th - 21st century - an indigenous science-based industry', *Irish Chemical News*, #2, May, pp. 37-63
[Irish-Chemical-News-2021-Issue-2.pdf \(chemistryireland.org\)](#)
- Childs, P.E., (2021b), 'The history of the chemicals from seaweed industry in Ireland', *Bulletin for the History of Chemistry*, 46(2), pp. 149-163
- Childs, P.E. (2021c), 'A history of the kelp industry and iodine works in Galway', *Journal of the Galway Archaeological and Historical Society*, **73**, pp. 52-69
- Childs, P.E., (2022a), 'Kelp gathering and the factory at Freagh, Co. Clare', *The Other Clare*, in press
- Childs, P.E., (2022b), *Donegal Annual*, in press
- Childs, P.E., (2022c), 'The iodine industry in Glasgow and Scotland', *Bulletin for the History of Chemistry*, in press

□

The iodine number (value)

[Iodine value - Wikipedia](#)

The iodine number is the number of grammes of iodine which react with 100 g of a substance, usually an oil or fat, and is used as a measure of the degree of unsaturation (number of double bonds).

The determination of iodine value is a particular example of [iodometry](#). A solution of iodine I_2 is yellow/brown in colour. When this is added to a solution to be tested, however, any chemical group (usually in this test $-C=C-$ double bonds) that react with iodine effectively reduce the strength, or magnitude of the color (by taking I_2 out of solution). Thus the amount of iodine required to make a solution retain the characteristic yellow/brown colour can effectively be used to determine the amount of iodine sensitive groups present in the solution. The chemical reaction associated with this method of analysis involves formation of the

diiodo alkane (R and R' symbolize [alkyl](#) or other organic groups):

The precursor [alkene](#) ($R_1CH=CHR_2$) is colourless and so is the [organoiodine](#) product ($R_1CHI-CHIR_2$).

In a typical procedure, the fatty acid is treated with an excess of the Hanuš or [Wijs solution](#), which are, respectively, solutions of [iodine monobromide](#) (IBr) and [iodine monochloride](#) (ICl) in glacial [acetic acid](#).

Unreacted iodine monobromide (or monochloride) is then allowed to react with [potassium iodide](#), converting it to iodine I_2 , whose concentration can be determined by [back-titration](#) with [sodium thiosulfate](#) ($Na_2S_2O_3$) standard solution.

Some iodine values (IV):

Oil/fat	IV gI/100g
Beef tallow	42-48
Butter	25-42
Cod liver oil	148-183
Olive oil	75-94
Sunflower oil	110-145
Palm oil	49-55

□

Iodine an essential element

Iodine is an essential trace element in our diet, responsible for the correct functioning of the thyroid. Iodine deficiency produces goitre, a swelling of the thyroid. Diets poor in seafood or in inland regions far from the sea, are often poor in iodine and iodine deficiency is a real problem in many countries. This is why many countries sell iodised salt. An adult needs 150 µg per day, pregnant women 220 µg per day. The iodine level in urine is used to assess iodine status and is linked to diet.

"The borderline iodine status of the Irish population persists unchanged over the past 20 years with the annual median urinary iodine (UI) varying from 62.9 to 105 µg/L; overall median 72.4 µg/L (WHO recommended 100 µg/L)."

[Iodine Status over Two Decades: Influence of Seaweed Exposure – Irish Medical Journal \(imj.ie\)](#)



Seafood and seaweed are major sources.
Mcg = μg = microgramme

Food Item	Quantity	Iodine Content
Iodized Salt	100 grams	3000 mcg
Cereals and Breads	100 grams	10-11 mcg
Meat	100 grams	26-27 mcg
Vegetables	100 grams	32-33 mcg
Fruits	100 grams	4-5 mcg
Haddock	100 grams	Almost 300 mcg
Malt bread	100 grams	29-30 mcg
Haddock	100 grams	300 mcg
Jaffa cakes	100 grams	More than 32 mcg
Naan Bread	100 grams	28-29 mcg
Trifle	100 grams	60 mcg
Mayonnaise	100 grams	35-36 mcg
Cod	100 grams	More than 90 mcg
Boiled Egg	1 egg	23.76 mcg
Low Fat Yogurt	1 cup	87 mcg
Strawberries	1 cup	13 mcg
Kelp	0.25 cup	415 mcg
Cow Milk (2%)	1 cup	58-59 mcg
Gouda Cheese	40 grams	13.6 mcg
Raw Oyster	13-14 grams	21-22 mcg
Ice Cream	45-50 grams	9.6-9.7 mcg
Cheddar Cheese	1 ounce	5-20 mcg
Cottage Cheese	Half cup with around 2 % milk fat	25-70 mcg

Discovering the elements

The real world is a jumble of awesome complexity and immeasurable charm. Even the inanimate, inorganic world of rocks and stone, rivers and ocean, air and wind is a boundless wonder. Add to that the ingredient of life, and the wonder is multiplied almost beyond imagination. Yet all this wonder

springs from about one hundred components that are strung together, mixed, compacted, and linked, as letters are linked to form a literature. It was a great achievement of the early chemists — with the crude experimental techniques available also with the ever-astonishing power of human reason (as potent then as now) — to discover this reduction of the world to its components, the chemical elements. Such reduction does not destroy its charm but adds understanding to sensation, and this understanding only deepens our delight.

P. W. Atkins, *The Periodic Kingdom: A Journey into the Land of the Chemical Elements* (1995)

Update on ULs adopt an element



The fundraising for the giant UL Periodic Table is progressing well – almost 80 of the 118 elements have now been ‘adopted’ and 19 corporate sponsors have also agreed to come on board. It is hoped to install the Periodic Table over the summer in time for the new academic year. More details from peter.davern@ul.ie
Some elements are still in need of adoption:
<https://cspereiodic.myshopify.com/>

Quirky Elemental Rhyming Facts

Peter Davern

Dept. of Chemical Sciences, University of Limerick
peter.davern@ul.ie



ARSENIC, As

**Though arsenic, king of poisons, preordained the next in line,
Paul Ehrlich's "magic bullet" helped new era to define.**

Arsenic is a solid, greyish metalloid that can occur naturally in its elemental form. It's perhaps better known for its oxide form (As_2O_3)—a white, tasteless, odourless, toxic, crystalline solid. Through the ages, particularly in France and Italy, this potent "succession powder" was used by the ruling classes to discreetly kill potential rivals to their reigns; as a result, it earned the titles of "the poison of kings" and "the king of

poisons."

Despite its notorious reputation, arsenic has a therapeutic side. In 1909, the German chemist Paul Ehrlich (1854–1915) discovered an arsenic-based medicine that became the first effective treatment for syphilis (a bacterial infection of the blood). Ably assisted by Japanese bacteriologist Sahachirō Hata (1873–1938), Ehrlich tested more than 600 different compounds in search of what he called a "magic bullet," that is, something that would kill the infectious bacterial cells while leaving the body's own cells unharmed. The successful breakthrough came with Compound 606 (later to be marketed as *Salvarsan*), and with it was born the era of chemotherapy – the treatment of disease by the targeted use of chemical substances.

□

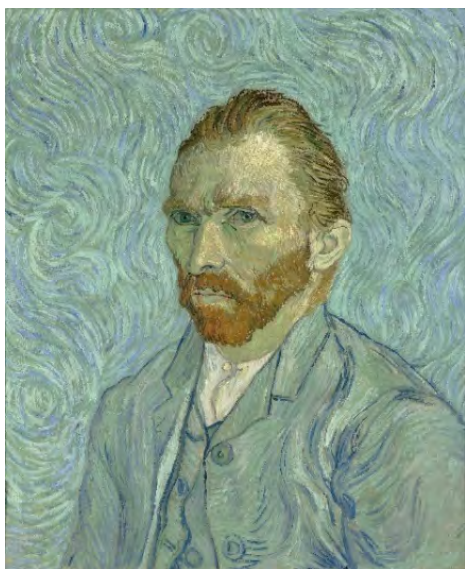




Lead, Pb

**You're stable, soft and work'd with ease – the Roman plumber's mate,
Van Gogh applied your salts in paint; fair skin you've help'd create.**

For centuries the heavy, soft, eminently workable, and dullish-grey element lead was the plumber's material of choice for fabricating water pipes and drains. In fact, the element is so stable that certain lead drainpipes installed in ancient Rome still function perfectly to this day. The word plumber derives from the Latin word for lead, *plumbum*, which in turn truncates to give the element its chemical symbol, Pb.



and tormented mind might have been symptoms of chronic lead poisoning, because he had a habit of sucking the paint from his brushes!

White lead ($2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$) was used in many cultures (back to the ancient Egyptians!) as a cosmetic for creating the illusion of fair skin. It gave users a milky complexion that implied a life in the shade, free from toil. This look contrasted with the ruddy, weathered complexion of the servants who chopped the wood and drew the water.

□

Until the full extent of lead's toxic nature was known, lead salts like red lead oxide (Pb_3O_4) and yellow lead chromate (PbCrO_4) were commonly used in paints and pigments due to their vibrant colour. The salts' high opacity also meant that a small amount of lead-based paint could provide coverage over a large surface area. Van Gogh's famed irritability

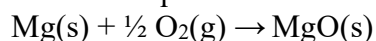
Chemical Myths Exploded! #4



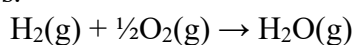
In this series we are looking at some areas of chemistry where there are common student misconceptions/alternative conceptions. These often come from the way the chemistry is taught or represented in books. Unfortunately, misconceptions can be hard to eradicate and it is best for the teacher to recognise what they are, to uncover students' ideas and deliberately target them. If you have queries about this series, ideas for difficult topics or about chemical bonding, please send them in. In the next Chemical Myths we will look at electrochemistry.

What is a molecule?

There is often confusion about atoms, molecules and giant network solids. It is not uncommon to find a mention of molecules of salt or of iron. Partly this comes from the way we write chemical equations:



It is easy to see oxygen (dioxygen) as a molecule (though half a molecule may confuse) but Mg and MgO look like an atom and a molecule respectively. The clue is partly in the state of matter - (s) indicating solid. Magnesium exists as a solid made up of magnesium atoms bonded together into a giant lattice by metallic bonds. There are no molecules or individual, separate atoms even in the smallest piece of magnesium. A small piece and a large piece of magnesium have the same basic structure, just different numbers of atoms bonded together. To react with oxygen gas, magnesium atoms have to break away from the solid and then react with oxygen molecules (breaking the O-O bond) and forming MgO solid, an ionic lattice. There are no MgO molecules only particles of MgO solid, which has a giant ionic structure and is composed of alternating magnesium (Mg^{2+}) and oxide (O^{2-}) ions. On the other hand, the reaction between hydrogen and oxygen to give water consists only of molecules.



It is better at the start to avoid half molecules in equations, as they don't exist initially, and are only a book-keeping exercise.

A molecule has a simple definition:

A molecule is a particle consisting of two or more atoms (the same or different) bonded together by covalent bonds.

A molecule may contain from 2 to 100,000+ atoms bonded together – giant molecules are often polymers (not always), made up of many repeating units. A sample of a molecular substance (one composed of molecules) contains billions upon billions of identical molecules. Thus 18 g of water contains 6.023×10^{23} molecules of water (an Avogadro number). This reminds us that molecules are very small and there are lots of them in even a small sample.

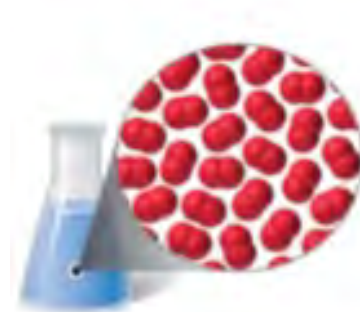


Figure 1: Liquid oxygen or hydrogen composed of diatomic molecules

A substance composed of molecules may exist as a gas (if the molecules are small and have weak intermolecular bonds, see Chemical Myths #3, *CinA!* #118), a liquid or a solid at room temperature. A molecular substance may pass from solid to liquid to gas

without the molecules breaking up, i.e. the molecules stay intact in the different states. This is because covalent bonds, which hold the atoms together in a molecule, are strong bonds. It is only at very high temperatures, e.g. in an incinerator, that molecules break up into atoms. At a high enough temperature all molecules will break up into atoms. If the covalent bonds are weak, they will break up more easily; if they are strong it will need a higher temperature to split them up. Thus we have atoms and ions in stars, but not molecules. The bonds that hold molecules together (the bonds between molecules) in the solid, liquid and gas are intermolecular bonds and these are easily broken. Thus many molecular substances have low mpts and bpts compared to ionic substances.

A unit cell is not a molecule

An ionic substance is not made up of 'ionic' molecules, e.g. Na^+Cl^- . To get beyond the idea of a molecule for ionic substances, books often give the diagram of a unit cell (Figure 2).

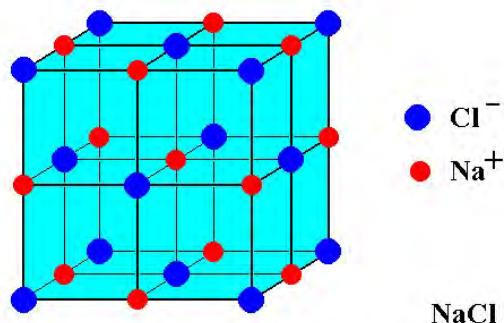


Figure 2: A unit cell of sodium chloride

This diagram is easily misunderstood. It does NOT represent a cubic molecule of NaCl . In fact, if you count up the atoms in the diagram you will not get the right formula for sodium chloride. (Try it!) This diagram is a unit cell, a building block of the crystal structure. If we count the atom (ions) correctly we will find that it contains 4 Na^+ and 4 Cl^- ions, giving the correct ratio. But the unit cell is only the simplest part of a giant structure, which (from our perspective) goes on infinitely in all three dimensions. Sodium chloride solid is NOT made up of lots of these cubes (like a bowl of sugar cubes): the smallest piece of NaCl(s) we

can see contains billions of Na^+ and Cl^- ions bonded together with the repeating structure seen in the unit cell.

A unit cell is not a molecule and does not exist in its own right.

The correct picture of the repeating unit is shown in Figure 3, a cube with flat faces, which are able to stack together.

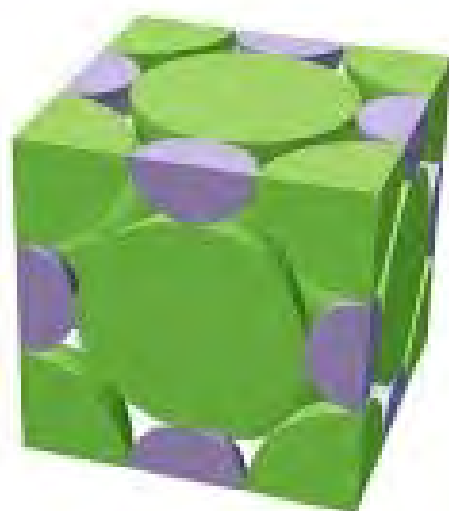


Figure 3: The correct picture of a unit cell of NaCl(s)

This simulation gif gives a good idea of how the giant structure builds up. [Sodium Chloride crystal lattice \(kings.edu\)](http://kings.edu/SodiumChlorideCrystalLattice)

Think of the sodium chloride unit cell as a cubical brick. Stacking them together produces the crystal (Figure 4).

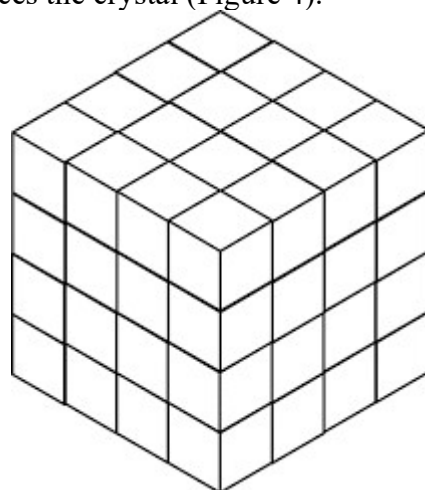


Figure 4: A stack of cubes (unit cells)

It does not contain NaCl(s) molecules, nor is it made of stacked cubes.

But the diagram/model unit cell does not get over the 3D, giant network nature of a crystal.

Figure 5 is better. Imagine this diagram going on forever in all three dimensions. The unit cell is only a small part of this structure, a convenient way to represent the structure, but it is not a molecule.

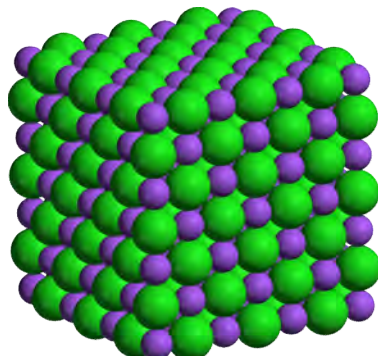


Figure 5: Space-filling model of NaCl(s) [Crystal structure - Wikipedia](#)

Another way that the structure in Figure 1 is misleading is that it gives the impression by using balls and sticks that the atoms (really ions) are bonded together by covalent bonds between pairs of atoms. Figure 4 is better as it shows the ions touching. The ions are held together by the attraction of opposite charges. This electrostatic field is the same in all directions and each ion is bonded to six others of opposite charge. When we explain ionic bonding, as in Figure 6, we reinforce the idea that NaCl(s) consists of pairs of atoms forming an ionic molecule.

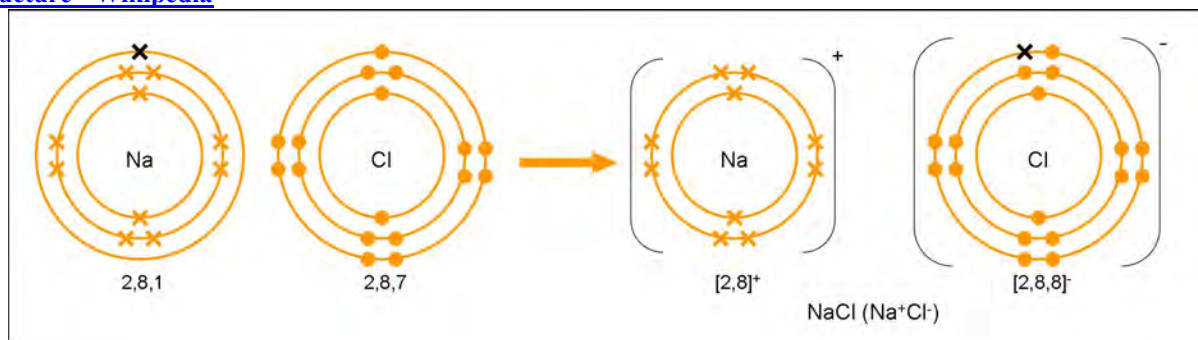


Figure 6: The traditional way of showing the formation of an ionic bond
[Chem Easy: Formation of sodium chloride, NaCl \(ionic compound\) \(chemistry98.blogspot.com\)](#)

This is such a powerful image that everyone remembers it, but we must explain that it is only part of the story and link it to the giant structure. If you don't your students will continue to think of NaCl(s) as an ionic molecule, Na^+Cl^- (s).

The same idea of giant network structures, and unit cells, also applies to the structure of metals (e.g. Na(s), Fe(s)) and molecular network solids (e.g. SiO_2 (s), diamond). In a metal there are no isolated atoms, as they are all bonded to each other by metallic bonds. In diamond carbon atoms are bonded to each other by strong covalent bonds, into a 3D giant structure. In SiO_2 (s) there are no SiO_2 molecules; Si and O atoms are bonded to each other by strong covalent bonds, into a 3D giant structure (Figure 7), which from our perspective goes on forever.

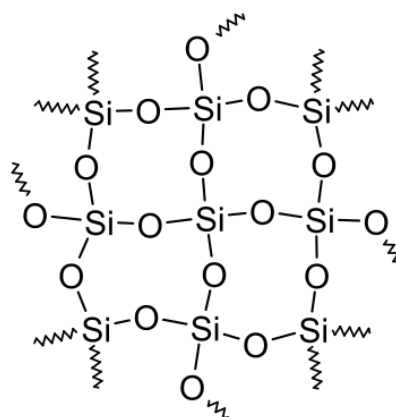


Figure 7: The covalently bonded structure of SiO_2 (s)

Can a molecule be an ion?

The definition of a molecule is a particle made from a finite number of atoms joined by covalent bonds. There is a misunderstanding that all molecules must be neutral

(uncharged). However, there are many molecular ions, where we have a covalently bonded group of atoms with a negative (or sometimes a positive) charge. These are very familiar in aqueous chemistry and metal salts: e.g. sulfate, SO_4^{2-} , nitrate, NO_3^- , carbonate, CO_3^{2-} , ammonium, NH_4^+ .

A solid salt or a salt solution contains large numbers of identical molecular ions; in 1 M sodium sulfate solution we would have 6.023×10^{23} sodium ions and 12.046×10^{23} sulfate ions.

Polymers are molecules

We are all familiar with plastics (polymers) in everyday life – plastic bags, cutlery, bottles, packaging. Often we don't think about what they are made of. Plastics may be rigid or flexible depending on their structure; they may soften on heating or they may not.

Most plastics we meet are molecular substances. They are composed of billions of large molecules, bonded to each other by intermolecular bonds. I often use spaghetti (Figure 8) as a model of a polymer: uncooked a bundle of spaghetti represents a rigid, hard plastic. Each strand is identical. When cooked it softens and forms a tangle of flexible strands – representing a flexible, soft plastic.



Figure 8: A model of a polymer – rigid and flexible

A strand represents a polymer molecule, in this case a linear one. The name plastic comes

from its properties, i.e. flexibility, and the name polymer from its structure. A polymer is made by joining many individual, often identical, molecules (units, mers) together to form a long chain. This is a new substance and the properties of the polymer are not the same as those of the monomers. Thus ethene, a gas, polymerises to form a white, waxy solid, polyethene (Figure 9). Small molecules are often gases or liquids, but as we increase the size of molecules and molecular mass, the mpt and bpt increase as intermolecular bonds get stronger.

We can write this as an equation:

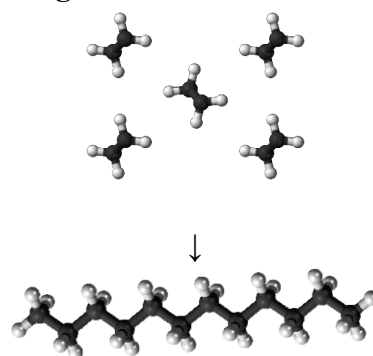
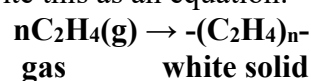


Figure 9: Ethene molecules (monomers) link together to form long chains (polymer)

The polymer molecules have the same structure but are often of different lengths, and linear molecules can stack together in parallel (Figure 10).

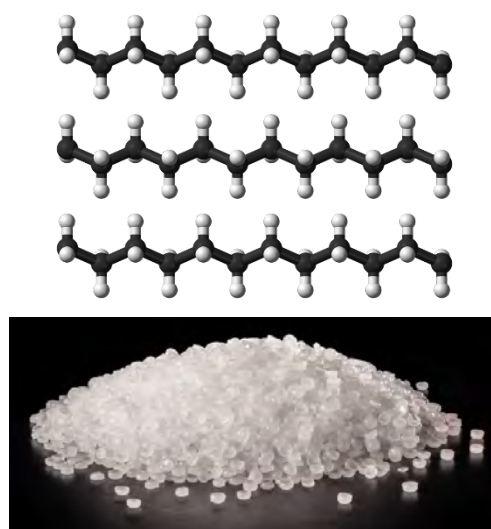


Figure 10: Polyethene molecules (chains) and polyethene solid

The limitations of our diagrams and models underestimate the size of polymer chains: in reality they are 100,000 atoms long. Another simple model is to make a chain out of a pile of paper clips. The individual clips are rigid, but the chain formed is flexible and made of identical units. (When these were available poppet beads made a good model.) If you have molecular models, you can also show how the long chains become very flexible.

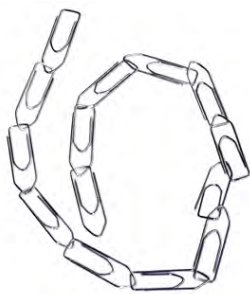


Figure 11: A paper clip model of a polymer

This is a cheap and versatile model. We can use different coloured clips to show a mixed polymer. You can show cross-linking between chains, or hang substituents on the chain. The more cross-linked a polymer, the less flexible it will be. When it is totally cross-linked then it is no longer be a molecular solid but becomes a giant, covalently-bonded structure. It will be hard and high melting – and often it will decompose before it melts. Thermoplastic polymers are molecular (e.g. polyethene, PVC); thermosetting polymers (e.g. Bakelite, Melamine) are not molecular, although they are covalently bonded. They are called thermosetting because the cross-linking is initiated by heat and/or a catalyst (Figure 12). Thermoplastics can be melted and reshaped but thermosetting plastics cannot.

One difference between a molecular solid and a polymer, arising from the way polymers are made, is that whereas in a molecular all the molecules are identical, in a polymer the chains are of different lengths, and we can only talk about an average molecular mass as there is a distribution of molecular sizes and masses.

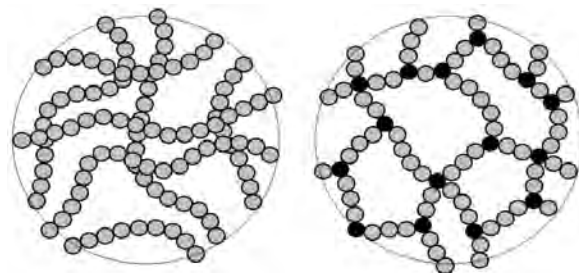


Figure 12: From flexible to rigid polymer by cross-linking [Thermosetting polymer - Wikipedia](#)

When does a molecule become a polymer?

There is no hard and fast rule to distinguish a molecule from a polymer: a polymer is just a very large molecule, made of repeating units. If we build up the alkanes by adding -CH_2 each time, eventually we will get to very large molecules i.e. a polymer. It is really a difference of degree not of type. Another name for polymers is macromolecules.

Some polymers can be depolymerised and broken up again into small molecules (monomers), which can then be reformed into new polymers. Many biological materials are polymers. There are four classes biological macromolecules: **carbohydrates, lipids, proteins, nucleic acids**. But that is another story, at the interface of chemistry and biology.

□

Chemists you should know: #10

Jean-Baptiste André Dumas (14 July 1800 – 10 April 1884)

Adrian J. Ryder

Email: tutorajr@gmail.com



The young Dumas

Family life

Jean-Baptiste Dumas' parents were Jean-Baptiste Dumas (born 29 August 1763), a talented draftsman and accomplished painter who, after working in Paris for several years, returned to his native city of Alès (Gard department in southern France some 80 kilometres inland from the coast of the Mediterranean) and became the town clerk, and Marie Madeleine Bastide (23/12/1780-20/6/1843), who married on 25th June 1798. No record of any siblings is found on family trees for Dumas and so it appears, unusually for the time, that he was an only child. Dumas was born 14/7/1800.

Dumas married Herminie Caroline Brongniart (5/11/1803 – 4/3/1890) on the 18th February 1826. She was the daughter of Alexander Brongniart (1770 – 1847) and Cécile Jeanne Coquebert de Montbret (1782 – 1862). Alexander was an illustrious geologist and the director of the Royal Porcelain Works at Sèvres. This marital alliance greatly advanced Dumas' social position and in later years he made his home one of the chief meeting places of scientific society in Paris. Herminie had two siblings: Adolphe Théodore (1801- 1876) and Matilde (1808 – 1882). Dumas and Herminie had two children: Ernest Charles

Jean (1827 – 1890) and Noëlle Marie Cécile (born 1831). Ernest married twice, on 23rd October 1850 to Julie Désirée Milnes-Edwards (1831 – 1857) and on the 8th December 1862 to her sister Camille Cécile Marie Milnes-Edwards (1832 – 1917). Noëlle married, on the 3rd May 1855, Charles François Hevré Mangon (1821 – 1888).

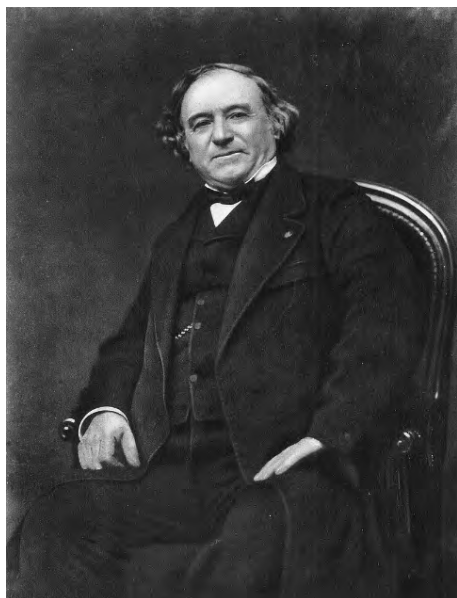
Education

After local schooling in Alès, Dumas, whose parents had prepared him for a career in the navy, became instead an apprentice to an apothecary in Alès in 1815. However, aged 16, following an unjust and physical assault by his master, he left the position and headed on foot to Geneva some 400 km away, where he had relatives with whom to stay. There he was able to continue his apprenticeship under a more reasonable master, Le Royer. He also attended the University, studying physics, chemistry and botany and became so accomplished that he was soon engaged with Pierre Prévost (1751-1839) in original experimentation on problems involving physiological chemistry and embryology. In 1818 one of the most distinguished physicians of Geneva, Dr Jean-François Coindet (1774-1834), thinking that the effect of burnt sponge as a treatment for goitre might be due to the presence of iodine, asked Dumas to investigate. (Iodine had only just been discovered by accident in 1811 by Bernard Courtois and in 1818 its properties were still being investigated.) Dumas did indeed show that iodine was not only present but went on to prepare medicinal doses and tincture of iodine for use. This saw the firm of Royer, who employed him, gain a very rewarding source of income over the years. In 1821 Dumas went on to study the electrical phenomena in muscles.

However, his life was to change in 1822 when he met Alexander Von Humboldt (1769-1859), who was visiting Geneva. Humboldt, one of the leading scientists of his day, was impressed by the young man and advised Dumas to move to Paris, where he would find more facilities for experimental work and employment opportunities.

Life in Paris

Dumas took Humboldt's advice and shortly after arrival in Paris became Professor of Chemistry in the Lyceum. Here he perfected his method of measuring vapour densities and in a paper in 1826 he described his work in determining the atomic weights of carbon and oxygen. His value for carbon was 12.02, compared to the current value of 12.24, and very close to the present-day value of 12.0107. He expanded these experiments over the years to include some thirty elements, setting the atomic weight of hydrogen to be 1.0. These results were not published until the years 1858 to 1860. As a result of his experiments, Dumas showed that in gases, under the same conditions of pressure and temperature, the molecules are spaced at equal distances from each other, i.e. take up the same volume.



Dumas in later life

In 1826 he published his text book, *Traité de Chimie Appliquée aux Arts*. This text ran to eight editions over the years, the eighth being issued in 1846. 1828 saw his research on the esters of ethanol published. In 1829 Dumas, with Théodore Olivier (1793-1853) and Jean-Claude Eugène Péclet (1793-1857), founded the École Centrale des Arts et Manufactures (later called École Centrale Paris).



The old École Centrale Paris

The new École met with great success and Dumas gave it great service as professor of chemistry. In 1878 Dumas, the surviving founding member, had the good fortune to be able to attend the fiftieth anniversary of his own foundation, and seeing it acknowledged as among the most important scientific institutions of the world. Over the next twenty years he published wide-ranging experimental results, which established organic chemistry as an integral part of chemistry and he can justly be regarded as the father of organic chemistry. In 1830 he obtained oxamide, $(\text{CONH}_2)_2$, by distillation of ammonium oxalate. In 1831 he discovered anthracene in coal tar and in the same year he prepared cymene, $\text{C}_{10}\text{H}_{14}$, from camphor. In 1833 he found that hydrogen was replaced by chlorine when reacted with oil of turpentine. The same year also saw him develop a method for estimating the amount of nitrogen in an organic compound, during which he made major changes to the existing combustion method. In 1834 he showed that methanol could be oxidised to formic acid (methanoic acid) and he also made chloral, Cl_3CCHO , by the reaction of chlorine with ethanol. Also in this year he coined the name chloroform, CHCl_3 , for the substance discovered in 1831 by the American Samuel Guthrie (1782-1848), and independently by both Eugène Soubeiran (1797-1859) and Justus Von

Liebig (1803-1873) in 1832. He also worked out the composition of CHCl_3 experimentally. In 1837 he produced an important paper with Liebig on radicals as the ‘elements’ of organic chemistry.

“In inorganic chemistry the radicals are simple; in organic chemistry they are compounds – that is the sole difference.”

In 1838 he discovered trichloroacetic acid, CCl_3COOH . In 1839 he isolated cinnamic aldehyde, $\text{C}_6\text{H}_5\text{CH}=\text{CHCHO}$, from oil of cinnamon. In 1842 he pointed out differences in the basic composition of proteins. Overall during his life Dumas published some nine hundred publications. He spent an immense amount of time on fundamental experimentation, justifying the claim that he was the father of organic chemistry.

Much of his work involved experiments using chlorine. It is reported that he was pointed in this direction by a peculiar occurrence at a soirée held in the Tuileries palace in the early 1830’s, where the guests had a bad reaction to a noxious gas being released by the lighted candles. He was asked by his father-in-law, Alexander Brongniart, to investigate and found the fumes to be caused by chlorine present in the candle wax. The chlorine had been used to whiten the candles and some of it had combined with the alkanes in candle wax during manufacture.

Dumas was appointed assistant professor at the Sorbonne in 1832 when Gay-Lussac gave up the position to take up the chair of chemistry at the Jardin des Plantes. Dumas became full professor there in 1841, a position he held until his retirement in 1868. Since the contemporary practice was to hold several academic appointments at once, Dumas also occupied a chair at the École Polytechnique (from 1835) and in 1839 became professor of organic chemistry at the École de Médecine. He lectured occasionally at the Collège de France and gave instruction in experimental chemistry to select students at his private laboratory from 1832 to 1848. From 1840 on he was one of the editors of the prestigious *Annales de chimie et de physique*.

In 1832 Dumas became a member of the French Academy of Sciences. From 1868 until his death in 1884 he served the Academy as permanent secretary of its department of physical sciences. He was awarded the gold medal of the Royal Society (honouring Faraday) in 1869, having previously been awarded the Copley Medal in

1843. Dumas was a member of various foreign scientific organisations. To mention just two: in 1838, he was elected a foreign member of the Royal Swedish Academy of Sciences. The same year he became correspondent of the Royal Institute of the Netherlands and, when that became the Royal Netherlands Academy of Arts and Sciences in 1851, he joined as a foreign member.

After 1848 Dumas exchanged much of his scientific posts for ministerial posts under Napoléon III! He was elected a deputy from the Department of Nord to the national legislative Assembly and acted as minister of agriculture and commerce for a few months in 1850-1851 and then minister for education. Subsequently he became a senator, president of the municipal council of Paris and his skills in analysis were put to good use on his appointment as master of the French Mint. He was president of Société d'encouragement pour l'industrie nationale from 1845 to 1864.



Société d'encouragement pour l'industrie nationale

In 1863 he was awarded the Grand Cross of the Legion of Honour. The fall of the Second Empire on the 4th September 1870, when France became a Republic, saw his official career suddenly come to an end. After this he produced little work of note but always encouraged developing talent. His scientific worth was again recognised by the award of the Albert Medal in 1877.

Dumas remained a devout Catholic throughout his life, despite the general anti-clericalism prevalent during the years of turmoil in the early 19th century, and would often defend Christian views against critics.

Conclusion

He died at Cannes in 1884, where he had sought a retreat from the severity of the Parisian winter, and is buried at the Montparnasse Cemetery in Paris, in a large tomb near the back wall, shown below.



The Dumas Family Vault



The internal plaque to Dumas

His is one of the 72 names inscribed on the Eiffel tower. His name is between those of Camille Polonceau, Engineer, and Émile Clapeyron, Engineer and Physicist, on the north-east (La Bourdonnais) side. Streets in his honour have

been named in Paris, Cannes, Toulouse, Clermont Ferrand and Lille Lomme.

Perhaps his life can be best summed up in his own words.

"I have seen many phases of life; I have moved in imperial circles, I have been a Minister of State; but if I had to live my life again, I would always remain in my laboratory, for the greatest joy of my life has been to accomplish original scientific work, and, next to that, to lecture to a set of intelligent students." Jean-Baptiste Dumas



The plaque on the facade of the l'Hôtel de Tavannes, Rue Saint-Dominique (Paris) where Dumas lived

Sources

<https://gw.geneanet.org/gwdefrem?lang=en&n=brongniart&oc=0&p=herminie+caroline>

https://en.wikipedia.org/wiki/Jean-Baptiste_Dumas

<https://www.encyclopedia.com/people/science-and-technology/chemistry-biographies/jean-baptiste-andre-dumas>

https://www.jstor.org/stable/25138751?seq=5#metadata_info_tab_contents

□

Chemlingo: Chemistry is a load of Twaddle

Peter E. Childs

If you were a 19th century industrial chemist you would be very familiar with degrees Twaddle. I came across it in connection with the iodine from seaweed industry, where the concentrations of seaweed extracts were usually measured in degrees Twaddle. The units were in common use, especially in Scotland, to measure the specific gravity (SG) of solutions, whose density was compared with water so that SG has no units. Water with a specific gravity of 1.00 was 0.00 on the Twaddell scale and a S.G. of 2.00 was 200. Thus a SG of 1.50 was 100 on the Twaddle scale. The scale was probably invented by a Glaswegian glassblower William Twaddell (1792-1839), who made hydrometers. There are also suggestions that it was invented by Charles Macintosh (1766-1843) but made by Twaddell. A hydrometer is a device for measuring the specific gravity of a solution (Figure 1.)

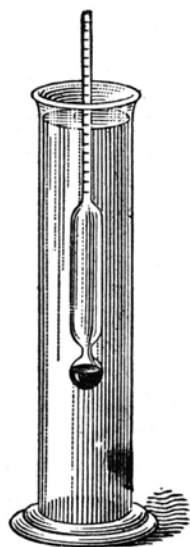


Figure 1: A hydrometer in use

The SG of a liquid is compared with water whose SG is 1.00 at 60 °F/15 °C. A hydrometer was widely used to measure the SG (density) of solutions like brines, sugar solutions, alcoholic beverages, and acids. The traditional hydrometers were not very precise and had a limited range. Twaddell invented a new scale, with smaller divisions, to cover the SG range 1.00 to 2.00. It was called degrees Twaddle, °Tw. A graduated

hydrometer floats in the liquid: if it is dense, the hydrometer floats higher and if less dense, it floats lower. The stem is graduated with the appropriate units. It was widely used by Scottish chemists.

Specific hydrometers were made and calibrated for specific industries. So we have saccharometers (measuring sugar solutions); lactometers (measuring milk); brineometers (measuring brines); alcoholometers (measuring alcohol solutions.)

$$^{\circ}\text{Tw} = 200(\text{SG} - 1)$$

Several different scales for measuring specific gravity were used in the 19th century, often linked to specific industries. The Brix scale, °Bx, was used in the wine and sugar industries. Invented by a German Mathematician Arnold Brix, around 1830. One degree Brix is 1 gram of [sucrose](#) in 100 grams of solution and represents the strength of the solution as [percentage by mass](#).

The Baumé scale, B° or Be°, was invented by a French pharmacist Antoine Baumé in 1768 and used in the wine industry. Having so many units in use is a recipe for confusion, although each tended to be specific to a given industry.

$$\text{SG } 1.07404 = 10.0 \text{ Be}^{\circ} = 18.0 \text{ }^{\circ}\text{Bx} = 14.8 \text{ }^{\circ}\text{Tw}$$

Hydrometers, which measure density, and hygrometers, which measure humidity, are often confused (see Childs, 2008). *Hydro-* comes from the Greek for water whereas *hygros-* comes from the Greek for moist or humid. They're both about water and both measure something (meter), and are thus easily confused.

References

Peter E. Childs, 'Hygrometer or hydrometer', *Education in Chemistry*, March 2008

[Hygrometer or hydrometer? | Opinion | RSC Education](#)

David G. Rance, What a load of Twaddle, *Slide Rule Gazette*, Issue 11, Autumn 2010

[Slide Rules Are Music To My Ears](#)

□

Diary

2022

60th ISTA conference

April 8-9

University College, Cork

dkennedy@ucc.ie

www.ista.ie

SMEC 2022

24-25 June

DCU

[SMEC - Science and Maths](#)

[Education Conference 2022](#)

[\(dcu.ie\)](#)

ECRICE 2022

July 11-13

Chemistry Teaching and

Learning in a Global

Unified World

Weissman Institute, Israel

[Ron.blonder@wizmann.ac.i](mailto:Ron.blonder@wizmann.ac.il)

[l](#)



ICCE 2022

18-22 July

Cape Town, S. Africa

[ICCE 2022](#)



27th BCCE 2022

31 July – 4 August

Purdue University

www.bcce2022.org



41st ChemEd-Ireland

October 15

TÚS, Moylish

Marie.walsh@tus.ie

Information page

Sponsors

The sponsors whose logos are featured on the outer back cover give donations of between €250 to €1,600 per year to enable the production and distribution of *Chemistry in Action!* free of charge to Irish Chemistry teachers. Some of these sponsors have been supporting the magazine since the first issue, and have helped to ensure its survival over the last 40+ years. Their help is much appreciated.

Contributions wanted!

Contributions are always welcome to *Chemistry in Action!* providing the material is of interest to second-level chemistry teachers. Articles, experiments/ demonstrations, teaching tips, book and AV reviews etc. are all welcome. Send by email as a Word document when submitting material. Do not embed diagrams, photos or tables but just insert between paragraphs.

You can contact the editor by email at: peter.childs@ul.ie or one of the assistant editors.

Internet version

The most recent back issues plus some TY Science modules and other resources are available at:

www.cheminaction.com

For information contact the web editor, Maria Sheehan at

mariashsheehan400@gmail.com

Editorial correspondence

To communicate with the editor for any reason, please use the following information:

Dr. Peter E. Childs

Hon. Editor

E-mail: peter.childs@ul.ie

Communications in e-mail are preferred.

You can also send contributions to one of the assistant editors:

Marie Walsh

marie.walsh@lit.ie

Maria Sheehan

mariashsheehan400@gmail.com

Sarah Hayes sarah.hayes@ul.ie

Anne O'Dwyer

anne.odwyer@mic.ul.ie

TY Science Modules

We have discontinued selling these modules in print, as postage got too expensive. At present 6 of them are available online, free of charge, at our website:

www.cheminaction.com

We hope to make more of them available in future.

Back issues

If you would like hard copies of the last few issues (from 114 onwards) please send **€5 per copy** (cheque or PO payable to P.E. Childs) to Dr. P.E. Childs, 6 Golf Links Road, Castletroy, Limerick.

Acknowledgements

The Editor would like to thank the President of the University of Limerick for encouraging the publication of *Chemistry in Action!* and for the use of university facilities in its production, printing and distribution. A special thanks to Marie Walsh for her invaluable assistance over many years in producing *Chemistry in Action!*, and to the other assistant editors. The financial help of the companies and bodies, whose logos are given below, is gratefully acknowledged, as they make it possible since 1980 to produce and distribute *Chemistry in Action!* free-of-charge to Irish chemistry teachers.



National Centre for STEM Education

