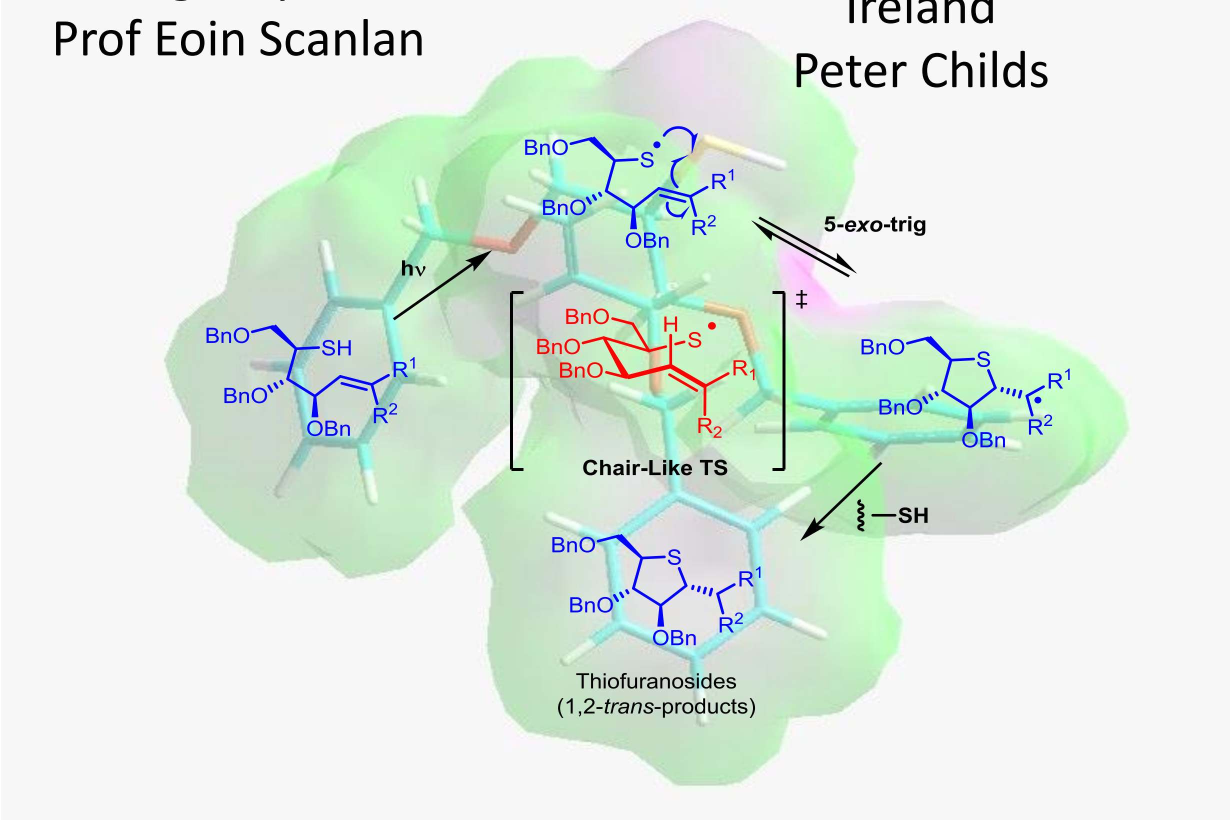
The Institute of Chemistry of Ireland

Irish Chemical News

Feature Articles:

Thiosugar Synthesis
Prof Eoin Scanlan

The State of Chemical Education in Ireland
Peter Childs



2014 Issue 1

Editorial

Welcome to the new issue of Irish Chemical News. We have two feature articles in this issue and one written by last year's Boyle Higgins awardee – Dr Shelia Willis of The Forensic Science Laboratory. One is written by Prof. Eoin Scanlan, who is in the Organic Chemistry Section of the School of Chemistry at TCD. His article describes his recent work in thiosugar synthesis. The second article is authored by Peter Childs from Limerick. He gives a review of the state of Science education in Ireland. The winning entry in this year's Schools Newsletter competition, which the Institute sponsors, is also included. Entitled *'How do Adolescents see Chemistry?*', it was won by a team from The Royal Belfast Academical Institution.'.

One of the aims of this issue is that it can be distributed as widely as possible, to members and non-members alike, to highlight the activities of the Institute and hopefully to grow our membership. All our readers are encouraged to visit the website, http://www.chemistryireland.org/index.html, regularly. Details of membership rates can also be found there.

We still need volunteers for articles that can be featured in ICN. There is a bias towards academic articles, so we especially ask our industrial members to participate. If you wish to contribute to the next issue, or have ideas of article types you wish to see, please do not hesitate to contact the editorial team (Robert Baker, Margaret Franklin or Brian Murray).

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Introduction from the President

As my first year as President ends and I looked back on the year I see a mixed bag of results. First I wanted to give ICI a higher profile by using Social Media. To this end we have success and we are now on LinkedIn, Facebook and Twitter. Three of our ladies have been responsible for setting up the pages and creating the content. Firstly Margaret Franklin set up the LinkedIn page and regularly adds content. Twitter was set up by Aurora Walshe with its lively content and Lisa Phelan set up the Facebook account again with good content. Aurora and Lisa our representatives for The European Young Chemist Network in Bucharest will be representing us at the Bucharest meeting the week of April 6th.

Again we sponsored the 65th Irish Universities Chemistry Research Colloquium held in Trinity this year and many impressive presentations were made. The winner of the ICI best talk was Michelle Conroy from UCC was presented with a cheque for €200 for her efforts. We also supported the Eurovariety 2013 held in UL and very well organised by Peter Childs. The Annual Awards Lecture 2013 series was held in Trinity this year on two evenings. The speaker was the highly published Prof Roesky (University of Göttingen). The event was sponsored by Lonza (Swords Plant) as a good will gesture as Lonza exited Ireland and moved production to China. On a lighter note the ICI team won the Science Week Quiz despite not doing well in the science fiction section.

I attended the EuCheMs General Assembly in Budapest and a new constitution was agreed and finally passed in Brussels in the past few weeks. This will be available on our web page soon.

For reasons beyond our control we did not have a Congress in 2013 but this year we are having Congress in September. It will be a joint effort between Limerick Institute of Technology (LIT) and the University of Limerick. There will be two main topics Biotechnology and Crystallisation. This is the International Year of Crystallography and a very appropriate theme. With the announcement by the IDA of several biotechnology companies setting up in Ireland and in the Limerick area biotechnology will be a topical of great interest. Fergal Barry of LIT is the main organiser. We hope to announce the agenda and speakers over the coming weeks.

The big disappointment is the poor uptake of membership. Membership is static and it's proving very difficult to attract new members and to get professionals involved on Council. I feel women in particular are underrepresented. I appeal to anyone who has ideas on how to bolster membership to talk to us. I did a presentation the Pharmachemical Ireland's RDI sub group at a meeting in Roche (Clarecastle) where there was good sentiment regarding the need for the chemistry profession to project its image and standing in the greater community. However it has not generated much by way of increased membership. Many companies are not members and over the next year I want to focus on this issue and seek more corporate support. We can only offer better member services if we have both chemists support and company backing. In relation to social media I also wanted to initiate an online discussion amongst chemists about our role and standing in the professional world. An initial attempt to get this started when up in 27th February on LinkedIn when I asked "*if all practicing chemists in Ireland should be members of the Institute and if not, why not? Should employers require their chemists to be members of ICI*" This attempt to initiate discussion results in no response so this is something Council and I will work in the coming year.

Patrick Hobbs MSc. FICI
President

Awards 2014

Eva Philbin Award 2014 – Prof. F. Ekkehard Hahn (University of Münster, Germany).

Prof. Hahn is one of the formost inorganic chemists in Germany, with research mainly focussed upon transition metal carbene complexes. He is the Chair of Inorganic Chemistry at the University of Münster and will deliver his lectures in late October. He will also give a public lecutre on the importance of Science. His website is: http://www.uni-muenster.de/Chemie.ac/hahn/hahn.html.

Boyle-Higgins Award 2014 - Professor Patrick J. Guiry, (UCD).

Prof. Guiry is this year's recipient of the Boyle-Higgins award. He will deliver his lecture "***Adventures in Asymmetric Catalysis, Natural Products and Medicinal Chemistry***" in UCD, on Thursday 10 April 2014.

The Institute of Chemistry of Ireland Congress 2012

The 2012 congress was held in UCC, chaired by Jeremy D. Glennon. The theme was Chromatography and a number of speakers gave interesting presentations. An essential part of any Congress is the poster presentations and below are the abstracts for the posters presented at this meeting.

Determination of Distribution Coefficients of Non Steroidal Anti-Inflammatory Drugs (NSAID) by HPLC on Reverse Phase and Immobilized Artificial Membrane Columns

Owen Foley [a], Dara Fitzpatrick [a]

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The prediction of drug distribution *in vivo* is heavily dependent upon accurate partition co-efficient (log P) or distribution co-efficient (log D) data for the successful application of Pharmacokinetic and Quantitative Structure Activity Relationship (QSAR) models. The Organization for Economic Co-operation and Development (OECD) stipulate that the measurement of ionisable drug compound partition co-efficient data, obtained by HPLC on a C18 column, be obtained at a pH where the ionisable drug is in its neutral form. However, most *in vivo* environments are in pH ranges where weakly acidic drugs are partially or fully ionised. Incorporation of log P guideline measurements results in a significant reduction in the accuracy of the QSAR and Pharmacokinetic models.

The development of bio-mimetic Immobilized Artificial Membrane chromatography, utilizing cellular membrane phospholipids as a stationary phase ligand, allows for increased accuracy of *in vivo* applicable log P and log D value acquisition and the improvement of QSAR modelling results.

Here, the distribution coefficients of a set Non Steroidal Anti-Inflammatory Drugs (NSAID's) including Indomethacin, Diclofenac, Flurbiprofen, Ketoprofen, Ibuprofen, Naproxen, Sulindac, Ketorolac, Piroxicam and Fenoprofen, are determined on both IAM and reverse phase columns across a range of pH values.

Sensitive Detection of Aminothiols in Serum by Silica Nanoparticle Modified Capillary Electrophoresis Coupled with Boron Doped Diamond Electrode

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Interest in the analysis and quantification of aminothiols has recently increased due to the significance of their levels in biological fluids and tissues in diagnosing several human pathologies. The Boron doped diamond electrode provides an easy method to detect aminothiols sensitively without any derivatization. Thus, by combining a BDD electrode with capillary electrophoresis, efficient separation and sensitive determination of N-acetyl-L-cysteine, L-glutathione reduced, L-glutathione oxidized, L-cysteine, DL-homocysteine, L-methionine, DL-homocystine and cysteine-glycine is achieved. Combined with off-line SPE for sample pretreatment, it is a useful tool for the study of oxidative stress and redox regulation. Glutathione is the most important thiol due to its role in protecting cells from toxic species.

Differentiation of chiral isomers and isomeric ratios by Broadband Acoustic Resonance Dissolution Spectroscopy (BARDS)

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The dissolution of a compound results in the introduction and desolvation of gas in a solvent. This process is due to gases adhered to or trapped within solid particles, and due to the dissolving compound lowering the solubility of gases in the solvent. The presence of desolvated gas increases the compressibility of the solvent, thereby reducing the velocity of sound passing through it. This effect is monitored by means of the frequency changes of mechanically induced acoustic resonances in the solvent. The response is strongly dependent on the physical and chemical characteristics of the solute compound. Diastereomers and epimeric compounds differ in physical properties and can produce variability in the response. The utilisation of chiral solvents yields interactions with enantiomeric compounds and produces variability in the acoustic effect, facilitating differentiation of enantiomers through a simple dissolution test.

Supercritical Fluid vs. Organic Solvent as a Reaction Medium in Silica Functionalisation

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A "green chemistry" approach for the preparation of silica bonded stationary phases has been developed in our laboratory that avoids the use of problematic organic solvents. By exploiting properties of supercritical carbon dioxide (sc-CO2), such as solvating power, lower toxicity and enhanced diffusivity, organosilanes can be reacted with surface silanol groups, for the clean, organic solvent-free synthesis of highly efficient silica bonded phases for liquid chromatography (LC) and capillary electrochromatography (CEC). Spectroscopic analysis including solid state NMR spectroscopy and chromatographic performance testing is used to characterise the silica bonded phases generated. In this work we examine the preparation of a silica hydride intermediate and of an octadecyl bonded silica stationary phase under supercritical fluid conditions and compare the results to those prepared using traditional organic solvents as the reaction medium.

Synthesis of 2.6 µm superficially porous particles and investigation of their kinetic performance

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Recent developments in particle technology have shown substantial interest in the use of core-shell particles for liquid chromatography[1]. Sub-2 µm particles have been very popular and well studied[2] and we are now seeing a trend moving again towards larger particles. The kinetic and chromatographic performance of two types of core-shell particles with an overall diameter of 2.6 µm, packed in narrow bore columns was investigated in this work. The main focus of the investigation was to look at the effect of the particle morphology, ie. the roughness vs. smoothness of the core-shell particles, and also the effect of particle size distribution on the overall efficiency of the column. To do this, Kinetex-2.6 µm-C18 columns (2.1 x 50 mm I.D and 2.1 x 100 mm I.D) was also studied as a comparison.

[1] Omamogho, J. O.; Hanrahan, J. P.; Tobin, J.; Glennon, J. D. *J. Chromatogr. A* **2011**, *1218*, 1942. [2] Gritti, F.; Omamogho, J.; Guiochon, G. *J. Chromatogr. A* **2011**, *1218*, 7078.

Synthesis and Characterisation of a Pentafluorophenylpropyl bonded silica stationary phase generated using supercritical carbon dioxide as a reaction solvent.

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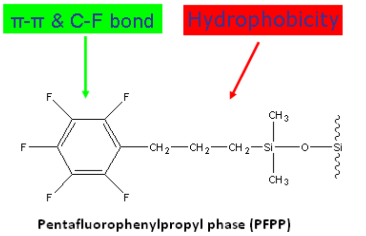
The use of sc-CO_2 for the synthesis of silica bonded phases has continued to attract greater interest over the decade. Wide ranges of temperature and pressure programming conditions, coupled with short reaction time and easily recycled reaction medium make sc-CO_2 a viable green chemistry alternative to conventional organic solvent based methods of preparation [1-3]. Pentafluorophenyl propyl (PFPP) silica bonded stationary phase provide different selectivity from C18 and phenyl stationary phases as the C-F bond is less polarisable than the C-H bond [4]. The bonded PFPP was characterised by elemental analysis, thermogravimetric analysis (TGA), scanning electron microscopy (SAM), and by solid-state NMR spectroscopy. Chromatographic characterization and performance of the PFPP phase was also investigated using the Neue test solute mixture. The results demonstrate that the PFPP phase can be prepared successfully under supercritical conditions of 100°C, 414 bar in a reaction time of 1 h with surface coverage comparable to conventional organic solvent based methods. Chromatography with Neue solute reveal rapid analysis within 7 min, coupled with a different selectivity from C18 phases as evidenced in the elution of butylparaben and dipropylphthalate before acenaphthene [4].



Pentafluorophenylpropyl phase (PFPP)

Fig. 1 Structure of silica bonded PFPP phases prepared in sc-CO_2, reaction conditions: 100 ºC, 414 bar, 1 hour (3 µm Exsil-Pure silica).

[1] B.A. Ashu-Arrah, J.D. Glennon, K. Albert, J. Chromatogr. A 1222 (2012) 38.
[2] B.A. Ashu-Arrah, J.D. Glennon, K. Albert, J. Chromatogr. A 1236 (2012) 42.
[3] C. Cao, A.Y. Fadeev, T.J. McCarthy, Langmuir 17 (2001) 757.
[4] B.A. Ashu-Arrah, J.D. Glennon, K. Albert, Manuscript No. JCA-12-1031. in print (2012)

Analysis of Neuroendocrine Tumor Markers by Hydrophilic Interaction Liquid Chromatography (HILIC)

Fengjun Shang [a], Victor Langsi [a], Jeremy D. Glennon [a]

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Neuroblastoma, a neoplastic disease of early childhood, is the third most common cancer in children. Measurements of catecholamine metabolites homovanillic acid (HVA) and vanylmandelic acid (VMA) serve as a screening test for neuroblastoma [1]. The metabolism of serotonin to 5-hydroxyindole-3-acetic acid (5-HIAA) is a diagnostic marker in urine for the 'carcinoid syndrome' [2]. Hydrophilic interaction liquid chromatography (HILIC) provides an alternative approach to effectively separate polar drugs, metabolites and biologically important compounds in proteomics, glycomics and clinical analysis. In this study, a rapid and sensitive method was developed to separate and quantify HVA, VMA and 5-HIAA using a ZIC-HILIC column. A set of nucleobases/nucleosides were employed to evaluate chromatographic properties of the sulfobetaine HILIC stationary phases. The retention mechanism of the column was investigated by adjusting the ratio of water in the mobile phase, salt concentration, buffer pH and ionic strength.
[1] Tsubono, Y.; Hisamichi, S. *N. Engl. J. Med.* **2004**, 350, 2010-2011. [2] Manickum, T. *J. Chromatogr. B* **2009**, 877, 4140-4146.

Capillary Electrophoresis with a Boron Doped Diamond Electrode for Trace Detection of Endocrine Disruptors in Water Samples

Damien J. Browne [a], Lin Zhou [a], John H.T. Luong [b], Jeremy D. Glennon [a]

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Off-line solid-phase extraction-capillary electrophoresis coupled with electrochemical detection (SPE-CE-ECD) has been used for the determination of bisphenol A (BPA), bisphenol F (BPF), 4-ethylphenol (4-EP) and bisphenol A diglycidyl ether (BADGE) in bottled drinking water. A key to the sensitive, reproducible, and stable detection of these endocrine-disrupting compounds was the use of a boron doped diamond (BDD) electrode in the amperometric mode. An off-line SPE procedure was utilized to extract and pre-concentrate the compounds prior to separation and detection with Bond Elut C18 as the sorbent. The oxidative detection of the endocrine-disrupting compounds was accomplished at +1.4 V vs Ag/AgCl without electrode pretreatment. The minimum concentration detectable for all four compounds ranged ~ 0.01 µM (S/N=3), or ~2.5 ppb using a 100:1 preconcentration factor. After exposing the plastic bottle water container under sunlight for a week, the estimated concentration of BPA in the drinking water was 0.03 µM. This proposed approach was rapid and effective for the determination of BPA present in bottled water.

Separation of Biomarkers by Micro-Electrophoresis with Chemiluminescence and Electrochemical Detection in Toner-Based Microchips

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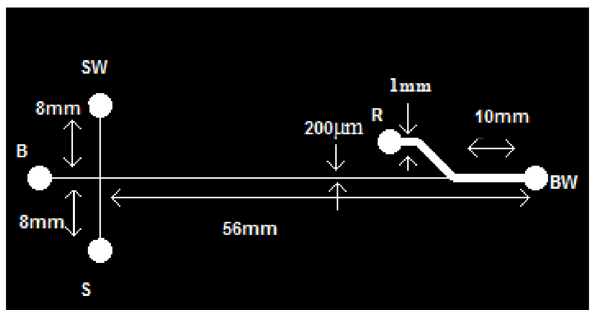
Since the introduction of micro-total analytical systems (µTAS) and lab-on-a-chip technology, microfluidic devices have been applied in almost every area of separation science. In this work, a laser printer is used to selectively deposit toner onto polyester film, and the resulting toner-based microchips are coupled with several detection methods, particularly Chip-Electrophoresis-Chemiluminescence (CE-CL) detection and Chip-Electrophoresis-Electrochemical detection (CE-EC). The detection limit of selected biomarkers can be as low as 1µM and the baseline separation is achieved within 60 seconds.

In addition, we have developed a range of micro-electrodes made of gold, silver and platinum by means of patterning and deposition techniques onto acetate. These electrodes have been designed for in-channel detection using toner-based microchips.



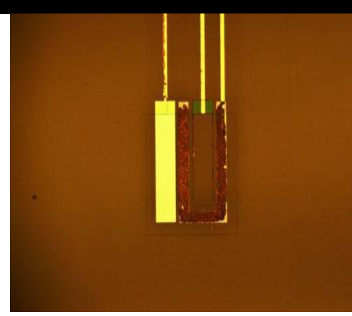


Fig. 1. View of toner microchip design for CE-CL

Fig. 2. Representation of the sensor design

Forensic Science – Fact and Fiction

Sheila Willis

The Forensic Science Laboratory

Sherlock Holmes is often used as a "symbol" of forensic science. Actually forensic science is a field where fact and fiction can merge. I visited The Reichenbach Falls where, according to the nearby plaque, Sherlock was thrown to his death by his nemesis Moriarty. This is fiction in the fiction because he recovered in response to public demand to appear in the beginning of the next episode. He is however a character that we have to question whether he is real or imaginary. I also visited the museum in Murringen, which is dedicated to him and in 2002 the Royal Society of Chemistry bestowed an Extraordinary Honorary Fellowship on Sherlock Holmes. Chief Executive of the Royal Society of Chemistry, Dr David Giachardi said:

"Of course Sherlock Holmes did not exist, despite the wishful thinking of millions of people at home and abroad who have followed his deeds in the books, on television, radio and in films He added: "Our particular interest is his love of chemistry, and the way that he wielded such knowledge for the public good, employing it dispassionately and analytically under scrutiny."

These are characteristics I would be pleased to be associated with as a forensic scientist.

It is a truly great honour to deliver the Boyle-Higgins Lecture and I thought it would be appropriate to reflect on another "symbol" associated with forensic science i.e. the microscope. Robert Boyle is reputed to have said that he could never imagine how it was possible for God to create a living thing as tiny as what he was looking at through the microscope. I was fascinated by the power of the microscope when I began to use it in my professional career. I initially worked in Clondalkin Paper Mills following my Ph.D. with Professor A.R. Manning. I experienced a culture shock on joining the paper mill following my time in UCD and I really missed the company of like-minded people. Information on papermaking was in short supply and this time predated the information age. A book by Julius Grant, which I used as a reference when examining paper under the microscope, was an exception. Imagine my surprise when I joined the fledgling forensic science laboratory to find that the same Julius Grant was a scientist employed by the defence to examine some of our findings. Grant was one of the famous people I encountered who used the microscope as an analytical tool. His most famous case was that of the Hitler diaries. An account of how he used his expertise to identify diaries Stern magazine had paid 10 million marks for is outlined in Panel 1.

In April 1983, the West German news magazine Stern published excerpts from what they claimed to be the diaries of Adolf Hitler, a series of books written between 1932 and 1945. Stern journalist Gerd Heidemann claimed to have paid 10 million German marks for the 60 small books, which had allegedly been smuggled from a crash site in Dresden by 'Dr Fischer'. One page was taken from the diaries and examined by handwriting experts in Europe and the USA, which resulted in numerous experts agreeing that the handwriting did in fact belong to Hitler. However when a press conference was held, Writer David Irving presented photocopies of another fake Hitler diary claiming it was from the same source as the magazine's material. This sparked further controversy, so the diaries were analysed further. Bundesarchiv, the German Federal Archives, soon established that the diaries were written on modern paper with modern inks, proving them as fakes. Furthermore, Dr Julius Grant in London conducted a forensic analysis of the diaries, agreeing that the diaries were in fact fakes.

A few days later, the diaries were released for testing by chemical expert Dr Julius Grant. He proved that the paper in the diaries was not in use until after World War II. The glue and ink were also modern. The text of the "diaries" was also found to be full of historical inaccuracies and anachronisms. The Sunday Times abandoned its serialisation and issued an apology.

Later, the Stern journalist, Gerd Heidemann, revealed he had in fact obtained them from a Stuttgart dealer in military relics, Konrad Kujau. The two men were found guilty of fraud and forgery in 1985 and sentenced to jail terms of four and a half years each. Kujau later made a career of his notoriety, selling his acknowledged forgeries of famous paintings until his death in September 2000. Gerd Heidemann was revealed in 2002 to have worked for the East German secret police. His Stasi file indicated he was still active in 1983, while the forgeries were taking place.

Panel 1.

Walter Mc Crone also used the microscope as an analytical tool coupling it to the database of his knowledge of minerals and precious stones. He was responsible for uncovering another fiction when he identified the so-called blood on the Turin Shroud as red ochre and vermillion rather than blood. His work was later confirmed when ^{14}C dating showed it to be a 14^{th} century artefact rather than the shroud used to bury Christ. One of Mc Crone's students, Skip Palenik runs a successful company in the States – Microtraces. He continues the type of work no longer popular in forensic laboratories where he examines microscopic traces for clues as to the origin of the item under examination – truly the stuff of Sherlock Holmes.

The microscope is used in the modern laboratory but less dramatically than the examples above. Figure 1 is one of the characteristic Maltese crosses seen in starch grains when they are viewed under cross polars.

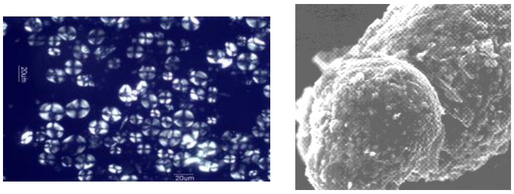
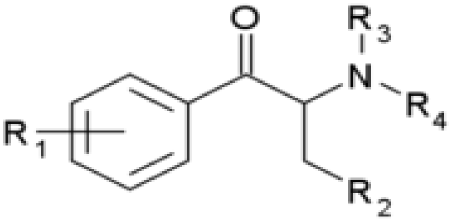


Figure 1. Left, starch grains and right firearm residue

Different information is gained from bright field, dark field or polarised light when using the microscope. Of course an additional level of information is gained when Scanning Electron Microscopy is used. Figure 1 shows the elemental composition as well as the backscattered image of a particle of firearm residue. The use of SEM is a relatively new microscopic tool but the traditional microscope examination is still the main examination method in some areas of forensic science. 1839 was the year when reliable procedures for microscopic detection of sperm were introduced. The microscope is still the main tool to identify sperm but DNA analysis to identify the source of the sperm increases the value to crime investigation today. Let me reflect for a while on the development of forensic science services in Ireland. The Garda Technical Bureau was established in 1937. At the time it was state of the art and included Mapping, Photography, Ballistics and Fingerprints. Lobbying for a forensic science laboratory began in 1961 as additional expertise needed for investigation of murders and sexual assaults was not available. The actual laboratory was not established until 1975. The case involving the murder of Lord Mountbatten, although, far from being the first major case examined in the laboratory, was a milestone and one I particularly remember because I gave evidence for the first time in the Special Criminal Court. It brought the laboratory into the spotlight because the evidence was principally technical. The defence employed a number of experts from home and abroad and the media from across the world were interested in the process. The trial established the laboratory as part of the criminal justice process in Ireland.

The same year, 1979, the decision was made that Drugs of Abuse should be examined in the laboratory. Prior to that Dr. Des Corrigan had been facilitating the State in providing Drug analysis from Trinity College Dublin. In 1994 a DNA service was established. The caseload submitted into the laboratory grew exponentially such that there were more than 15,000 cases in 2010. Numbers have fallen in recent years, partially as a result of an initiative to introduce presumptive testing of minor Cannabis cases by the Gardai. Cannabis, Cannabis resin, heroin, cocaine, amphetamine were the traditional controlled Drug materials received into the laboratory. Variations in trends followed fashion and availability. In recent years, the analytical challenges increased because of the availability of synthetic “look-alikes”. These materials mimic the psychoactive properties of the traditional drugs and slight variations can put them inside or outside the law. The substituted cathinones are a case in point where the isomers can include R_3 and R_4 being incorporated into a ring structure as well as the obvious variations of the alkyl group.



There are a number of publications from colleagues in the laboratory on the separation and identification of the isomers of cathinones. Power et al. Forensic Science International 211(2011)6-12

The prosecution of cases using the Misuse of Drugs Acts need a certificate of analysis from the laboratory. This is accepted as evidence of a controlled substance. Often other aspects of forensic science are relevant in the surrounding circumstances. The cases tried in the higher courts are those where the issue is sale or supply rather than possession. In such instances, the packaging can have just as much interest. In one case I examined, a small amount of Cannabis resin was in possession of the suspect, but the issue was whether these wrapped items could be associated in any way with a much larger quantity, which had been buried. Plastic bags are made from extruded polymer and the machinery leaves marks and defects. In this case it was possible to illustrate that the bags were made on the same machine a short time apart. There were other materials linking the two lots of Drugs including a perfect “physical fit” match between paper caught in one lot and torn paper from the bag carrying the bigger lot. However the plastic causes the case to stand out in my mind because I used it to gather more information about the manufacturing process. We visited a number of factories and set proficiency testing exercises for ourselves and other laboratories before the trial. This was done to demonstrate the competency to carry out the comparison.

Another Drugs trial that stands out in my mind is one where the Drug was imported strapped to a woman’s body. The medical examination included swabbing the abdomen to recover what looked like adhesive material. Adhesive tape, which had been used to strap the drug to her body, was recovered from the woman’s hotel room. There was a plentiful supply of fibres matching the jumper worn by the woman on the adhesive tape but I struggled for quite a while with the decision of whether or not infra-red spectra of the adhesives matched. It was a common adhesive and I eventually realised that the peak at ca 1000 cm^{-1} in the spectrum from the swab was likely to be from talc. This was in keeping with the information received later that the woman had showered prior to the arrest.

While a lot of my career involved the physical and chemical examinations of a range of materials from explosives to fibres, DNA has become the dominant tool in forensic science since the discovery of its value in the investigation of crime by Sir Alec Jeffries in 1984. Of course, as a chemist, rather than concede that the biologists have the upper hand, I consider DNA to be a large molecule and therefore very much in the domain of the chemist.

The Forensic Science Laboratory began using DNA technology in 1995. The first time a profile was produced in a case was the murder of Imelda Rinny and her son in Co. Clare but that case was never contested in court as Brendan O'Donnell, who was the accused, committed suicide before the trial. The first contested case was the *DPP v Mark Lawlor*. In the intervening years, the technology has changed considerably. In 1995, a bloodstain approximately the size of a coin was needed to generate a profile. Today a profile can be generated from a few cells and therefore developed from invisible contact traces. An important development for which Mullis received the Nobel prize in 1993 was PCR or polymerise chain reaction which facilitated the controlled replication of DNA producing enough to be then characterised. In an aside it is interesting to note that Mullis in his Nobel acceptance speech described his early experimentation with potassium nitrate and sugar to make rockets.

The DNA profiles used in forensic science are produced from parts of the genome that are not coding and sometimes referred to as "junk DNA". This means that the profiles cannot be used to provide phenotypic information. The only observable information that can be obtained from a profile is the sex of the donor.
The original so-called DNA fingerprinting used multilocus probes. Single locus probes were then used before moving on to STR or short tandem repeats technology, a version of which is in use today. DNA is a topic in itself and it is difficult to read any fiction today without reference to its use. Whether DNA is the technique in use or not, the laboratory processes involve more than the analytical technique.

The forensic science process begins at the scene. Sometimes a scientist attends the scene but more usually trained Garda personnel collect samples relevant to the crime. These are submitted to the laboratory where the cases are prioritised based on importance and the potential for the forensic examination to assist in the investigation. The case may be stored before being allocated to a scientist but when the scientist becomes involved, frequently the first steps involve recovery of the relevant traces and this step is critical to the success of the remaining examination. A peer review process follows the analysis, the items are returned to the Gardai and the report written. In some instances the laboratory has no further involvement while in other cases, the scientist is required to attend court to give their findings as expert witnesses.

The above is a factual account of how forensic science operates in my laboratory. What about our fictional character? Sherlock Holmes was using scientific techniques in a much more colourful fashion. He shares with the modern day fictional CSI heroes the ability to deliver very definite results in a very short time. In the case of CSI, every case is solved in 47 minutes to allow for the ads in the one-hour slot.
The early fictional characters and those of the modern era use technologies that are either true to life or slightly ahead of their time. Ludwig Teichmann in Krakow in 1853 developed the first microscopic crystal test for hemoglobin. In 1887 Conan Doyle in "A study in Scarlet" had Holmes utter the phrase " don't you see that it gives us an infallible test for blood stains?" He used the information available and projected it beyond reality at the time. In 1863 Schonbein used peroxide to oxidize hemoglobin, a technique still in use today, and in 1966 Brian Culliford developed reliable protocols for typing polymorphic protein and enzyme markers.

This tendency for the fiction writers to be ahead of reality has an impact that the Americans have coined "the CSI effect". It influences jury expectations, heightens criminals' awareness, causes civilians to be very aware of care of the scene and a tendency to have an absolute belief in the prosecution case. The latter points are taken from the literature but I can't help but note that the absolute belief in the prosecution case is not borne out by the outcome of some high profile cases for example the O.J. Simpson case.

I find these concepts very interesting because they get to the heart of the public's understanding of science. It seems to be very difficult to get the correct balance. There is either a very high expectation of what is possible or a complete mistrust of the findings.

In my experience sometimes myths are just as acceptable as scientific findings. When I started work, hay barn fires were frequently submitted to the laboratory with a request as to whether or not they started as a result of spontaneous combustion. I could find no test to check this proposition and had to limit my examination to whether or not fuel was used to start the fire. Members of the Gardai were convinced that the presence of "clinkers" a form of hardened ash was characteristic of spontaneous combustion. The area of fire investigation continues to lend itself to myths. Fact and fiction again merge in this area. Cameron Todd Willingham was executed in Texas in 2004 having been found guilty of arson. The findings of this, and many other similar cases are now open to question, in that the finding of arson was not on any scientific basis. The television program "Law and Order" has built this into some of their story lines while an outline of the facts in the above case are available in the film "Incendiary - the Willingham case".

Fire investigation is particularly difficult. It is the one crime where a lot of the evidence is destroyed. The laboratory involvement is primarily confined to whether or not hydrocarbon fuels are detected in the debris. Petrol, paraffin and diesel are easily detected and separated from each other in the debris from fires. The debris is heated in a sealed container and a sample of the headspace injected into a GC or more usually now a GCMS. The presence of the partially evaporated fuel is of course not evidence of arson. There can be a number of innocent explanations for the presence of fuel and as with all other case types, the findings must be interpreted in the context of the case.
One of the concerns, my colleagues and I have debated over the years, is how we avoid giving misinformation. The option, of reporting the facts and leaving them speak for themselves, was

shown to be flawed on a number of occasions. John F. Kennedy said "the great enemy of the truth is very often not the lie – deliberate, contrived and dishonest- but the myth- persistent, persuasive and unrealistic."

When reports were confined to the facts, the type of questions raised by the defence tended to be based on reliability; discrimination and statistics and they don't always address the issues at the heart of interpretation. The questions relating to transfer and persistence are not addressed. Trace materials such as fibres and glass are lost from the surface at an exponential decay rate. The rate of decay and time scale varies from one material to another. Fibres for example are known to decrease by 80% in the first hour but information of the persistence of DNA is less well known. This type of information is not probed when the reports are confined to the analytical facts so the philosophy was adapted quite early in the life of the laboratory that the true interpretation could only be carried out in the context of the case. This seems such common sense when discussed but in many subtle ways, is easy to gloss over. A matching DNA profile is of little value; we might agree in a husband/wife killing but will be extremely significant in a stranger rape. A profile on a discarded cigarette butt will vary in significance depending on the context of how and when it was discarded etc.

Evett et al published a number of articles in Science and Justice relating to these issues and formulated three principles as follows Interpretation of scientific evidence is carried out within a framework of circumstances. The interpretation depends on the structure and content of the framework. Interpretation is only meaningful when two or more competing propositions are addressed. The role of the forensic scientist is to consider the probability of the evidence given the propositions that are addressed. This is in essence using a Bayesian approach to update probability. Bayes theorem is formulated as follows-

$$LR = \frac{\text{Probability of evidence if C is True}}{\text{Probability of evidence if }\overline{\text{C}}\text{ is True}} = \frac{P(F/Ci)}{P(F/\overline{C}i)}$$

Posterior odds are equal to prior odds multiplied by the likelihood ratio. In a court scenario, the posterior odds can be equated as guilt or innocence, which is the preserve of the court, the prior odds are formulated from all the surrounding information collected by the police and prosecution and the likelihood ratio is the effect the scientific findings have on the prior odds. We recognise of course that the court doesn't formulate the above but it gives the scientist a framework in which to assess the value of their contribution. If we consider a trivial example such as a person is seen breaking a window. A person is arrested nearby and his clothes taken for examination. The scientist may recover glass fragments and use tests such as refractive index to compare the recovered fragments with the samples from the broken window. The logical approach i.e. applying Bayes to this scenario is to consider the probability of the evidence if the suspect broke the window over the probability of the evidence if someone else broke it. In these competing scenarios, we need information on how likely glass is to transfer in the course of breaking the window and what is the frequency of glass on clothing of persons in the general population. These can be seen to be the prosecution and defence propositions and by framing the findings in this way, the true value of the findings are more likely to be probed. If for example, the suspect says he is a glazier, the expectation is that he will have glass on his clothing. Thus the issues probed include the transfer and persistence relevant to the findings and often known only to the scientist. Focusing on the reliability or otherwise of refractive index measurements may cause relevant issues to be glossed over.

Forensic science although capable of tracing its roots back in time, is a relatively newly organised domain. As with other disciplines the formulation of standards is an ongoing issue. Standards and the formulation of norms is an interesting concept in itself. If complexity and consensus are plotted against each other, we have two extremes of low complexity and high consensus. In this situation standards are relatively easy to formulate. In instances of high complexity and low consensus, chaos reigns. The areas in between are those where professional judgements is needed. Forensic Science is similar to other disciplines in that there is ongoing work to expand the area of standards. I am involved in this process. I am leading a group of scientists from six countries across Europe in an EU funded project entitled "Development and implementation of an ENFSI standard for reporting evaluative forensic evidence" We are using the approach outlined above and I have hopes that it will help to ensure that balanced evidence is given. In recent times, DNA is being over interpreted because the emphasis is on the result of the comparison of two matching profiles rather than considering the context. The correct use of the developing standard should prevent this situation recurring.

I titled this talk "Fact and Fiction" because I think they are inextricably linked in forensic science. Myths and fiction affect how the law interacts with science. Science and law are strange bedfellows. In the court room, the lawyers arena, their rules hold and their need from the scientists seem to be for black and white answers in a world where most things are shades of grey. In fiction the protagonist is able to make an instant pronouncement while the factual scientist needs lots of support and background work. There has been much criticism of forensic science in recent years. The National academy of Science in the US with the report "The Way Forward" was particularly critical of the traditional areas. Much of the misinformation would be avoided if the Bayesian approach described above were used.

Forensic science has an established place in fiction and in the real world of crime investigation. It will continue to develop and encounter controversy but it is vital that it maintains the scientific method.

I love the poem Brief Reflection on Cats Growing in Trees by Miroslav Holub as a reminder of how we always need to keep an open mind.

Brief Reflection on Cats Growing in Trees

When moles still had their annual general meetings
and when they still had better eyesight it befell
that they expressed a wish to discover what was above.

So they elected a commission to ascertain what was above.
The commission dispatched a sharp-sighted fleet-footed
mole. He, having left his native mother earth,
caught sight of a tree with a bird on it.

Thus a theory was put forward that up above
birds grew on trees. However,
some moles thought this was
too simple. So they dispatched another
mole to ascertain if birds did grow on trees.

By then it was evening and on the tree
some cats were mewing. Mewing cats,
the second mole announced, grew on the tree.
Thus an alternative theory emerged about cats.

The two conflicting theories bothered an elderly
neurotic member of the commission. And he
climbed up to see for himself.
By then it was night and all was pitch-black.

Both schools are mistaken, the venerable mole declared.
Birds and cats are optical illusions produced
by the refraction of light. In fact, things above

Were the same as below, only the clay was less dense and
the upper roots of the trees were whispering something,
but only a little.

And that was that.

Ever since the moles have remained below ground:
they do not set up commissions
or presuppose the existence of cats.

Or if so only a little.

A Radical Approach to Thiosugar Synthesis

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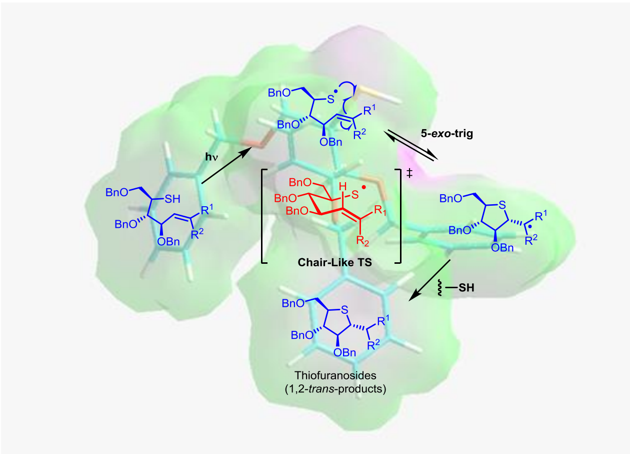

Introduction

Thiosugars are carbohydrate analogues where one or more oxygen atoms are substituted with sulfur in both furanoside and pyranoside structures.[1-3] These compounds have attracted significant interest in medicinal chemistry in recent years due to their potent biological activity as inhibitors of glycosidase enzymes.[4-6] Glycosidases are essential enzymes involved in catalyzing the hydrolysis of glycosidic bonds.[7, 8] Cellular glycosidases are heavily involved in the processing of *N*-linked glycoproteins.[9] A number of thiosugar-based therapeutics have been developed including treatments for diabetes, antiviral and anticancer compounds.[10-12] A small number of thiosugars have been isolated from natural sources; these include 5-thiomannose, salacinol and kotalonal.[1, 3, 13]

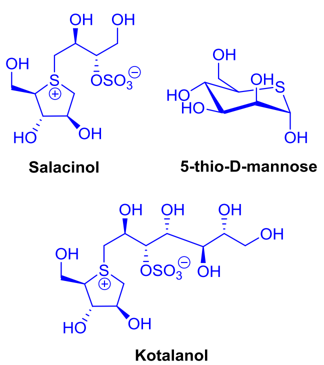

Figure 1. Structures of naturally occurring thiosugars.

In order to study the biological activity of thiosugars and to fully exploit their therapeutic potential, it is necessary to investigate new synthetic methodologies to access their core structures and to prepare analogues. In recent years, a range of efficient strategies have been investigated for the synthesis of thiosugars and these have been extensively reviewed elsewhere.[1, 14-17] Herein we review our recent synthetic studies into the use of intramolecular, thiyl-radical mediated cyclization reactions as a novel strategy for preparing thiosugars as glycosidase inhibitors.[18, 19] Very few examples of intramolecular thiol-ene reactions have previously been reported. Surzur and co-workers have investigated the cyclization of alkenyl mercaptans and they showed that the pent-4-enylthiyl radical **2** generated from the thiol **1** upon UV-light irradiation, cyclized to give a mixture of both five- and six-membered rings, with the six membered rings being formed preferentially.[20, 21] The reversible nature of the thiol-ene reaction allows reaction conditions to be varied in order to promote formation of either the kinetic or thermodynamic product.[22, 23]

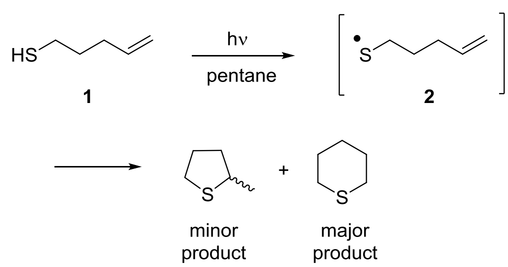

Figure 2. Early studies into the cyclization of alkenyl mercaptans by Surzur and co-workers.

The use of intramolecular thiyl-radical cyclization reactions has not previously been investigated for thiosugar synthesis despite offering several synthetic advantages over ionic methodologies. The reaction can be initiated either photochemically or thermally, and the efficient radical chain process offers excellent yields and atom economy.[23] By taking advantage of the reversible nature of the radical cyclization and by promoting either the 5-*exo* or 6-*endo* cyclization, it is possible to prepare both pyranose and furanose thiosugars from the same starting materials. These reactions can be carried out under very mild activating conditions and can tolerate of a range of protecting groups.[24-26] They are also compatible with aqueous conditions which may allow for fully unprotected or partially protected substrates to be used.[24]

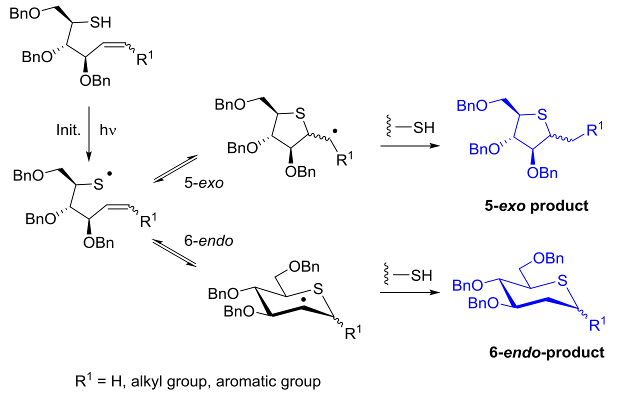

Figure 3. General scheme outlining intramolecular, thiyl-radical cyclization reactions to access both 5-*exo* and 6-*endo* thiosugar products.

In our initial studies into the preparation of thiosugars *via* the intramolecular thiol-ene process, we studied the products formed upon cyclization onto a terminal alkene. The alkenyl mercaptan starting material **3** was prepared starting from commercially available *O*-benzyl protected arabinose.[18] Photolysis of thiol **3** under optimized reaction conditions in the presence of a radical initiator 2,2-dimethoxy-2-phenyl-acetophenone (DPAP), and a photosensitizor, 4-Methoxyacetophenone (MAP), at room temperature for 60 min furnished the 6-*endo* product **9** as the major product in 72% yield.[18] The 5-*exo* products **6** and **7** were also isolated albeit in a low combined yield of 12%. This is the expected product distribution for an intramolecular, thiol-ene cyclization reaction involving a terminal alkene. On the basis of stereoelectronic factors, the 5-*exo*-trig cyclization processes should be favored over the corresponding 6-*endo* mode.[23] However, because of the reversibility of the addition of the thiyl-radical onto alkenes, the six-membered ring can be formed preferentially. Compound **9** is an example of a 1,2-dideoxy thiosugar. Similar compounds have previously been prepared as glycosidase inhibitors, starting from glycals.[17]

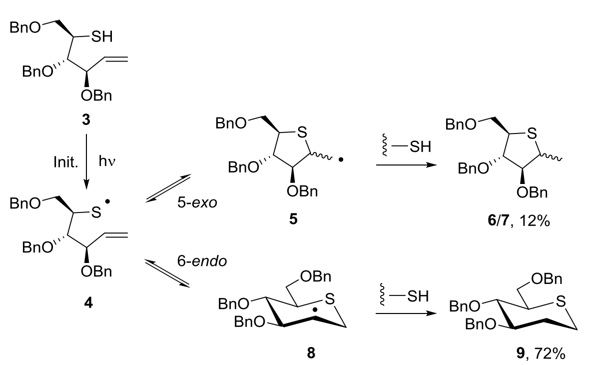

Figure 4. Product distribution of thiyl-radical cyclization reaction starting from alkenyl mercaptan **3**.

The resulting thiopyranoside **9** was deprotected using Birch reducing conditions; thereby demonstrating that fully deprotected thiosugars suitable for biological screening could be accessed using this methodology.

Following the encouraging results obtained from the cyclization reactions onto a terminal alkene, we next set out to investigate cyclization reactions onto substituted alkenes.[19] It was anticipated that substituted alkenes would promote the 5-*exo* cyclization pathway resulting in formation of substituted thiofuranosides. Treatment of thiol **10**, itself prepared from *O*-benzyl protected arabinose,[19] under the previously optimized cyclization conditions developed for the terminal alkene,[18] furnished the expected 5-*exo* products **13** and **14.** These were the only products observed in this reaction and were isolated in a yield of 91% as a mixture of diastereoisomers **13/14** (3:1, β:α). The free-radical cyclization reaction proceeded in high yield with complete regioselectivity for the 5-*exo* products and good diastereoselectivity in favor of the 1,2-trans product **13**. The competing 6-*endo* product **16** was not observed under these conditions. This result clearly demonstrated that 5-*exo*-trig radical cyclizations of a thiyl-radical onto a substituted alkene could be applied to the preparation of thiofuranosides in high yield.

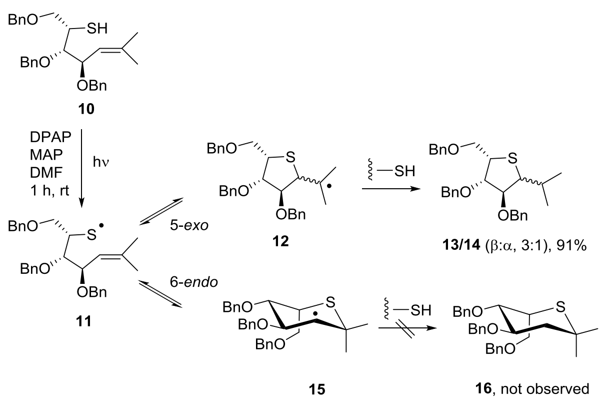

Figure 5. Product distribution of thiyl radical cyclization reaction starting from alkenyl mercaptan **10**.

The diastereoselectivity of the free radical cyclization can be rationalized by considering the structure of the transition states.[27-29] In the case of thiyl radical **11**, formation of the chair-like transition structure **A** is probably favored since it minimizes steric interactions between the isopropyl group at C-1 and the benzyl protecting group at C-2 which gives the 1,2-trans product **13** as the major diastereoisomer. The 1,2-cis product **14** was formed as the minor product. The structure of each diastereoisomer **13** and **14** was confirmed by detailed NMR analysis techniques, including Rotating frame nuclear Overhauser effect spectroscopy (ROESY). An alternative pair of transition state structures (**C** and **D**) can also be proposed for the formation of **13** and **14** whereby the benzyloxymethyl group occupies an equatorial orientation and the two benzyloxy protecting groups are both axial. This alternative TS places the majority of substituents in a quasi-axial orientation. The alternative TS is worth considering since it has known that in L-hexose sugars the bulky hydroxymethyl group can lock the conformation to one in which it is equatorial even if this means that other substituents have to adopt an axial orientation. In this case it would be the boat-like TS **D** that would result in formation of the observed 1,2-trans product. Detailed computational studies are underway in order to further investigate the transition structures for this process.

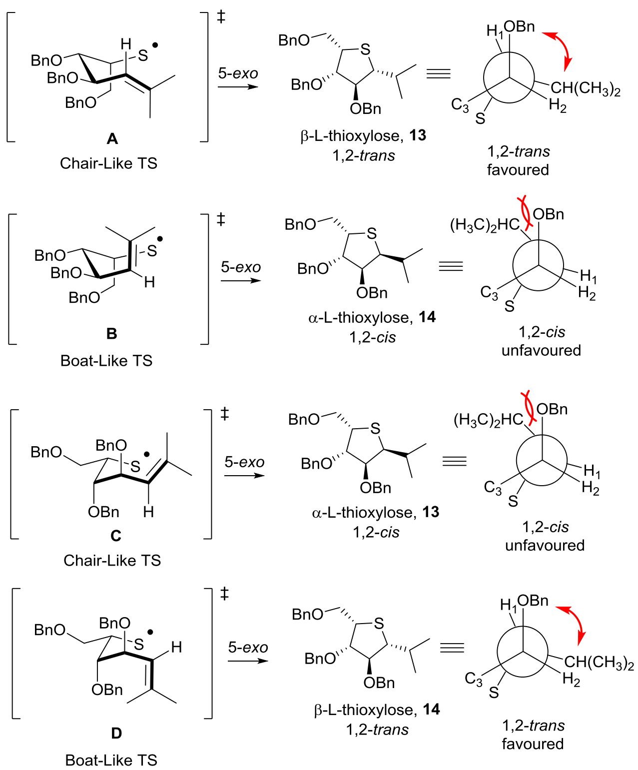

Figure 6: Proposed Transition State structures for cyclization reaction of **11** to furnish **13** and **14**.

Using this novel radical methodology, a number of novel thiofuranoside products were prepared in good yield and with good to excellent diastereoselectivity.[19] Examples of C-linked thiofuranosides containing pendant aromatic groups were prepared as putative glycosidase inhibitors. Examples of thiosugars ligated with a Dansyl fluorophore were also prepared in order to furnish fluorescently labeled thiosugars.

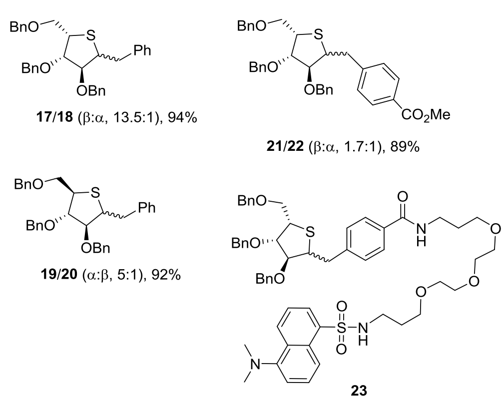

Figure 7. Structures of novel thiofuranosides prepared via free radical cyclization methodology.

Concluding Remarks and Future Outlook

This review article highlights the recent advances made in the synthesis of thiosugars using free-radical mediated, intramolecular cyclisation reactions. The methodology offers an efficient and high yielding strategy for accessing novel thiosugras as putative glycosidase inhibitors. Careful consideration of kinetic and thermodynamic factors allows access to both thiofuranosyl and thiopyranosyl products. The methodology is robust and diastereoselective, allowing rapid access to thiosugar derivatives with high yields under carefully controlled conditions. The level of diastereocontrol observed for the 5-*exo* cyclization reactions is remarkable given that the systems contain multiple stereogenic centers and that all reactions were carried out at room temperature. Investigations into the use of this methodology for the preparation of other sulfur containing heterocycles are ongoing in our laboratory and results will be reported in due course.

Acknowledgements

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The State of Chemical Education in Ireland

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Introduction

In this article I want to survey the state of chemical education in Ireland in 2014. This is a big topic as it covers all aspects of the education system from **primary level to postgraduate** (fourth) level, including the training of science teachers, and also includes consideration of the employment of chemists, particularly in Ireland's successful pharmachemical sector, and the professional status of chemists. I reviewed the challenges in chemical education in the mid-90s in my Boyle-Higgins lecture in 1995 (Childs, 1995) and have more recently surveyed the situation in Ireland in the book *Chemistry Around the World* (Childs, 2010a) and also in Childs, 2010b. However, there have been so many changes since then and since we are currently in a time of rapid change, it is appropriate to review the existing situation and also look at some of the current and future issues. Chemical education is healthier at the moment at both second-level and third-level than it has been for many years; chemical research in third-level institutions (as well as the newly-emergent area of science education research) is flourishing; and the bio/pharmachem industry has weathered the recession well and continues to grow. It is probably true to say that Ireland now punches above its weight (i.e. its size and population) in both scientific research and also in its high-tech industry (pharmachem and ICT). The quality of chemical education in schools and third-level institutions is the key to sustaining these achievements, and this in turn depends on the quality of our second-level and third-level teachers.

Changes over the last 35 years

I have been in Ireland since 1978: initially in Thomond College of Education and then in the University of Limerick, where I taught Chemistry to undergraduates and trainee science teachers and was also involved in chemistry pedagogy for pre-service science teachers (PSSTs). The chemical education scene has changed over that period in many ways and in the sections below I will review the changes and the state of play in each area. Figure 1 shows the structure of the Irish education system.

A number of important reports have been published in Ireland and in Europe in the last 10-15 years, which are concerned with science education, particularly in schools. Some of these reports are listed in Appendix 1. One major issue is the demographic change in Ireland in the last few years, resulting in a bulge in

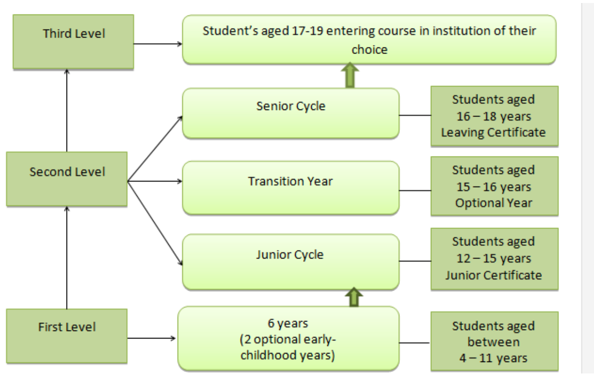

Figure 1. The structure of the Irish education system.

student numbers now working its way through primary schools. Table 1 shows the number of Irish births from 2006 to 2013 and the ~ date of entry into post-primary school. From birth it takes ~12 years to enter post-primary education and another 5/6 years to the LC exams. So the LC class of 2012 would have been born in ~ 1995 when the birth rate was 48,530. We have had a lot of immigration and more recently some emigration since then, but this figure is in line with this year's LC numbers of 55,815. The birth rate figures jump around 2001, and from 2009 they have started to decline. The figures indicate an expansion of primary numbers from ~2006 until ~2014 and in post-primary from ~2014 to 2020, which will continue to increase from year to year, before starting to decline. These data have major implications for schools and third level institutions and more schools, more teachers and more places at third level will be needed in the future. Figures from the ESRI show that Ireland still has the highest birth rate in the EU – 15.6/1000 compared to the EU average of 10.4/1000. (http://www.esri.ie/__uuid/9495a3d4-7e97-4588-a1d3-c091fa1e7838/NPRS2012.pdf)

Table 1. Irish birth rates 2006-2013.

Year	No. of births	~Date in post-primary
2006	64,237	2018
2007	71,389	2019
2008	75,173	2020
2009	75,554	2021
2010	73,724	2022
2011	74,650	2023
2012	~71,986	2024
2013	<72,000	2025

A recent publication (July 2013) looks at 'Projections of full-time Enrolment in Primary and Second Level, 2013 – 2031' (available at http://www.education.ie/en/Publications/Statistics/Statistical-Reports/Projections-of-full-time-enrolment-Primary-and-Second-level-2013-2031.pdf), and is an update of one published in 2012; the data are shown in Table 2. These projections are more than those made a year earlier and are also probably out-of-date and

Table 2. Estimated numbers at primary and post-primary levels 2012-15

Year beginning	First Level	Second Level
2012 (provisional)	526,426	327,320
2013	539,127	335,250
2014	552,019	339,332
2015	563,744	343,208

underestimate the growth in student numbers. This September (2013) ~71,000 students entered primary school. These figures have massive implications for schools and for third level institutions in the future. More schools, more classrooms, more teachers will needed at primary and post-primary levels to cope with the increase in numbers. The most probably scenario for change would suggest an increase in enrolments at primary level to 596,440 by 2019, and a continuous decline thereafter, to a level of 462,763 by 2031 and a year-on-year increase in second-level enrolments to a peak of 416,262 over the period considered (occurring in 2026), with a decrease in enrolments occurring from that point, to a level of just under 387,400 by 2031.

Primary level: Primary Science

Science was only formally introduced into primary schools in 2003, although in the 1980s there was a pilot project on primary science, the Primary Schools Science Project (PSSP), running in Limerick, as a collaboration between Thomond College of Education, the Limerick Education Centre and Mary Immaculate College, Limerick. The work of this project fed into the curriculum revision that led to the introduction of primary science. Science had been there in primary schools before but was dropped in the 1930s in favour of Irish. Ireland was behind other European countries in making science a core component of the primary curriculum. Science is one component in years 1-6 as a component of Social, Environmental and Scientific Education, and consists of four strands:

- Living things
- Energy and forces
- Materials
- Environmental awareness and care.

However, there are still concerns about the amount of time spent on science in primary schools, the poor science background of primary teachers, the limited time spent on science in the primary teacher training colleges, the poor liaison between primary school and junior secondary school, and the lack of science-based CPD for primary teachers. Several projects are running to encourage primary science (SciFest, BT Young Scientists, Discover Science etc.), and there is some excellent science teaching going on in primary schools.

Post-primary level

Junior cycle – Junior Certificate Science

The current Junior Science course is a general science course, which involves Biology, Chemistry and Physics. This course was introduced in 2003 and included for the first time the assessment of practical work (Coursework A and B), worth 35%. Science is offered at Higher and Ordinary level and is taken by just over 90% of students, with slightly more boys than girls taking it.

Table 3. Junior Certificate Science statistics 2011-2013 (Source: State Examination Commission)

	2011	2012	2013
Total JC cohort	59,823	58,798	56,930
JC Science HL (%)	42,423 (78.69)	39,990 (76.02)	38,072 (75.31)
JC Science OL (%)	11,489 (21.31)	12,615 (23.98)	12,485 (24.69)
JC Science Total	53,912	52,605	50,557
% boys:girls	51.9:48.1	52.1:47.9	52.6:47.4
% cohort taking JC Science	90.12	89.47	88.81

However, the numbers of boys and girls taking it is nearly in balance (Table 3). Science is not a compulsory or core subject but is unique among Junior Certificate subjects in feeding into five Leaving Certificate subjects: Agricultural Science, Biology, Chemistry, Physics and Physics with Chemistry. A major strength of the Irish system is that all junior cycle students take Mathematics, either at Higher, Ordinary or Foundation level. The existing traditional syllabus is in the process of a phased replacement by Project Maths, which emphasises the applications of Mathematics. Box 1 shows the content of the current Junior Science course.

There are a number of concerns around the Junior Science course:

a) Most science teachers will teach Junior Science, but the majority of these have a Biology background and are not as confident in teaching Chemistry and Physics. This leads to an emphasis on Biology, which may explain the dominance of Biology in Leaving Certificate science. The RSC has just started (in 2012) courses in Ireland, based on a UK model, for non-specialists (mainly Biologists) to equip them to teach Chemistry more confidently and effectively.

b) The lack of technical assistance in schools for science teachers means that science teachers have to be both laboratory technician and teacher. With a full teaching timetable this is difficult and means that the quality of practical work suffers. A few schools, particularly private schools, have managed to employ laboratory technicians, and

1. Biology

1A Human Biology – food, digestion and associated body systems

1B Human Biology – the skeletal/muscular system, the senses and human reproduction

1C Animals, plants and micro-organisms

2. Chemistry

2A Classification of substances

2B Air, oxygen, carbon dioxide and water

2C Atomic structure, reactions and compounds

3. Physics

3A Force and energy

3B Heat, light and sound

3C Magnetism, electricity and electronics

Box 1. Content of the Junior Certificate Science course.

this has improved their delivery of science as a practical subject. (This same concern applies to Leaving Certificate sciences as well.)

c) Teachers have expressed a lot of concern since the introduction of the new syllabus and the assessment of practical work about their lack of preparation for this, particularly the project work in Coursework B, and the problems of running project work with large classes. The mandatory experiments (Coursework A) have become cookbook exercises, dominated by writing reports (often in a rigid format), with no consistent external monitoring. Inspectors may inspect the reports during whole school inspections but this does not monitor how practical work is actually done.

The concerns about the past are nothing compared to the concerns about the future. At the moment Ireland is in the throes of a major, top-down revision of the Junior Cycle course. This is due to start in September 2014 with English and Science will follow in 2015. The teachers' unions have expressed major concerns about the lack of consultation, the implications for resources, the amount of CPD to be provided, a focus on generic skills rather than subject content, and the change from an externally monitored state examination (the Junior Certificate) to school-based assessment, mainly based on continuous assessment. The science community is also concerned that Science will not be a core subject (confined to Irish English and Mathematics), and that the science course will be reduced from 240 to 200 hours contact time. The syllabus committee is working at the moment on the science specification. There is also an option for individual schools (or groups of schools) to develop short modules (100 hours), which could be science-based.

Senior cycle – Leaving Certificate Science

There are five Leaving Certificate science subjects: Agricultural Science, Biology, Chemistry, Physics and Physics with Chemistry. Each of them is offered at Higher and Ordinary levels. Figure 2 shows the percentage of the Leaving Certificate cohort who took each subject over the past 12 years, since the first examinations of the revised Chemistry and Physics syllabi, introduced in 2000. The data are normalised to allow for variations in the LC cohort from year to year. The Chemistry and Physics syllabi replaced the 1983 syllabi; a new Biology syllabus was introduced in 2002 and first examined in 2004, as it was over 30 years old. It has just been announced that the Agricultural Science syllabus will be revised for 2015, having been introduced in 1972. The combined Physics with Chemistry course has not been revised for over 40 years, although the NCCA did produce a draft syllabus some years back. None of the current LC science syllabi includes assessment of practical work, except through written questions. Although school-based practical assessment was proposed for the 2000 syllabi, agreement could not be reached with the teachers' unions and the proposal was shelved. The assessment of practical work in Irish science courses has been reviewed recently by Kennedy (2012).

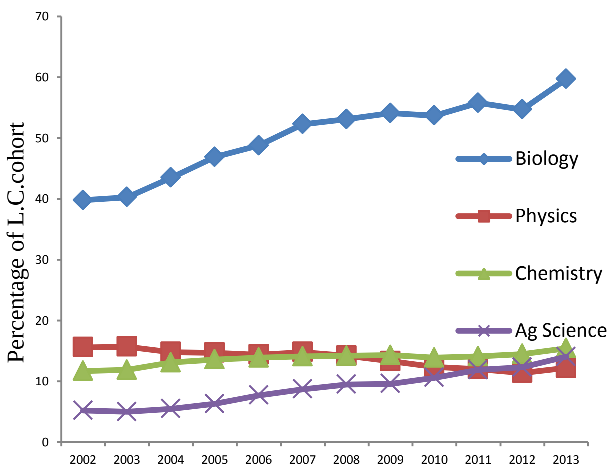

Figure 2. Percentage uptake of LC Science subjects (2002-2013)

These syllabi include mandatory experiments, which must be performed and written up and the notebooks available for inspection. Table 4 shows the topics covered in the current syllabus. The Chemistry course has the following components:

• pure chemistry, 70%
• applications of chemistry, 22.5%
• chemistry for citizens, 7.5%

Table 4: The content of the 2000 LC Chemistry syllabus (DoES)

Ordinary and Higher Level Syllabus
Ordinary/Higher Level Core
1. Periodic Table and Atomic Structure
2. Chemical Bonding
3. Stoichiometry, Formulas and Equations
4. Volumetric Analysis
5. Fuels and Heats of Reaction
6. Rates of Reaction
7. Organic Chemistry
8. Chemical Equilibrium
9. Environmental Chemistry: Water

Ordinary/Higher Level: Option 1
1A. Additional Industrial Chemistry
1B. Atmospheric Chemistry

Ordinary/Higher Level: Option 2
2A. Materials
2B. Additional Electrochemistry and the Extraction of Metals

However, what is actually taught and how it is taught is often determined by the examination and reviews of the examination papers showed an inconsistent assessment of the 30% for applications and chemistry for citizens (often referred to as Science Technology and Society, STS) and that the examination papers also favoured lower order questions, with very few higher order questions.

The actual numbers taking the LC science subjects are shown in Table 5. Chemistry stands out as the science subject with the highest proportion of HL candidates and it also is the science subject with the closest gender balance. The dominance of Biology is striking and its popularity has increased from 40 to

Table 5. LC Science - % doing Higher Level and Ordinary Level 2013

	2013	HL 2013 (%)	OL 2013 (%)	%LC Cohort 2013	Ratio F:M 2013
Biology	31,500	74.4	25.6	59.7	1.45:1
Chemistry	8,155	82.8	17.2	15.45	1.13:1
Physics	6,448	74.9	25.1	12.2	0.31:1
Phys.+Chem.	423	78.0	22.0	0.80	0.57:1
Ag. Science	7,414	80.3	19.7	14.05	0.60:1

60% over this period; Physics has been in slow decline and Chemistry has recovered from a low of 11% to just over 15%. The other striking thing is the growth of Agricultural Science, now the third most popular science. Only Biology, at 4th place, is in the top 10 LC subjects. The existing Chemistry syllabus can be accessed at http://www.education.ie/en/Schools-Colleges/Information/Curriculum-and-Syllabus/Senior-Cycle-/Syllabuses-and-Guidelines/lc_chemistry_sy.pdf, together with Guidelines for Teachers.

All the three main science syllabi are in the process of being revised. The draft syllabi were distributed for consultation in 2011 and after this the final forms of the syllabi were produced and are on the NCCA website. This is a major revision in content and in approach, focusing on learning outcomes rather than detailed specification of content and depth of treatment. The most radical change is the inclusion of 20% for practical assessment. It is intended to use a school-based practical assessment, as well as monitoring students' practical reports. The details of this still have to be decided and the assessment of ~45,000 students across all three sciences is a formidable logistical challenge, which will also be very expensive. It is also proposed to alter the form of the written examinations to make them less predictable and a better test of understanding rather than memory. The draft Chemistry syllabus can be consulted at http://www.ncca.ie/en/Consultations/Senior_Cycle_Science/CSLC.pdf. It has recently been announced that the new LC syllabus is not likely to be introduced until 2020.

Table 6 shows the structure of the draft syllabus, which consists of 5 units of study. Compared to the existing syllabus there are fewer sections but each of the unit is broken down (Figure 3) into sub-topics.

Table 6: The structure of the draft new LC Chemistry syllabus (NCCA)

Unit 1: Scientific methods Unit 2: Properties, structures and bonding Unit 3. Controlling and using chemical change Unit 4: Organic chemistry Unit 5: Environmental chemistry

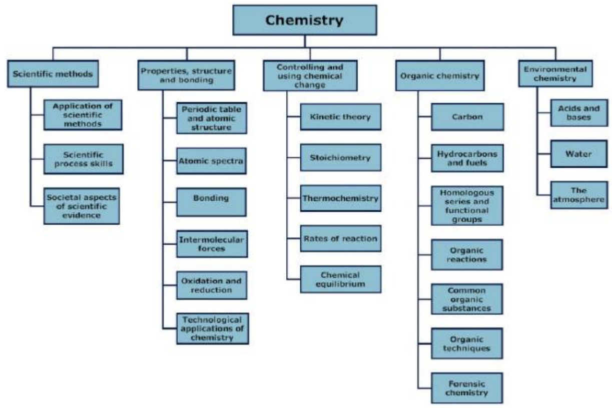

Figure 3. The structure of the draft LC Chemistry syllabus 2013 (NCCA)

There are a number of concerns about the new LC Chemistry syllabus (which also apply to the other sciences):

a. The level of detail in the learning outcomes with respect to depth of treatment and the difference between the HL and OL course.

b. The level of CPD which will be provided to support the new approach and content;

c. The major issues surrounding the assessment of practical work, both the in-school assessment by teachers and the practical proposed examination;

d. The impact of a change in the style and format of the examination on teaching;

e. The degree to which the new syllabus will mesh with the content and approach of the proposed new Junior Science course, as there is already concern about the large jump in demand and difficulty between junior and senior cycles.

f. The perennial question of adequate resourcing and suitable laboratory facilities, particularly if there are greater demands on practical work, and the lack of technical support in Irish schools.

Transition Year Option: the place of science

The Transition year Option (Figure 1) is an optional year after the junior cycle and can be considered as a third year of the senior cycle for those schools that offer it and those that take it. However, although there is no set curriculum and no examination, apart from general guidelines, these do specify that the year should not be used as an extra Leaving Certificate year. The year is designed for personal development and maturation, so that students will enter the Leaving Certificate course a year later and progress to third level a year older than usual. Some research has shown that students who take the TYO perform better in their Leaving Certificate examinations. Hayes (2011) has conducted a major study of the place of science in the TYO, which showed that around two-thirds of teachers do teach parts of the Leaving Certificate course.

Often teachers do not know how to make use of this opportunity to explore science outside the confines of a syllabus and the TY Science project at the University of Limerick has been developing STS-type modules for the TYO since 2003. The TYO offers science teachers an opportunity to make science interesting and rekindle their students' interest in science, which is often extinguished by the Junior Science course. There is some evidence that using interesting materials and teaching science in a different way does encourage more students to take science for their Leaving Certificate, particularly the physical sciences. TYO is definitely an opportunity waiting to be used by science teachers to promote their subjects.

Tertiary level – Chemistry/science courses

There are 7 universities and 15 Institutes of Technology (including DIT) in Ireland and all of them offer courses in Chemistry (or Chemistry-related courses) and in other sciences. Third level courses run from level 6 (Certificate), level 7 (Pass Degree/Diploma), level 8 (Honours degree), level 9 (Master's degree) and level 10 (Doctorate). (National Framework for Qualifications, www.nfq.ie) Originally the Institutes of Technology (IoTs), then designated as Regional Technical Colleges, were set up to offer courses to technicians (at levels 6 and 7), but have moved into offering level 8 and research degrees (levels 9 and 10). There is now considerable duplication of courses at third level and competition between institutions for the same students. In the CAO system students put down their top 10 choices for both level 8 and level 6/7 courses and will usually be offered places from both lists. Given a choice most students accept a level 8 place, usually at one of the universities. This means that the cut-off points for entry to courses is usually much higher for level 8 courses and often higher at universities than at IoTs. Entry to third level is determined by the points achieved for the 6 best LC subjects (maximum 600 points), plus 25 points for a D grade or higher in Higher Level Mathematics since 2012. The bonus points for Mathematics have increased the points for most courses. The cut-off points needed for any particular course, reflects supply and demand: how many student apply in relation to the number of places offered. Thus popular courses, or those with few places on offer, will have a high cut-off. Traditionally Medicine and Pharmacy have had the highest points.

A positive change in the last few years has been an increase in first preferences for science and technology courses, which has resulted in better students being offered places as the cut-off level is higher. Thus Science at UCD had dropped to 300 points and within 6 years had reached 500 points. However, there is no overall planning of the type of courses offered or the number of places available, and a few years ago the universities were filling their courses with weaker students, at the expense of level 6/7 courses in IoTs, some of which dropped as low as 150 points. These issues were discussed in the RIA symposium on *Making the best of third level science* (RIA 2009). Table 7 shows first preferences for level 8 courses from 2009-2013, and these show the small increase in popularity of science and technology courses (excluding heathcare).

The influx of funding for research from SFI and other programmes since 2000 has increased the research effort in Irish third level institutions and Ireland's international research record has improved considerably. The health of fourth level Chemistry is evidenced by the numbers attending and the quality of students

Table 7: Level 8 First Preference Application by Discipline (HEA, 2013)

2009 – 2013 Discipline	**2009**	**2010**	**2011**	**2012**	**2013**
Engineering	2,309 (3.9%)	2,530 (4.1%)	2,588 (4.2%)	2,668 (4.3%)	2,813 (4.6%)
Construction	2,318 (3.9%)	1,824 (2.9%)	1,379 (2.2%)	1,188 (1.9%)	1,035 (1.7%)
Computing	2,669 (4.5%)	2,984 (4.8%)	3,374 (5.5%)	4,037 (6.5%)	4,022 (6.6%)
Science	3,911 (6.7%)	4,194 (6.8%)	4,029 (6.6%)	4,337 (7.0%)	4,570 (7.5%)
Total Technology	***11,207 (19.1%)***	***11,532 (18.6%)***	***11,370 (17.7%)***	***12,230 (19.8%)***	***12,440 (20.5%)***
Agriculture and Veterinary	1,393 (2.4%)	1,431 (2.3%)	1,665 (2.7%)	1,862 (3.0%)	1,848 (3.0%)
Nursing	5,227 (8.9%)	5,541 (8.9%)	5,585 (9.1%)	5,775 (9.3%)	5,807 (9.6%)
Medicine	3,356 (5.7%)	3,755 (6.0%)	3,591 (5.8%)	3,719 (6.0%)	3,480 (5.7%)
Dentistry	304 (0.5%)	347 (0.6%)	298 (0.5%)	295 (0.5%)	287 (0.5%)
Other Healthcare	3,148 (5.4%)	3,583 (5.8%)	4,068 (6.6%)	4,217 (6.8%)	4,415 (7.3%)
Arts and Humanities	14,550 (24.7%)	15,851 (25.5%)	15,395 (25.0%)	14,688 (23.7%)	14,453 (23.8%)
Education	6,813 (11.6%)	6,608 (10.6%)	6,652 (10.8%)	6,081 (9.8%)	5,558 (9.2%)
Business and Law	9,666 (16.4%)	9,216 (14.8%)	8,547 (13.9%)	8,509 (13.8%)	8,432 (13.9%)
Social Services	1,699 (2.9%)	2,311 (3.7%)	2,367 (3.9%)	2,375 (3.8%)	2,033 (3.3%)
Services	1,436 (2.4%)	1,907 (3.1%)	1,930 (3.1%)	2,095 (3.4%)	1,986 (3.3%)
Total	**58,799 (100%)**	**62,082 (100%)**	**61,468 (100%)**	**61,846 (100%)**	**60,739 (100%)**

presenting each year at the Institute of Chemistry of Ireland's Chemistry Colloquium. More funding is available for research (through SFI and IRC) than ever before, but ~50% of the postgraduates in Science are from outside Ireland. The indigenous pipeline for Chemistry postgraduates, which starts in schools, is not producing enough, well-qualified graduates to fill all the available positions. There is also concern about the career paths for research scientists in Ireland, as industry and academia cannot absorb all the PhDs produced.

Concerns have been expressed about grade inflation at both the Leaving Certificate level and at degree level (see www.stopgradeinflation.ie). The evidence shows that despite widening the ability range of pupils doing the LC, the % getting top grades have increased and the average CAO score has increased. Concern about this was raised in 2009 and 2010 by several business leaders and the Minister of Education and Skills initiated an enquiry. This confirmed the findings of an independent group that the % getting high grades has increased in all LC subjects. The same concerns have been expressed at third level where despite greater numbers of students (>60% of the LC cohort), with a wider range of ability entering the system, the % getting top grades (1 and 2.1 degrees) has increased. There is also considerable variation between institutions, despite similar intake. This raises concerns about the effectiveness of the external examiner system to monitor standards between institutions. Employers have expressed concerns about the quality of Irish graduates and about the possible 'dumbing-down' in the Irish education system at all levels.

Chemistry teacher training

Science teachers are produced by two routes in Ireland: the four-year concurrent model, where students from school study science, education, subject pedagogy and do teaching practice. They are able to teach Junior Science and usually two LC science subjects, sometimes with Mathematics. Such courses are now offered by several institutions: DCU, UL, NUIM, UCC, UCD. There is a move to convert the 4-year, level 8 course into a five year level 9 course, where students graduate with a master's degree (already underway in NUIM and UCD). The older consecutive route is the one year (now two years) Professional Diploma in Education (PDE), formerly the H.Dip.Ed, and this is done after completing a science degree. This course is offered by TCD, UCD, UCC, NUIM, NUIG and Hibernia. (See Table 10 for details of courses offered.) The Task Force on the Physical Sciences (Task Force, 2002) was set up at the turn of the century to see how to promote the physical sciences in schools. There was concern that although numbers in Biology were healthy, both Physics and Chemistry were declining in popularity, and (mistakenly) concluded, in my opinion, that a shortage of teachers was a major factor. Since then the output of science teachers has increased dramatically and Ireland has been producing a surplus of science teachers for some years, including in the physical sciences. Very few pre-service science teachers (PSSTs) are able to find jobs when they graduate and must wait years for permanent jobs. The recession and cutback in teacher numbers has made this worse. It should improve in the future as the bulge of students in primary level moves into second level. However, it is a reminder that there is no planning concerning second-level teacher numbers and it is left to the whims of the market. Teaching is still a popular choice and the concurrent courses attract large numbers of well-qualified students.

Teacher education provision is to be concentrated in six regional groupings, centred around universities (Table 8), and the report emphasises the importance of research for teacher educators. This is based on the 2012 Report of an expert group (DoES, 2012).

Table 8: The six regional groupings of initial teacher education (DoES, 2012)

Dublin City University – St. Patrick's College Drumcondra – Mater Dei Institute of Education
Trinity College Dublin – Marino Institute of Education – University College Dublin – National College of Art and DesignNational
University of Ireland Maynooth – Froebel College
University of Limerick – Mary Immaculate College – Limerick Institute of Technology
University College Cork – Cork Institute of Technology
National University of Ireland Galway – St. Angela's College Sligo

All teachers must now be registered with the Teaching Council, who check qualifications and assess whether someone is allowed to teach a subject. Box 2 shows the requirements for a Chemistry teacher, although the 30% is being revised to a minimum of 60 ECTYS credits (a level 8 honours degree is 240 credits). There is no comprehensive data on the numbers of science teachers with a particular teaching specialism and the latest figures for 2012-13

Special Requirements for Recognition to Teach Chemistry

Applicants must provide officially certified evidence of satisfactory achievement in primary degree studies (or equivalent) as outlined hereunder:

- content or where studies were in a related subject area will require specific assessment to determine equivalence
- Details of course and practical work content completed during the degree programme together with teaching/tutorial times, list of experiments and practicals
- Explicit details of standards achieved in degree studies in Chemistry with at least an overall Pass result in the examinations in Chemistry
- The study of Chemistry as a major subject in the degree extending over at least three years and of the order of 30% at a minimum of that period
- Details of the degree course content to show that the knowledge and understanding required to teach Chemistry to the highest level in post-primary education has been acquired
- Details of degree course content where the studies involved modular or applied subject

Recognition to teach Chemistry also confers recognition to teach Science in the Junior Certificate programme.

Box 2. Requirements for teaching LC Chemistry (www.teachingcouncil.ie)

are given in Table 9 for teachers registered to teach a particular subject. All teachers now have to be registered with the Teaching Council in order to get a job or to retain their job. To satisfy the Teaching Council the second level teacher has to have had enough hours (ECTS credits) in their degree. This means that teachers are now identified by what they can teach. In the DoES 2012/13 Statistical Report there is a listing of registered teachers. However, the total number is listed only 9,785, which is far less than the 25,374 second level teachers given elsewhere in the Report. Is this because the data hasn't caught up with the registrations? If so this means we would have to scale up the figures given by ~2.5 to get the correct figures. However, the subject specialism listed is still interesting in what they tell us about the subject balance within second level science teachers. There have to be more science teachers in schools since the numbers listed are less than the numbers of schools offering the LC science subjects. However, teaching a subject does not imply a qualification in the subject and once registered and in a school, a teacher can be asked to teach any subject!

Many science teachers teach more than one subject and many also teach Mathematics. From these data science teachers make up 11.35% of all second level teachers. Given that there are 694 second level schools it seems likely that not all science and Mathematics teachers are included in these statistics. Many

Table 9: The numbers of registered science teachers 2012-2013 (Source: DoES)

	Males	Females	Total
Biology	105	259	364
Chemistry	63	134	197
Physics	60	43	103
Agricultural Science	27	45	72
Total science teachers	255	481	736
Mathematics	141	249	390
Total second-level teachers	3,541	6,244	9,785

people teaching Mathematics do not have a primary qualification in Mathematics and there is an ongoing CPD programme to qualify out-of-field teachers in Mathematics, which is training hundreds of teachers. On a smaller scale short courses in Chemistry for Non-Specialists were started in 2012 by the Royal Society of Chemistry's Education Division Ireland Region.

What these figures do show is that Biology teachers make up nearly 50% of science teachers and 65.3% are female. If we add in Agricultural Science to Biology, the life sciences teachers make up 59% of this population of science teachers. Physics teachers are particularly thin on the ground and the gender balance in the teachers reflects the gender balance in the LC science student population.

If we scale up the figures above by 2.5 this would mean there are about 1,840 science teachers. Given that there are 694 second level schools, all of whom teach Junior Science and some LC science subjects, we would expect all schools to have at least 3 science teachers and some have many more. If we took an average of 5 per school, this would give a total of 3,475 science teachers. This would be a substantial pool of possible members for the ISTA, which has ~ 1,000 members. It will be interesting to see if the DoES 2013-14 Statistical Report will include all second level teachers and their specialism.

Research in chemical education

One encouraging development in science education in Ireland over the last 10-20 years has been the growth of research in science education. This is evidenced by a number of centres for science education research (in DCU, DIT, UCC, UL WIT), the increasing output of postgraduate awards (Masters and PhDs) in science education, publications, conferences presentations and participation in international projects. Ireland is or has been a partner in several EU FP7 projects at the moment (ESTABLISH and SAILS – DCU; PROFILES – UCC; TEMI and Chain Reaction – UL), as well as Tempus (SALiS – UL) and Comenius projects (Chemistry is all around us – LIT). DCU hosts a biennial Science and Mathematics Education Conference (SMEC), and Ireland has hosted Variety in Chemistry Education and Eurovariety in Chemistry Education conferences, for third level chemistry lecturers. The annual ChemEd-Ireland conferences started in UL in1982 and now rotate around several third level institutions. Several taught MSc courses in science education are available for science teachers (in UCC, DCU, TCD, WIT).

Table 10: Science education in Irish third level institutions

Institution	Centre	EU Projects	Concurrent STE	Consecutive STE	MSc course
Dublin City University DCU St. Patrick's College	CasteL	ESTABLISH and SAILS Fibonacci	Yes – any two from Chemistry, Physics and Mathematics	No	Yes
Dublin Institute of Technology DIT					
University College Cork UCC	Eureka	PROFILES	Yes	Yes	Yes
University of Limerick UL	NCE-MSTL	TEMI, Chain Reaction and SALiS	Yes Biology and Ag. Science with Chemistry or Physics; Chemistry and Physics	No	
Waterford Institute of Technology		CALMAST			Yes (Primary Science)
NUI Maynooth NUIM			Yes – 5 years to Masters level	Yes	Yes – integrated with concurrent course
NUI Galway NUIG				Yes	
University College Dublin UCD			Yes Chemistry, Biology or Physics with Mathematics, 5 years to MSc level	Yes	Yes – integrated with concurrent course
Trinity College Dublin TCD				Yes	Yes

The future of chemistry and chemical education in Ireland

There are many encouraging signs regarding the future of chemistry and chemical education in Ireland:

- The chemical and pharmaceutical industry is still remarkably healthy and productive, even though it is increasingly focusing on biopharmaceuticals. The pharmachemical industry worldwide has been shaken up in the last 10 years by mergers, many drugs going off patent (the patent cliff), and a lengthy economic recession, with resultant plant closures and job losses. The industry in Ireland has weathered this remarkably well: many of the closed plants have been sold to other companies, companies have continued to invest and expand, and new pharmachemical companies have arrived. The Irish pharmachemical industry continues to provide high-quality jobs, albeit in small numbers (~30,000), and together with the ICT industry, has played a major role in keeping the Irish economy afloat during the recession. However, there has been a shift from chemical to biochemical-based drugs, altering the skill-set needed for new employees from pure chemistry to biochemistry.

- Numbers studying LC chemistry have increased and the subject has improved its market share slightly, although it has not recovered to the level of the early 1980s. Of the three main LC sciences, Chemistry is the one with the best gender balance, with a small excess of girls over boys.

- Science courses, including Chemistry–related courses, at level 6 and 8 have shown an increase in demand and the CAO points required have increased. This means that courses are being filled with better quality students than even 5 years ago.

- Investment in research by SFI and other bodies, has resulted in a massive increase in research effort, the number of research centres and institutes, and in the production of PhDs, publications and an increase in Ireland's research standing.

- Science teaching is still a popular choice (whether by the concurrent model of 4 years post second level or the consecutive model –now 2 years, post level 8 qualification). Thus the number of people choosing to train as science teachers is high and they are well qualified, although the physical sciences are still less popular than life sciences. However, there is a massive over-production of teachers and most of these teachers cannot find jobs in Ireland.

- Research in science education (including chemical education) has increased dramatically with several research groups based in third level institutions, involvement in several EU FP7 and Tempus projects, increased output of Masters and PhD students, and an increased number of publications, conferences and a more prominent international profile

However, there are some concerns, despite the many positive signs, and these are discussed briefly:

- The Junior Cycle is undergoing major reform at the moment, with a shift from a terminal examination to school-based continuous assessment, and a focus on key generic skills. Science is not a core subject and the subject will be cut from 240 hours to 200 hours. The content of the new course is currently under review and the new Science course is due to be introduced in 2015. The teachers' unions are concerned about lack of consultation, the speed of change and the change in assessment. The existing jump in difficulty from junior to senior cycle, already seen as a problem, in Science will be greater in the new proposals.

- The main LC Science subjects are also under revision and new syllabi in Biology, Chemistry and Physics have been developed and approved. There is a major change in structure, content and approach and a focus on learning outcomes rather than depth of treatment. A major change is the proposal for 30% of the marks to be given for practical work, though a school-based but externally monitored practical examination. This has not been properly piloted and there are major questions about the logistics and cost of such an assessment, particularly if done for all three sciences, totalling over 40,000 students. It is not known when the new syllabi will be introduced.

- It was often said that Ireland was short of science teachers, particularly for the physical sciences, and this has led to many new providers of science teachers, mainly through the concurrent model. Ireland now has a surplus of science teachers and a shortage of jobs, so that the majority of newly qualified science teachers cannot find employment, and those that do find themselves on part-time or temporary terms for many years. The situation may improve in the future with the growth of post-primary student numbers, but Ireland will still be over-producing science teachers.

- There is still no career-long scheme for professional CPD for teachers, to ensure that they refresh their subject knowledge and teaching skills throughout their careers. At the moment although there are a number of providers of CPD (ISTA, PDST, RSC, third-level institutions), participation at such courses is voluntary. There is also a need to resource schools adequately to teach practical subjects like science, and in particular to provide technical assistance for teachers in managing laboratories and preparing practicals. Very few schools have technicians, but in those who do, this has greatly improved their provision of practical work and reduced the burden on teachers.

- Although there has been a welcome increase in the number and quality of students opting for science courses at third level, particularly at level 8, there is still concern about the wide ability range of students, and their poor preparation for third level courses. This takes three forms: first, the current system favours rote learning and examination technique to maximise points, but does not encourage creativity or independent learning; secondly, many students meet particular subjects for the first time at third level, and thus start from scratch; thirdly, although all students take some level of Mathematics in the senior cycle, they do not always display the proficiency needed for success in third level science and technology courses, and there is concern that the new Project Maths course omits key areas of Mathematics. There is a need for remedial work at third-level, based on diagnostic testing, to bring all students to a suitable level and also to provide tuition in study and research skills appropriate for third-level study.

- The demographic change in the country, due to a high birth rate, now moving through primary schools, is going to have a major impact on post-primary schools and then later on third-level. This will mean new schools, more teachers, more pressure on places, and higher costs at all levels of the system. Under-resourced and under-staffed third-level institutions will be under even greater pressure in the next 10 years or so.

- The influx of research money from SFI and Europe has revolutionised scientific research in Ireland. However, there is a danger that this will result in a downgrading of the value of teaching. A focus on research can mean a neglect of teaching undergraduates, who are the future research students Ireland needs. It is already apparent that there are not enough Irish students to take up the increased number postgraduate opportunities, and Ireland is importing significant numbers of postgraduates. This is in many ways a good thing but it would be dangerous to become over-dependent on foreign students to fill our graduate schools, as has happened in the USA.

Some recommendations for action and change:

a) The combination of growth in numbers in education and the decreasing resources for education has serious implications for the future, at all levels of education. Teachers will be required to teach greater numbers with fewer resources in the future, with implications for quality. The same will also apply at third level, with fewer staff and more students. Some way needs to be found to harness the surplus of young science teachers being trained, who cannot find work in Irish schools (see f) below)

b) There is a need to rethink the purpose and nature of the school leaving examination to develop the skills and abilities needed for employment and for third level, as the system at the moment favours and rewards rote learning. There is little room for creativity, inquiry-based learning or problem solving in the Irish science curriculum. The inflation of grades is a result of the predictability of the examinations and teaching to the test. Teaching is often driven by the assessment and whatever the aims and objectives of the syllabus, these will not be achieved if the assessment does not test them.

c) Provision needs to be made for more innovation and experimentation in the school curriculum, outside the existing system controlled by the NCCA. Room needs to be given for groups to develop, test and evaluate alternative syllabuses with different approaches e.g. a like a Salter's context-based syllabus. At the moment the centralised curriculum development process in Ireland means that we end up with 'one size fits all' and 'any colour as long as it's black' in relation to the curriculum. In the UK, for example, schools have a choice of examination boards and also different Chemistry courses. Project Maths has been criticised because it has dropped some key areas of Mathematics by making the subject more widely acceptable. Why could we not have the old syllabus and project Maths running in parallel, allowing schools to choose which course to follow for their students? One group aiming to be scientists and engineers could then take the old course, while the majority do project Maths. At the moment if the syllabus committee gets it wrong, there is no recourse to any alternatives and schools are stuck with the syllabus for years.

d) There has been a lack of joined-up thinking in curriculum development between the NCCA (who design new syllabi and formulate the overall programmes), the Department of Education and Skills (where the Minister signs off on new courses and their implementation, and also runs the Inspectorate which monitors standards in schools), the State Examinations Commission (which decides the format of examinations, designs and oversees the marking of the papers, and determines standards), and the Teaching Council (which decides the qualifications for teachers of particular subjects). In my opinion there is not a close enough link between the NCCA and the SEC, so that the curriculum and assessment are designed together, not sequentially. This would mean, for example, that when a syllabus was put out for consultation there would also be details of how the syllabus was being examined, and likewise the final syllabus would be issued together with sample examination papers. In the past teachers have not known until the year before the first examination what the papers would look like.

e) Science-based industries have made a major contribution to Ireland's economy and have helped to keep it afloat during the recession. Over 50% of exports in 2009 were due to the pharmaceutical sector. (Moran, 2010) The science-based industries, which depend on the quality of science education in schools and third level institutions for their future employees, have funded some worthwhile interventions to encourage science teaching in schools, but these efforts are piecemeal and uncoordinated. I suggest that these science-based industries should be encouraged to set up a Science Education Trust Fund, based on a voluntary levy based on their turnover. The fund would then be used to fund curricula innovation, new teaching approaches, development of new materials, promotion of science, CPD for teachers etc.

f) Implement all the recommendations of the 2002 Task Force on the Physical Sciences (Task Force, 2002), which diagnosed the problems in relation to the physical sciences and made a series of important recommendations, most of which have not implemented. These included the renovation, equipping and resourcing of school laboratories; providing science technicians; introducing a proper life-long CPD programme. The provision of science technicians for schools, even on a part-time basis, would be the single most important step that could be taken to improve the quality of science teaching in schools. It would also provide employment for young, unemployed science teachers and for technicians.

g) Develop a career-long, in-service programme of CPD to refresh and update science teachers, whereby they would be seconded out of school at regular intervals (for example, a minimum of 1 school term every 5 years) and replaced by newly graduated science teachers. (Such a scheme was recommended by the Wilson report in 1985 and never acted upon!) Such a CPD programme would be compulsory and linked to keeping their registration status. This would revitalise the profession; it would ensure that teachers were always up-to-date in both their science and their science pedagogy; it would provide an outlet for the surplus of new science teachers, who would be required to replace the teachers out of school for CPD, and would give them valuable experience and a foot on the employment ladder. It would also be desirable to bring in a requirement that all second level teachers take a relevant Master's degree after some years in service, and in the case of science teachers this would be in science education and would be part of their CPD. The existing teacher education courses, whether concurrent or consecutive, should all be upgraded to Master's level, so that eventually all teachers would have a Master's qualification (as in Finland).

h) Continue and increase the support of science education research (SER), with the aim of improving the teaching and learning and science at all levels. The results of research need to be integrated into curriculum development, assessment and CPD, to ensure that teaching and learning become evidence-based. Since 2000 Ireland has made a major investment in scientific R&D through Science Foundation Ireland, but unlike the National Science Foundation in the USA, a significant percentage of SFI's budget is not currently allocated to education and training, including science education research. Making this a major priority, alongside science research, would help to improve the education system that produces the scientists of the future.

i) Improve links between schools and third level institutions, by more institutions developing school-focused initiatives like those from the Chemistry department in TCD. Third level lecturers need to be fully aware of what is happening in schools and the content of the science curriculum. More emphasis needs to be placed on easing the transition from school to university and in helping those students who have not done a particular science in school. There is no requirement to have studied Chemistry in school for studying Chemistry at third level and often over half of first year Chemistry classes have done no Chemistry since the Junior Certificate.

j) More value and reward needs to be given for teaching at third level in regards to promotion, and a programme of CPD for third level teachers needs to be put in place. There are encouraging signs of research into teaching and learning at third level through NAIRTL, and the Irish Variety in Chemistry teaching conferences. However, such initiatives only reach a small proportion of third level lecturers. The number and quality of students going on to postgraduate work, and their enthusiasm and interest in Chemistry, will largely be determined by the quality of the teaching they have received in their undergraduate degrees.

Conclusion

This has been a brief and rather superficial look at the state of chemical education in Ireland in 2014. There are many things to be encouraged about at present, but major challenges and changes are coming down the line in the future. The biggest challenge will be the increase in numbers coming through the education system, at a time when staff:student ratios have never been worse and when resources have never been tighter. The proposed changes in the junior cycle and then in the senior cycle science subjects have major implications for science teachers and for the preparation of students for further study. Students may be less prepared for LC Chemistry in the future and maybe less prepared for third level study. There are major reservations about the speed of curriculum change and the resourcing of such change, to make it effective and sustainable.

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Dr Peter Childs is an Emeritus Senior Lecturer and Director of the Chemistry Education Research Group (CERG), at the University of Limerick. He has been involved in chemical education for 40 years, both in teaching chemistry at third level and in helping to train chemistry teachers and working with chemistry teachers in schools. He is an Associate Director of the National Centre for Teaching and Learning in Mathematics and Science (www.nce-mstl.ie). He is a past President of the Irish Science Teachers' Association and of the Institute of Chemistry of Ireland, and past Chair of the EuCheMS Division of Chemical Education. He started Chemistry in Action! magazine for Irish chemistry teachers in 1980, the ChemEd-Ireland conferences in 1982 and the Schools Information Centre on the Irish Chemical Industry in 1989.

Recent research in the group includes the teaching of the particulate nature of matter, science in the Irish Transition Year, teaching organic chemistry, trainee chemistry teacher's chemical misconceptions, language in science education, and developing context-based and inquiry-based teaching materials for the Irish Transition Year (TY Science).

He was a partner in the EU Tempus project SALiS (2010-12), which focuses on the training of pre- and in-service science teachers in methods of low-cost active learning and inquiry based science education. He is the lead investigator at the University of Limerick for the new FP7 TEMI project, which is looking at the engagement phase of IBSE using mysteries and discrepant events to engage student's interest in science.

HOW DO ADOLESCENTS SEE CHEMISTRY?

166,091 pupils

sat GCSE Chemistry in the UK in 2013 reported the Guardian, representing 3.1% of all, a rise of 0.1% from 2012 and 0.3% from 2011. 174,428 undertook Biology and Physics managed 160,735, while subjects like History and Geography attracted well over 220,000 pupils apiece.

5.2% more

Pupils completed Chemistry A-levels in 2013 than 2012 reported the BBC

30 of the U.K.'s 70 university chemistry departments closed between 1995 & 2005

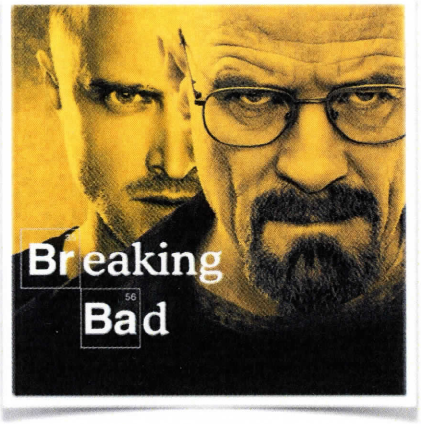
in the face of waning undergraduate enrolment in chemistry and a lack of funding to teach the subject. The situation has since turned around dramatically, with about 10 chemistry departments reopening in recent years. As well as recruiting more students, many U.K. university chemistry departments are also now recruiting staff.

A Challenge or a Chore?

The popularity of Chemistry and that of Science as a whole appears to be nearing highs in academical institutions across the United Kingdom scarcely seen since the nineteenth century when Chemists like Edward Franklin pioneered new methods for determining the cleanliness of water and protecting the public from outbreaks of Cholera-but to what can we attribute this success? Government campaigns promoting STEM subjects or good representation in mainstream media through television series like Breaking Bad?

We conducted a survey of 97 RBAI pupils to try and unearth their views on Chemistry.

Television programmes like CSI are notorious for scientific inaccuracies, but may unfortunately form the basis of many teenagers' perception of Chemistry



The largest influence on how the layman views Chemistry?

An American crime drama television series set in Albuquerque, New Mexico, ***Breaking Bad*** is the two-year-long story of Walter White (Bryan Cranston), a struggling high school chemistry teacher who is diagnosed with inoperable lung cancer at the beginning of the series.

He turns to a life of crime, producing and selling methamphetamine, in order to secure his family's financial future before he dies.

Whether or not the applications of Chemistry in this television series are damaging to its image is debatable; however the mainstream media exposure ought to be celebrated regardless.

The Survey

97 RBAI pupils were asked the following questions;

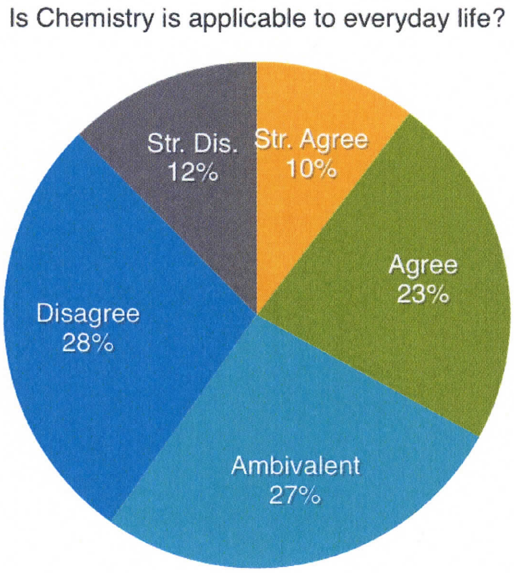
1. Do you agree Chemistry is difficult?
2. Do you agree Chemistry is often applicable to everyday life?
3. Do you agree Chemistry is an enjoyable subject?
4. Do you agree Chemistry will be relevant to a future career?
5. Do you agree Chemistry is taught in a fun and engaging manner?

And we garnered the following results;

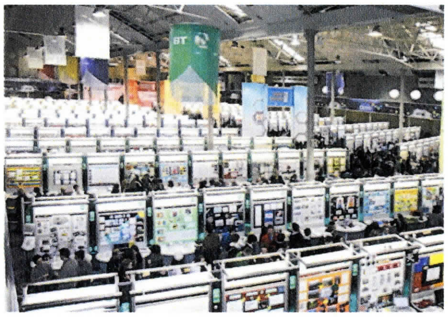
	Strongly Agree	Agree	Ambival-ent	Disagree	Strongly Disagree
1	22	28	23	17	7
2	10	22	26	27	12
3	17	18	23	20	19
4	11	19	20	25	22
5	8	18	22	26	23

The results of the first question will be unsurprising to many; Chemistry has long since been known as one of the most challenging subjects available to pupils at A-level or GCSE; demanding not only the regurgitation of large amounts of material and understanding of complex abstract concepts but also good mathematical and problem-solving skills.

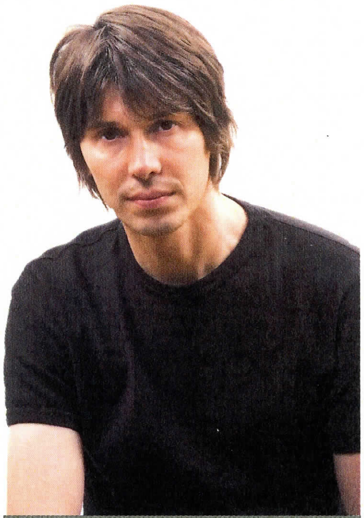
The tendency of pupils to overlook the real-life applications in Chemistry is more worrying; despite the Russell Group's acknowledgement of Chemistry as a facilitating subject and its stipulation as a requirement for some of the UK's most competitive courses like Medicine and Veterinary Science pupils still seem disconnected from the role of Chemistry outside the classroom



The disinclination of students to view Chemistry as pertinent to future careers is perhaps the most worrying; Chemistry has remained critical to Western Europe's industry and economy since Louis XVI offered 12,000 livres—approximately £250,000 today—for the best way to turn common salt into washing soda for the manufacture of soap.

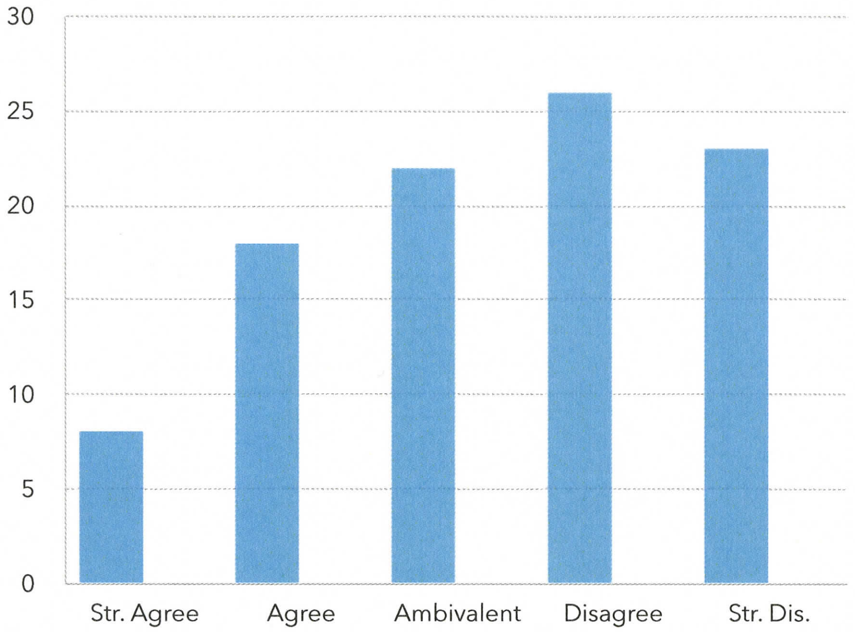


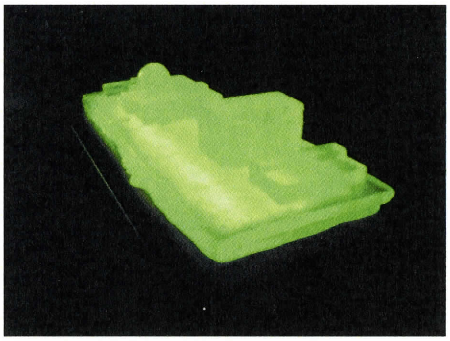
A scene from last year's BT Young Scientist competition, held annually in Dublin, which this year has attracted over 2000 entries from over 4400 pupils across Ireland!



Might Chemistry benefit from a champion much as Physics has from professor Brian Cox?

Is Chemistry taught in an engaging manner?





Kate William's exhibition at the Dublin Science gallery from 2011 on the theme of 'The Beauty of Chemistry'

This artwork uses uranium glass to create a sculpture of Sizewell Nuclear Power Station. Ultraviolet light from underneath the sculpture excites particles of uranium dioxide inside the glass to generate a bright, acid lime green glow

It's clear from these results that while efforts to promote Chemistry have been met with success, more needs to be done to demonstrate to pupils the importance of Chemistry and ensure it is taught in a fun and engaging manner.

Competitions like the aforementioned BT Young Scientist event provide an opportunity for pupils to develop and demonstrate passion for the subject as well as encouraging creativity and innovation beyond that which can be found in the classroom.

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Teacher: Mrs. Parks
Royal Belfast Academical Institution
Telephone: 028 9024 7464

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