# Chemistry In Action!

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Famous Irish Chemists - *Dervilla Donnelly*

# Contents #123



## Disclaimer



**Cover design: George Fitzgerald, Möbius Design, Limerick**
**Cover photo: Portrait of Professor Dervilla Donnelly by Emer O'Boyle (UCD)**

**Editor: Peter E. Childs** peter.childs@ul.ie
**Assistant editors: Marie Walsh, Maria Sheehan (web editor), Sarah Hayes, Anne O'Dwyer**

# Editorial #123

## The importance of listening

Every teacher knows the importance of listening to your students. It is how we find out if our teaching is working, if our exams are too hard or easy, whether our students are understanding new ideas etc. The NCCA and the Minister of Education don't have a good record of listening to teachers. Despite strong representations from science teachers about the Junior Cycle Science course (loss of content, vague learning objectives, a common exam paper, a change in the grading), it has gone ahead with no significant changes. If you're going to change something it is best done before it is implemented and becomes embedded in the education system. The Minister of Education, Norma Foley, had proposed moving some LC assessments in English and Irish to 5th year but backtracked in February 2023 the face of teacher opposition. This was a sensible decision. On 20/9/23 Norma Foley announced that the proposal to have 40% of the new LC courses assessed internally by teachers was being scrapped. This was in the face of the refusal of teachers through their unions not to assess their own students. She cited the developments in AI as a reason for reviewing the issue.

She also announced an acceleration of the introduction of new courses, so that the new specifications in Biology, Chemistry and Physics will be introduced in September 2024, along with the new LC course on Climate Action and Sustainable Development, on a phased basis.

This gives the Subject Development Groups a very short time to finalise the new courses and their assessment component, which in itself is not a trivial task. The SDGs haven't met since 2021. However, so far the NCCA and the SDGs have not listened to science teachers' major concerns about the new specifications (see the 2014 Hyland report, now 7 years old.) The new LC Agricultural Science course shows the dangers of going ahead without listening to teachers' concerns. Flawed Leaving Certificate Agricultural Science Syllabus Examined for the First Time – IASTA This relates especially to the vague description of content and learning outcomes, so that teachers don't know what to teach or to what depth they are expected to teach. So that it is left to individual teachers, or perhaps textbook writers, to decide what to teach, which may or may not match what is examined. This is a potential disaster, which we have covered here more than once. Lessons need to be learned from the rollout of the Ag. Science course, the views of the ISTA, and experience of other countries. Teachers (and the SEC) need a more detailed syllabus, with depth of treatment, not a vague specification, better learning outcomes, rather than one which specifies almost nothing. I am not sure whether the Minister has heard teachers' concerns, but so far the NCCA and SDGs don't seem to be listening. The only thing worse than an old, out-dated syllabus, is a new, flawed specification.

## LC grade inflation continues

Another concern concerning the LC exams is the problem of grade inflation, which in 2023 has been continued after Covid, authorised by the Minister for Education. This is discussed in detail on p. 10. Grade inflation at second level or at third level does nobody any good. There was a case for not penalising students during Covid and lockdown, but this has now passed, and Ireland should have followed the UK example of starting to reduce grades back to their pre-Covid level. The longer you leave readjusting the grading system the harder it is. It is now easier to get H1s and maximum points than ever, and to get a first or 2.1 degree at third level. The opposite problem is found with the Junior Cycle exams: here we have deflation of grades so ti is almost impossible to get the top grade (Distinction). We should listen to those immortal words of Gilbert and Sullivan: *"When everybody's somebody, then no-one's anybody."* (*The Gondoliers*) When everybody gets a prize, however they have done, then the prizes are worth nothing.

*Peter E. Childs* Hon. Editor (1980-)

# In this issue: #123

*CinA!* likes to bring relevant educational reports to the attention of our readers, so that we can all keep up with what's happening. (If any have been missed please let us know.) Several reports have come to our attention this year. The links to the reports are given so that you can look up and read the originals.

The Dáil Committee on Education, Further and Higher Education, Innovation and Science published an extensive report on the *Future of STEM in Irish Education*, including all the submissions, and we publish the main recommendations, plus a commentary by Professor Áine Hyland, who gave evidence to the Committee (p. 18.) You can access transcripts of the sessions online. Debates – Committee on Education, Further and Higher Education, Research, Innovation and Science – 33rd Dáil, 26th Seanad – Houses of the Oireachtas

The second report from the University of Limerick on the Framework for Junior Cycle was published in May and a summary of the main conclusions is given (p. 31).

In this issue we also look at grade inflation in the LC (p. 10) and the 2023 LC science results (p. 11). The marking of the JC exams has also raised concern this year and is discussed on p. 16. *"If we reject the idea of meritocracy, rewards based on merit, what we will end up is mediocrity, a lowering of achievement."*

We also carry a short report on the $42^{nd}$ ChemEd-Ireland held on October 21st in TCD (p. 20.) We hope to publish the Proceedings in the Spring issue, #124.

On p. 35 we carry a book review on an important book on *Inclusive and Accessible Secondary Science* by Jane Essex.

Peter Davern provides us with two more of his Quirky Elemental Facts in Rhyme (p. 38-39.)

As regular readers know *CinA!* has a long history of publishing historical articles, especially those by Adrian Ryder. In this issue we start a new series on 'Famous Irish Chemists', and to redress the balance, we will start off by profiling Irish women chemists. (There is actually an entry on Irish Women Chemists on Wikipedia.) It is also usual to feature dead chemists in such articles, but to kick off the series in this issue we look at the life of Professor Dervilla Donnelly (UCD), one of Ireland's most distinguished living chemists (p. 40).

Adrian Ryder's 'latest 'Chemists you should know' series features the wealthy English eccentric, Henry Cavendish (p.43).

We have three articles of everyday chemistry. On p. 48 in the series on Amazing Minerals we look at Quartz, $SiO_2$. In the latest Chemlingo Peter E. Childs looks at 'What a difference a letter makes' in chemistry. Silicon and silicone are not the same!

We are in a golden age of battery development for energy storage and other uses. On p. 55 we look at Vanadium flow batteries as a strong candidate for cheap, long-lasting energy storage.

Part 3 of 'The sulfur story: devil's gold or essential element?' looks at 'Sulfuric acid, $H_2SO_4$', arguably the most important industrial chemical (p. 58.)

We hope there is plenty on this issue to inform you and for you to chew on.

**WANTED:** photos of old chemistry/science labs.

## Mind the gap!

**How has the new JC science courses affected the teaching of LC sciences? *CinA!* would like to hear your experience of teaching LC science following on from the new JC Science course? How do you allow for the reduced content, unclear depth of treatment and the common level exam? Are students prepared for the LC courses and are they more demotivated than before?**

# Education News and Views

## Congratulations to Dr Declan Kennedy – President of ICASE 2023-2026

Dr. Declan Kennedy, UCC, has long been active in ICASE, the International Council of Associations for Science Education, of which the ISTA is a member. He is World Headquarters Coordinator and has been elected President for a 3-year term from 2023. Ms. Mary Mullaghy is Treasurer and Dr. Ryan Gallagher is Membership Secretary of ICASE, so Ireland is well represented in ICASE.

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## 8th ICASE world conference comes to UCC 2026

There was great excitement in Dubai at the recent 2023 ICASE World Conference on Science and Technology Education when it was announced that the School of Education UCC had won the bid to host the 2026 ICASE World Science and Technology Conference. ICASE is the International Council of Associations for Science Education and is the professional organisation representing science education associations throughout the world.

The ICASE World Conference is held every three years at various venues around the world, e.g. Australia (2007), Estonia (2010), Malaysia (2013), Turkey (2016), Thailand (2019) and Dubai (2023). The holding of the 2026 conference in UCC will be the first time that the conference has taken place in Ireland.The 8th ICASE WORLD CONFERENCE ON SCIENCE AND TECHNOLOGY EDUCATION will be held in 2026 at University College Cork (UCC), Ireland. It will be hosted by the School of Education UCC and preparations have already begun to ensure an exceptional and stimulating conference of international standard. This outstanding university opened its gates to just 115 students in 1849 and now has a student population of over 24,000. A warm welcome awaits all ICASE conference delegates to UCC!

**Dr Declan Kennedy, President of ICASE and Senior Lecturer in Science Education UCC, handing over the ICASE plaque to Professor Chris Williams, Head of College of Arts, Celtic Studies and Social Sciences in UCC.**

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## J. Chemical Education reaches 100th birthday

Congratulations on 100 years

JOURNAL OF CHEMICALEDUCATION

**The Journal of Chemical Education at 100**

The year 2023 marks the 100th volume of the Journal of Chemical Education. So far this year there have been several collections highlighting 100 years of teaching and learning that have posted as Virtual Issues, with more to come. Editorials in the Journal itself have pointed to 100 years of teaching Analytical Chemistry (February Issue), Biochemistry (April Issue), Inorganic Chemistry (June Issue), Organic Chemistry (June Issue). A focus on Physical Chemistry, Chemistry Education Research, High School Chemistry and Chemistry Outreach will round out the year of these special Virtual Issues. Read more>>

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## Did you know? Stormy Science

Met Eireann named seven storms this season and they were named after Irish scientists.

### Storm names and scientists' details

**Agnes:** Agnes Mary Clerke: Irish astronomer and science writer. Her best-known work, "A Popular History of Astronomy during the Nineteenth Century" was published in 1885.
**Fergus:** Fergus O'Rourke: scientist who contributed to myrmecology and medical entomology. Provided an authoritative description of Irish ants and an early

consideration of the importance of ants as disease vectors.
**Jocelyn:** Jocelyn Bell Burnell: Northern Ireland astrophysicist, who discovered the first pulsating radio stars, or pulsars in 1967.
**Kathleen:** Kathleen 'Kay' McNulty Mauchly Antonelli: one of the mothers of computer programming.
Kathleen Lonsdale: Irish crystallographer, demonstrated the crystal structure of benzene.
**Lilian:** Lilian Bland: Anglo-Irish journalist and pioneer aviator, the first woman in Ireland to build and fly an aircraft, and quite possibly the world's first woman to build her own airplane, the Bland Mayfly.
**Nicholas:** Nicholas Callan: physicist, invented the induction coil that was used in early telegraphy and is still being used in some electronic devices today.
**Vincent:** Vincent Barry: organic chemistry, best known for leading the team which developed the anti-leprosy drug clofazimine.

There are plenty of other Irish scientists' worth remembering who haven't been included in this year list, as there is a maximum number of names assigned per Met Service. Met Éireann respects, honours and is grateful for all Irish contributions to science and technology.
For more information on storm names and past storms, go to Storm Centre and Major Weather Events.

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## Exploring the values that inform STEM curricula development and selection in the Junior Cycle

The initial findings of an SSPC sponsored Impact Case Study: Education and Public Engagement have been released. SSPCE is an SFI-funded centre based at the University of Limerick.

**The project and research**

Secondary school participation in Science, Technology, Engineering and Mathematics, and aspirations to STEM careers, are patterned along gender, class, ethnicity and identity lines. The curriculum forms part of a joined-up approach to widening STEM participation, however, the curriculum is not systemically included in initiatives promoting STEM. Yet, the curriculum is a tool for enacting inclusion and equitable education where systems of inclusion and exclusion are considered. This research examines the transformation of original knowledge, e.g. physics, into pedagogic discourse, e.g. school physics. Competing interests, ideologies and the objectives of the stakeholders involved in the recontextualization process, shape the curriculum and students are socialised through the norms it transmits. This means the curriculum can sustain inequitable patterns or represent the interests of traditionally excluded groups.
Using a lens of diversity and inclusion and focusing on the macro and meso levels of curriculum development, the research involves interviewing individuals from the STEM curricula development and selection fields, as well as the analysis of secondary data such as 21 textbooks across the four subjects.
The initial results are given at the link below.
https://sspc.ie/exploring-the-values-that-inform-stem-curricula-development-and-selection-in-the-junior-cycle/

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## Dublin's Science Heritage

Ingenious DUBLIN

An exhibition on the scientific heritage of Dublin, based on the work of Mary Mulvihill, was launched in The Little Museum of Dublin on 18/10/23. The exhibition is called Ingenious Dublin, based on Mary's book *Ingenious Ireland* (now back in print.)


The exhibition is also linked to a series of evening lectures.

**Tuesday 21 November 5.30pm – 8.00pm**
Professor Patrick Wyse Jackson
– *Geology and Photography, the work of John Joly*
Professor Brendan Kelly
– *Grangegorman and the Dublin Asylums: Learning from the History of our Forgotten Psychiatric Institutions*

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**Tuesday 28 November 5.30pm – 8.00pm**
Professor Peter Gallagher
– *Dunsink Observatory and Ireland's contributions to astronomy*
Discussion with Clodagh Finn, Dr Mary McAuliffe and Dr Claire O'Connell
– *Women in Irish Science and Technology*
Ingenious Dublin Exhibition | The Little Museum of Dublin
See also:
Ingenious Ireland

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## Scientific merger

Science Foundation Ireland (SFI), the state funding body for scientific research, and the Irish Research Council (IRC), which funds postgraduate research, are to merge into one body, Research and Innovation Ireland (RII). This is a result of the Impact 2030 policy document and a bill to establish the new body has been published. The brief will not be confined to STEM subjects but will cover all areas.
(https://assets.gov.ie/224616/5f34f71e-e13e-404b-8685-4113428b3390.pdf)

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## New Science Advisor to be appointed

Currently Ireland does not have an independent Science Adviser to advise the government on scientific issues, like climate change and sustainability. From 2012 to 2021 it was a joint role with Director of SFI, rather than being a separate office. The new SA will chair a forum of experts to advise on scientific issues.

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## Junior Cycle results at last

The 2023 Junior Cycle exam results were released, finally, on October 18th. This was the second year when all subjects were examined, following Covid, and there were a record number of candidates – 70,727, up 5% on 2022. This is due to the birth bulge moving through the education system, due to hit the Leaving Certificate exams in 2025 and then third level.
All subjects, except English, Irish and Maths, are examined at common level, with 6 broad grade descriptions.
See below on p. 11ff. for a longer discussion of the results.

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## Changes in new LC announced

gov.ie - Minister Foley announces update to Senior Cycle Redevelopment (www.gov.ie)
On 20/9/23 the Minister of Education, Normal Foley made important announcements about the new LC courses. She revealed that the 40% coursework component (including practical work in the sciences) would not now be assessed by teachers but would be moderated externally by the SEC. The teachers' unions had refused to cooperate with teacher-based assessment. The introduction of the new LC science courses is to be speeded up so that they will start in Sept. 2025. This means the course specification will have to be finalised and in schools and with publishers by Sept. 2024. This doesn't give much time to revise the courses and the Subject Development Groups (SDGs) haven't met since 2021. The SEC will also have a lot of work to do in designing new exams and also the coursework items, as these will now be externally assessed. This will be a massive challenge especially for practical work.
The new LC course on 'Climate Action and Sustainable Development' will also be introduced, on a pilot basis, in Sept. 2025. I have reservations about the narrow focus of this course. It should be an Environmental Science course, with a wider brief, and it should specify 'Climate Science', as science is the essential basis for any action.

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## I Wish 2023 Survey

IWish Booklet 2023 RGB
The voluntary group I Wish which seeks to promote STEM careers to girls is now 10 years old and has published its latest survey of opinions on STEM.

**RTE.ie: 67% of teenage girls lack information on STEM careers - I Wish report.**
**https://www.rte.ie/news/business/2023/1024/1412705-i-wish-stem-survey/**
A new report from I Wish shows that 67% of teenage girls lack essential information about careers in Science, Technology, Engineering, and Mathematics (STEM).

The "I Wish Report 2023" - which looks at female Transition Year students' perspectives on STEM careers - also reveals that 64% of respondents cited their lack of information on STEM college courses as a considerable barrier to pursuing careers in these fields.

The I Wish organisation aims to inspire teenage girls globally towards STEM and it asked 2,335 teenage girls about perceived barriers to a career in the industry.

The report found that 41% of students emphasised the need for more career guidance and work-related activities during their school years.

Surprisingly, 21% of girls reported never having a career guidance class, despite 97% having access to a guidance counsellor.

I Wish said these findings result in a failure to bring STEM to life for girls and the opportunities to design a better and more inclusive future through STEM.

The 10th annual STEM Showcase event will take place on February 8, 2024 at the RDS Dublin.
Registration is open at iwish.ie/register, with an estimated 3,000 female students expected to attend.

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## Who speaks for STEM in school ?

Ireland is lucky to have several organisations representing STEM in schools.

The oldest established (in 1951) is the Irish Science Teachers' Association (ISTA). It has in the past represented all science teachers, including primary science and agricultural science teachers.
ISTA

In 1985 the Irish Agricultural Science Teachers Association (IASTA) was founded to represent the interests of Agricultural Science teachers. They also usually teach other sciences and so are also members of the ISTA.
About – IASTA

Science (and STEM) has become more important in the Primary Curriculum and in 2019 a new association, IAPSE (Irish Association for Primary Science Education) was launched.

We mustn't forget the TE in STEM.
The Technoteachers Association has been in existence for over 30 years representing and supporting teachers of traditionally woodwork and drawing, which today has become:

- Materials Technology Wood/Wood Technology
- Technical Graphics/Graphics
- Design & Communication Graphics
- Construction Studies
- Technology
- Graphics and Construction

About TechnoTeachers

The Engineering Technology Teachers' Association (ETTA) was founded in 1983 for teachers of Engineering, Technology and Design and Communication Graphics.
ETTA.ie

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# CONFERENCES


The Institute of Chemistry of Ireland (ICI) is delighted and honoured to be organising the 9th EuChemS Chemistry Congress (ECC-9), to be held in Dublin, Ireland, from 7th – 11th July, 2024.

The 9th EuChemS Chemistry Congress will have an exciting scientific programme with world-leading plenary speakers, invited speakers and short oral presentations, supplemented with a series of poster presentations, focused around eight scientific themes:

- **Energy, Environment and Sustainability** (including Emerging Sustainable Chemistry, Technologies, Biomass Valorisation, Green Synthetic Methodologies, Circular Bioeconomy, Food)
- **Physical, Analytical and Computational Chemistry** (including Machine Learning/AI)
- **Advances in Synthetic Organic Chemistry** (including Asymmetric Methodology, Inorganic Methodology, Green Synthetic Methodologies)
- **Chemistry Meets Biology For Health** (including Medicinal, Bioinorganic, Bioorganometallic, Radiochemistry, Food and Nutrition)
- **Catalysis** (including Organometallic Catalysis, Organocatalysis, Biocatalysis, Photoredox Catalysis, Electrocatalysis)
- **Supramolecular Chemistry** (including Chirality, Molecular Machines, Dissipative Systems, MOFs, Molecular Nanotopology, Sensors, Metallo-Supramolecular Chemistry, Molecular Logic, Host-Guest Chemistry, Self-Assembly Materials and Higher Order Structures)
- **Nanochemistry/Materials** (including Organic and Inorganic, Material Science, Devices, Circuits, Systems, Neuromorphic Networks, and Bio-Inspired Computing)
- **Education, History, Cultural Heritage, and Ethics in Chemistry**

**For more information see** EuChemS 2024

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## 16th ECRICE 2024

**"Chemical Education for Sustainable Development: Empowering Education Communities"**
**5-7 Sept. 2024**
**NOVA, Lisbon, Portugal**
[Home | 16 European Conference on Research in Chemical Education :: 5-7 September 2024 (chemistry.pt)]

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## 27th. International Conference on Chemical Education

***"Power of Chemistry Education for Advancing SDGs"***
**15-19 July 2024**
**Pattaya, Thailand**
[27th IUPAC International Conference on Chemistry Education - ICCE 2024 (icce2024thailand.com)]

ICCE 2024 PROGRAM THEMES

- Chemistry Education in Informal Education and Life-long Learning Context
- Redesigning Chemistry Laboratory Teaching
- Innovative technology for chemistry education
- Systems thinking in Chemistry Education
- Chemistry and Science Teacher Education and Continuous Professional Development
- Chemistry and Chemical Science Education for Environmental and Social Sustainability
- Policy, Reform, and Quality Assurance in Chemistry Education
- Ethics, Diversity, Equity and Inclusion in Chemistry Education
- Emerging Educational Trends in Chemistry in the 21st Century

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## BCCE 2024

***"Distilling Solutions for Chemical Education"***
**28 July-1 August 24**
**University of Kentucky**
**Call for Symposia and Workshop Abstracts:**

Members of the chemistry education community are invited to submit abstracts for symposia and workshops to be held at the 2024 Biennial Conference on Chemical Education (BCCE), which will be held at the University of Kentucky July 28-August 1, 2024. The conference will be organized around four themes – Classroom Practice and Learning Environments, Curriculum and Cognition, Assessment and Research Methods, and Professional Development – within the K-12, two-year college, and university communities.

College/university faculty and staff, K-12 teachers, graduate students, postdocs, and anyone else working in chemical education are welcome to submit a symposium or workshop. The deadline for symposium and workshop abstracts is November 10. To submit an abstract or to see developing information about the conference, visit http://bcce.divched.org/ or contact the program co-chairs, Kim Woodrum or Irv Levy or the workshop chair, April French at bcce2024@uky.edu.

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## ASE Annual Conference

**4-6 January 2024**
**University of Northampton**
[ASE 2024 Annual Conference | www.ase.org.uk]

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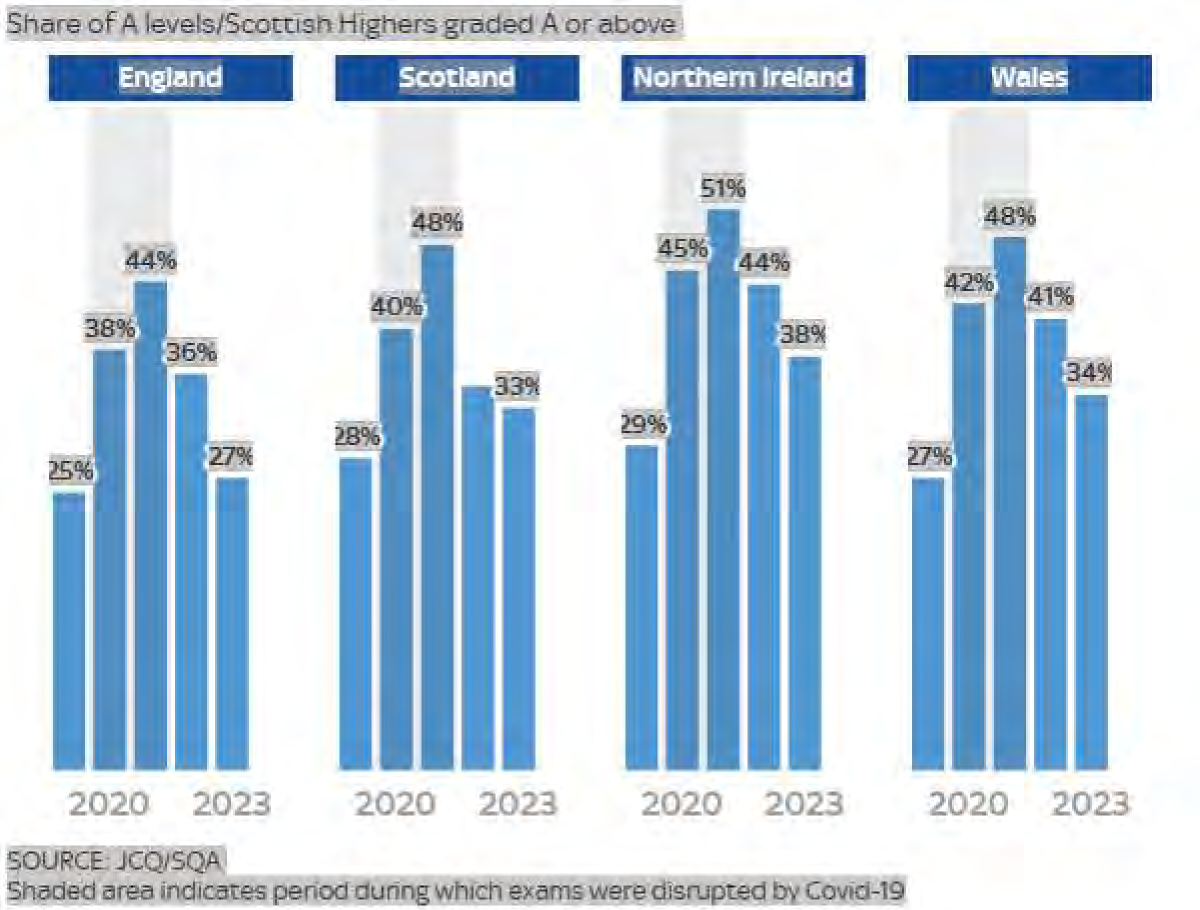
# The great grade inflation debacle

## UK figures 2019-2023

The figure below shows the senior cycle results for A grades or above from 2019 (pre-pandemic) to 2023 (post-pandemic) for the four UK regions.




A-level results: Number of top grades down on last year but still above pre-pandemic levels | UK News | Sky News

There is clearly a move in the UK to return to pre-pandemic (normal) grading, reducing the grade inflation seen during the pandemic and after. A* and A grades were awarded to 27.2% of students in 2023, compared to 36.4% last year, 44.7% in 2021 and 38.5% in 2020.
But the number is up by 1.8% compared to pre-pandemic levels, when 25.4% of A-level entries were awarded A or A* grades. Pupils in England saw the biggest drop in top marks, with the share of exams graded A or above down by 9% compared to 2022.

Welsh students saw a 7% drop in top grades while Northern Ireland saw a decrease of 6%.

This a welcome return to normal grading, even though over the previous years there has been steady grade inflation at A level an also at degree level. Grade inflation does nobody any good and it is good to see that the UK, unlike Ireland, has seized the nettle and is returning grades to the pre-pandemic distribution, unlike Ireland.

# LC Results 2023

A summary of the LC science results is given in Table 1 and the % uptake shown in Figure 2.

**Table 1: LC Science uptake for 2023 and 2022**
**(Total number of candidates: 2023 58,006; 2022, 58,056)**

| Subject | Year | HL(%) | OL(%) | Total | % LC cohort |
|---|---|---|---|---|---|
| Biology | 2023 | 28,723 (83.0) | 5,879 (17.0) | 34,602 | 59.65 |
| | 2022 | 28,671 (84.1) | 5,409 (15.9) | 34,080 | 58.7 |
| Chemistry | 2023 | 8,068 (82.7) | 1,682 (17.3) | 9,750 | 16.8 |
| | 2022 | 8,481 (87.6) | 1,198 (12.4) | 9,679 | 16.7 |
| Physics | 2023 | 6,143 (81.6) | 1,383 (18.4) | 7,526 | 13.0 |
| | 2022 | 6,487 (83.5) | 1,280 (16.5) | 7,767 | 13.4 |
| Ag. Science | 2023 | 6,132 (82.2) | 1,328 (17.8) | 7,460 | 12.85 |
| | 2022 | 6,218 (83.9) | 1,195 (16.1) | 7,413 | 12.7 |
| Phys.+Chem. | 2023 | 344 | 63 | 407 | 0.7 |
| | 2022 | 369 | 61 | 430 | 0.75 |

**Comments:**

The uptake in 2023 in 2023 was broadly similar to 2022. Biology remains the dominant LC science subject, with just under 60% of the LC cohort taking it. This is followed by Chemistry, Physics and Ag. Science. Physics has regained its place as the 3rd most popular science. Biology, Chemistry and Ag. Science all showed a small increase in numbers from 2022 to 2023. All the sciences have HL uptake of over 80% but in 2023 students shifted towards OL in Biology, Chemistry, Physics and Ag. Science. Does this reflect uncertainty in the students as to whether they could tackle the HL papers after their disrupted education over covid. This cohort did not take the Junior Cycle exams and so this year was their first experience of external examination.

The graph below (Figure 1) shows fairly consistent uptake of the LC science subjects since 2013, although Biology continues to be far and away the most popular science subject.

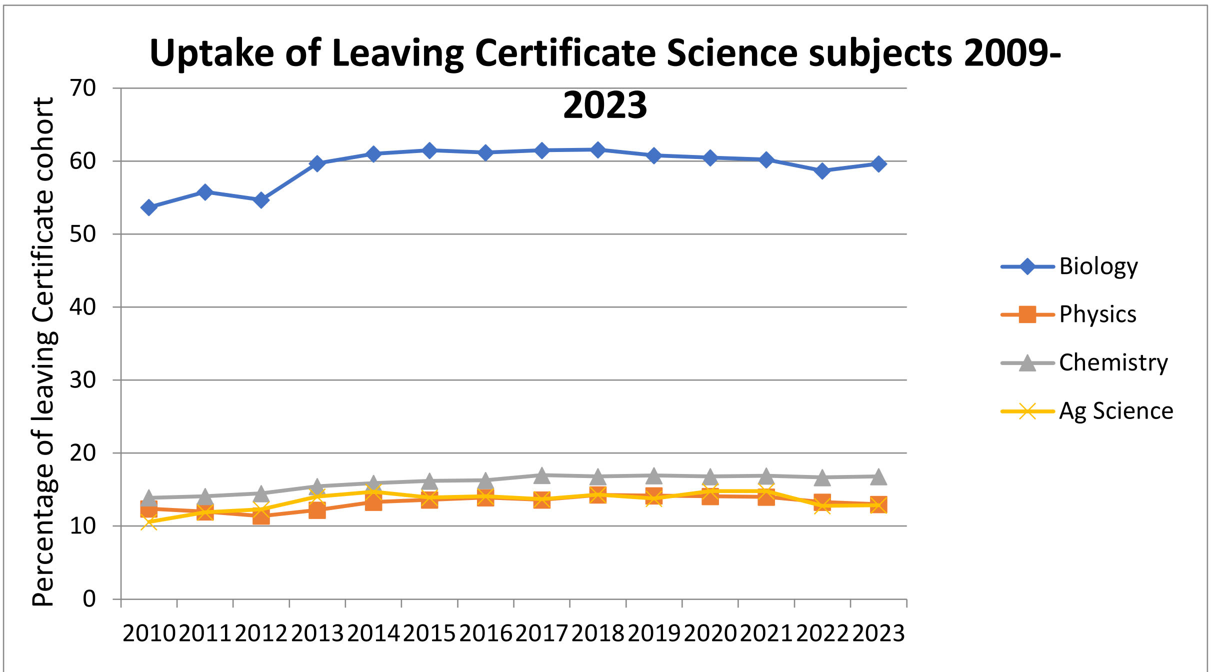



**Figure 1: Percentage uptake of LC science subjects from 2009 to 2023**

# Grade inflation in the LC sciences

Table 2 shows the change in the % of students getting H1s from 2019 (pre-Covid) to 2023, showing the effect of grade inflation due to the disruption of teaching an state exams during the covid pandemic. Unlike the UK, Ireland has not reduced grade inflation, in fact it has deliberately retained it.

**Table 2: Percentage of H1s from 2019 to 2023 in HL Maths and LC Sciences**

| Subject | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| **Maths** | 6.4 | 8.6 | 15.1 | 18.1 | 10.9 |
| **Biology** | 8.2 | 11.6 | 17.4 | 17.6 | 18.8 |
| **Chemistry** | 13.5 | 18.1 | 23.4 | 19.1 | 22.8 |
| **Physics** | 10.9 | 16.1 | 21.1 | 23.7 | 20.8 |
| **Ag. Science** | 5.0 | 9.5 | 11.3 | 5.8 | 12.4 |

**Comments:**

Maths is clearly the odd one out as in 2023 the % H1s decreased (-7.2%), but all the LC sciences showed an increase apart from Physics (-2.9%). This may reflect the problems with Maths paper 1. The main thing to note is the significantly higher %s of H1s , meaning that the grading curve has been shewed artificially to the right, from 2020 to 2023 compared to 2019, the last 'normal' LC year. From 2020 onwards the grades have been inflated, first by using teacher assessments and then by maintaining these inflated grades now, even when we can go back to assessment by state examination.

This is reflected in the number of students now getting the maximum possible points, 625, including 25 bonus points for HL Maths (Table 3). Table 4 shows the distribution of CAO points from 2019 to 2023, showing the effect of inflation on the points used for third-level entry. Note also the small increase in LC numbers from 2019 to 2023 (+3.5%).

Numbers will continue to increase as the bulge (due to increased birth rate and immigration) enters senior cycle this year. Over 70,000 students took the Junior Cycle exams this summer.

**Table 3: Number of students with maximum CAO points (600-625)**

| | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| **Number (%)** | 781 (1.4%) | 1,812 (3.1%) | 3,330 (5.7%) | 3,205 (5.5%) | 2,800 (4.8%) |

**Table 4: Change in numbers in differ CAO bands 2019-2023 (% in brackets)**
**(Source:** Central Applications Office (cao.ie)**)**

| Year/ Points | 625 | 600-624 | 500-599 | 400-499 | 300-399 | 200-299 | 100-199 | <100 | Total |
|---|---|---|---|---|---|---|---|---|---|
| **2019** | 207 (0.4) | 574 (1.0) | 6,684 (11.9) | 13,489 (24.1) | 14,266 (25.4) | 10,732 (19.1) | 6,557 (11.7) | 3,562 (6.4) | 56,011 |
| **2020** | 577 (1.0) | 1,235 (2.1) | 9,512 (16.5) | 15,932 (27.7) | 14,229 (24.7) | 9,068 (15.8) | 4,764 (8.3) | 2,252 (3.9) | 57,569 |
| **2021** | 1,342 (2.3) | 1,988 (3.4) | 12,133 (20.9) | 16,189 (27.9) | 12,865 (22.2) | 7,544 (13.0) | 3,623 (6.3) | 2,268 (3.9) | 57,952 |
| **2022** | 1,122 (1.9) | 2,083 (3.6) | 11,353 (19.6) | 15,367 (26.5) | 13,667 (23.5) | 8,466 (14.6) | 4,083 (7.0) | 1,915 (3.3) | 58,056 |
| **2023** | 952 (1.6) | 1,848 (3.2) | 11,378 (19.6) | 15,852 (27.3) | 13,902 (24.0) | 8,233 (14.2) | 4,022 (6.9) | 1,819 (3.1) | 58,006 |

## Comments:

The size of the LC cohort has changed very little over the past 5 years (+1,995, 3.6%). The number of students with the maximum 625 points (inc. the Maths bonus) has jumped from 207 (0.4%) in 2019 to 952 (1.6%) in 2023, peaking at 1,342 (2.3%) in 2021. In addition, the % of students with more than 300 points (halfway up the CAO scale) has gone from 62.8% in 2019 to 75.7% in 2023. For reference in 2010 it was 56.1%. This represents a massive inflation of grades without any real change in the student population. In fact, as more students stay on at school and take the LC exams you would expect the grades to shift downwards not up. The same argument applies to third-level, where a larger and academically more diverse population should result in a lower % getting 1st and 2.1 degrees, not more, as is the case. Grade inflation at third-level has been highlighted in both Ireland and the UK.

This reminds one of the Dodo in Alice in Wonderland who said after the race, "*Everybody has won and all must have prizes.*" In fact, if everybody wins and gets a prize, then nobody wins, as winning is meaningless. We must remember, of course, that the Dodo is now extinct. If we reject the idea of meritocracy, rewards based on merit, what we will end up is mediocrity, a lowering of achievement.


Figure 2 below clearly shows the sudden increase in higher grades in HL science subjects from 2020 onwards, compared to the previous 10 years.

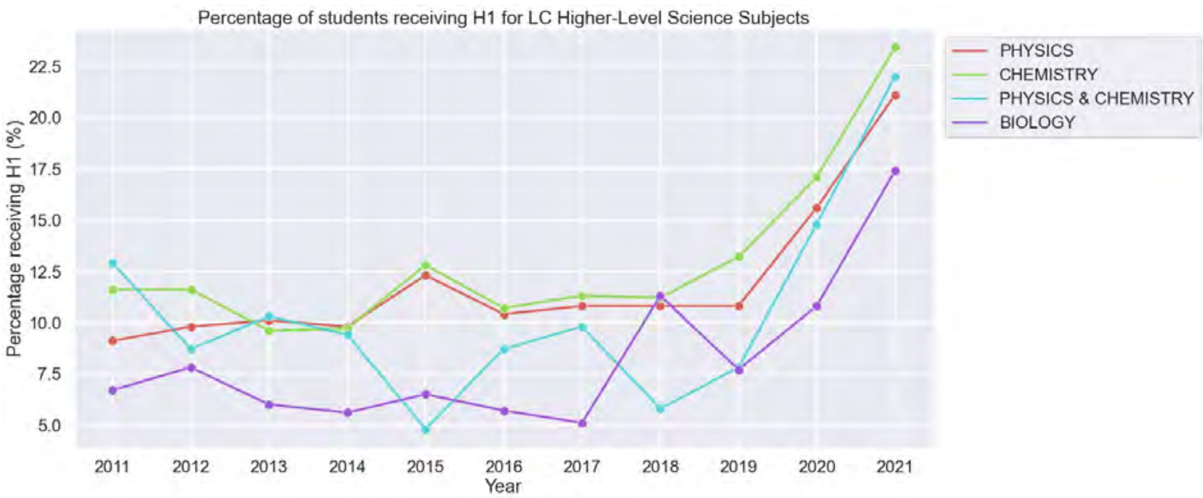



**Figure 2: Percentage getting H1s in science subjects 2011-2021.**
**Source: Grade Inflation in Leaving Certificate 2020 & 2021 | Athena**

## The dangers of grade inflation

We now have had another year of LC grade inflation, following on from 2020, 2021 and 2022, when grades made allowance for the disruption to students due to Covid. This was the year when things should have started to go back to normal, as they have done in the UK, especially in England. However, in Ireland the Minister of Education and, Norma Foley, made a decision, and gave a pledge, that the 2023 LC grades would be comparable to the 2022 grades, **in the interest of fairness.** This year's LC cohort missed out on their Junior Certificate exams and so this year was their first public examination. Everyone took the exams as normal, although papers were still modified to some extent, but the raw 'achieved' marks were scaled up on average by 7.9%, resulting in 71% of grades being adjusted up, to bring them into line with the 2022 grades. It is only fair in the sense that it is similar to the previous abnormal and inflated grades, so that 2023 students wouldn't be disadvantaged in CAO points compared to students bringing forward results from 2020-2022.

This means that the LC grading system has now been distorted for 4 years, due initially to the decision to base the 2020 grades on teachers' assessments of their own students, as due to Covid no school exams could be held. Not surprisingly teachers gave their students higher grades than they would have received for taking the exams. The real error was to allow these inflated grades to go ahead without adjusting them down, to allow for teacher bias. You can see this effect on the number of students getting 600 or more points (Table 3). Many more students thus applied to the CAO with maximum points, making it difficult for third-level institutions to distinguish between similar candidates for popular, high demand courses. Even getting 625 points, the maximum possible, couldn't guarantee that you would get your first choice and last year (2022) over 50 courses had to resort to a lottery for their places. It is hard to see how this was fair to students.

It also meant that weaker students were getting into courses that they wouldn't have qualified for before, because now they have the requisite points. Reports are back of greater dropout rates of students who are 'qualified' but who are under-prepared for third-level courses. This is not, of course, the only factor affecting dropout rates: the disturbed educational experience at school before and during their third-level courses will have had their effect; also students were facing unprecedented economic pressure especially for accommodation and the increased cost of living.

The inflated grades also disadvantaged students who applied with grades achieved in 2019 or before, when normal assessment criteria applied. It also affects students coming from other jurisdictions with A-levels or other qualifications. This will be a particular problem this year as A-level grades have started to return to pre-pandemic levels, while LC grades have remained inflated. When (if?) LC grades start to return to normal, these later cohorts with 'normal' grades will be disadvantaged against students applying from the inflated years. Inflation, whether economic or academic, does not seem to do anyone any good and it is harder to deflate grades than to inflate them.

Another serious effect of grade inflation in Ireland is to reduce the credibility of the LC exams outside Ireland and for employers in Ireland. Many Irish students go abroad to study or for further study, and inflated grades will not help them to gain places if their grades are suspect. The cartoon below makes this point. Grade inflation is like devaluing your currency nobody wants to but it anymore.


**"Big deal, an A in maths. That would be a D in any other country"**

The first mistake was to allow highly inflated teacher-assessed grades to go through unchallenged. They should have been scaled back at this stage to a more reasonable distribution. The second mistake was to compound this error by continuing to maintain high grades, even to the extent in 2023 of reinflating the grades even though based on exam results. The process of returned to pre-Covid levels should have started this year, as has been done with A-levels, with a progressive return to normal grading, over say three years. The longer it is put off the more resistance there will be/ The continuation of inflated grades distorts the LCs value for third-level entry and employers and undermines its credibility, at home and abroad. A-level students are now at disadvantage applying to Irish third-level institutions when their grades are converted to CAO points.

Irish LC grades will become less valuable abroad – this is what inflation does to a currency. When everyone gets As, As become worthless. It will take political courage to seize the nettle and reduced grades to pre-pandemic levels. This is essential to preserve the credibility and academic value of the LC for third-level entry and employers.

In the *Irish Times* for 30/8/23 Professor Pól Ó Dochartaigh (deputy president and registrar, university of Galway) had an interesting article on grade inflation in which he identified four groups of students who will be affected by grade inflation. These were high achievers who face random selection for top courses; weaker students who are given false expectations of their ability; those in Ireland taking exams other than the LC – the International Baccalaureate or A-levels; students applying from outside Ireland whose results in different exam systems are effectively devalued.

He closes the article by saying: *"... if other countries catch on to our continued grade inflation, they may devalue our Leaving Cert, which will have knock on consequences for Irish students wishing to study abroad in future years. It is time to put this right."* Leaving Cert 2022 Results – Inflation, deflation or in-line! « Oralytics

# What's going on with the junior cycle exams?

Breda O'Brien had an interesting article in the *Irish Times* for the 21/10/23 titled: 'What is going on with grade deflation in the Junior Cycle?' (What is going on with bizarre grade deflation in the junior cycle? – The Irish Times) It made me go and look at the grades for Science in the junior cycle under the new system and before when it was the Junior Certificate. In the table below you can see the comparison of the grading system for the Junior Certificate (<20) and the Junior Cycle. Since 2022 all subjects have been graded on the new system using grade descriptors rather than letter grades. Science was assessed on the new system from 2019 so 2018 was the last of the old system.

**Table 1: Old and new JC grading systems**

| | Junior Certificate | | Junior Cycle | |
|---|---|---|---|---|
| Level | Percentage | Grade Descriptor | Percentage | Grade Descriptor |
| Higher, Ordinary, Foundation/ Ard, Gnath, Bonn | ≥ 85 to 100 | A | ≥ 90 to 100 | Distinction |
| | ≥ 70 and < 85 | B | ≥ 75 and < 90 | Higher Merit |
| | ≥ 55 and < 70 | C | ≥ 55 and < 75 | Merit |
| | ≥ 40 and < 55 | D | ≥ 40 and < 55 | Achieved |
| | ≥ 25 and < 40 | E | ≥ 20 and < 40 | Partially Achieved |
| | ≥ 10 and < 25 | F | ≥ 0 and < 20 | Not Graded (NG) |
| | ≥ 0 and < 10 | NG | | |

The first thing to note is that the two grading systems are almost the same. To get an A in the Junior Cert. you needed 85% or more, versus 90% for a distinction in the Junior Cycle. This means it is slightly harder to get a Distinction grade descriptor (GD) than an A. A B grade ran from 70 to 85% (range of 15%) and a Higher Merit GD from 75 to 90 (a range of 15). A C grade ran from 55 to 70% (a range of 15%) and a Merit from 55 to 75% (a range of 20). A D grade ran from 40 to 55% (range of 15%) and an Achieved GD from 40 to 55% (range of 15%). Below 40% down to 25% (range of 15%) was an E and less than 40% to 20% (a range of 20%) was a Partially Achieved GD. An F was 10 to 25% (range of 15%) compared to 20% to 0 a NG, less than 10 on the old system.

So we have gone from a scale with uniform intervals (15%) in the Junior Certificate to one with various intervals in the Junior Cycle. I can be argued that 15% is a wide range of marks, so that a 55% and a 70% get the same grade, but in the new system a 555 and a 75% both get merits. This system disadvantages good students and makes it harder to get a Distinction and Higher Merit.

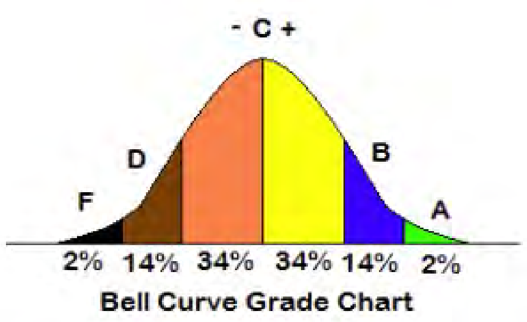
However, we are not comparing like with like. We have a new Science specification (versus the old Science syllabus), with reduced content and vague learning outcomes. There is general agreement that the content and demand of the new Science course is less than the old, making students less prepared for the LC science courses that follow on. In addition, the two levels of assessment with Higher and Ordinary papers, together with slightly different content, has been done away with in infavour of a single, common level paper. This means that all students, across the whole range of ability, are taking the same paper. There are CBAs but these do not contribute to the final grade although they will be part of the student's profile. Given these changes, one would predict, assuming no major change in the student population, that it would be easier to get the higher grades in the new system than in the old. Also, given that there has been significant grade inflation in the Leaving Certificate, as a knock-on effect of Covid and teacher assessments, one might expect grade inflation in the Junior Cycle exam. What Breda points out in her article is that the opposite has happened. The relevant data is given below in Table 2.

**Table 2: Junior Cycle grades – new and old grading system (SEC)**

| Year/New | Distinction | Higher Merit | Merit | Achieved | Partially achieved | NG |
|---|---|---|---|---|---|---|
| **2023** | 4.0 | 27.7 | 39.4 | 18.7 | 8.7 | 1.4 |
| **2022** | 3.8 | 25.4 | 41.7 | 19.3 | 8.9 | 0.9 |
| **2021** | | | | | | |
| **2020** | | | | | | |
| **2019** | 2.0 | 25.4 | 49.0 | 17.2 | 5.9 | 0.5 |
| **2018** | | | | | | |
| **Old HL** | **A** | **B** | **C** | **D** | **E** | **F/NG** |
| **2017** | 9.5 | 28.8 | 31.8 | 22.1 | 1.6 | 0.2/0 |
| **2016** | 9.7 | 30.2 | 34.7 | 22.9 | 2.2 | 0.2/0 |
| **2015** | 10.2 | 32.2 | 37.4 | 18.6 | 1.2 | 0.2/0 |
| **2014** | 11.4 | 31.1 | 36.4 | 19.5 | 1.5 | 0.2/0 |

No grades are available on the SEC website for 2021 & 2020 when exams were cancelled and for 2018.

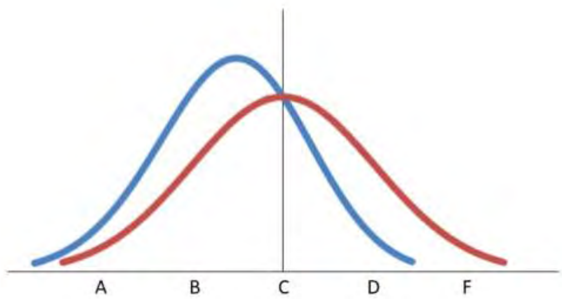
It is clear that the marking scheme for the new course is similar for each year above – 31.7-27.4% get Distinction or Higher Merit, with an average of 3.2% getting Distinction. From 2017 to 2014 at HL on the old course, between 42.4 to 32.5% got an A or B grade, and an average of 10.2% got an A. Again, the grading year to year is similar but it is clearly easier to get and A or B on the old course, although this is the HL course and would be taken by better students. Thus they are not directly comparable. At the moment it is much easier to get a HL H1, on harder papers with more content, than to get a Distinction in the Junior Cycle! This on an easier course with an easier paper! The marks are clustered around the Merit grade (with a 20% spread) and these results would discourage the good student and might put them off taking LC sciences.




It looks as though they were marked on a curve (see diagram), assuming a normal distribution. Only geniuses get As! Whether this is valid is debatable, as the normal curve assumes a random distribution. Listen to what Benjamin Bloom said:

***"The normal curve is a distribution most appropriate to chance and random activity. Education is a purposeful activity and we seek to have students learn what we would teach. Therefore, if we are effective, the distribution of grades will be anything but a normal curve. In fact, a normal curve is evidence of our failure to teach"***

***"If we are effective in our instruction, the distribution of achievement should be very different from the normal curve. In fact, we may even insist that our educational efforts have been unsuccessful to the extent that the distribution of achievement approximates the normal distribution"*** (Bloom, 1968, p. 2).




**Two different grading curves**

The red curve is a normal distribution and looks like the Junior Cycle results spread. The blue curve would bebetter. A criterion-referenced grading system would be more appropriate for Junior Cycle and would reward good and conscientious students. In a norm referenced grading system students are compared with each other; in a criterion referenced system students are marked independently as to whether they meet specified criteria. This rewards good teaching and good students.

The marking bands should return to a uniform 15% spread per band, this in itself would produce more Distinctions and be a fairer assessment. Why it was changed is hard to defend.

Breda O'Brien concludes her article:

*"Senior Cycle reform is coming and most teachers feel some trepidation. Currently we have Junior Cycle reform with some good aspects, especially in relation to student-centred learning. But other aspects are far less laudable, not least the common level papers that are not fit for purpose and the bizarre distribution of grades.*
*Let us not make the same mistakes with the Senior Cycle please."*

This article is worth reading, from which the Bloom quotes were taken.
The Story of the Normal Distribution of Grades – Teach to Impact (teach2impact.com)
Bloom, B. S. (1968). Learning for mastery. *Evaluation Comment* (UCLA-CSIEP), 1(2), 1-12.

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# The Future of STEM in Irish Education

## – a commentary on the Report of The Joint Oireachtas Committee on Education, Further and Higher Education, Research, Innovation and Science (JOCEFHERIS), July 2023.

**Áine Hyland ahyland@ucc.ie**

An important report on *The Future of Science, Technology, Engineering and Maths (STEM) in Irish Education* was published by the Joint Oireachtas Committee on Education, Further and Higher Education, Research, Innovation and Science (JOCEFHERIS) in July 2023 https://www.oireachtas.ie/en/committees/33/education/ . The report is comprehensive and detailed, containing no fewer than 305 pages (including appendices). It is written in a clear, accessible and inclusive style. Its recommendations are based on submissions and evidence from relevant, experienced and interested stakeholders from both within and outside the Irish education system.

The JOCEFHERIS is one of a number of Select Committees set up by the Oireachtas to consider matters of expenditure, administration and policy connected with government departments. All the main political parties as well as some Independents are represented on Joint Committees. They play an important role in ensuring that government departments (and associated public bodies) are accountable and seen to be accountable to the Oireachtas. According to its website, JOCEFHERIS *"shadows the Department of Education and DFHERIS. It seeks to provide a meaningful input into legislation and policy so that Irelan's education system benefits all of society and is recognized internationally as a world class system in terms of research, innovation and science".*

The Joint Committee on Education has fourteen members, nine of whom are TDs and five are Senators, representing Fianna Fáil, Fine Gael, the Green Party, Sinn Féin and the Labour Party, as well as three Independents. It is chaired by Paul Kehoe T.D., Fine Gael. The other members are Deputies Sorca Clarke, Cathal Crowe, Mairéad Farrell, Carol Nolan, Jim O'Callaghan, Marc Ó Cathasaigh, Padraig O'Sullivan, Aodhán Ó Ríordáin and Senators Aisling Dolan, Eileen Flynn, Rónán Mullen, Fiona O'Loughlin and Pauline O'Reilly .

JOCEFHERIS takes its role very seriously and has published a number of reports since it was set up at the beginning of the life of the 33rd Dáil. In addition to the report on *The Future of STEM Education*, it has published a report *on Leaving Cert Reform* (May 2022); *School Bullying and Mental Health* (August 2021); and *The Impact of Covid 19 on Primary and Secondary Education* (Jan 2021). It has also scrutinised and commented on recent educational legislation including the *Research and Innovation Bill* 2023. Members of the Committee have also visited Mountjoy and Dóchas Prison Education Centres and Education Centres in Cork and Limerick.

Its recent report on STEM in Irish education is a particularly good example of the inclusive and transparent way in which the Joint Committee on Education approaches its work. It initially invites written submissions from relevant stakeholders at all levels of education and then hosts a series of workshops and meetings, at which it interrogates the submissions and provides an opportunity for debate and discussion. These meetings are public meetings and are streamed on the Oireachtas television channel. They are subsequently accessible as podcasts. All submissions are publicly available during the deliberations of the committee and are published as appendices to the final report.

It is worth reading the report in full, as it provides an excellent flavour of the current state of thinking about STEM at all levels of education. The recommendations of the report are evidence-based and are grounded in the submissions from stakeholders and the roundtable discussions. Each chapter of the report is self-explanatory and includes quotations from stakeholders leading to coherent and logical conclusions and recommendations.

The following paragraphs provide a summary of the report and a précis of its ten key recommendations.

## Summary of the Report on the Future of STEM in Irish Education:

There was a consensus among all the stakeholders that early childhood is the ideal time to introduce STEM concepts as young children are naturally curious and inquisitive. Since introducing STEM at this age requires a structured pedagogical approach, Early Childhood Education should be the responsibility of the Minister for Education.

As regards teacher education, a mandatory module on integrated STEM Education should be provided in all Initial Teacher Education (ITE) courses, and to all Early Years Education, Primary Teachers as part of their continuous professional development (CPD).

The National Children's Science Centre, in gestation for many years, should be opened as a matter of urgent national priority. It will send out a message that Ireland is very serious about science education for Primary and Post-Primary students.

The Department of Education should publish revised specifications for Physics, Chemistry and Biology at Senior Cycle by the end of 2023. A key priority should be that the revised syllabus for each subject is far more detailed with comprehensive instructions for teachers.

Recruitment and retention of qualified teachers is a matter of critical concern. An Expert Working Group on Teacher Supply for STEM Subjects and Computer Science should be established by the Department of Education.

Evidence shows that talented and gifted students are not supported enough. The Department of Education should develop a National Programme for High Performing Students in Primary in and Post-Primary Schools to enable them to reach their full potential.

An Expert Working Group on Pathways from Further Education to Higher Education should be established to ensure that all citizens are given the opportunity to progress in their lives and fulfil their true potential. Apprenticeships are now seen as gateways to exciting and fulfilling careers.

Funding must be provided to the Technological Universities (TU)s to ensure there is sufficient physical capacity and lecturer capability to deliver on the increased numbers of Craft and New Generation Apprentices. In a spirit of genuine partnership and joined up thinking an Expert Working Group on STEM Subjects and Increased Female Participation should be established by the Department of Education.

Digital learning has become fundamentally important in all our lives. The Department of Education should publish an Implementation Plan so that the excellent Digital Strategy for Schools to 2027 becomes a reality.

The other recommendations in the report are also very important in terms of driving the STEM agenda forward and making a real difference in creating a Whole STEM Culture throughout the Irish education system.

## TEN KEY RECOMMENDATIONS

Below are the ten key recommendations of the report, listed by order in which they appear in the main body of the Report. They are of equal value.

1. Responsibility for all Early Years Education should be transferred from the Minister for Children, Equality, Disability, Integration and Youth to the Minister for Education to ensure, *inter alia*, that STEM education is an integral part of the Early Childhood Care and Education programme (ECCE).

2. A mandatory module on integrated STEM Education should be provided in all initial teacher education (ITE) courses, and to all Early Years Education, Primary Teachers as part of their continuous professional development (CPD) These models should be geared towards teaching and learning that supports inquiry, experimentation and higher-order thinking and skills in the STEM areas.

3. The National Children's Science Centre should receive the full support of Government with a view to an early launch in Q4 2023. Once opened, it is recommended:

- The Centre receives ring fenced funding on a multi annual basis from the Department of Education to ensure it is adequately resourced to fulfil its mandate.
- The Centre liaises with the Department of Education Inspectorate so that it can play a central role in supporting STEM in the Primary and Post Primary School Curriculum.
- The Department of Education issues a circular to all Primary and Post Primary Principals with a view to ensuring students visit the Centre as part of the STEM Curriculum.

4. The Department of Education should publish revised specifications for Physics, Chemistry and Biology at Senior Cycle by the end of 2023. A key priority should be that the revised syllabus for each subject is far more detailed with comprehensive instructions for teachers. The Committee recommends that the National Council for Curriculum and Assessment (NCCA) reviews the proposed design of the new specifications to ensure teachers are properly supported and students are taught to the highest professional standards.

5. An Expert Working Group on Teacher Supply for STEM Subjects and Computer Science should be established by the Department of Education in Quarter 4, 2023. The Group should be chaired by an external expert and comprise teachers, the National Council for Curriculum and Assessment (NCCA), Relevant Teacher Training Institutions, Subject Matter Experts and senior officials from the Departments of Education and Further and Higher Education, Research, Innovation and Science.

6. The Department of Education should develop a National Programme for High Performing Students in Primary and Post-Primary Schools to enable them to reach their full potential. The Department should liaise with the Centre for Talented Youth (CTYI) in Ireland at Dublin City University (DCU) in

this regard with a view to agreeing on a Service Level Agreement (SLA) that would include, *inter alia*, Training for Teachers in Programme Delivery. The Programme should be rolled out nationwide so that all relevant students have equal access to it.

7. An Expert Working Group on Pathways from Further Education to Higher Education should be established by the Minister for Further and Higher Education, Research, Innovation and Science. The Group should be chaired by an external expert and be comprised of senior Department and Higher Education Authority (HEA) Officials, the Irish Universities Association (IUA), the Union of Students in Ireland (USI), the Technological Higher Education Association (THEA), SOLAS, Industry Representatives and Staff Unions. The Group should identify current opportunities and barriers to progression from Further to Higher Education and establish how to develop links between both sectors that allow for more seamless progression.

8. The Higher Education Authority (HEA) should provide ring fenced funding to the Technological Universities (TU)s, as necessary, to ensure there is sufficient physical capacity and lecturer capability to deliver on the increased numbers of Craft and New Generation Apprentices. To this end:
• The Department of Further and Higher Education, Research, Innovation and Science Emergency should provide Short Term Funding to bridge the gap.
• From 2023, the Department should provide multi annual funding through a new Apprenticeship Fund.
• The Higher Education Authority (HEA) should commence a review of the Craft and New Generation Apprenticeship Building Requirements by Q3, 2022, with the aim of delivering the buildings required to ensure apprentices are educated to the highest international standards within a 3-year period.

9. The Department of Further and Higher Education, Research, Innovation and Science Education should establish a consolidated system for the compilation of disaggregate data collation and measurement on the researchers to include gender, disability, ethnic minority and economic status. The data should also record the nature of individual research being undertaken and the proposed outcomes. This data should be used to inform the development of educational policy on an ongoing basis.

10. The Department of Education should publish an Action Plan to implement the Digital Strategy for Schools to 2027 by Q4 2023.

## Conclusion

It is heartening and encouraging to read a report which presents and summarises so clearly the challenges facing STEM in the Irish education system in the coming years, and also comes up with practical and implementable solutions. Its recommendations are realistic and achievable. The report gives a voice to students, teachers and other stakeholders who highlighted issues relating to STEM in the education system that need to be addressed.

For example, recommendation four, which states that *"revised specifications for Physics, Chemistry and Biology at Senior Cycle should be far more detailed than is proposed, with comprehensive instructions for teachers"* has been widely welcomed by science teachers and students. The Committee's recommendation that *"the National Council for Curriculum and Assessment (NCCA) review the proposed design of the new specifications to ensure teachers are properly supported and students are taught to the highest professional standards"* could not be clearer. A similar recommendation was made in the committee's May 2022 *Report on Senior Cycle Reform,* which stated that *"a key priority for the Department of Education must be that the revised syllabus for each subject is far more detailed with comprehensive instructions for teachers"*. Unfortunately, that recommendation has not been implemented in the revised senior cycle subject specifications which have been released to date. Given the all-party support for this recommendation, it is important that the NCCA heeds and implements it.

Finally, the author of this article is particularly pleased that the Joint Oireachtas Committee recommended that the setting up of the proposed National Children's Science Centre be prioritised by government. The Centre, which is being driven by a voluntary board of individuals committed to science education, will be a joint venture between the board and government. The Office of Public Works has prepared impressive plans for the centre in the currently unoccupied North Wing of the National Concert Hall building on Earlsfort Terrace. Planning permission has been granted by Dublin City Council and a decision on an appeal is expected shortly from An Bord Pleanála. The proposed Science Centre will have three floors of immersive, interactive exhibits and a state-of-the-art planetarium. It will also house a modern science laboratory for students and teachers and will provide outreach support to schools and education centres. Given the oft-stated commitment by successive government to STEM education, it is extraordinary that Ireland remains the only country of the OECD that does not have a National Children's Science Centre. We look forward to this gap being filled in the near future – and we thank the Joint Oireachtas Committee for their support and endorsement. □

*Professor Áine Hyland is Emeritus Professor of Education at UCC. She authored the important ISTA report on the new LC science subjects (The Hyland Report).* ISTA-Hyland-Report-low-res-update-1.pdf

**N.B. A full list of the Report's Recommendations is given below.**

# The future of science, technology, engineering and maths (STEM) in Irish education - Dáil Report


In July 2023 the Dáil Joint Committee on Education, Further and Higher Education, Research, Innovation and Science released its important report on STEM education. The main recommendations are given below and you can read the full report at 2023-07-13_report-on-the-future-of-science-technology-education-and-maths-stem-in-irish-education_en.pdf (oireachtas.ie).

## RECOMMENDATIONS: PRIMARY EDUCATION

1. Responsibility for all Early Years Education should be transferred from the Minister for Children, Equality, Disability, Integration and Youth to the Minister for Education to ensure, inter alia, that STEM education is an integral part of the Early Childhood Care and Education programme (ECCE).

2. ECCE Initial Teacher Education (ITE) must contain STEM modules to enable STEM Education to begin in early childhood, as supported by the Early Childhood Curriculum Framework, AISTEAR.

3. The Primary School curriculum must include:
• A stipulated weekly time allocation for science as this has been under pressure in recent years.
• A stipulated time per term for work involving integrated STEM projects across other subjects and across all primary grades.
• Both practising and student teachers must be provided with exemplar support materials to build confidence and facilitate teaching Science in addition to a programme of initial and in-service teacher education focused on supporting integrated STEM.

4. A Mandatory Module on Integrated STEM Education should be provided in all Initial Teacher Education (ITE) courses, and to all Early Years Education, Primary Teachers as part of their Continuous Professional Development (CPD) These models should be geared towards teaching and learning that supports inquiry, experimentation and higher-order thinking and skills in the STEM areas.

5. Additional targeted teacher allocation should be given to schools so that small schools can provide STEM subjects with small classes and thereby equitably maintain student choice and equality of opportunity. This additional teacher allocation could be provided by way of curricular concession. Curricular concession should also be provided where schools wish to provide new subjects such as Computer Science.

6. The Department of Education should restore middle management positions removed from schools and undertake an assessment of School Leadership posts at Primary level. This would afford them the opportunity to delegate STEM-related preparation for teaching and learning to an in-school management team member.

7. All new school builds and school upgrade programmes should include a STEM resource room(s) that can be used for project work (and could double up for use in other subjects) to support inquiry and experimentation.

8. Outdoor learning provides children with an opportunity to experience the value of exploring the natural world and their environment. Sufficient investment must be provided to develop outdoor spaces in schools, particularly those currently without access to such spaces, to facilitate the interdisciplinary nature of STEM.

9. The National Children's Science Centre should receive the full support of Government with a view to an early launch in Q4 2023. Once opened, it is recommended:
• The Centre receives Ring Fenced Funding on a Multi Annual Basis from the Department of Education to ensure it is adequately resourced to fulfil its mandate.
• The Centre liaises with the Department of Education Inspectorate so that it can play a central role in supporting STEM in the Primary and Post Primary School Curriculum.
• The Department of Education issues a Circular to all Primary and Post Primary Principals with a view to ensuring students visit the Centre as part of the STEM Curriculum.

## RECOMMENDATIONS: POST-PRIMARY EDUCATION

10. Junior Cycle Short Courses should be expanded to include more integrated STEM options.

11. Foundation level Irish at Junior Certificate in Mathematics should be retained to ensure that weaker students engage with the subject in a positive way.

12. The Department of Education should publish revised specifications for Physics, Chemistry and Biology at Senior Cycle by the end of 2023. A key priority should be that the revised syllabus for each subject is far more detailed with comprehensive instructions for

teachers. The Committee recommends that the National Council for Curriculum and Assessment (NCCA) reviews the proposed design of the new specifications to ensure teachers are properly supported and students are taught to the highest professional standards.

13. Modularisation should be introduced for STEM subjects, to comprise:
• Written assignments prepared in class under the class teacher's supervision, marked by the State Examinations Commission (SEC), with a broad range of options to give student's the maximum freedom to select topics as a way of encouraging self-directed learning.
• An oral presentation using power point slides on the selected topic, recorded and assessed by the class teacher with external validation checks by the State Examinations Commission (SEC).
It is recommended for all subjects, that 2 Modules are completed over Senior Cycle, one in 5th and 6th Year. A written examination would then take place in each subject at the end of 6th year. The Marking Scheme should be determined by the Department of Education in liaison with the National Council for Curriculum and Assessment (NCCA) and the State Examinations Commission (SEC).

14. All Senior Cycle students should have the option of combining traditional Leaving Certificate (LC) and Leaving Certificate Applied (LCA) STEM Subjects. To this end, the Department of Education, in liaison with the National Council for Curriculum and Assessment (NCCA), should review the LCA Model, to identify how the evidentially successful parts of it regarding STEM could be incorporated into the traditional Senior Cycle.

15. Supporting integrated STEM work in Junior Cycle will require teachers with understandings across Physics, Chemistry and Biology. Teaching Council Registration requirements should stipulate that teaching credits are required in all three subjects to teach Science at Junior Cycle.

16. An Expert Working Group on Teacher Supply for STEM Subjects and Computer Science should be established by the Department of Education in Quarter 4, 2023. The Group should be chaired by an external expert and comprise teachers, the National Council for Curriculum and Assessment (NCCA), Relevant Teacher Training Institutions, Subject Matter Experts and senior officials from the Departments of Education and Further and Higher Education, Research, Innovation and Science.

17. In the interim, the Department of Further and Higher Education, Research, Innovation and Science should seek Expressions of Interest (EOI) from Higher Education Institutions regarding the provision of Post Graduate Accreditation to teach Computer Science at Senior Cycle to Honours level.

18. The Ministers for Education and Further and Higher Education, Research, Innovation and Science, should jointly review the Teaching Council Regulation that precludes Technological Universities from 'taking the lead' in Teacher Training Provision and amend the legislation, if necessary.

19.The Department of Education should develop a National Programme for High Performing Students (identified from the results of the Drumcondra Standardised Tests in English and Mathematics from Second Class and onward) in Primary and Post Primary Schools to enable them to reach their full potential. The Department should engage with the Centre for Talented Youth (CTYI) in Ireland at Dublin City University (DCU) in this regard with a view to agreeing on a Service Level Agreement (SLA) that would include, inter alia, Training for Teachers in Programme Delivery. The Programme should be rolled out nationwide so that all relevant students have equal access to it.

20.The State Examinations Commission (SEC) should review the Junior Cycle and Senior Cycle Mathematics Papers so that students with low or poor literacy levels are not placed at a significant disadvantage.

21 .Integrated STEM options in Transition Year (TY) should be available in all Post Primary Education Settings to help promote a STEM Culture.

22.An Integrated STEM project should be incorporated into the Transition Year curriculum and awarded credits towards the terminal Leaving Certificate Examination Result in the relevant subject.

23.The Department of Education should establish an Online Streaming Initiative within DEIS Schools as a pilot initiative, so that students have the choice to study all STEM subjects at Higher Level. The selected schools should have a geographic spread. Pending evaluation, the Initiative should then be rolled out nationwide as a Model of Best Practice. To this end, comprehensive training should be provided to participating teachers as well as Compensatory Allowances.

24.The Senior Cycle Curriculum should prepare students for Apprenticeships, Further Education and entering the Workplace.

25.The Ministers for Education and Further and Higher Education, Research, Innovation and Science should develop a joint Apprenticeship Communications Campaign that can be rolled out to all Secondary Schools.

26.Whole School Inspections (WSE) should be used to track schools progress in promoting Science, Technology, Engineering and maths (STEM) and offer support to nonparticipating schools.

27.A Mandatory Module on supporting integrated STEM Education should be provided to all Guidance Counsellors as part of their Continuous Professional Development (CPD). It should include, inter alia, awareness of STEM roles, career opportunities and role models.

## RECOMMENDATIONS: TERTIARY EDUCATION

28.Department of Further and Higher Education, Research, Innovation and Science (DFHERIS) should establish the Civil Service Research Network (CSRN) by Q4 2024.

29.The issues of Staffing Levels and Precarious Employment in both the traditional and Technological Universities need to be reviewed urgently or by end of 2022 at the latest, by the Minister for Further and Higher Education, Research, Innovation and Science, in liaison with the Universities. Staffing Levels have not increased in line with extra students, courses and increased services provided by Third Level Institutes and, so, there needs to be an analysis / workforce plan of staffing requirements to restore staff levels. In addition, the Employment Control Framework is completely arbitrary and needs to be abolished. The aim must be to ensure there are sufficient staff at all grades to deal with the projected increase of students, extra courses and increased services. Regarding Precarious Employment, the Review should include an examination of Hourly Paid Academic Contracts, Researchers, Postgraduate Workers and outsourcing of Support staff roles.

30.An Expert Working Group on Pathways from Further Education to Higher Education should be established by the Minister for Further and Higher Education, Research, Innovation and Science. The Group should be chaired by an External Expert and be comprised of Senior Department and Higher Education Authority (HEA) Officials, the Irish Universities Association (IUA), the Union of Students in Ireland (USI), the Technological Higher Education Association (THEA), SOLAS, Industry Representatives and Staff Unions. The Group should identify current opportunities and barriers to progression from Further to Higher Education and establish how to develop links between both sectors that allow for more seamless progression.

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Group should identify current opportunities and barriers to progression from Further to Higher Education and establish how to develop links between both sectors that allow for more seamless progression.

34.The Higher Education Authority (HEA) should provide ring fenced funding to the Technological Universities (TU)s, as necessary, to ensure there is sufficient physical capacity and lecturer capability to deliver on the increased numbers of Craft and New Generation Apprentices. To this end:
• The Department of Further and Higher Education, Research, Innovation and Science (DFHERIS) should provide Short Term Funding to bridge the gap.
• From 2024, the Department should provide Multi Annual Funding through a new Apprenticeship Fund.
• The Higher Education Authority (HEA) should commence a Review of the Craft and New Generation Apprenticeship Building Requirements by Q3, 2022, with the aim of delivering the buildings required to ensure Apprentices are educated to the highest international standards within a 3-year period.

35.The cost of apprenticeships and lack of financial support provided to apprentices needs to be addressed, as follows:
• Providing financial support to eligible apprentices through the SUSI Grants Scheme for periods of Block Release and for the purchase of expensive tools and equipment, where necessary.
• New generation apprentices should receive the same financial payment from SOLAS as the craft apprentices.
• Additional financial supports should be given to employers to facilitate hiring apprentices with disabilities, those from minority backgrounds and female apprentices.

## RECOMMENDATIONS: FEMALE PARTICIPATION, DIVERSITY AND INCLUSION

36.An Expert Working Group on STEM Subjects to Increase Female Participation, Diversity and Inclusion should be established by the Department of Education to review current policy and teaching of these subjects from Primary School up to Senior Cycle. The Group should be
chaired by an external expert and comprise teachers, the National Council for Curriculum and Assessment (NCCA), Subject Matter Experts, industry representatives, disability representatives and senior officials from the Department of Education.

37.The Department of Further and Higher Education, Research, Innovation and Science Education should establish a Consolidated System for the compilation of disaggregate Data Collation and Measurement on the researchers to include gender, disability, ethnic minority and economic status. The data should also record the nature of individual research being undertaken and the proposed outcomes. This data should be used to inform the development of educational policy on an ongoing basis.

38.The Departments of Education and Further and Higher Education, Research, Innovation and Science, in liaison with the relevant Higher Education Institutions (HEI)s, should recruit Disabled, Ethnic Minority and Economically Disadvantaged Students on Initial Teacher Education (BED) and Master of Education (MED) courses that qualify them to teach STEM subjects at Post Primary level. Students would receive bursary’s and be prioritised for student accommodation.

**RECOMMENDATIONS: DIGITAL STRATEGY IN EDUCATION TO SUPPORT STEM**

39. The Department of Education should publish an Action Plan to implement the Digital Strategy for Schools to 2027 by Q4 2023.

40. The Department of Education should develop A National Online Learning Programme, to be rolled out to all primary and secondary schools, as a matter of urgent priority, to include:
• One centralised Learning Platform.
• Appropriate support and training for all principals and teachers and parents who are home schooling.
• Remote device purchase that ensures disadvantaged students have access to devices for online learning.
• Adequate broadband for online learning.
• Provisions for Blended Learning, and
• Transition Measures for Schools as the Plan is rolled out.

41. Senior Cycle students should be allowed complete their Senior Cycle examinations and assignments on a computer or other appropriate digital device from 2024 onwards.

42. Digital literacy classes should be introduced from Junior Cycle onwards from September 2024 to ensure all students are digitally literate.
Teachers should be provided with training in this area as part of their Continuous Professional Development (CPD) with financial allowances for teaching Digital Skills.

The Report also contains the full texts of all the written submissions made to the Committee. There were also several oral sessions and the minutes of these can be accessed on the Dail website.

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# Primary STEM Report


Microsoft Word - 2023-06-22 Final STEM Report NCCA.docx

The ***STEM Education: Curriculum & Literature Overview & Primary Science Education: Systematic Literature Review Report,*** commissioned by the National Council for Curriculum and Assessment (NCCA) was published in July 2023. Dr Cliona Murphy and Prof Hamsa Venkat lead a team of CASTeL academics, Dr Margaret Leahy, Dr Nicola Broderick. Dr Orla Kelly, Prof., Deirdre Butler, Dr Lorraine Harbison, Dr Yvonne Naughton and Caoimhe Lawlor, in conducting a curriculum review and literature-based overview of Primary STEM integration and a systematic literature review of Learning in Primary Science Education. The Primary STEM integration overview is rooted in the reports, draft curricula, and the literature bases relating to the focal topic drawn on in these documents, with the overview of digital technologies also drawing from a comparative analysis of a sample of international curricula. The Primary Science Education literature review is based on a systematic review of relevant, internationally peer-reviewed research articles from the last decade, guided by a comparative analysis of the structure and science content seen across the same sample of international curricula. The Full Report Can be found at the link above.

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## OIDE launched

A new support service for teachers and school leaders has been launched, named OIDE (which means teacher in Irish), amalgamating the previous bodies – CSL, NLPT, JCT, PDST. Its aim is to support the professional learning of school leaders and teachers. It is in the process of being set up but the existing resources for junior science and LC sciences will be migrated over to the new website. It was launched on 1/9/23 but it is still being set up.
www.oide.ie

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## Dundalk IT to host national centre for teaching STEM

May 8, 2023

The Engineering Technology Teachers Association's first official headquarters will be located in the town.
A Memorandum of Understanding signed in Dundalk this afternoon will see the town become the national centre for teaching Science, Technology, Engineering and Mathematics (STEM) for post-primary and further education.
The first official headquarters of the Engineering Technology Teachers Association (ETTA) will be located at the LMETB's Advanced Manufacturing Training Centre of Excellence in the town.
The CEO of the Louth/Meath Education Training Board Martin O'Brien says the new centre will contribute hugely to creating the next generation of top-class Irish engineers.
ETTA.ie

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## Vanadium oxidation states

Vanadium is a transition metal and can exist in several oxidation states in solution, each with a characteristic colour. The demonstration where vanadium cycles between the four states is colourful and dramatic. Each oxidation state has a different colour in solution.


**VanadiumColors.png (300×226) (wikimedia.org)**


**Vanadium oxidation states**

| State | Ion | Colour in solution |
|---|---|---|
| +5 | $VO_2^+$ | Yellow |
| +4 | $VO^{2+}$ | Blue |
| +3 | $V^{3+}$ | Green |
| +2 | $V^{2+}$ | Violet |

N.B. Going from +5 (yellow) to +4 (blue) the solution goes through green due to the mixture of colours. The process can be reversed by adding dilute $KMnO_4$ solution.

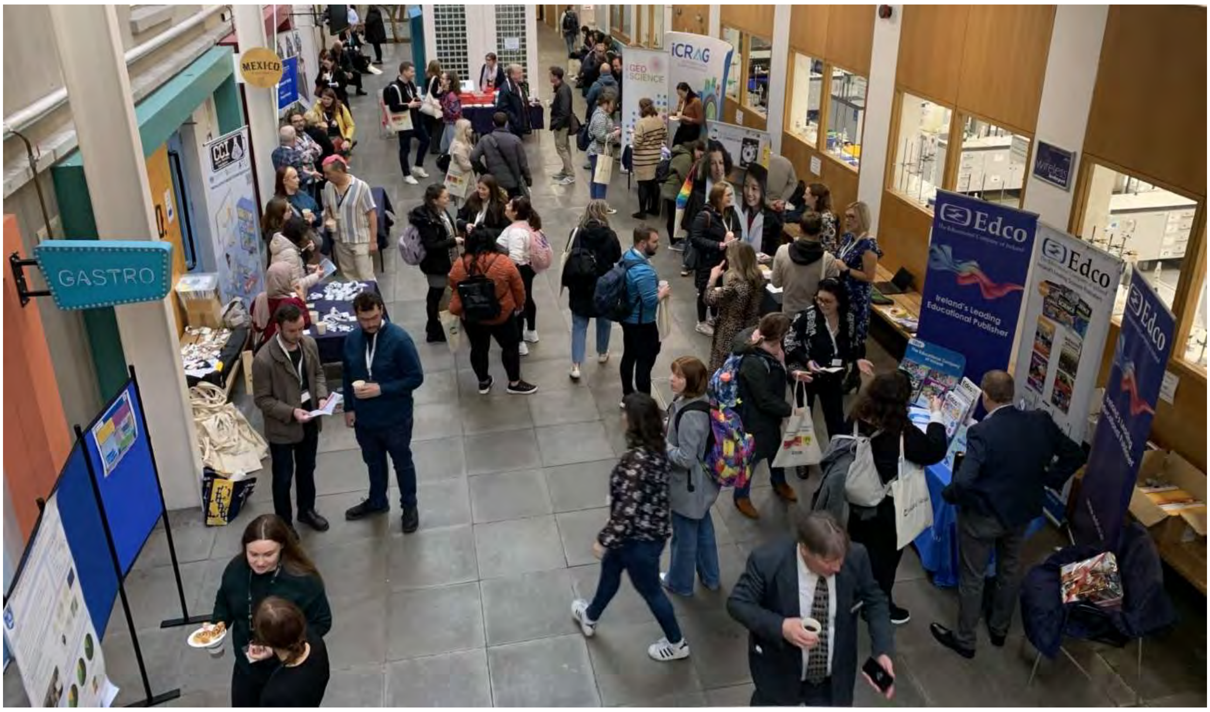
**YouTube video showing the oxidation states of vanadium:**
**https://youtu.be/ymNLgH0mLQ8**

**You can get the instructions for this demonstration at** The oxidation states of vanadium | Experiment | RSC Education

## CONFERENCE REPORT

**42nd ChemEd-Ireland**
***'The future is green'***
**21st October 2023**
**Trinity College, Dublin**

This group photo captures part of the audience at this year's ChemEd-Ireland, held in the Hamilton Building, Trinity College, Dublin on Saturday 21st October 2023. Over a 100 people were registered and there was a full programme of talks and workshops from 10 to 4 on the theme 'The future is green'. There was a lively buzz over coffee and pastries in the atrium, where the various stands were located. The main green emphasis was on battery technology to provide energy storage and transportation in the future. It is hoped to have the talks as articles in the Proceedings in the Spring issue of *Chemistry in Action!* (#124).




The two plenary speakers were both ex-TCD: Michelle Browne (now in Berlin) spoke about the hydrogen economy and chemistry's contribution, and Serena Cussen (Sheffield) spoke about the hunt for new batteries. Both of them described their own career progression as women who broke through the glass ceiling.

There was a choice of two, 30-minute, workshops, held before and after lunch. They were all housed in the large Cocker Laboratory, just off the atrium in the Hamilton Building. The four workshops on offer were: ‘Activities in Junior Cycle’ (Michael Kavanagh), ‘Big impact in little chemistry’ (Johanne Brolly, RSC), ‘Green is safe’ (Sean Kelleher and team, OIDE), ‘Current Chemistry Investigators’ (Natalia Domenech, TCD).

Other speakers included Claire Murray talking about outreach and Citizen Science, Humphry Jones talking about designing their super new labs at St. Columba’s College, Natalia Domenech talking about the Current Chemistry Investigators (CCI) outreach programme (TCD and ATU Sligo), and last but not least, a very informative and funny talk from Gerry Hyde, the new senior examiner for LC Chemistry (replacing Fiona Desmond). A droll sense of humour seems to be a requirement for this job. There was also a briefing on the Chemistry Olympiad by Brian Murray, on OIDE (the new support service for teachers) by Sean Kelleher, and a talk about using demonstrations and how to survive them by Chris Lloyd of SSERC (but worryingly without wearing safety glasses). The finale to this talk was very impressive: an alcohol-powered rocket which zoomed across the lecture theatre.

The venue was excellent, and everything was within a short distance (coffee, stands, lectures and workshops), with a short walk to get an excellent hot lunch. Congratulations to John O’Donoghue and his team for putting on an interesting and useful conference, and to the Chemistry Department at TCD for hosting it. Hosting ChemEd-Ireland is great PR for the university and chemistry department. Even the weather stayed fine. Next year’s ChemEd-Ireland conference will be in UCC, hosted by Declan Kennedy, on the 19th October. **Book the date now!**

The photos in this report were supplied by John O’Donoghue.

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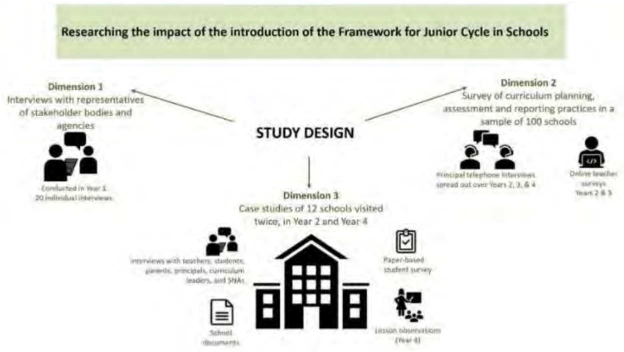
# The introduction of the Framework for Junior Cycle (10/5/23)

[Junior Cycle National Project | University of Limerick (ul.ie)]


The first report was published in October 2022 and can be accessed at the link above. This new report is the second of a series of reports from a 4-year longitudinal study exploring the implementation, enactment and impact of the Framework for Junior Cycle in post-primary schools in Ireland. The study employs a mixed-methods, multi-dimensional research design that aims to capture the views of teachers, principals, students, parents and wider educational stakeholders. This second interim report draws primarily on the research data collected from the twelve case study schools in the Spring of 2022. This data is complemented by the data set from the first phase of the teacher surveys.

McGarr, Oliver; Mc Cormack, Orla; O'Reilly, John; Lynch, Raymond; Power, Jason; Hennessy, Jennifer; et al. (2023). *Exploring the introduction of the Framework for Junior Cycle: A longitudinal study. Interim report No. 2. University of Limerick. Report.* Limerick: University of Limerick https://doi.org/10.34961/researchrepository-ul.22656892.v1




**Part 1 summary: Teacher perspectives pp. 83-86**

The majority of teachers believed there was a need for curricular change at Junior Cycle. Four main purposes associated with the Framework for Junior Cycle were identified. This included making schools and classrooms more inclusive; an increased focus on skills development; a decreased emphasis on summative examinations; and adopting more student-centred pedagogical approaches.
When asked to comment on the Framework for Junior Cycle teachers tended to talk about issues of direct relevance and concern for them rather than commenting on the broad breadth of changes set out in the Framework for Junior Cycle. Areas discussed frequently included the CBAs, SLARS, the Assessment Task, common level specifications, Learning Outcomes and Wellbeing.
Teachers believed CBAs supported student engagement, enjoyment, motivation and skills development. Teachers perceived the percentages allocated from CBAs to students overall grade in state examinations to be too low. They also raised concerns about the number of CBAs students had to complete in a short period of time and the time taken for their completion. Difficulties associated with CBAs were viewed to contribute to both student stress and difficulties in management of the work. On balance, the teacher data suggests that CBAs were perceived as being somewhat distinct from normal classroom teaching.
Teachers raised concerns about the clarity and shared understanding of the descriptors associated with the CBA evaluation and the capacity of students to produce work that

would meet the (perceived) high expectations associated with the higher-level descriptors, with potential negative effects on student motivation and wellbeing. The Assessment Task was, on balance, not considered a valid measurement of student effort and learning.

Teachers valued Subject Learning and Assessment Review (SLAR) meetings where they shared examples of work and engaged in professional discussions to support judgement. On balance, these SLAR meetings were seen to promote consistency and fairness in judgement. Concerns remained however about the national standardisation of teacher assessment between schools.

Assessment of the common level specifications emerged as a concern as the common level exam papers were perceived as too challenging for some students and too easy for others. Teachers noted that some students lacked the literacy level required to engage fully with exam questions, particularly related to comprehension questions and the limited space to provide answers. The exam was perceived to offer limited choice to students and concerns were raised about the capacity of a single two-hour exam to offer sufficient scope for students to demonstrate their learning.

The majority of teachers perceived Learning Outcomes (LOs) to be clearly communicated, achievable and a good representation of the knowledge, skills and values within each subject. Views were more mixed in relation to the broadness of LOs. While some teachers appreciated the freedom and choice LOs afforded, others expressed concern about the depth to which they needed to be explored. Tentative data also indicates that there is significant variation in this regard across subjects.

The grading bands associated with the terminal exam were perceived to be too broad with respect to the 'merit' band. Some concerns were raised about the difficulty in securing a 'distinction'.

The introduction of Wellbeing was welcomed as formally enabling conversations and planning although this was seen to have reduced class periods in other subjects, which was a concern for some. The majority of teachers indicated that they were applying the Wellbeing indicators in teaching and noted that the Wellbeing guidelines were being used in a whole-school approach. These teachers perceived that Wellbeing was contributing to student development.

Some schools designed their own Short Courses (SCs) based on teacher interest/expertise, student interests and local contexts. On the whole, these teachers found the experience of designing SCs enjoyable.

The inclusion of Level 1 and 2 Learning Programmes was welcomed, in particular in relation to the range of ways student learning can be demonstrated through Priority Learning Units (PLUs). Some concerns were expressed about teachers' understanding of the Level 2 Learning Programmes, progression routes, the lack of suitable textbooks and support for developing suitable forms of assessment.

Widespread engagement with Professional Development (PD) support was evident from teacher survey responses, especially with the Junior Cycle for Teachers (JCT). Opportunities to share and discuss practice were welcomed, with some concerns expressed about the composition of school clusters. Resources and practical examples, including online resources, were considered very supportive, although they were noted as lacking at the start of the change. Subject Associations were also highlighted as supportive, especially in making sense of LOs and being subject-focused. Concerns were raised about the clarity of focus of some aspects of PD and views were mixed in relation to the extent to which the PD responded to teachers' questions and concerns, particularly in the early stages of the change. Some gaps were highlighted in particular in relation to PD for all teachers on Level 1 and 2 Learning Programmes.

School leadership was identified as a key dimension for enactment and school management were perceived to be supportive of the Framework, discussing it at staff meetings and supporting teacher use of professional time. Collaborative relationships between teachers were highlighted as a significant support. Investment in digital technologies has been a useful enabler for the Framework.

Teachers reported three main barriers to change: time, resources and the scale of the changes. Teachers' capacity to find time to engage fully with the changes, to plan, to develop resources was a core concern.

Teachers in some schools felt that a lack of resources and supportive digital technology within the school impacted on their capacity to enact the changes. The amount of change introduced, the language of the changes and understanding of what the changes were about were a barrier for some. Despite barriers, the majority of teachers reported satisfaction with their work in Junior Cycle, believed they were making a significant educational difference in the lives of their students.

Across the schools, teachers identified ways in which the changes impacted on their practice with two main themes evident. Firstly, teachers felt that they now implement more student-centred and student-led pedagogical approaches and a wider range of assessments methods. Secondly, teachers felt that they had more freedom to be creative and introduce new, engaging, and fun activities or topics within their classroom. Some teachers felt that the changes had minimum impact on their practice. These teachers felt that they were either already engaging in such practices, they lacked the time to implement such changes into their practice or the continued presence of the state examination impacted on their capacity in this regard.

Teachers identified three main (related) ways in which students learning was impacted by the changes. Firstly, teachers felt that students had greater voice, responsibility, and ownership of their learning. Secondly, students were deemed to learn and interact more with their peers. Finally, classrooms were considered to be more fun and engaging for students.

Most teachers felt that the changes increased their level of collaboration with other teachers, creating more positive and supportive relationships with their colleagues. A number of teachers also spoke about the increased workload they had experienced as a result of the changes.

Teachers in the majority of schools felt that a gap existed between the Junior and Senior Cycle. These teachers felt that the workload, expectations of students and the amount of writing in the Leaving Certificate examination, in comparison to the Junior Cycle, was the cause of this gap. However, differing views existed on this issue and may reflect differences at a subject level. For example, some teachers believed that such a gap has always existed between Junior and Senior Cycle while others questioned whether the impact of Covid was the reason for the perceived gap. Others felt that the focus on Key Skills in the Framework for Junior Cycle supported students at Senior Cycle.

According to the teachers, the Covid pandemic and related school closures impacted on teachers and students in five main ways. Firstly, teachers explained how group work, as well as trips and engagement with the local community were suspended during this period. Some felt that online teaching and learning was not suitable for their students, with students finding it difficult to connect and stay engaged in an online forum. Teachers felt that the pandemic and school closures reduced and hindered their own engagement and understanding of the Framework for Junior Cycle. Some teachers also feared that students had extensive gaps in their knowledge as a result of school closures and that students lacked motivation to study and learn as a result of the State examinations being cancelled.

**Summary of Part 2: Student Perspectives pp 136-137**

Several themes emerged from the analysis of the student survey and focus group discussion data. In terms of teaching and learning, students favoured engaged, collaborative, creative, and active learning experiences which offered a balance between individual and group work. They valued choice in their learning, and they appreciated when stimulus variation was introduced to support their engagement. They disliked didactic approaches, and most were averse to the practice of notetaking and methods of learning that were passive and teacher-centred.

A significant number believed that their learning needs and interests were met during their Junior Cycle, particularly during its early years. A substantial majority also believed they were supported in their transition to post-primary school.

Assessment and performance were to the forefront of the vast majority of students' minds as they navigated everyday life at school. While many students deemed exams/tests to be a suitable form of assessment, large summative exams were a source of stress for many students and most viewed them as not adequately assessing their

'full potential'. Students called for more choice and less pressure in exams, and they deemed grading bands to be too broad.
Students had a preference overall for continuous assessment and, in this vein, they were aware of the positive aspects enabled by the CBAs. They enjoyed inquiry-based learning, the development of research and presentation skills, and groupwork/teamwork which they believed CBAs helped to support. However, the students believed that CBAs did not deliver many of the benefits that continuous assessment promises. Students saw CBAs as largely disconnected from summative exams and this induced a sense of futility and frustration for them, because students were predominantly concerned with their grades in exams. Students appeared to see CBA work as 'extra' and thus putting pressure on the perceived core priority of study and exams. Moreover, the perceived lack of credit attached to CBAs in the overall scheme of their Junior Cycle caused frustration for these students. Homework was perceived as a source of negativity too. Some did not see 'the point' of homework, particularly at stressful times when they had a lot of CBAs at once and/or were studying for exams.
Students across the schools reported experiencing significant stress with regard to their everyday workloads and struggled to balance homework, CBAs and study for tests and exams. This appeared to have a negative impact, in some cases, on the rapport and relationships between teacher and student, with many students resenting the 'pressure' they experienced in this regard.
The stress experienced in managing everyday workloads, combined with the pervasiveness of academic pressure, induced most of the participating students to adopt mechanisms and strategies for coping. For most, this involved on-going surveillance and evaluations about whether specific content and learning activities were 'relevant' in order to be successful in exams. Some students were acutely aware of 'playing the game' as they attempted to learn off answers and make strategic decisions about what to memorise.
The adoption of a strategic and disciplined academic focus was also very strong across the majority of case study schools. Students believed that in order to be successful at Junior Cycle they must: engage in early and sustained academic engagement, engage in diligent notetaking, build a repository of notes for study, ensure adequate preparation for any forthcoming tests and place a strategic focus on homework.

**Part 3 summary: Parents' perspectives pp 144-145**

Parents value a broad educational experience that develops important life skills for the children and that values students' social development, their sense of belonging and enjoyment of school.
Parents' experiences of their child's transition to post-primary school varied with some reporting positive experiences and supports from the school while others were critical of the supports provided. Restrictions caused by the Covid pandemic impacted on students' transition to post-primary schools in many instances.
Parents were very supportive of the introduction of the CBAs and cited many benefits for their children, however they expressed disappointment that the students' work was, from their perspective, not afforded sufficient importance in the context of the overall assessment at Junior Cycle.
It appears that some parents lack clarity on the assessment at Junior Cycle assuming that continuous assessment is employed, and that CBA work is more heavily weighted in the context of the overall assessment at Junior Cycle.
Parents' views on the nature and extent of reporting from schools were mixed. Some praised the reporting practices employed by the school whereas others were critical of the reporting and expressed a need for more timely reports that, not only reported on academic progress, but also reported on their child's social development and how they were 'fitting in' to school.
According to almost all parents, the Covid pandemic had a significant impact on their child's education. It was believed that this impacted on their transition to post-primary school, their levels of motivation, their social development, mental health and impeded their learning.

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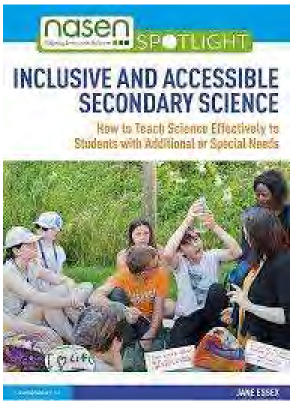
# Book Review

## Inclusive and Accessible Secondary Science

***How to Teach Science effectively to students with Additional or Special Needs***

**Anne O' Dwyer & Miriam Hamilton**
Mary Immaculate College, Limerick
Anne.Odwyer@mic.ul.ie and Miriam.Hamilton@mic.ul.ie




This book is a fantastic resource and a timely publication with a global trend leading towards inclusive education, for those with disabilities and learning difficulties. Although the limited funding and research in science education for those with learning disabilities is acknowledged, the author, Jane Essex, shares professional learning and empirical evidence to illustrate through practical examples how science can be taught to all learners. Too often science is seen as an 'elite' subject with high status, and only accessible for high-achieving learners. However, paradoxically, the fact that science is seen as 'hard', means that success in the subject is highly rewarding for learners and enhances the self-esteem of those with learning disabilities. As many second-level science teachers are subject specialists, they may lack competence in pedagogical approaches most appropriate for the various learning difficulties.

The opening section of the book outlines the many benefits for the learner in learning science. These include scientific concepts and processes, as well as a better understanding of the wider world. While pupils' enjoyment of science and hands-on work is acknowledged, the author recognises that an important source of enjoyment is the intrinsic satisfaction of learning and the consequent success that goes with it. The book will be a useful resource for teachers as its practical nature does not simply illustrate science as an opportunity for 'messy play' and 'hands-on learning', but is meaningful in how it provides opportunities for exploration and experimentation - linking to key concepts and topics in the second-level science curriculum. The opening section of the book outlines how learning science benefits those with learning difficulties as it supports their personal development, transferrable skills, cultural participation and empowerment. This section also recognises the opportunities for teachers' professional growth and learning.

The second section of the book recognises the challenges teachers face with curriculum content, which they feel 'they need to cover', and the possible pitfalls to be aware of, in order to better support learners. Although many second-level learners may be operating at the concrete stage of cognitive development, many curricula concepts require abstract understanding. The author discusses Piaget's levels of cognitive development and the CASE (Cognitive Acceleration through Science Education) project, recognising that many mainstream learners, as well as those with learning disabilities, struggle with abstract concepts if they are not appropriately introduced and developed. She also illustrates a hierarchy of science learning processes using Bloom's Taxonomy of learning. Furthermore, this section details ways in which those with learning difficulties may differ from their peers in executive functions such as attention span, short term recall and reduced processing capacity. Evidence has shown that direct instruction and explicit instruction are effective in reducing cognitive load for learners. Those with learning difficulties can also encounter difficulties with functional skills, literacy and communication. This section provides useful insight into how to assess the readability of science resources. As well as exploring psycho-social factors that can affect lessons, and difficulties with experimental and investigative science skills, Section Two concludes with a useful summary of how a Universal Design for Learning (UDL) can improve educational equity in science education.

In the third section of the book, the author discusses the problems with how second-level science is currently assessed, and why it is contributing to low attainment for those with learning difficulties. She emphasises that relevance in assessment is as important as relevance in learning. As discussed in Section Two of the book - if memory capacity and recall are a challenge, knowledge-orientated examinations create an obstacle. Cumulatively, these factors prevent those with learning difficulties from demonstrating their learning effectively. However, the author outlines how assessment can be enhanced when appropriate strategies are used to better reflect learning. Reading questions aloud and allowing extra time are discussed as measures that may help when external examinations are a requirement. Facilitating pupil self-assessment and the use of criterion-based assessment help to develop learners' self-esteem in examinations. Although 'pencil and paper' style tests are a staple in most second level science classrooms, it should not be assumed that pupils who do not do well in these tests did not learn. The author specifies that not all learning can be assessed in the same way; detailing examples of how to meaningfully assess learners' skills, affective development and acquisition of factual knowledge and consequently respond to and provide learners with feedback.

Section Four expertly provides lesson ideas through an inclusive lens, where the author deals with topics such as the nature of matter, giving practical classroom advice on how teachers might manage the particular challenges for learners with learning difficulties. The author exemplifies how teachers might explore matter by transitioning from the more tangible states of matter, solids and liquids to the more abstract state of gases. The suggestions, advice, lesson exemplars and ideas in this chapter are all carefully underpinned by theoretical perspectives. However, the theory is presented in an accessible and connected way. This section is useful as it structures teaching a topic through introductory activities, moving to consolidation of concepts, and extending to applications of the conceptual knowledge the learners have assimilated, in order to connect to everyday experiences of the learner. The author shares some interesting pedagogies such as the 'circus of mini experiments' approach to answer a suite of questions related to a particular scenario. The use of storytelling as a hook for children to understand many material-based and other science concepts is notable as the author argues in favour of the narrative being a wholly accessible form of communication in science. The level of detail provided for the teacher across the extensive suite of lesson ideas shared is commendable, as is the frequent reference to classroom management approaches to manage the more challenging lesson topics. The use of links to external resources and effective use of figures in this section further support the quality of pedagogical content provided for the reader. The author is not afraid to highlight the riskier approaches to teaching, for example in the Earth and Space lessons. Finally, where there are opportunities for linkage between concepts, as in the section on Light and Sound, the author is adept at extracting opportunities for the teacher to link and integrate concepts and activities to support holistic learning.

Section Five is effective in reminding the reader of the versatility of the book. Whether read in full or 'dipped into', the value for practitioners is clearly articulated. The author revisits the key aims of the book to provide opportunities for diverse learners to access science topics in an engaging, inclusive and enjoyable way. The focus of this conclusion serves to empower teachers to make informed choices about how to approach the teaching of science, without being prescriptive. It is genuinely refreshing in an era where the focus on transdisciplinary teaching has emerged as a dominant curricular shift that, as the author articulates how this book reinforces: "*the characteristic of science as discipline, rather than a 'watered down' version of it"*(p.123). It certainly succeeds in terms of the author's intention, to open new conversations about science pedagogy.

The final section, Section Six, laments the lack of specific and appropriate science resources for learners with challenges, additional or specific learning needs. This is based on the assumptions that science as a discipline can be focused on '*typically achieving pupils'*. Nonetheless, the author provides insights into organisations who are indicating a more active interest in the needs of diverse learning in science classrooms. The author has categorised a plethora of organisations and professional bodies based on their provision of resources for: general science, practical science, biology and field work, material science, and physics. This is an extremely useful resource for teachers planning inclusive science schemes and lessons. Alongside these science specific categorisations, the author advises that teachers first begin seeking support for learners with SEN, specific learning difficulties and/or sensory impairment by accessing local provision, such as the psychological service or the hearing impairment inclusion support service. This section offers a comprehensive guide for practitioners needing guidance on where and how to access appropriate educational supports.

## Biography

*Dr. Anne O' Dwyer & Dr. Miriam Hamilton are Science Education lecturers in the Dept. of STEM Education in Mary Immaculate College, Limerick. Both are qualified second-level science teachers. Miriam has had over 20 years experience teaching second-level Science.*

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**N.B. The previous issue of *Chemistry in Action!*, #122, Summer 2023, contains a number of articles from the DISSI project, dealing with diversity, equity and inclusion.**

## Report on the Faraday Lecture of 1877 by A.W. Hoffman, extolling his own teacher, Justus von Liebig.

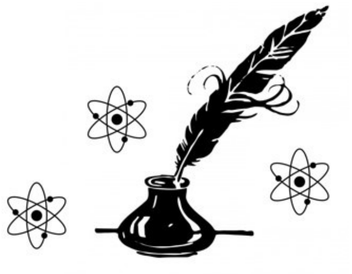
***Chemical News* 5/1/1877 vol. 35 p.9**

*"It is often asked how ought science to be taught and what manner of men should be the teachers? In this country, at the present day – and more, we fear, than in times bye-gone – the whole duty of the teacher is summer up in 'preparing' pupils for examinations. Students 'read' instead of working for degrees and honours. Universities are regarded not as places for original research, but for cram. Now to us it seems that the question, How is chemistry to be taught? – and for every science the essential principle is the same – may best be answered by another, 'How did Liebig teach?' For in addition to all his other merits he was the great type of the science teacher. The answer is ably and most truthfully given by Dr. Hofmann:- 'We felt then, we feel still, and never while we live, shall we forget Liebig's marvellous influence over us; and if anything could be more astonishing than the amount of work he did with his own hands it was probably the mountain of chemical toil he got us to go through. I am sure that he loved us in return. Each word of his carried instruction, every intonation of his voice spoke regard; his approval was a mark of honour, and of whatever else he might be proud, our greatest pride of all was in having him for our master. It was our delight, too, to know that we helped him that whilst we received his lessons we were also performing his work. The aid he thus obtained he was too just ever to deny or underrate; nay, his generosity often attributed to a pupil the whole credit of a successful experiment suggested by himself on the basis of previous trials and discoveries of his own, and of his deductions therefrom. Of our young winnings in the noble ground of philosophical honour, more than half were free gifts to us from Liebig; and to his generous nature no triumphs of his own brought more sincere delight than that which he took in seeing his pupils' success, and in assisting while he watched their upward struggle.'*

*We should recommend every science-teacher to ask himself seriously, how nearly he is approaching, or endeavouring to approach, to this ideal? Is he training up investigators and filling their minds with an ardent love of truth for its own sake? If not – if he is either unwilling or unable to tread, thought a great distance, in the footsteps of Liebig – let him doubt whether he is 'the right man in the right place.' Some teachers may perhaps plead that the are the victims of a bad system – that their pupils are expected not so much to 'know' as to 'pass' – and that their reputation and efficiency are measured by such passing. If so, let them join in with those who waging war against this miserable system. The only examination for a man of science is to prove,* ***rebus gestis****, that he can work."*

*****

# Quirky Elemental Facts in Rhyme



## Neodymium, Nd

*enn-dees* *two* *four* *three*

**Nd's the tarnish'd lanthanoid with states II, IV, and III,**

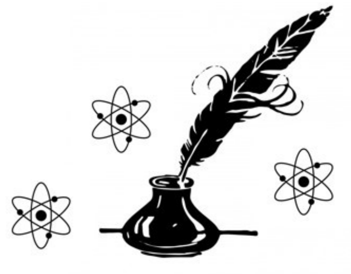
*enn-eye-bee*

**For über magnets, small yet strong—you'll ne'er beat NIB!**

Neodymium is element number 60, and is fourth in the lanthanoid series. It is a silvery-white rare-earth metal, which readily tarnishes in air. It is one of the few lanthanoids with three oxidation states available to it, namely II, III, or IV ($Nd^{2+}$, $Nd^{3+}$, or $Nd^{4+}$). Most other lanthanoids make do with just one or two of these states.

Neodymium's alloy with iron and boron (also known as NIB) is one of the most powerful permanent magnets commercially available. The impressive strength of even the smallest of these magnets has helped advance the miniaturization of electronic devices, such as mobile phones, earphones, and loudspeakers. NIB magnets are also ubiquitous in modern cars: the are used in starter motors, door locks, window lifters, fuel pumps, and windshield wipers. In fact, motor vehicle production consumes most of the neodymium produced each year!

# Quirky Elemental Facts in Rhyme



## Samarium, Sm

*ess-emms*

**Lecoq explored Samarsky's ore, Sm's fine lines to see,**

*pree-nib* *see-oh-five*

**Pre-NIB its $Co_5$ held sway, thus headphones came to be.**

Samarium is element number 62, and is sixth in the lanthanoid series. It was discovered in 1879 when French chemist Paul-Émile Lecoq de Boisbaudran (1838–1912) observed some previously unassigned spectral lines in the atomic spectrum produced by a sample he had skillfully extracted from the mineral samarskite. Lecoq de Boisbaudran named the new element after samarskite. Samarskite had been named after Colonel Vasili Samarsky-Bykhovets (1803–1870), the chief of staff of the Russian Corps of Mining Engineers between 1845 and 1861. Colonel Samarsky achieved the rare and highly desirable distinction of having an element named in his honour, albeit indirectly.

Samarium's alloys with cobalt (for example, $SmCo_5$) produce magnets that are 10,000 times stronger than magnets made from iron. Samarium-cobalt magnets were instrumental in the miniaturization of headphones (before the later development of the even stronger NIB magnets). This innovation ushered in the age of the personal stereo in the early 1980s.

# Famous Irish Chemists #1

## Professor Dervilla M. X. Donnelly

Professor Dervilla M. X. Donnelly is one of the most respected and influential chemists of UCD School of Chemistry. She began her teaching career in UCD in 1956 in the old School of Chemistry which was based in Merrion Street, Dublin 2 and later moved with the university to Belfield, Dublin 4. Throughout her truly extraordinary career to date she combined contributions in teaching and research at UCD School of Chemistry, with leadership in science policy and a range of public service contributions at national level and is also respected internationally for her research and publications.

**Portrait of Dervilla Donnelly by Emer O'Boyle, UCD Artist-in-Residence.**

A chemistry graduate of UCD, Dervilla Donnelly studied for her PhD under Professor Thomas S. Wheeler at UCD, returning to teach after postdoctoral studies at UCLA. She was appointed Professor of Phytochemistry (the study of chemicals with biological activity derived from plants, particularly wood) in 1979 and her research was of particular interest to the forestry industry in Ireland. Her research employed a combination of organic synthesis, structural studies, mycology and ecology and it provided an excellent training for students interested in pursuing careers in the pharmaceutical industry, biotechnology, or academia. She established worldwide research links and developed collaborations with international researchers. Dervilla's skills and her commitment to European research were recognised by her election as Chairman of the European Science Research Councils in 1985, Vice-President and Member of the Executive Council of the European Science Foundation 1990-1997 and Vice-President and Member of the European Science and Technology Assembly in 1994. A selection of her other international appointments through the 80s and 90s included her role as President of the Phytochemical Society of Europe 1982-84, Vice-President of the Society of Chemical Industry in the UK, and a member of Council of the Royal Society of Chemistry. In 2000 she was appointed to the Austrian Council for Science and Technology, a position she held for 10 years. In recognition of her research, she holds honorary doctorates from the University of Nottingham, The Queen's University Belfast, Trinity College Dublin, and the National University of Ireland.

She was elected to membership of the Royal Irish Academy in 1968 and served three times as vice-president of the Academy. In December 1989, she was elected the first female president of the Royal Dublin Society and in 1995, where she remains an Honorary member of its Council and Chair of the RDS-Irish Times Boyle Medal National Committee. Shortly after her retirement from UCD, she was appointed as Chair of the council of the Dublin Institute for Advanced Studies by the Minister of Education, a post she held for 15 years. She later served as Chair of the Custom House Docks Development Authority and the National Education Convention.

Professor Donnelly was also a Member of the Science and Technology Innovation Council (2001) and Vice-Chair of the Board of Governors and Guardians of the National Gallery of Ireland (2001-2002). She was the

Chairman and Director of the Commission on Assisted Human Reproduction between 2000-2005 at the request of the Minister for Health. She also served on the Board of the National Museum of Ireland and Chairman of its Audit committee and Board Member of the Chartered Accountants Regulatory Board.

**Professor Donnelly celebrates her Lifetime Achievement Award *(Photo: WITS)***

Professor Donnelly is a tremendous example to women in STEM and in many senses paved the way for many more female chemists in academia in Ireland. Her inspiration to women in the Sciences was recognised 2011 with a Lifetime Achievement Award from Women in Technology and Science (WITS) in June 2011. Dervilla has inspired generations of UCD science students, in particular for female scientists. She also inspired second level students across Ireland through her role as a judge from the very first year of the Aer Lingus Young Scientist Exhibition in 1964, a role she continued for 40 years.

In 2000 she was awarded UCD's Charter Day Medal, for her contribution to the country and the university and in the same year, received the Boyle-Higgins Gold Medal Award from the Institute of Chemistry Ireland. Professor Donnelly became the first woman to be awarded the Cunningham Medal by the Royal Irish Academy (RIA), the Academy's highest honour, in recognition of her outstanding achievements and held many influential and important roles which influenced science policy in government and contributed to the scientific and arts communities.

In April 2023 we were delighted to unveil a specially commissioned portrait of Professor Donnelly at a ceremony in UCD hosted by the School of Chemistry's EDI Committee. In recognition of her very particular connections with UCD Chemistry, the painting by UCD Artist-in-Residence, Emer O'Boyle, now hangs at the main entrance to UCD School of Chemistry in the O'Brien Centre for Science - South above the heritage chemistry bench, which came from our old laboratory (see the photograph on the bench), before a major refurbishment of Science South provided the School with world-class facilities.

Her portrait was presented to her by a former PhD student and current RIA President, Professor Patrick Guiry, who said of Professor Donnelly:

Dervilla has inspired generations of UCD science students through the clarity of her lectures to being such a superb role model, in particular for female scientists. She also inspired second level students across Ireland through her role as a judge from the very first year of the Aer Lingus Young Scientist Exhibition in 1964, a role she continued for 40 years. On a personal note, having been one of her 85 PhD students, I know I speak for all her research family when I say that we are thankful for her support, career advice and kindness. Above all she instilled in us a high standard of scientific rigour and integrity that remains with us throughout our careers.[1]

**Professor Patrick Guiry presents Professor Dervilla Donnelly with her portrait.**

Impossible though it sounds, Professor Donnelly manages to find time to enjoy some free time, particularly in her favourite sport, horse-racing. Dervilla has a golden rule: *"that one day a week I don't do any chemistry, and every Saturday you'll find me at a racecourse somewhere in the State"*. Dervilla and her sister have a share in several horses and say, *"we only need one more leg to have a complete animal!"*[1]

Professor Donnelly's work has shaped the development of UCD School of Chemistry and her model of excellence is continued with the award of the Professor Dervilla Donnelly Medal to the highest achieving student of our BSc in Medicinal Chemistry & Chemical Biology.

Head of School, Professor James Sullivan, says of Professor Donnelly “She’s renowned in the school for her science, her fostering of collaborations and her mentorship. Her research group graduated over 80 PhD students, many of whom are in senior positions in academia or industry in Ireland and abroad."

The School of Chemistry was delighted to present the portrait to Professor Donnelly in person and all guests were delighted to hear our honourable Emerita Professor speak at the event.

## References

[1] Introductory address delivered by Professor Pat Guiry on 16 June 2015, on the occasion of the conferring of the Degree of Doctor of Science, *honoris causa* on Dervilla Donnelly

[2] Introductory address delivered by Professor G.T. Wrixon, Vice-Chancellor of the University, President, University College Cork - National University of Ireland, Cork on 25th April, 2002, in St. Patrick's Hall, Dublin Castle, on the occasion of the conferring of the Degree of Doctor of Laws, honoris causa, on Dervilla Maura Xavier Donnelly.

**Reprinted by permission from Portrait of Professor Dervilla Donnelly - UCD School Of Chemistry**

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# Chemists you should know #13
## Henry Cavendish (1731-1810)
Adrian Ryder tutorajr@gmail.com

### Introduction

**Figure 1: The classic caricature of Henry Cavendish**

The Honourable Henry Cavendish was born on 10th Oct. 1731 in Nice, Kingdom of Sardinia, where his mother had gone for the sake of her health. The Cavendish family can trace its origins back to the Norman conquest, to Robert de Gueron, who assisted William the Conqueror in his 1066 invasion of Britain. The surname changed to Cavendish in the 14th Century.

Lord Charles Cavendish, (17/3/1704-28/4/1783), the fifth son of the second Duke of Devonshire, was the father of our Honourable Henry. Charles married Lady Anne de Grey (1706-1733), fourth daughter of Henry, Duke of Kent, and had two sons Henry (b. 1731) and Frederick (b.24/6/1733), by her. Anne died on Sept. 20th 1733, leaving her husband to rear the two infants at his house in Great Marlborough Street in Soho, London. This house on the corner of Great Marlborough Street and Blenheim Street (now Ramillies Street) was originally two separate houses facing directly onto Great Marlborough Street, which were converted into one being 45 feet wide and extending to a depth of 200 feet through the gardens along Blenheim Road. At the bottom of the garden were stables, part of which, following Henry's return from University, were converted for Henry's use becoming 1 Blenheim Road. This part comprised an underground kitchen, and four rooms over the stables. Part of the stables were used by Henry for his experimental work. Henry lived there while his father was alive.

Henry's early schooling was done at home, after which he became a pupil in Dr Newcome's school at Hackney in 1742, remaining there till 1749 when he entered Peterhouse, Cambridge, matriculating in the first rank there on 18th Dec 1749. He stayed here until 1753 but, like many others of the time, did not graduate. It has been suggested that his reluctance to submit to the stringent religious tests applied in his day to candidates for degrees, was the real reason for his departure from Cambridge without a degree.

Henry's brother Frederick followed him through the Hackney school and entered Cambridge in April 1751. Unfortunately, Frederick fell from an upstairs window trying to repeat Benjamin Franklin's noted experiment on the nature of lightning with a kite during an approaching storm and fell from an upper window of the College. He suffered severe head injuries, and although recovering after a long period of convalescence, was left mentally incapacitated for the rest of his life. Frederick was left a legacy by his mother, this was controlled by trustees, of whom both his father and Henry were members. Frederick lived in later life in the village Market Street, near St. Albans in Hertfordshire and died there on Feb. 23rd 1812. His disability did allow him to attend society occasions, where his amiable disposition and eccentricities were accepted, even though termed 'mad' by his acquaintances.

Lord Charles Cavendish spent his life firstly in politics and then increasingly in science, especially in the Royal Society of London, which awarded him the Copley Medal in 1757 *"on account of his very curious and useful invention of making thermometers, showing respectively the greatest degrees of heat and cold which have happened at any time during the absence of the observer.*"

In 1758 he took Henry to meetings of the Royal Society and also to dinners of the Royal Society Club. In 1760, Henry himself was elected to both these groups, where he was assiduous in his attendance. Unlike his father, Henry took virtually no part in politics but followed his example in the world of science, through his researches and his participation in scientific organisations. He was active in the Council of the Royal Society of London (to which he was elected in 1765). Henry's first published paper "containing his experiments relating to fixed air" saw him emulate his father by being awarded the Copley Medal in 1766.

Henry's father died in 1783 and his financial position, up to then controlled by his father, saw him become an unusually wealthy man. During his father's life-time Henry had received an annuity of £500, a large sum in those days, most of which was spent on books and scientific apparatus. However, an uncle, who made a fortune in the Indies supported him during the lean period and on his death left him his entire estate and a further fortune was inherited from an aunt. Henry was now a very wealthy man and moved his main residence to Clapham Common, to Cavendish House (demolished 1905), where he filled the house and grounds with scientific apparatus including extensive astronomical equipment.

**Figure 2: Rear view of Cavendish House**

In addition, books were to be found in all corners of the building. He kept a town residence at the corner of Montague-place and Gower Street where books and scientific apparatus were its main furniture (see Figure 3,)

**Figure 3: Henry Cavendish's town residence today.**
**Note windows closed to avoid the dreaded window tax of 1698.**

A further house of his was located in Dean Street, Soho, and fitted out by him as a scientific library, which was open to all involved in research. Despite being the owner, Henry scrupulously signed out any books taken by him to read, just like any other user of the library.

Henry was an exceptionally shy man who was uncomfortable in society and avoided it when he could. He would only converse with one person at a time and then only if the person was male. He studiously avoided any contact with females, even to the extent of leaving notes in the hallway for servants concerning everyday matters like dinner. He conversed little, always dressed in an old-fashioned suit, and developed no known deep personal attachments outside his family. It has been suggested that he suffered from Asperger's Syndrome, a form of Autism.

**Figure 4: Henry Cavendish**

## Scientific work with gases

In 1766 Cavendish published his findings on the preparation of 'Flammable Air' showing it was different from the other known gases. This 'flammable air' was later named hydrogène (water-former) by Antoine Lavoisier (1743-94), in English hydrogen. Henry's 'flammable air' was collected from the bubbles rising from the reaction of iron filings with dilute sulphuric acid (Figure 5).

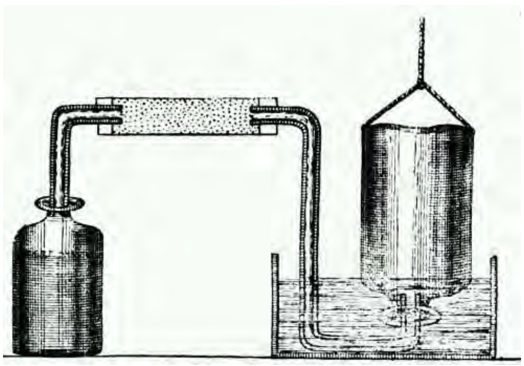

**Figure 5: Cavendish's apparatus for the collection of 'flammable air' (Hydrogen)**

Henry's experiments on the new 'flammable air' led him to be the first to show that when burnt it formed water (1781), thus refuting the ancient Greek theory of the four elements making up the composition of the world: Fire, Earth, Air and Water. In doing so Cavendish prepared the way for modern chemistry.

In 1785 Henry continued his work on gases by investigating the composition of ordinary air. He found that when he had removed the phlogisticated air (nitrogen) and dephlogisticated air (oxygen) from a sample of air, a volume of gas amounting to $^{1}/_{120}$ of the volume of the nitrogen remained. He assumed that errors in his experiments were the reason for the small discrepancy. However, in the 1890s, two other British physicists, William Ramsay and Lord Rayleigh, realized that their newly discovered inert gas, argon, was responsible for Henry's problematic residue; Cavendish had not made an error but he did miss a discovery.

## The Cavendish experiment

The other piece of experimental work for which Cavendish is chiefly known is his work on the density of the Earth (now known as the Cavendish experiment), which was published in 1798.

The experimental apparatus consisted of a torsion balance with a pair of 2-inch diameter, 1.61 lb. lead spheres suspended from the arm of a torsion balance and two much larger stationary lead balls (350 pounds). (Figure 6) Cavendish intended to measure the force of gravitational attraction between the two. The balance had been made by the geologist John Mitchell, who had died before he could begin the experiment. Henry acquired the apparatus and after modifications to eliminate temperature differences and induced air currents by the isolation of the apparatus in a closed room, he viewed the resulting findings through telescopes set through the walls. The entire apparatus was placed in a wooden box about 2 feet thick, 10 feet tall, and 10 feet wide, all in a closed shed on his estate. (Figure 7)

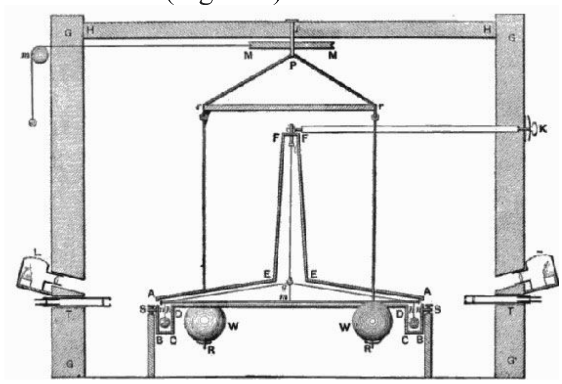

**Figure 6: Diagram of the Cavendish Experiment**

**Figure 7: Artist's drawing of the experiment being performed (with cutaway wall opening.)**

Using this apparatus Cavendish calculated the attraction between the balls from the period of oscillation of the torsion balance, and then he used this value to calculate the density of the Earth. He found that the Earth's average density is 5.48 times greater than that of water. This figure is within one percent of the currently accepted figure.

## Royal Society activities

Cavendish's interest and expertise in the use of scientific instruments led him to head a committee to review the Royal Society's meteorological instruments and to help assess the instruments of the Royal Greenwich Observatory. Other committees on which he served included the committee of papers, which chose the papers for publication in the *Philosophical Transactions of the Royal Society*, and the committees for the transit of Venus (1769), for the gravitational attraction of mountains (1774), and for the scientific instructions for Constantine Phipps's expedition (1773) in search of the North Pole and the Northwest Passage.

In 1773, Henry joined his father as an elected trustee of the British Museum, to which he devoted a good deal of time and effort. Soon after the Royal Institution of Great Britain was established, Cavendish became a manager (1800) and took an active interest, especially in the laboratory, where he observed and helped in Humphry Davy's chemical experiments. Henry was a dedicated experimenter rather than a theoretician and produced a mere eighteen scientific articles over the course of his life. Of the papers only one, a study of electricity in 1771, was theoretical. Much of his unpublished work was only found after his death in many detailed manuscripts of experimental work, covering literally all of the physical sciences of the day.

In spite of Cavendish's shyness he was recognised as one of the most accomplished scientists of the age, not only in England but also abroad, which led him to be elected as one of the eight foreign associates of the French Institute on 25/3/1803.

Henry died 24$^{th}$ Feb. 1810 (aged 78) in London and was buried in All Hallows

Church, Derby (now Derby Cathedral) in the Cavendish tomb.

**Figure 8: The Cavendish family tomb**

He was a member of the influential Cavendish family, who are still wealthy landowners in Derbyshire. Their seat is at Chatsworth House.

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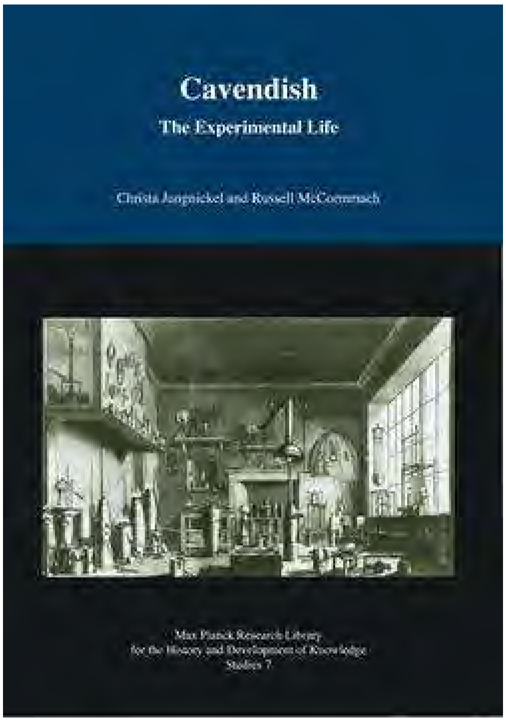



*Cavendish: The experimental life*, Christa Jungnickel, Russell McCormmach, Max Planck Institutfor the History of Sciencee 2nd. Edition 2016 MPRL | Cavendish (mpg.de) This book can be read online and is the most detailed treatment of Cavendish's life and work.

□

*"His Theory of the Universe seems to have been, that it consisted solely of a multitude of objects which could be weighed, numbered, and measured; and the vocation to which he considered himself called was, to weigh, number and measure as many of those objects as his allotted three-score years and ten would permit. This conviction biased all his doings, alike his great scientific enterprises, and the petty details of his daily life."*
**— George Wilson, Life of the Honorable Henry Cavendish**

*"Cavendish gave me once some bits of platinum for my experiments, and came to see my results on the decomposition of the alkalis, and seemed to take an interest in them; but he encouraged no intimacy with any one, and received nobody at his own house. ... He was acute, sagacious, and profound, and, I think, the most accomplished British philosopher of his time."*
**— Sir Humphry Davy**

# Amazing Minerals: #2 Quartz, $SiO_2$

One of the most familiar minerals to be seen in nature is quartz (silica), with its characteristic white crystals found in rocks. Oxygen and silicon are the two most abundant elements in the earth's crust, which is largely made of silicates (compounds of metals with silica) and quartz makes up about 10% of the earth's crust.

What do the following have in common? Glass, concrete, computer chips, solar panels, breast implants, bath sealant, non-stick cookware? They all use or are made from silica sand, which contains >95% quartz.

**Figure 1: Pieces of quartz**
**White Quartz - The Purifying Stone (beyondrocks.in)**

When pure and free of defects quartz can also form lovely transparent crystals. It is also found in common sand, with various colours and purities.

**Figure 2: Quartz crystals found in nature**
**Quartz - Simple English Wikipedia, the free encyclopedia**

Not all sand is silica. Sand is made by the wearing away of rocks over thousands or millions of years into small particles. The composition of the sand (and its colour) depends on the rock(s) it was made from. Typical beach sand is tan (sandy) in colour due to small amounts of sand. Pure white sand is often pure silica. Black sands come from black volcanic rock (basalt), but some black sands are made from ilmenite and are a source of titanium dioxide. A typical Irish sand is shown in the photo below. Sand also contains ground up shells which are calcium carbonate. Hence beach sands have been used traditionally by farmers to neutralise acid soils.

**Figure 3: Beach sand in Donegal (P.E. Childs)**

Massive amounts of sand are mined each year, mainly for construction and concrete. 1 $m^3$ of concrete (2,300 kg) needs 700 kg sand (30.4%). Each year about 30 billion t of concrete is made, which will use 4.5 billion t of cement and 10 billion t of sand. All told about 50 billion t of sand are mined each year! Around 240 million t of silica sand are mined each year.

## Crystal structure of quartz

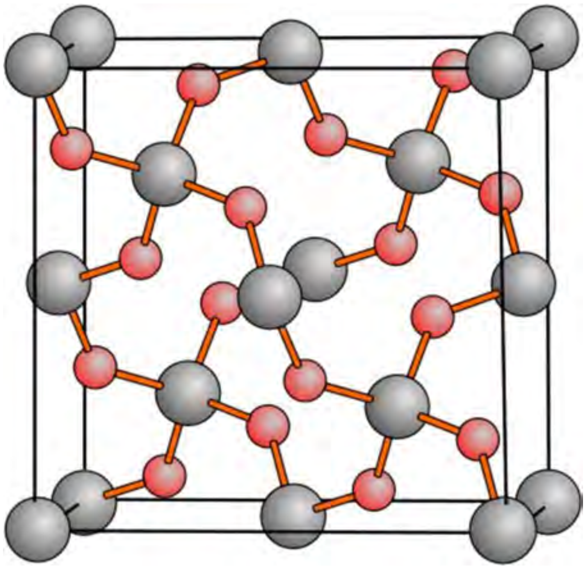


**Figure 4: Cristabolite – a high temperature form of quartz (an FCC structure)**

The chemical formula for quartz is $SiO_2$ and it is a good example of a covalent network crystal, with a simple structure based on $SiO_4$ tetrahedra. Each Si is bonded to 4 oxygen atoms forming a tetrahedron, and each oxygen is shared between two silicon atoms. The bonding is covalent and so a crystal of quartz, however large or small, is effectively a single molecule, as every atom is connected to others through covalent bonds. It is also described as a covalent network solid. The strong Si-O covalent bond and the strong structyre means that silica has a high mpt (1,725°C). Mixing silica with other oxides lowers the mpt, enabling glass to be made and worked at a lower temperature.

## Gemstones

A number of precious and semi-precious stones are different crystalline forms of quartz. Many gemstones are coloured forms of quartz. Some are listed below. The colours are due to small amounts of transition metal ions in the silica matrix. (Getting Out • The Silica family of Gems (tumblr.com))

- **Amethyst**
- **Opal**
- **Citrine**
- **Chalcedony**
- **Rose quartz**
- **Chrysoprase**
- **Agate**

## Silicones

Silicon is in group 14 (IV) and so favours 4-covalent bonding. As well as the inorganic silicates, found in many rocks, based on the $SiO_4^{4-}$ unit, silicon also forms analogues of organic compounds in the silanes (e.g. $SiH_4$) and silicones, which are polymers of silicon, oxygen and alkyl groups, typically $(-R_2Si-O-SiR_2-)_n$. They were originally thought to be like ketones and so were called silicones by Frederick Kipping in 1901, but are now called siloxanes, and polysiloxanes. Silicon and silicone are often confused in the media but they are a world apart! It's the difference between a silicon chip in a computer and a breast implant. The letter 'e' makes a big difference. Silicones are all around us in many everyday products. Silicones have widespread uses: breast implants, bath sealants, cookware, high temperature seals, insulation, high temperature oils (Figure 5.) Silicone rubber is water and heat resistant and non-stick, so it can be used in cookware.

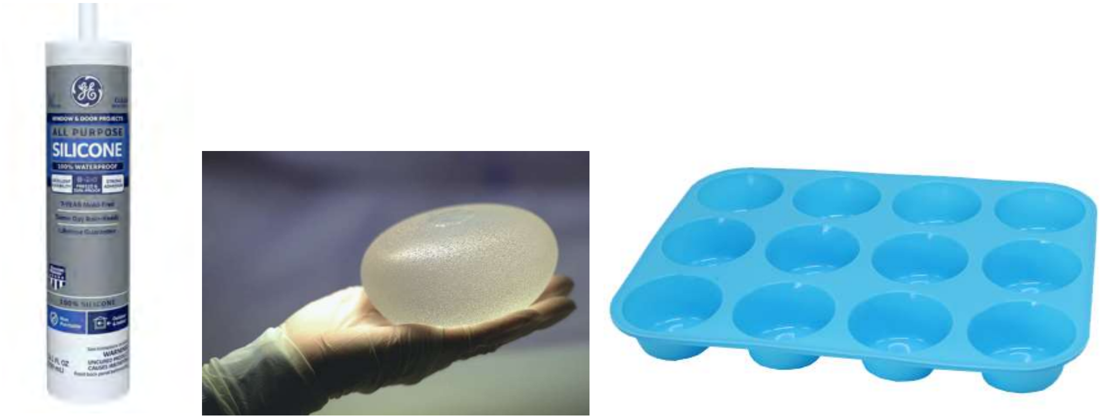



**Figure 5: Some everyday uses of silicones**

## From silica to silicon

A major use of pure silica is to produce silicon, a semi-metal, which can be turned into high-purity silicon chips for semiconductors and integrated circuits, or into solar cells. Silicon is also the raw material from which silanes (silicon analogues of alkanes) and silicones (siloxanes) are produced.

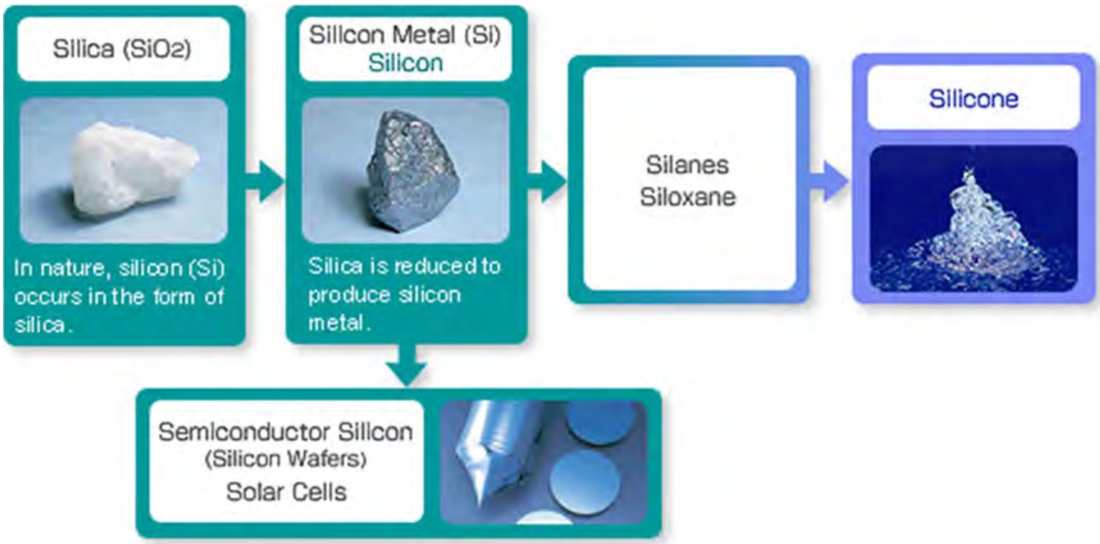



**Figure 6: From sand to silicones and silicon chips**
[Shin-Etsu Silicone : What is silicone? : What is silicone made of? (shinetsusilicone-global.com)](https://shinetsusilicone-global.com)

Silicon is produced from pure silica by carboreduction. Coke and silica are heated together in an electric arc furnace and the carbon reduces the silica to silicon and produces carbon monoxide (Figure 7.) The furnace runs at 1500-2000°C well above the mpt of silicon (1410°C) and molten silicon (99.8% pure) is run off. For a video showing the production and refining of silicon: https://youtu.be/D1ALNg3z2gk

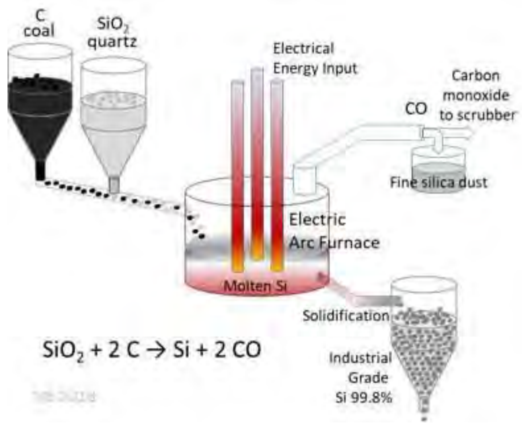


**Figure 7: The production of silicon from silica**

This is still not pure enough to make microchips and purer silicon is made by converting silicon into volatile chlorosilanes (e.g. $SiH_3Cl$) and decomposing them to form pure silicon. The silicon ingots are further purified and converted into a single crystal by zone refining. A molten region heated by RF power moves up the ingot and impurities are concentrated in the molten silicon, the silicon cooling to form a single crystal behind the molten front. The impurity zone can be cut off and then the cylindrical silicon ingot is then sliced into wafers, polished and used to produce integrated circuits. (For more on zone refining see Zone melting - Wikipedia and https://youtu.be/So4byMgO03Q )

This is done at Intel's FAB plants in Leixlip. The largest wafer made now is 12 inch (300 mm) in diameter and can contain tens of thousands of individual chips. It is not overstating the case to say that silicon, from silica, runs the modern world.

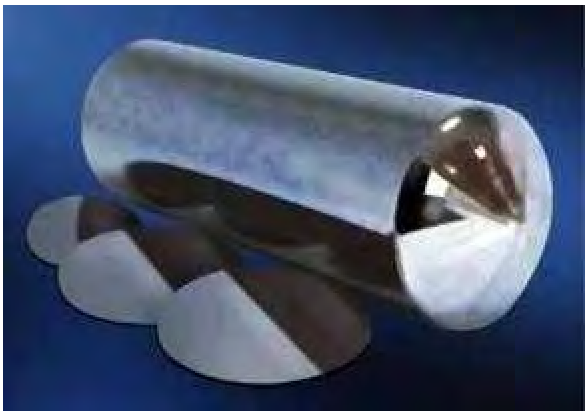


**Figure 8: Single crystal 6 inch diameter Si ingot and silicon wafers**
6 Inch Mono Crystal Silicon Ingots - China Silicon Ingot and Ingots (made-in-china.com)

Silica can also be reduced to silicon using magnesium or zinc metals. 1 t of silicon needs 12 MWh of electricity. In 2022 8,000,000 t of silicon were produced globally. The world's two largest producers are China (6,000,000 t) and Russia (640,000 t), giving them an effective monopoly on the raw material for silicon chips and solar cells.

## Polycrystals versus single crystals

EG-Si is polycrystalline and it is melted in a special furnace, and using a seed crystal. An ingot of single crystal Si is slowly drawn up out of the furnace. A polycrystal is made of many small crystals or grains, randomly 'stuck' together, atoms/ions are ordered withing the grains. A single crystal is one large crystal, where the atoms/ions have the same structure throughout. Single crystal silicon is used for making silicon wafers for integrated circuits (chips). Polycrystalline silicon is cheaper and is now used in making solar cells. An amorphous solid has no long-range order of the component atoms/ions. These different forms with the same chemical formula, are shown below (Figure 9.)

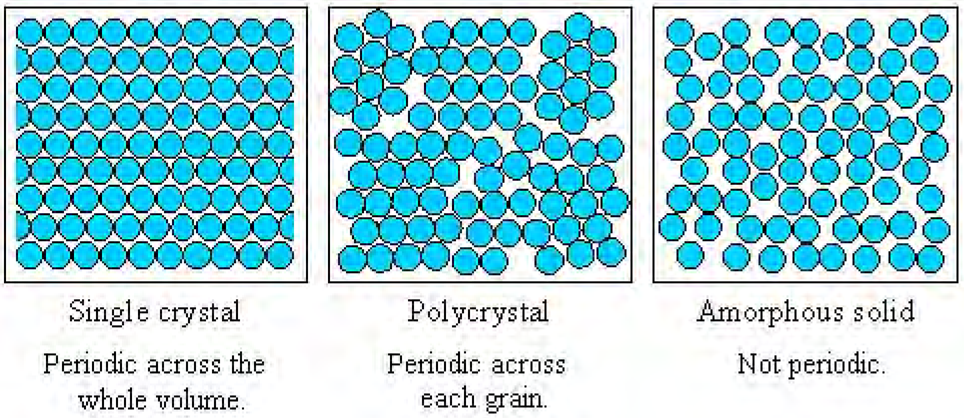



**Figure 9: Single crystal, polycrystal and amorphous crystal compared**
**[Difference between single crystal and Polycrystalline solids? | EduRev IIT JAM Question](#)**
**[Quartz - Wikipedia](#)**

## Glass – the unique material

([What is glass? | How is glass made? - Explain that Stuff](#))

We take glass for granted as its cheap and all around us – in windows, glasses and scientific glassware. It is often said that chemistry could not have developed without the use of glassware for a variety of purposes. It is transparent, heat and chemical resistant. We can use plasticware for lots of things but you can't head them in a Bunsen flame. Our images of school chemistry are often of test-tubes, flasks and beakers. Sand is a key raw material for glass.

When sand is melted and allowed to cool, instead of turning back into an opaque solid, it cools to forma transparent glass, which has the amorphous structure of a liquid (as seen in the diagram below.)

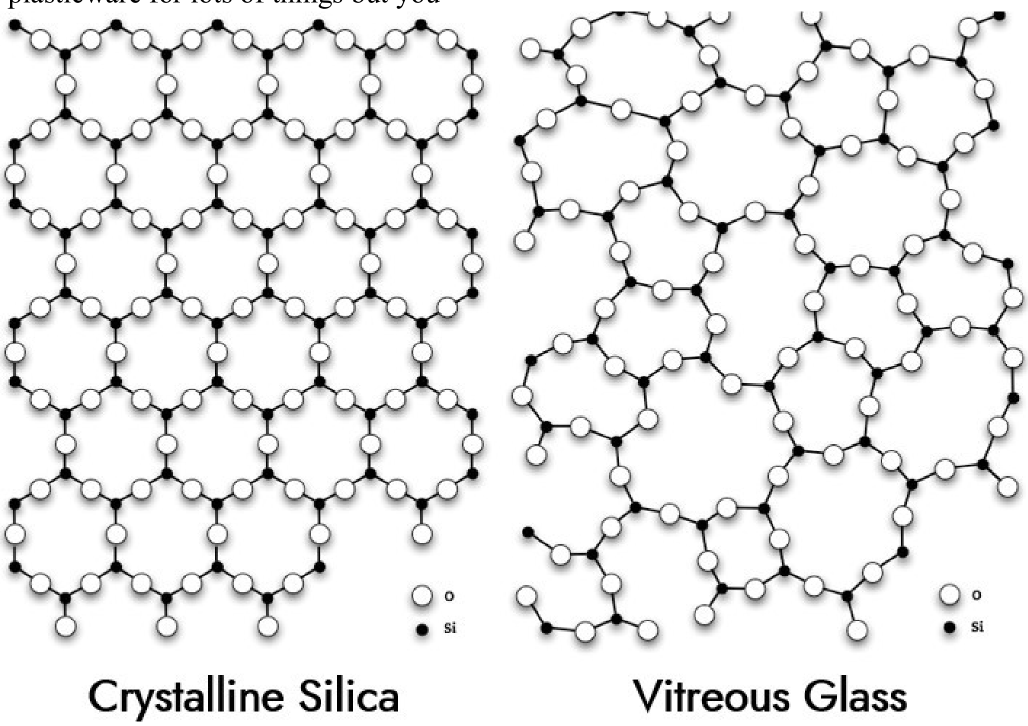



**Figure 10: Difference in structure of crystalline silica and amorphous silica glass**
[Molecular Engineering - Perfecting Glass Composition (glassflake.com)](#)

Glass has been known since antiquity and I am always fascinated in museums to see Roman glass dishes and goblets. Pure sand melts at too high a temperature for ordinary fires but if mixed with sodium carbonate and calcium carbonate, the mpt is lowered and molten glass can easily be obtained. When molten it can be poured into moulds and when still hot can be shaped or blown.

The most common and cheapest glass is made from sand, sodium carbonate and calcium carbonate and is often know as soda glass. It also often contains small amounts of magnesium oxide or aluminium oxide. Heating just sand and sodium carbonate forms the soluble water glass. Borosilicate glass, famous as Pyrex glassware, contains boric oxide ($B_2O_3$). Lead oxide (PbO) is added to make glass with a brilliant lustre (lead crystal). Typical glass compositions are shown in the table below.

**Table 1: Typical glass compositions: 1. Soda glass for bottles and windows. 2. Borosilicate glass for labware and cookware. 3. Lead crystal. 4. Silica glass. 5. Roman soda-lime-silica glass.**
All About Glass | Corning Museum of Glass (cmog.org)

| | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Silica | $SiO_2$ | 73.6% | 80.0% | 35.0% | 96.5% | 67.0% |
| Soda | $Na_2O$ | 16.0 | 4. | – | – | 18.0 |
| Lime | CaO | 5.2 | – | – | – | 8.0 |
| Potash | $K_2O$ | 0.6 | 0.4 | 7.2 | – | 1.0 |
| Magnesia | MgO | 3.6 | – | – | – | 1.0 |
| Alumina | $Al_2O_3$ | 1.0 | 2.0 | – | 0.5 | 2.5 |
| Iron Oxide | $Fe_2O_3$ | – | – | – | – | 0.5 |
| Boric Oxide | $B_2O_3$ | – | 13.0 | – | 3.0 | – |
| Lead Oxide | PbO | – | – | 58.0 | – | 0.01 |

Glass is chemically resistant although it dissolves slowly in alkalis and hydrofluoric acid can dissolve and etch glass.

Quartz (and sand) is indeed an amazing mineral which underpins our modern world – in our buildings of concrete and glass, in the myriad uses of silicones, and in the ubiquitous silicon chip in our smart phones and computers.

## Project ideas

TY is an ideal time to do some interesting project work relating to the materials covered in this article. Cement is made in Ireland, and we have seen recently, with the mica and pyrite problems, how failing to control the chemistry of the aggregate used in making concrete can have harmful effects. Glass making also has a long history in Ireland and although we don't make the silicon wafers, in Intel we have a major industry making silicon chips. There is scope here for project work on cement and concrete, on silicon chips, and on silicones: the chemistry involved, how they are made and used in Ireland, the careers in the various industries etc. The various gemstones based on silica and the origin of the colours, and the colours of stained glass, would also make an interesting project.

□

# Chemlingo: What a difference a letter makes

Peter E. Childs

## One letter alters the chemistry

Spelling matters in chemistry as readers of this Chemlingo column will know. A change of just one letter can have a profound effect on the meaning, just as a zero can affect the value of a number. Sometimes a simple spelling mistake can alter the chemical significance totally, e.g. talk of 'silicon breast implants' or 'silicone chips'. The popular confusion between silicon and silicone is a good example of the importance of a single letter in chemistry. It's the difference between sand and bath sealant in fact, between hard rock and squashy plastic.

When we discuss the different families of hydrocarbons their systematic names differ by only one letter, e.g. alkane, alkene, alkyne. Another example would alcohols and aldehydes, very different when their trivial names are used – ethyl alcohol and acetaldehyde – but easily confused when systematic names are written – ethanol and ethanal, differing by just one letter again. The small linguistic difference conceals a vast difference in chemistry, between a pleasant high and a permanent headache. In some ways the old names were easier for students to learn and remember and we underestimate the problems that the small difference of a single letter can make.  No doubt you can think of other examples.

## Two nations separated by a common language

Another area where changing a single letter in chemical names crops up is in the difference between American and UK English. This confusion is propagated by the dominance of American chemistry textbooks. One example is the controversial spelling of sulfur/sulphur. The sound of ph- and f- is the same and in some European languages 'f' does the job that 'ph' does in UK English e.g. pharmacy becomes farmacie in Romanian. The different spellings of sulphur go back a long way, but if we were consistent why not fenol, fosforus and nafthalene? One could argue that 'f' for 'ph' is a simplification, but the loss of the alternative often means the loss of an importance linguistic tradition. IUPAC has now standardised on sulfur.

Most of the differences between US and UK English involve the loss of a letter in the US spelling. This was deliberate policy by Noah Webster in 1828 in compiling his famous dictionary, to reinforce the break between the newly-independent American colonies and their former colonial master, and to remove what he thought were inconsistencies. This was a cynical act of murder of the English language by decimation. All words ending in –our became –or as in flavour/flavor, and colour/color. Words with the compound letter 'ae', from the Greek, which used to be written as a single letter were slashed to 'e'. So we have in US English cesium not caesium, hemoglobin not haemoglobin, anesthetic not anaesthetic and so on. More shocking perhaps is heme rather than haem, which is cheating as consistency should yield just 'hem', which wouldn't sound right. To most Europeans this assassination of 'ae' is not 'aesthetically' pleasing and also alters the sound of the word. There can also be confusion of meaning e.g. paed/ped for child but ped- also means feet in UK English and soil in geology (pedology). There's a big difference between paediatrics (about children) and pediatrics (about feet).

What shall we say not about losing a letter but changing one letter for the other with almost the same sound? The 's' (English) or 'z' (American) debate gives us fertilizer and fertiliser for example. I find it hard to remember which is which. We also have two spellings of Al - Aluminium/Aluminum.

It's a reminder to us that language in science can be a confusing but crucial part of teaching and learning, and a potential minefield for beginners.

□

# Vanadium flow batteries: storing renewable energy

Vanadium exists in several accessible oxidation states in solution and these have been harnessed since the 1980s to make a new type of battery for storing renewable energy: **the flow battery**. There are several types of electrochemical cells: primary, secondary and fuel cells. (These are often called batteries but strictly speaking a battery is when two or more cells connected together, as in a 12V car battery with 6, 2V lead acid cells.)

**Primary cells** contain the chemicals needed for an electrochemical reaction to produce electricity, but once discharged cannot be recharged; **secondary cells** contain all the necessary chemicals but when discharged can be recharged by passing electricity through the cell to reverse the cell reaction; in a **fuel cell**, the chemical reactants are fed in from outside and consumed in the cell but the cell continues to produce electricity as long as the reactants are supplied. **The flow cell** (battery) is like a fuel cell in that the reactants are stored outside the cell, but the reactions can be reversed recharging the cell and making it suitable for electricity storage.

The chemistry of a battery determines the cell voltage, so that a lead-acid cell has a voltage of 2V. The capacity of a cell (or battery) is determined by the amount of chemicals in the cell. So a larger cell has the same voltage but lasts for longer.

The vanadium flow battery was developed in Australia in the 1980s by Professor Maria Skyllas-Kazacos and her team in Australia, utilising the four oxidation states of vanadium. These are known as vanadium redox flow batteries (VRFB).
Vanadium redox flow batteries can provide cheap, large-scale grid energy storage. Here's how they work - ABC News

This short video explains how redox flow batteries work. https://youtu.be/t9zwgL7UpDA

## The chemistry of the vanadium flow battery

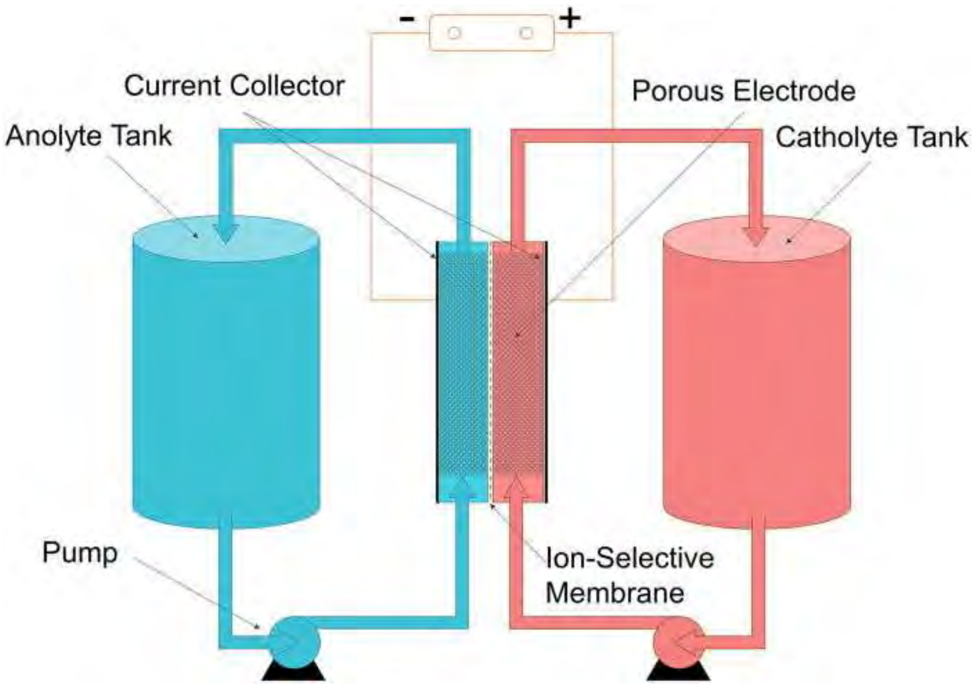


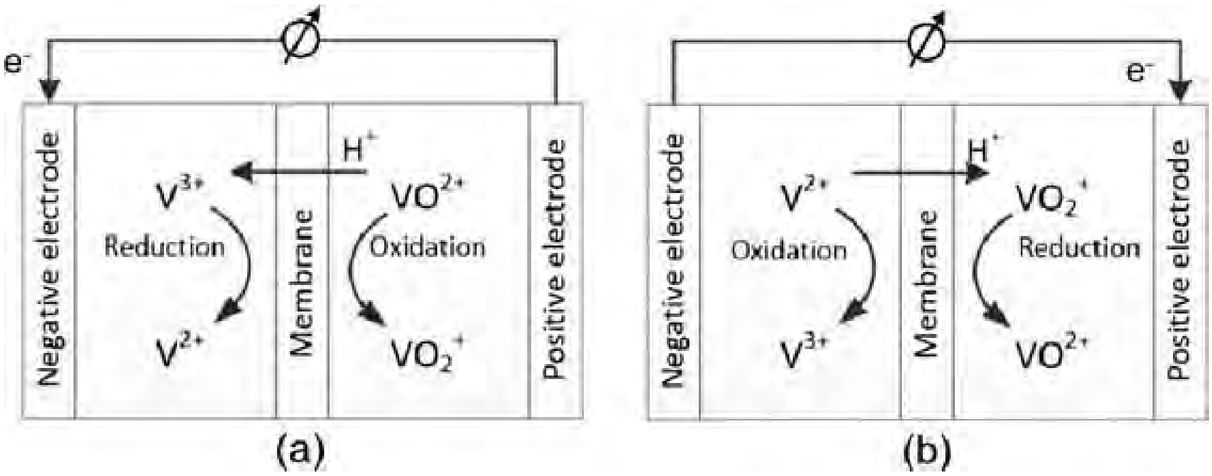

**Figure 1: Schematic of a vanadium flow battery**
Redox Flow Battery - Vanadium redox battery - Wikipedia

The reactants (electrolytes) are stored in two tanks and fed into the cell, which contains an ion-selective membrane to separate the two halves of the cell.

Both electrolytes are vanadium-based. The electrolyte in the positive half-cell (catholyte) contains $VO_2^+$ and $VO^{2+}$ ions, while the electrolyte in the negative half-cells (anolyte) consists of $V^{3+}$ and $V^{2+}$ ions.

**Vanadium oxidation states:**

| **Ion** | **O.D.** |
|---|---|
| $V^{2+}$ | +2 |
| $V^{3+}$ | +3 |
| $VO^{2+}$ | +4 |
| $VO_2^+$ | +5 |




Cathode Anode Anode Cathode

| **Charging cycle** | | **Discharge cycle** | |
|---|---|---|---|
| $V^{3+} + e^- \rightarrow V^{2+}$ | $VO^{2+} \rightarrow VO_2^+ + e^-$ | $V^{2+} \rightarrow V^{3+} + e^-$ | $VO_2^+ + e^- \rightarrow VO^{2+}$ |
| +3 +2 | +4 +5 | +2 +3 | +5 +4 |

**Figure 2: A schematic of a vanadium redox flow battery: (a) charge reaction and (b) discharge reaction.**
(16) (PDF) Redox Flow Batteries: Fundamentals and Applications [open access] (researchgate.net)

On charging: electrons are supplied from outside and reduce $V^{3+}$ to $V^{2+}$ (cathode) and at the anode $VO^{2+}$ is oxidised to $VO_2^+$.

On discharging: electrons are produced in the cell as $V^{2+}$ is oxidised to $V^{3+}$ (anode) and at the cathode $VO_2^+$ is reduced to $VO^{2+}$.

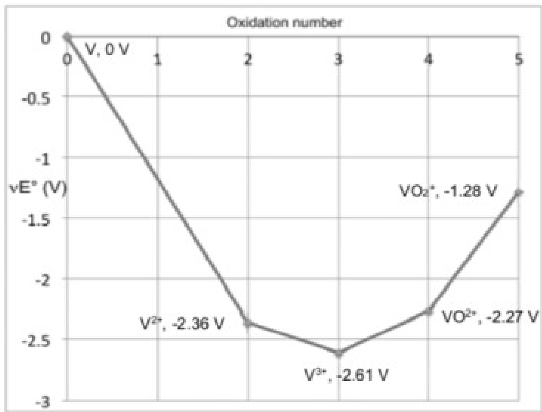



**Figure 3: The electrode potential (Frost) diagram for vanadium in acid solution**

The electrode potential (Frost) diagram for vanadium in acid solution in Figure 3 above shows that $V^{2+} \rightarrow V^{3+} + e^-$ and $VO_2^+ + e^- \rightarrow VO^{2+}$ are both spontaneous reactions (downhill on the diagram) so that the cell reaction is spontaneous and can liberate energy as electricity, with a cell voltage of ~1.3 V.

$$V^{2+} + VO_2^+ \rightarrow \rightarrow V^{3+} + VO^{2+}$$

**N.B. oxidation is loss of electrons and reduction is gain (OIL RIG); in electrochemical cells oxidation happens at the anode and reduction at the cathode.**

The flow cell produces electricity as long as the reactants are supplied. Thus its capacity can be enormous and the cells can be recharged thousands of times, leading to a long service life. However, the vanadium flow cell is large compared to lithium storage batteries and it is not suited for use in cars, but ideal for storage. Aqueous solutions are used so there is no risk of fire. Vanadium is fairly abundant and easy to handle, compared to lithium.

Vanadium flow batteries, consisting of multiple cells, are already in use for energy storage. The largest installed VRFB to date was commissioned in Dalian, China in 2022 and is a 400 MWh, 100MW battery.
World's Largest Flow Battery Energy Storage Station Connected to Grid----Chinese Academy of Sciences (cas.cn)


**Figure 4: A flow battery installation by Sumitomo**
**Batteries | Sumitomo Electric Industries**

*"Sumitomo Electric began developing redox flow batteries in 1985 and commercialized them in 2001. We deliver our products to electric power companies and consumers worldwide, and have built a track record through economic evaluations, microgrid demonstrations, and smart factory applications in distribution networks. Redox flow batteries are rechargeable batteries that are charged and discharged by means of the oxidation-reduction reaction of ions of vanadium. They have excellent characteristics: a long service life with almost no degradation of electrodes and electrolytes, high safety due to being free of combustible materials, and availability of operation under normal temperatures. These make the batteries ideal for use in power grid systems. Redox flow batteries are thus expected to serve as a technology to stabilize the power grids that will be needed to expand the introduction of renewable energy including solar and wind power."*

## Other flow battery chemistries

Other flow batteries are being developed besides the vanadium flow batteries.

- $Zn\text{-}Br_2$
- Fe-Cr
- Zn-Ce

Flow batteries aren't new. The zinc–bromine flow battery ($Zn\text{-}Br_2$) is the oldest flow battery chemistry, patented by John Doyle on September 29, 1879. Walther Kangro demonstrated flow batteries based on Ti–Fe and Cr–Fe.in Germany in the 1950s.

**More reading:**

Flow batteries, the forgotten energy storage device (acs.org)

Flow batteries: how they work and Australia's prospects (cosmosmagazine.com)

Flow Batteries: Chemicals Operations that Promise Grid-Scale Storage - Features - The Chemical Engineer

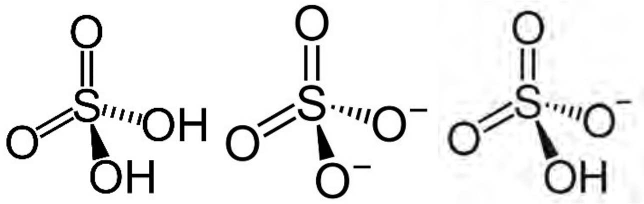
□

# The sulfur story: devil's gold or essential element? 3. Sulfuric acid, $H_2SO_4$

Sulfuric acid must be one of nastiest substances around, because of its corrosive nature, but it is also one of the most important chemicals in the modern world. Justus von Liebig famously said in 1843: *'It is no exaggeration to say that we may judge the commercial prosperity of a country from the amount of sulfuric acid that it consumes.'* It has been called the king of chemicals and madern society couldn't function without it. Large scale *c*ommercial production of sulfuric acid started in 1746 when Roebuck invented the lead chamber process. This process was still being used in the Czech Republic in 2004!

**What is the chemical produced in the largest quantity worldwide?** The answer is sulfuric acid – 275 Mt in 2022 and over 50% of it is used to make fertilizers. The largest producer is China (74 Mt), followed by the US (37 Mt), India (16 Mt), Russia (14 Mt) and Morocco (7 Mt). (Mt is a Mega metric tonne, $10^6$ tonnes).

It is most familiar in the laboratory in diluted form but concentrated sulfuric acid or oleum, also known as oil of vitriol, is a dense, oily and highly corrosive liquid, and must be handled carefully. A key safety precaution is never to add water to acid, but always acid slowly to excess water. The conc. acid reacts vigorously with water, liberating heat, enough to turn water into steam. Its reaction with sucrose in the familiar demonstration, converting it to carbon, is an example of its corrosive power. The concentrated acid is a strong oxidising agent; the dilute acid is just a dibasic acid. As a dibasic acid it forms two families of salts: sulfates ($SO_4^{2-}$) and hydrogensulphates ($HSO_4^-$). Each of these ions and sulfuric acid have a tetrahedral structure as predicted by VSEPR theory (Figure 1). Sulphur forms a series of oxyanions in different oxidation states and these will be considered in another article.



Sulfuric acid  Sulfate ion  Hydrogensulfate ion

**Figure 1: Sulfuric acid and its anions**

**Why oil of vitriol?** Vitriol comes for the Latin word for glass. The common hydrated salts of sulfuric acid were long known – blue vitriol ($CuSO_4$), green vitriol ($FeSO_4$), white vitriol ($ZnSO_4$) and red vitriol ($CoSO_4$). They were called *vitriols* because they form glassy crystals.

**Figure 2: Crystals of green vitriol, $FeSO_4.6H_2O$**

When heated the vitriols decompose giving water and sulfur trioxide, which combine to give sulfuric acid. This discovery is usually ascribed to the 8th century Muslim alchemist Jabir ibn Hayyan, known in English as Geber. Green vitriol, $FeSO_4.7H_2O(s)$, also known as copperas, was used (Figure 2). This method was also used in Nordhausen, Germany and so was called Nordhausen acid. The concentrated acid was an oily liquid and thus became known as oil of vitriol. It was an important substance for the alchemists, as it would dissolve everything except gold.

$6FeSO_4.7H_2O(s) \rightarrow 3Fe_2O_3(s) + 42H_2O + 6SO_3(g)$

$SO_3(g) + H_2O \rightarrow H_2SO_4(aq)$

It took 10 lb green vitriol to produce 1 lb sulfuric acid.

This method could only produce small quantities of acid, so it was expensive, but sulfuric acid became important in the industrial revolution in the textile industry and a better method of production was needed. Burning sulfur produces sulfur dioxide, which can be oxidised to sulfur trioxide, which dissolves in water to give sulfuric acid. However, it needs a catalyst and early chemists learned that potassium nitrate speeded up the process. In 1736 Joshua Ward (1685-1761) set up in partnership with John White to make sulfuric acid at a vitriol works in Twickenham, and later in 1740 in Richmond. He made the acid in large glass vessels, which limited the amounts that could be made at one time, so it was still expensive but still only 1/10$^{th}$ of the previous price. The fragile glass vessels limited how much could be made at once.

The production of sulfuric acid involves the following steps:

a) extraction of sulfur from native S, pyrites, or oil refining.

b) conversion of sulfur to sulfur dioxide.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

c) conversion of sulfur dioxide to sulfur trioxide (needs catalyst).

$$SO_2(g) + \tfrac{1}{2} O_2(g) \rightarrow SO_3(g)$$

d) conversion of sulfur trioxide to sulfuric acid.

$$SO_3(g) + H_2O \rightarrow H_2SO_4(aq)$$

$$SO_3(g) + H_2SO_4(aq) \rightarrow H_2S_2O_7(aq)$$

## The lead chamber process

John Roebuck and his partner Samuel Garbutt solved the problem of scale by doing the reactions with sulfur and nitrate in large chambers made from lead sheets, as sulfuric acid does not react with lead. In 1746 they opened a factory in Birmingham and in 1749 a second one at Prestonpans, Scotland. This enabled larger quantities of more concentrated acid to be made and the price of sulfuric acid tumbled. The lead chamber process was improved over time and lasted until the 20$^{th}$ century. Figure 3 shows a typical lead acid chamber in the late 19$^{th}$ century. I visited one in Leeds in the late 1960s and the Open University made a programme on the last lead chamber works in the UK in 1973. The references by Clow and Clow give details of the early industry.

Initially sulfur from Sicily was used, where it occurs naturally as a result of volcanic action (see part 1). A dispute over cost in 1836 led to the British manufacturers switching to iron pyrites, $FeS_2$, as the source of sulfur, obtained from mines in Wales and Ireland. Avoca Mines was a major source of pyrites. Initially potassium nitrate was used but manufacturers switched to sodium nitrate from South America in the early 19$^{th}$ century, releasing the potassium nitrate for use in gunpowder and fertilisers.

In the lead chamber processs, sulfur and sodium or potassium nitrate were burnt together, in batches, producing sulfur dioxide, $SO_2$, and nitrogen oxides, which catalysed the oxidation to sulfur trioxide, $SO_3$. This then dissolves in water in the bottom of the chambers or better in dilute sulfuric acid to give more concentrated sulfuric acid. Gay-Lussac and Glover towers were added to improve the chemical efficiency of the process by reducing the loss of chemicals to the atmosphere.

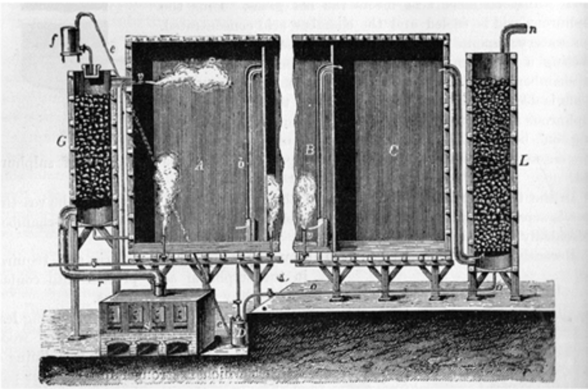


**Figure 3: Schematic of a lead chamber plant (Rudolf von Wagner, 1892, Fig. 263, *Manual of Chemical Technology*, New York: D. Appleton & Co., p. 268)**

## The contact process

In 1831 an English vinegar maker, Peregrine Philips Jr., patented the contact process, where a stream of sulfur dioxide and air were oxidised to sulfur trioxide over a platinum catalyst, and then absorbed in water or sulfuric acid. This process could produce a purer, cheaper and more concentrated acid, but was technologically more complex, and it was not used commercially until 1875 in Germany. It is now the dominant process, except that now a vanadium(V) oxide ($V_2O_5$) catalyst is used (introduced 1901).

The process can be divided into four stages:

1. Combining of sulfur and oxygen ($O_2$) to form sulfur dioxide, then purify the sulfur dioxide in a purification unit.
2. Adding an excess of oxygen to sulfur dioxide in the presence of the catalyst vanadium pentoxide at 450 °C and 1-2 atm.
3. The sulfur trioxide formed is added to sulfuric acid which gives rise to oleum (disulfuric acid)
4. The oleum is then added to water to form sulfuric acid which is very concentrated. Since this process is an exothermic reaction, the reaction temperature should be as low as possible.

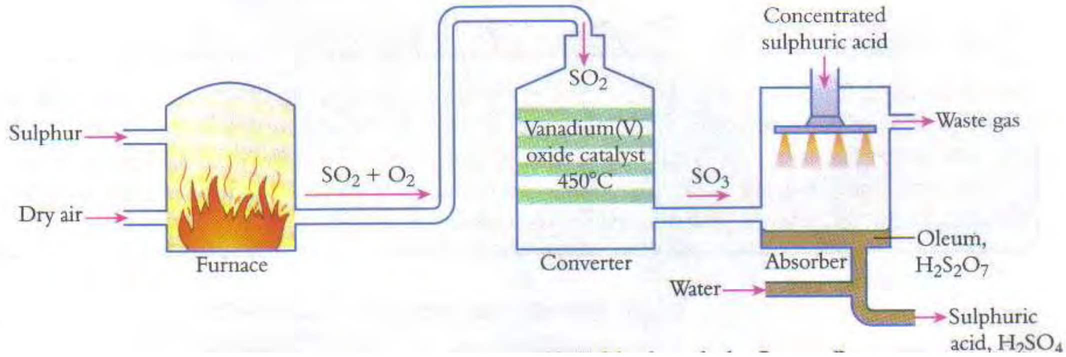



**Figure 4: Schematic diagram of the contact process**

Most sulfur is now obtained by stripping impurity sulfur from sour oil and gas.

Ireland has had a number of sulfuric acid plants since the 18th century, in the North and South, usually associated with fertiliser works. The first 'vitriol works' was built in 1767 by Waddell Cunningham and Thomas Gregg near Lisburn. The first uses were in bleaching textiles, which speeded up the process from days to hours. Other works opened in the North and in 1807 the Dublin Vitriol Works was opened in Dublin. The fertiliser manufacturers built their own sulfuric acid plants, including IFI (formerly NET) at their Arklow works. I was able to visit before it closed in 2002. It used pyrites from the nearby Avoca mines.

## Uses of sulfuric acid

The uses of sulfuric acid have changed over the years, but it remains the most important chemical, used in many industries. Initially in the 18th century it was used in the metal trades and in the textile industry. It was used to make other acids (hydrochloric, nitric and phosphoric) and then was used to make synthetic soda by the LeBlanc process. The middle of the 19th century saw the rise of the fertiliser industry and sulfuric acid was used to make superphosphates. It was used in making explosives and other chemicals. Many of these uses remain as the list below shows.

- Production of fertilizers, such as superphosphate of lime and ammonium sulfate

- Manufacturing of other chemicals, such as hydrochloric acid, nitric acid, sulfate salts, synthetic detergents, dyes, pigments, explosives, and drugs
- Cleaning of metals and removal of impurities from oil
- Petrochemical refining and catalysis
- Paper production

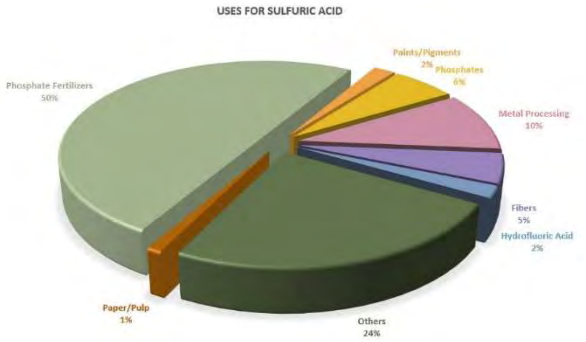



**Figure 5: Uses of sulfuric acid**

[Sulfuric Acid - H2SO4 (sulfuricacidtank.com)]

It is hard to overestimate the importance of sulfuric acid in the development of the chemical industry, as well as the textile and metal industries and agriculture.  It played a key and often overlooked role in the industrial revolution, enabling the expansion of many industries.

## Environmental aspects

Sulfur is ubiquitous in the environment as it is part of the sulfur cycle, part natural and part manmade. There are at least three environmental problems associated with sulfuric acid:

1. Acid precipitation (acid rain) due to emissions of SO2 into the atmosphere;
2. Acid mine drainage from old metal or coal mines;
3. Cracking of concrete blocks contaminated with pyrites ($FeS_2$).

Manmade sources in the atmosphere include metal smelting and burning fossil fuels; natural sources include volcanoes and microorganisms. Once released into the atmosphere as $SO_2$ or $H_2S$, these are eventually converted into sulfuric acid, which falls as acid deposition (acid rain.) This was a major problem in the 70s and 80s, but has been reduced by burning cleaner fossil fuels and by cleaning up industrial exhaust gases. Volcanoes also emit large quantities of $SO_2$ and this is converted into sulfuric acid in volcanic lakes and in the atmosphere.

Metal sulfides are found in coal and in many metal deposits, produced under anaerobic conditions. When these are exposed to air and water, together with microorganisms, acid mine drainage (AMD) is produced, which contains sulfuric acid.

Recently, in Ireland there has been a problem with pyrites contamination of concrete building blocks. When exposed to air and water, the pyrites produces sulfuric acid, which reacts with $CaCO_3$ producing gypsum, which causes sweeling and cracking.

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## In Part 4: The metal sulfates: from bluestone to gypsum

# Diary

**2024**

**ASE Annual Conference**
**4-6 January 2024**
**University of Northampton, UK**
**ASE 2024 Annual Conference | www.ase.org.uk**

**ISTA Annual Conference**
**1-2 March 2024**
**SETU, Waterford**
**ISTA**

**9th EuChemS Chemistry Congress**
**7-11 July 2024**
**Dublin, Ireland**
**EuChemS 2024**

**27th. International Conference on Chemical Education**
***"Power of Chemistry Education for Advancing SDGs"***
**15-19 July 2024**
**Pattaya, Thailand**
27th IUPAC International Conference on Chemistry Education - ICCE 2024 (icce2024thailand.com)

**BCCE 2024**
***"Distilling Solutions for Chemical Education"***
**28 July-1 August 24**

**16th ECRICE 2024**
***"Chemical Education for Sustainable Development: Empowering Education Communities"***
**5-7 Sept. 2024**
**NOVA, Lisbon, Portugal**
**Home | 16 European Conference on Research in Chemical Education :: 5-7 September 2024 (chemistry.pt)**

**43rd ChemEd-Ireland**
**19 October 2024**
**Cork, UCC**
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- **Proceedings, ChemEd-Ireland 2023**
- **The sulfur story: Sulfates**
- **Amazing minerals: Gypsum**

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