Chemistry in Action!

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Editor: Dr. Peter E. Childs, Thomond College of Education, Limerick

Inter-Cert. Science Notes

Organising student experiments in science classes

Rev.Donald J.Collins, St.Peter's College, Wexford

(from a talk given at the I.S.T.A. A.G.M., Kilkenny 1980)

Why organise student experiments at all?

There are various reasons for organising student experiments:
a) Science is a practical subject and can be used to educate the whole person, in an interesting and enjoyable way;
b) Practicals are a good training in observation;
c) Practicals help a student to be accurate, since they can't be done without accurate measurement and drawing;
d) They can help a student to think independently;
e) They can help in exams, since the student who has done an experiment will usually remember more of it than one who hasn't;
f) They are important preparation for those going further in science, whether to a university or R.T.C.;
g) Experiments help a student to understand scientific principles better.

Objections commonly raised against school practical work.

There are many reasons for the neglect of student experiments and surveys amongst U.C.D. students who did chemistry and physics at school showed that very few of those who did a science at school did many experiments. Some of the more common reasons for neglecting practical work are as follows:

a) "*I won't get the course covered*".
This is just a matter of organisation, which can be adjusted according to the ability of the class. When the students do an experiment they remember it better and this cuts down the time needed for explanation and revision. (The list of experiments given in the Appendix were done with average science classes at Inter-Cert. without omitting any of the course and with time for revision – so it can be done.)
b) "*Students make too much of a mess*".
If they are trained correctly from the beginning there will be little problem. Doing experiments gives a good training in responsibility and can be used to teach neat and careful working habits.
c) "*I haven't time to prepare experiments*".
Once the laboratory is organised properly then one or two free class periods a week is all that is necessary.
d) "*Experiments are mere 'cookery*'".
Perhaps they are, but for juniors they are important ways of learning methods and techniques, and give vital training in careful observation and with older students the need for accuracy can be introduced.

"Many teachers are, unfortunately, products of a system that didn't do practical work – and tradition dies hard"

The reasons above may not be the real reasons. Many teachers are, unfortunately, products of a system that didn't do practical work – and tradition dies hard. Many teachers have had no training in doing practicals at school level and they lack the necessary confidence in the laboratory. They also need experience and tuition in making and repairing simple apparatus, improvisation etc. (Ed. This is where in-service courses have a vital role to play in retraining teachers for new roles. "Chemistry in Action" will also try to fill some of the gaps in these areas.) Many students say that "they understand it better through experiments" and we should listen to them. "Science is meant to be a practical subject."

How can student experiments be organised effectively?

Inter-Cert. classes usually have 4 periods a week, 2 being a double period. There are thus over 30 double periods in a year. Most of these I use for experiments, especially in the first two years. There is still plenty of time for the theory and for teacher demonstrations.

In the Appendix I give a list of suggested experiments for Inter-Cert.Science. Some of these may be omitted or simplified for weaker classes. They should be augmented by demonstration experiments in the theory classes. The order of the experiments can be altered by the teacher according to his teaching scheme. I suggest that the physics experiments be done first, before the easier (less mathematical) chemistry and biology experiments. You may disagree with this order. The first year experiments concentrate initially on the necessity of and the training in accurate observation and measurement, which is basic for all branches of science.

"the success of such experiments depends on two factors – laboratory organisation and class organisation."

Once the teacher is convinced of the need for and the value of student experiments, then the success of such experiments depends on two factors – laboratory organisation and class organisation.

a) *Class organisation*: At the beginning of each year every Science class is divided into 10 groups, if there are 20 or more students. Each group has a number and the students stay in the same group all year (sometimes for three years). I try to put at least one good student in each group (especially at the senior level). One student can be placed in charge of the group – he takes the responsibility for equipment allotted to the group. Each group has a set place to work through the year. (In every class group no. 1 will work in the same place etc.)

b) *Laboratory organisation*: For the experiments there are two sources of equipment – the group's press and stock items.

(i) Group's press: Each group will have basic equipment in the press allocated to it and numbered, Group 1 etc. (see below). The student in charge will check the equipment before and after each experiment: a list is attached inside the press door. A label with the group number is placed on each item, especially the non-glass items. This system means that you need only 10 of each item to stock the laboratory and often items are sold in 10's by lab. suppliers.
<u>Suggested equipment in the group press:</u>
Retort stand and fittings, including a filter ring;
Bunsen burner, tripod and gauze;
Calorimeter and jacket; overflow jar; forceps; deflagrating spoon;
Graduated cylinder; 400 and 100 cm3 beakers; two test-tubes; gas jar and lid; thistle funnel; flask;
Funnel; evaporating dish; glass rod; petri dish.

(You can increase or decrease this list at your convenience.)

(ii) <u>Stock items</u>: Other items needed for individual experiments are taken from the stock by the teacher (or student) and given out (in 10's) to one student who gives them out and collects them up at the end.
Label benches and presses (using letters or equipment names). Place items on or in these according to the section on the course: label the equipment also showing where it goes. It is useful to make a catalogue of the materials and apparatus in each laboratory. Expensive items should be kept in one laboratory and returned there after use. Organising the laboratory takes quite a lot of time but once it is done it takes very little to keep it in order thereafter. As long as equipment is cleaned and returned immediately after use there should be no problem. Accidents and breakages should be reported to the teacher at once.

At the beginning of a practical class, some time is given to explaining the steps of the experiment, the various precautions needed (including safety aspects) and the readings or observations to be made. Diagrams, readings to be made, and steps in the experiment should all be given on the blackboard (or on an OHP). The experiments should be finished at least 5 minutes before the end of the class to give time to tidy up and put equipment away. The students should be encouraged to write their own accurate and concise reports. Initially this requires much time and patience to ensure that the reports are fairly scientific. The copies can be checked at intervals and marks given.

APPENDIX
<u>Number of experiments done for Inter-Cert. Science</u>

	Physics	Chemistry	Biology	Total
First year	10	10	7	27
Second year	8	9	9	26
Third year	5	5	6	16
	23	23	22	69

(Although “Chemistry in Action” deals specifically with chemistry, we have given all the experiments suggested by Rev.Collins for the Inter-cert. course, since the chemistry component should be seen as part of a whole and integrated as far as possible with the physics and biology. They are given in the order: Physics, Chemistry and Biology.)

PHYSICS EXPERIMENTS

First year

1. Measurement of straight lines; relationship of inches and cm; graphs.
2. Measurement of curved lines (3 methods); relationship between circumference and radius of a circle.
Measurement of area – connection between area of a circle and the square of its radius (homework).
3. Measurement of volume – regular and irregular objects; use of overflow jar and graduated cylinder.
4. Measurement of small objects; use of burette.
5. Centre of gravity of a piece of cardboard.
6. Verification of the law of the lever – 2/3 weights.
7. Mass of an object using a metre stick; mass of metre stick.
8. Density of solid using scales.
9. Density of a liquid; use of pipette.
10. Verification of Archimedes’ principle; density of a solid and a liquid. Verification of law of flotation; specific gravity of a solid and a liquid.

Second year

1. Comparison of densities using U-tube; Hare’s apparatus.
2. Approximate density of air.
3. Verification of the law of the spiral spring and its use.
4. Verification of Charles’ law.
5. Specific heat capacity of a metal and a liquid.
6. Specific latent heat of fusion of ice.
7. Measurement of the dew-point.
8. Freezing point of naphthalene using a cooling curve.

Third year

1. Velocity of sound; resonance, echoes.
2. Law of reflection; position of the image in a plane mirror.
3. Plotting the field of a bar magnet.
4. Measuring the resistance of a piece of wire; demonstration of Ohm’s law.
5. Heating effect of an electric current.

CHEMISTRY EXPERIMENTS

First year

1. Examination and identification of various substances.
2. Making bluestone crystals.
3. Separation of ammonium chloride and common salt; distillation.
4. Separation of salt and sand.
5. Simple chromatography using coloured pens.
6. Preparation of oxygen and its properties.
7. Preparation of carbon dioxide and its properties.
8. Air contains water vapour.
9. Salts in water; dissolved gases in water.
10. Water of crystallisation. Combination of hydrogen and oxygen to give water.

Second year

1. Brownian movement using Indian ink.
2. Solubility curve of potassium chlorate.
3. Preparation of silver chloride.
4. Percentage of oxygen in magnesium oxide.
5. pH of various substances; examination of indicators.
6. Preparation of the allotropes of sulphur.

7. Preparation of zinc sulphate.
8. Preparation of copper nitrate.
9. Preparation of sulphur dioxide and its properties.

Third year
1. Effect of heat on sodium hydrogencarbonate.
2. Preparation of magnesium hydroxide.
3. Examination of the hardness of water and how it can be corrected.
4. Preparation of sodium chloride from sodium hydroxide and hydrochloric acid: titration.
5. Measurement of heat of neutralisation.

BIOLOGY EXPERIMENTS

First year
1. Using the microscope: examination of paper, hairs etc.
2. Using the microscope: examination of onion cells.
3. Using the microscope: examination of prepared cells (simple plant structure).
4. Examination of the broad bean seed.
5. Conditions for the germination of seeds.
6. Simple tropisms experiments: phototropism, geotropism.
7. Effect of exercise on respiration – vital lung capacity.

Second year
1. Dissection of the earthworm.
2. Testing various foods for starch etc.
3. Enzymes: effect of an enzyme (saliva); optimum temperature and pH on saliva; pepsin.
4. ìExamination of soil: physical properties (using graduated cylinder and sieve); % of ïwater; % of humus; water and air.
5. íPermeability; capillarity of soil; chemicals in the soil;
6. îpH of soil.
7. Transpiration: water from leaves.
8. Osmosis experiments; sugar syrup; potatoes.
9. Photosynthesis experiments: necessity of light, CO2, chlorophyll.

Third year
1. Examination of prepared slides of fungi, algae etc.
2. Examination of blood.
3. Effect of exercise on heart rate.
4. Ecology – general study of area.
5. Ecology – special examination of one section (shrub/pond/rockpool etc.).
6. Ecology – quadrat, transect, berlese funnel etc.

With many biology experiments the different sections of the experiment are done by different groups: these then share their reports with the other groups. Ideal experiments for this type of sharing are tropism, food tests, soil experiments and photosynthesis.

You may well disagree with Rev.Collins on his order and selection of experiments. The aim is to show a workable scheme which brings in a lot of experimental work in all three sciences. We would like to hear your general comments on sequencing the Inter-cert. syllabus and detailed comments on the chemistry part of the course: send in your scheme of chemistry experiments or ideas for introducing chemistry through experiment. Simple experiments using simple apparatus and chemicals are best: they should be safe and related to everyday life if possible.

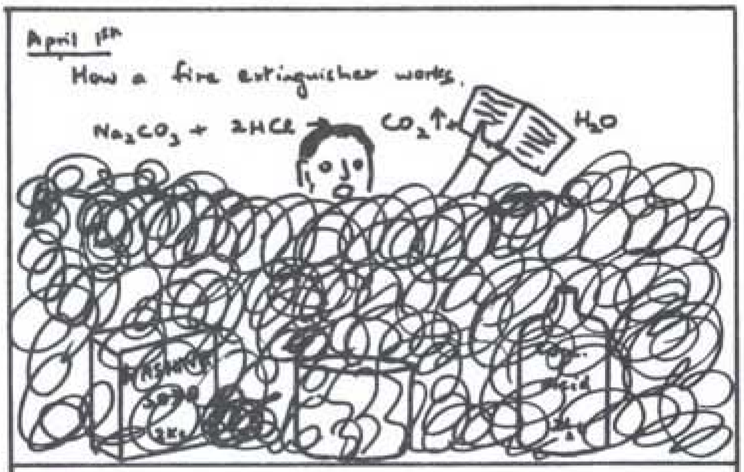
It's interesting to note how many topics in both Physics and Biology are either used by chemists or are taken up and developed in higher Chemistry courses.

Testing for gases using plastic syringes

A note in S.S.R. 54(189), June 1973, 770 by J.R.Rose gives a good idea for testing gases e.g. CO_2 with limewater using a disposable plastic syringe. It is often awkward to collect a sample of gas for testing with a liquid reagent e.g. by bubbling gas through a glass tube. A neat solution is to suck up a few mL of limewater into a 10 or 20 mL syringe and hold it over the test-tube where the gas is being evolved. Now withdraw the plunger slowly and gas will be seen to bubble through the limewater. If CO_2 is present in the gas it can easily be seen to turn chalky. The used reagent is then expelled and a fresh test solution can be sucked up. This method works very well and could be used for any similar test or for getting an aqueous solution of say HCl or NH_3 for testing.

Plastic syringes have many uses in the introductory science laboratory and are quite cheap to buy. More ideas for using them will be given in later issues. If you have any ideas on how to use them – send them in.

A cautionary tale



"Help ! I'm sure it said add 2kg of washing soda to a bottle of acid. What went wrong?"

How much gas did he produce? Work it out and see p.17

THE CHEMICAL INDUSTRY IN IRELAND IN THE 1980'S.

Presented at the Annual Congress, Sligo, May 16th, 1980.

Desmond M.Fitzgerald, M.Sc., F.I.C.I.
Assistant Director, Federation of Irish Chemical Industries.

"I perceive that divers of my friends have thought it very strange to hear me speak so irresolvedly, as I have been wont to do, concerning those things which some take to be the elements, and others to be the principles of all mixt bodies. But I blush not to acknowledge that I much less scruple to confess that I doubt when I do so, than to profess that I know what I do not."

So said our distinguished fellow-countryman and great natural philosopher, The Honourable Robert Boyle, in the opening section of his best-known book, "The Sceptical Chymist", which was first published in 1661. Such caution, and such intellectual modesty, well become any theoretical or experimental scientist who attempts to chart new frontiers of human knowledge. However, in talking about the Irish chemical industry, I feel so proud of its total contribution to the well-being of the Nation that I cannot hope to emulate the modesty displayed by Boyle when I set out to describe our industry as it stands today.

It would scarcely be an exaggeration to describe as "meteoric" the rate of growth of the chemical and pharmaceutical industries in Ireland over the past 15 years. As a brief illustration of this, I would simply mention the following facts.

1. In terms of percentage annual growth, both in turnover and in output, the Irish chemical industry has for many years been the fastest-growing chemical industry in the European Community.
2. The value of Irish exports of chemical, pharmaceuticals and related products has risen from about £0·5 million in 1964 to more than £450 million in 1979, and employment in this sector has risen from some hundreds in 1964 to well over 10,000 today.
3. In recent years, Ireland has been a substantial net exporter of pharmaceuticals, and now ranks around tenth in the world league of pharmaceutical exporting countries. We are also a big net exporter of other organic chemicals. In some other important product sectors, such as fertilisers, we may reasonably expect that the value of our exports will exceed that of our imports in the foreseeable future.

The Irish chemical industry today has little or no historical connection, either in terms of ownership or of technology, with such chemical industry as existed in Ireland prior to the Second World War. We owe our present industry, almost entirely, to the imaginative incentive policies developed by successive Irish Governments over the past 20 years, which have been implemented with flair, enthusiasm and persistence by the Industrial Development Authority. The hard and effective selling by the IDA of the attractions of Ireland as a manufacturing base, especially for export-oriented projects, has persuaded many multi-national firms of the highest repute to establish major investments here in chemical and pharmaceutical manufacture. Such names as Pfizer, Merck Sharp & Dohme, Mitsui, Syntex, Smith Kline & French, Eli Lilly, Henkel, Squibb, Asahi, Snia Vicosa, Ciba-Geigy and many more are "household words" at least to the industrial chemist, if not always to the general public. The enormous success of the IDA in attracting firms of this calibre to Ireland over the past 15-20 years – often in the face of intense competition from comparable State development agencies in other European countries – has clearly been the crucial factor in the evolution and growth of the Irish chemical industry as we see it today.

The structure and composition of this industry are very different from the typical pattern which one finds in the larger industrial nations of Europe and elsewhere. An unusually high proportion of the newer Irish projects relate to the manufacture of bulk drug substances (i.e. pharmaceutical active ingredients) and of fine chemicals of a non-pharmaceutical nature, whereas the development of new industries making heavy inorganic or organic chemicals has been much more limited. Notable examples of the latter type may be counted on the fingers of one hand, e.g. the very large-scale production by Pfizer Chemical Corporation at Ringaskiddy, Co.Cork of citric acid from beet molasses, and the new chemical complex of Nitrigin Eireann Teoranta at Marino Point in Cork Harbour, making ammonia, urea, fertilisers and downstream products from the almost pure methane which is piped in from the offshore gas field off the Cork coast. The NET investment in the first stage of this complex (approx. £130 million at 1979 money values) is the largest single investment so far made in a chemical project in Ireland.

The main reasons for the unusual structure of the present Irish chemical industry are, in my view, as follows:

(a) The small size of the Irish home market would not in itself constitute a viable economic base for the production of basic inorganic or organic chemicals, apart perhaps from fertilisers. To achieve competitive production costs, basic or “heavy” chemicals are normally made in very large single-stream continuous-process plants. The economics of production of such chemicals are very dependent both on the size of the plant and on the extent to which its design capacity is being fully utilised. Since the transport costs associated with heavy-chemical production can represent a significant proportion of the delivered cost of the product, plants making heavy chemicals are usually located close to the most important market area and/or close to the main sources of the primary raw materials. Additional cost advantages may be gained if they are located close to a prime source of energy, e.g. a coalfield or a source of hydro-electricity.

(b) Apart from our deposits of lead-zinc ores, and of a few other useful minerals such as dolomite and barytes, Ireland is singularly deficient both in primary energy feedstocks and in the types of mineral which could form a basis for heavy-chemical manufacture. The combined effects of our geographical isolation from the European market centres, of our lack of relevant minerals and of our severe dependence on imported energy, plus the absence of a home market of adequate size, militate strongly against the development of heavy-chemical industries in Ireland. The large-scale production of chlorine by electrolysis of brine, and the petrochemical cracking of hydrocarbon feedstocks to give the lower olefins, are generally considered to be the two essential corner-stones of a diversified organic-chemical and polymerisation industry. Neither of these developments can be envisaged in Ireland in the foreseeable future (for the reasons mentioned earlier), but it is possible that the discovery and development of a major oil resource in Irish offshore waters could alter this prediction.

(c) On the other hand, the production of bulk drug substances and of other fine chemicals is quite a different story. Such products generally have both a high unit value and a high added value. The associated transport costs do not constitute a significant proportion of the total delivered cost, so that the proximity of the plant is much less crucial than in the case of heavy chemicals. The production of fine chemicals is generally less capital-intensive, less energy-intensive and somewhat more labour-intensive than the manufacture of heavy chemicals. The fact that economically-sized fine-chemical plants generally employ some tens (rather than many hundreds) of people, and that they rarely have unique or complex infrastructural requirements (compared with most heavy-chemical industries, means that a wide range of locations in Ireland are potentially suitable for profitable operation. This factor makes such industries especially attractive to the IDA as a means of spreading new employment throughout the country, of alleviating local or regional problems, and thereby of promoting the attainment of national socio-economic objectives. Conversely, the high level of unit profit associated with fine-chemical manufacture (as compared with the production of heavy chemicals) means that the fine-chemical producers have been able to derive maximum benefit from most parts of the Irish economic incentive package, especially from Export Profits Tax Relief.

(d) The accession of Ireland, some years ago, to the European Economic Community has enhanced its attractions as a manufacturing base in Europe for multi-national firms whose main production operations lie outside the EEC. Through the 1960’s and part of the 1970’s, its labour costs were attractive by comparison with other European countries and, unlike most under-developed countries, it has the advantage of possessing an educated labour force. The fact that English is the spoken language of the nation, and that there are adequate supplies both of graduate/post-graduate scientists and engineers and of laboratory technicians from Irish educational institutions, are perceived by foreign multi-nationals (especially U.S. firms) as additional points in Ireland’s favour. The present national balance of trade in chemicals, pharmaceuticals and related products may be seen from figures published by the Central Statistics Office. In both tables, the 1979 figure, without brackets, is followed by the corresponding 1978 figure (in brackets).

INSERT TABLE HERE

Two interesting features may be noted from these trade statistics, viz.:
1. In both 1978 and 1979, organic chemicals and pharmaceuticals were the only product sectors which showed a positive balance of trade in Ireland’s favour, and this balance in both cases appears to be increasing.

2. In both these years, the total value of chemical imports significantly exceeded that of exports, and this gap (at least in absolute terms) appears to be widening. The reason for this overall trade deficit in the chemical and allied products sector is that very large quantities of chemicals are imported into Ireland to meet the requirements of industries other than the chemical manufacturing industry. Examples of this would include polymers of various types (either in primary form for shaping by Irish plastics fabricators, or in shaped form such as fibre, film, sheet, tubes etc.), solvents, acids and other chemicals used by the engineering industry; ore-treatment and other ancillary chemicals used by the mining industry; and polychlorinated solvents for use in dry-cleaning. Each of the main product groups listed in these tables is broken down into several sub-divisions in the published statistics but, in most cases, specific figures for Irish imports and exports of individual chemical species are not available from official sources.

As I said earlier, the present Irish chemical and pharmaceutical industry is a very young industry, and contains a preponderance of firms of the highest international calibre. Since it is predominantly export-oriented, both its market prospects and its growth potential are influenced much more by global economic trends than by local trends which are specific to the Irish economy. Because most of the Irish manufacturing plants were designed and built within the past ten years, their process technology is quite up-to-date and is backed up by the ongoing research and development work of their parent companies, thus maximising their competitive capability in world markets. While I naturally share the regret expressed from time to time by many people at the relatively small proportion of Irish-owned firms in this important sector of our manufacturing industry (a regret which, I am sure, would also be shared by Robert Boyle and the many other great Irish chemists of past generations), I nevertheless feel that we are very fortunate, both for economic and for social reasons, in having these great foreign companies in our midst.

I would hope that, in the future, our Government and the IDA would be as successful in developing the growth potential of indigenous chemical and pharmaceutical manufacture (both State-sponsored and private-sector) as they have already been in encouraging foreign manufacturing investment in Ireland. Looking forward into the 1980’s, I would also hope that the multi-national firms already established here will continue to use Ireland as a base for further growth and diversification and (once they have passed through the traumas of design, construction, commissioning and consolidation) that they can be convinced of the attractions of using Ireland also as a location for some part of their corporate R & D activity. This latter trend is already evident to a very small extent (mostly in the field of trouble-shooting and process-optimisation research), but we could do with a great deal more. A shining exception to the present Irish pattern is Loctite, a multi-national company specialising in complex polymer adhesives, which did create a substantial R & D component in its Dublin Subsidiary, with the result that a whole range of important new products were invented and developed in Dublin and are now of great value to Loctite world-wide. I hope and expect that some, at least, of the “big-name” firms mentioned earlier will soon follow Loctite’s example. As you probably know, there is a reasonably attractive package of Irish economic incentives (ranging from the R & D grants and other inducements offered by the IDA, to the subsidised post-Doctoral Industrial Research Fellowship Scheme recently launched by the National Board for Science and Technology) which are aimed at promoting such developments.

Having spent my formative years as an industrial chemist working for one of the largest and most diversified European chemical and polymer companies, I am very conscious of the techno-economic advantages of synergism in the chemical manufacturing industry, especially those which can result from the location of many apparently unrelated manufacturing plants on a single shared site. Apart from the obvious benefits of this arrangement in terms of reduced infra-structural and services costs (roads, steam-generation, effluent-treatment etc.), it can often happen that the apparently waste product from one plant can be used to create added value in some other plant on the same site. I sometimes feel that insufficient attention has been given by our national planners to this type of synergism, which can be especially advantageous to the chemical industry however, the tendency in recent years to locate a number of separately-owned chemical plants in the area around Cork Harbour (and especially in Little Island) is, in my view, an important step in the right direction.

I hope I have by now made it clear that the technological modernity and sophistication, the typical plant size, product range and ownership structure of the Irish chemical and pharmaceutical manufacturing industry are such that these plants are about as far removed as possible from the layman’s concept of “dark Satanic mills”. Because of the factors just mentioned, these plants have been designed and operated in such a way as to conform with the highest standards of safety, health and environmental protection which apply anywhere in the world. The proportion of fixed capital expenditure which has been devoted to these matters is very considerable, and the in-house safety and environmental standards set by the companies themselves are generally much higher than anything which may be required by existing or impending legislation. In fact, on many matters of this type (such as improved safety in chemical transport, and the development of adequate controls on waste disposal) the chemical industry, through my Federation, has over the years advocated and encouraged the enactment of new and tighter legislation. Bearing in mind that the EEC Directive of March, 1978 on toxic and dangerous wastes will be brought into Irish law within the next month or two, our industry is greatly concerned at the lack of progress in Ireland towards the creation of one or more scientifically-controlled dumps for such wastes. We feel that the absence of such facilities may impair the further growth and diversification of the present Irish chemical industry, and may discourage other foreign companies from establishing production in Ireland. I cannot help feeling that the lack of progress on this matter reflects a lack of understanding of the real infrastructural needs of a developing chemical industry. I can readily understand that nobody wants to see a chemical dump created on their doorstep, but I must admit that I feel rather cynical, and a little sad, at the fact that barren tracts of useless land suddenly become transformed into unique areas of great scenic beauty once it is proposed that they be used for an industrial purpose.

The continued growth and well-being of the Irish chemical and pharmaceutical industry are, in my opinion, important to all chemists in Ireland, whether employed in the industry or not. Each and every chemist can play some part in providing other sectors of the community (from secondary school-children to media people and legislators) with a fair and accurate picture of the advantages, and of the risks, which are associated with the operations of the chemical industry in Ireland. All I ask of you is that you investigate all the relevant aspects, establish the facts and then – tell the truth.

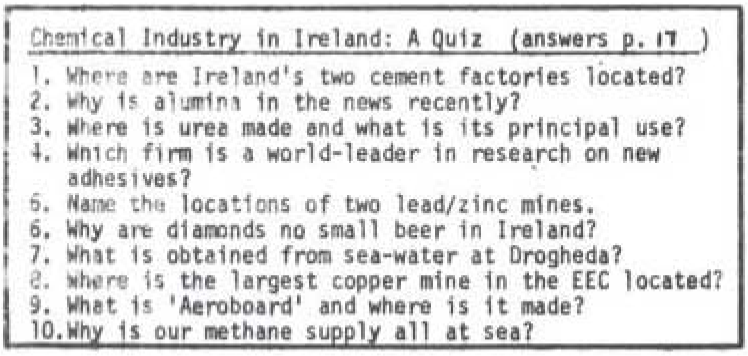
INDUSTRIAL CHEMISTRY AT SCHOOL

Who makes what, where and how?

As chemistry teachers we need to be aware of what the chemical industry in Ireland is doing. Who is making what products? Where are they doing it? How are they doing it? What are their raw materials? What are the products used for? These are questions we ought to ask and try to find answers to. The chemical industry is an important factor in the modern Irish economy (see Mr.Fitzpatrick's article, p.5), a source of many jobs, and an illustration of the importance of chemistry in Irish life. By keeping abreast of what is going on you can bring the information in as illustrations at suitable points in the course, or in a career talk.

If we don't know what's going on then we can't do this and our chemistry courses become too academic, out of touch with economic reality, irrelevant to most of the pupils, and inadequate as a preparation and as a stimulus to a career in chemistry or a career using chemistry. I would hold that this can be done effectively without watering down the 'hard stuff' as Adrian Somerfield seems to fear (see p.21). Try doing the quiz below to see how your knowledge rates on the chemical industry in Ireland. We will try to make you aware of what's going on around you, but you need to use the material provided in your lessons and to keep up-to-date yourself by reading newspapers and magazines. The quotation below from the Journal of Chemical Education makes the case for applied chemistry in the curriculum better than I can.

"All the existing high school curricula try to show how a chemist works in a research laboratory, emphasising practical work, and concept formation. This approach usually does not show how these chemical concepts are applied outside the school laboratory or that we live in a world which is increasingly dependent on the chemical industry and on industrial research and its applications. The teaching of chemistry without discussing this industry, omits a most important aspect of modern life and, by implication, indicates that industrial achievements are not important. One result of this omission is the well publicised negative attitude of the general public toward chemistry as a whole with a consequent overemphasis in the media on the hazards of pollution, carcinogenesis, chemical warfare, radioactive waste disposal, etc. These issues are indeed part of the facts and problems of daily life, but the publicity that they attract gives an unbalanced picture of the nature of science, in general, and of chemistry, in particular."
N.Nae, A.Hofstein, D.Samuel
J.Chemical Education, 57, 366-368, 1980



Chemical Industry in Ireland: A Quiz (answers p. 17)

1. Where are Ireland's two cement factories located?
2. Why is alumina in the news recently?
3. Where is urea made and what is its principal use?
4. Which firm is a world-leader in research on new adhesives?
6. Name the locations of two lead/zinc mines.
6. Why are diamonds no small beer in Ireland?
7. What is obtained from sea-water at Drogheda?
8. Where is the largest copper mine in the EEC located?
9. What is 'Aeroboard' and where is it made?
10. Why is our methane supply all at sea?

"The time has come when it is necessary to decide afresh what our children should know about chemistry and its part in the modern world and then to decide how this material can be presented. The course would be developed along two lines, one concerned with basic chemical theory and the other with the relevance of chemistry to everyday life."
B.M.Prestt
Education in Chemistry, 7, 66, 1970

"Looking at a school chemistry syllabus, it is difficult to realise that we live in a world which is increasingly dependent on the work of the chemist. School chemistry courses show almost no sign of the change which has taken place in the last few decades; for present-day needs they are completely irrelevant. They

have no more claim for inclusion in the educational pattern than Latin."
B.M.Prestt
Education in Chemistry, 7, 66, 1970

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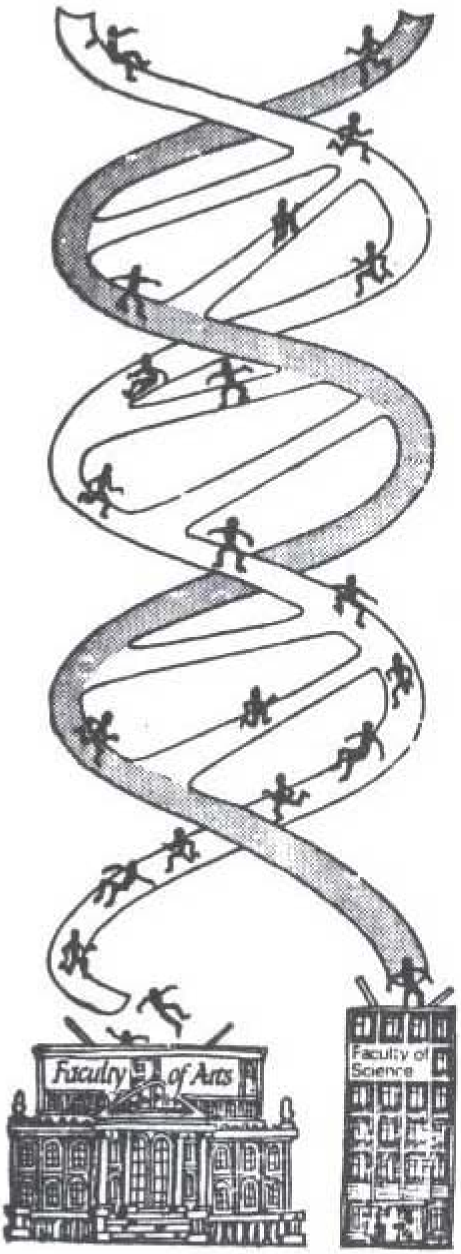
<u>All things change – and all remains the same</u>
"The decade of the sixties, the post-sputnik 1 era, saw the emergence of new science curricula in chemistry (CBA, 1964; Chem Study, 1965; Nuffield, 1966) developed by various curriculum groups. The curricula produced replaced trivial, outdated content with contemporary modern knowledge and changed the learning approach from one of amassing factual information towards developing an understanding of the principles of chemistry and of the processes for achieving scientific knowledge. The content moved towards physical chemistry and physics and thereby became more rigorous and abstract. From the viewpoint of chemistry per se the courses were excellent. Chemistry students reached the nest stage of education better prepared though fewer in number. From the perspective of a general education for all students, the courses have been less successful. Coincident with lower enrolments in university science courses was the rise in 'anti-science' attitudes among humanities and social science students. A simple causal relationship is not suggested, but it is noted that by the time the new chemistry curricula were introduced, society was becoming sharply conscious and aware of the unsocial consequences of unbridled scientific and technological advance. The quality of life seemed in jeopardy.
So science education is in trouble again in less than fifteen years, and new syllabuses and courses are called for."
Will Hughes
"Chemistry: pure vs. applied", in New movements in the study and teaching of chemistry, ed. D.J.Daniels, Temple Smith, London, 1975



Diagram, p.7, from *Education in Chemistry*, 7, 66, 1970

A little knowledge is a dangerous thing

A little knowledge is a dangerous thing

"Do you like it? I make my own soda water as well - it's very easy."

Leaving Certificate Chemistry Notes
"IN PRAISE OF PRACTICALS"

Michael O'Dwyer, C.B.S., Sexton Street, Limerick.

The following contribution is from an experienced teacher who has spent eight years teaching leaving certificate chemistry. Michael O'Dwyer gives an approach to starting off year 5, firmly based on practical work by the pupils. This may give you some ideas to use in your own classes.

"We learn a lot from what we do, but very little from what we are told."

September 1980 Here goes! Thirty new students eager to study Chemistry for their Leaving. "Can we do practicals this year, Sir?" is the demanding question from 'Backbencher', recently crowned with an A in Intermediate Science. "Of course!" is the confident answer.

Practical 1. Comparing the accuracy of pipettes, burette and graduated cylinders, and hence to determine the density of tap-water.

Obviously, a very simple experiment requiring the use of an accurate (0·01g) top-pan balance. An essential start to the course as it gives the teacher an opportunity to establish strict laboratory procedures and the students use fundamental equipment, some for the first time.

Practical 2. Analysis of milk: percentages of moisture, organic and inorganic matter.

This experiment requires evaporating basins and bunsens and can be made very satisfying if students use milk produced from different dairies!

Practical 3. Salts of sodium: identification of anions.

Equip each pair of students with four test-tubes and a dropping pipette. Supply samples of sodium carbonate, sodium chloride and sodium sulphate for analysis using concentrated sulphuric acid (CAUTION!). Suggest suitable confirmatory tests for each anion to facilitate the student's identification of the salts.

Practical 4. Salts of potassium: identification of anions (similar to Expt.3).

I use potassium bromide, potassium iodide and potassium nitrate disguised to challenge the student.

OCTOBER At this stage I hope students will be familiar with the ideas of stoichiometry and should be able to tackle simple volumetric analysis.

Practical 5. How concentrated is hydrochloric acid?

Here I get students to standardise a solution containing a known mass of HCl using sodium hydroxide solution. Ensure that all titration procedures are practised.

Practical 6. Repeat practical 5 using sulphuric acid.

These practicals are very satisfactory. It is essential to use very dilute solutions.

Practical 7. Determining the percentage of citric acid in different varieties of lemon squash.

We make up a number of solutions containing a known mass of lemon squash, using some of the brands available in supermarkets. Titrate 25mL portions with 0·1M sodium hydroxide using phenolphthalein indicator. I use the following equation when doing the calculations:

$$\underbrace{H_3(C_6H_5O_7).H_2O}_{\text{citric acid :}} + 2NaOH \rightarrow Na_2H(C_6H_5O_7) + H_2O$$

Practical 8. Analysis of Harpic: how much sodium hydrogen sulphate (bleaching agent) does it contain?

Prepare a solution containing 10g of the toilet cleaner per litre. Standardise the solution using 0·1M sodium hydroxide using phenolphthalein indicator.
The relevant equation for the reaction is:

$$NaHSO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$$

<u>NOVEMBER</u> At this stage I find that the student’s confidence in experimentation has been developed and their interest in chemistry aroused. I also find that the students become organised in their approach, they are more precise in their work and they enjoy their study. We are now ready to tackle the more complicated practicals as the course develops.

References for practicals 7 and 8: “Practical Chemistry”, Lambert and Muir, p.315, Heinemann 1973.

Comment: Having just done a similar practical to no.8 I found that 12g/L of Harpic was too dilute for titration with 0·1M sodium hydroxide and we had to use 0·01M NaOH instead. It pointed out the need to check a titration roughly before doing it properly: this not only checks whether the solutions are the correct concentration, it gives you an idea what the end-point is and it gives practice in observing the indicator colour-change. This can be done economically and quickly by using the dropper method e.g. using a dropper put 25 drops of base + 1 drop of indicator in a clean test-tube. Then add the acid drop by drop, shaking between drops, until the indicator just changes colour. The number of drops then gives the approx. no. of mL of acid that would react with 25mL of base. Doing this can save embarrassment and time when a reaction from the ‘book’ doesn’t work.
Ed.

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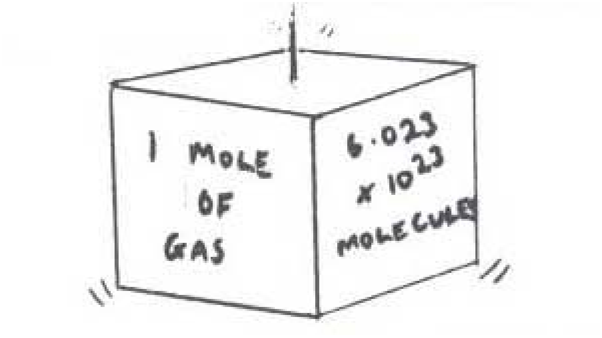
HOW BIG IS A MOLE OF GAS?

Everyone knows that 1 mole of an ideal gas occupies 22·4L at S.T.P. (0ºC and 1 atm pressure). But most people don’t know what 22·4L looks like i.e. what a mole of gas looks like. Make a model cube from cardboard or polystyrene sheet or ceiling tiles with a volume of 22·4L i.e. a cube 28·2cm (11·1") a side. This is easily made and most people are surprised at the size of a mole. A cube has six sides: put a different label on each side in large letters e.g. 1 mole of an ideal gas; 6·023 x 1023 molecules of an ideal gas; 22·4 Litres of gas; 1 molecular mass of a gas; 44g of carbon dioxide; 2g of hydrogen; 32g of oxygen etc. The cube can then be put on display to constantly reinforce these basic ideas – one good way is to hang the cube from the ceiling so that it turns slowly in the breeze!



“Data, however fascinating, is not insight.”
R.Kluger

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Chemistry in Action is starting here a series of simple experiments designed to get over and illustrate the basic principles of stoichiometry i.e. chemical formulae, equations, the mole concept etc. These ideas are basic to a study of chemistry. Without understanding them a student cannot really move on confidently in chemistry, leastways not with understanding. Often these basic ideas are learned by rote to solve problems and are not really understood fully, even one might hazard with many third-level students. Doing simple experiments that elucidate some of these basic concepts is very important. The experiments must be simple, using simple apparatus, so that the point of the experiment is not lost behind a jungle of apparatus and techniques. No-one can rediscover for themselves all the basic ideas, concepts and facts of chemistry – but to see initially that these ideas are based on experiment should lead to a firmer grasp of the ideas and a more firmly based belief in the truth of what we read in books. Because, like it or not, the scientist and particularly the teacher (at any level) is often the most credulous of mortals: if it is in a book we believe it, since it is not practical to check everything ourselves. But at least using these simple experiments your pupils will make a start in confirming for themselves that the basic truths of chemistry are based on experiment.

In this issue two illustrations of stoichiometry are given, and other examples will be given in later issues. If you have a favourite and well-tried experiment on stoichiometry and the mole concept, please send it in.

STOICHIOMETRY 1 Determining chemical equations

(Use these experiments on Stoichiometry as they suit your course: they may fit better into the Inter-Cert. course than the Leaving Cert. Course, depending on how you teach it. However, all chemistry students need to experience some of these experiments at some time.)
The chemical equation is fundamental to understanding chemistry. It describes the reacting quantities and amounts of products that will be formed. Often equations are accepted on 'Faith' and are arrived at by applying rules of valence, oxidation state etc. It is very easy to determine the chemical equation in the laboratory using simple equipment. The procedure can also be used to introduce volumetric analysis which is based on the stoichiometry of a reaction.

Reaction between sodium hydroxide and hydrochloric acid.

Apparatus:	test-tubes droppers 0·1M sodium hydroxide solution 0·1M hydrochloric acid solution acid base indicator e.g. bromothymol blue (blue, base yellow, acid)
Background:	The molarity or concentration of a solution tells us the number of moles of substance per litre. 1M NaOH solution contains 1 mole i.e. 4·0g NaOH(s) per litre. 0·1M NaOH solution contains 0·1 mole i.e. 0·4g NaOH(s) per litre. Similarly 0·1M HCl solution contains 0·1 mole i.e. 3·65g HCl per litre.
Method:	Using a dropper put 20 drops of 0·1M sodium hydroxide solution into a clean test-tube. Add 1 drop of the acid base indicator. The equation for the reaction is: x NaO^H (aq) + yHCl (aq) —› products Now add 0·1M hydrochloric acid from another dropper, drop by drop, shaking after each drop, until the indicator changes colour. Record the number of drops used. Try and add drops as evenly as possible. Repeat the experiment to check your answer.

Working: Collect the class results for the number of drops used and average them. The average should be close to 20 drops. Obviously, equal volumes of acid and base have been used. Since they are the same concentration, equal numbers of moles must have reacted.

=» x = y, x/y = 1

Thus the simplest equation for the reaction is:

$NaOH$ (aq) + HCl (aq)

Comment: This method could be used for any reaction where the end-point i.e. the end of the reaction, can be identified using an indicator or other method. Once the equation is known we can use this method to introduce volumetric analysis or to determine quickly and roughly the concentration of an unknown solution. This will be described in a later issue. Another good reaction to study would be the neutralisation of sodium carbonate: using methyl orange or bromothymol blue as the indicator this is an example of a 1:2 reaction.

CHEMISTRY IN ACTION – ALL AROUND

There are examples of chemistry in action all around us, and reading the newspapers can give some good topical ideas for use in teaching. Often the chemical facts will be not clear and sometimes inaccurate, but the articles can be a good basis for starting a discussion or illustrating a point done in theory or for revision. Two examples are given below taken from one day’s offering. Why not start a cuttings file of material that can be used in your chemistry or science classes? Send in some examples for future issues of Chemistry in Action.

DANGER – CHEMICALS IN TRANSIT

Dangerous substances act: an act controlling the transport of hazardous chemicals recently came into force (15/9/80). 25 chemicals are covered by the act and it would be an interesting exercise to get your leaving cert. class to use the published list of names and answer some questions:

What are the correct/systematic name for the substances?
What are their main hazards?
What are the chemicals used for?
What are their chemical formulae?

The list of chemicals is as follows:

Acetone
Acrylonitrile
Ammonia
Benzene
Butane
Chlorine
Ethanol
Ethyl acrylate
Formic acid
Hydrochloric acid
Hydrofluoric acid
Hydrogen peroxide
Methanol
Methyl acrylate
Methyl ethyl ketone
Nitric acid
Potassium

cyanide
Potash lye
Propane
Sodium cyanide
Soda lye
Sulphuric acid
Toluene
Xylene
Butane/propane mixtures

ALL SALTS AREN'T SALT

To the man in the street there is only one type of salt: the 'salt n' vinegar' type, common salt, or sodium chloride to the chemist. To the chemist, however, a salt is any compound formed when an acid and base react. A salt is usually the ionic compound of a metal, which dissolves in water to give ions. Common salt is the most common 'salt' in nature: it is the main constituent of the saltiness in sea-water, it is found in solid salt deposits in various countries and it is a major element of body fluids, and essential to our diet.

Several papers reported a case on 15th. Sept. where a man went into a shop for 7lb of salt and was sold 7lb of ammonium sulphate by mistake (they are both white, crystalline solids). They are both salts of course but only one is suitable for human consumption. Ammonium sulphate is used as a fertiliser and would cause severe bowel problems if eaten.

Again we have a good basis for an experiment for your fifth/sixth year classes. Given two unlabelled white powders, how could you tell which one is sodium chloride and which one ammonium sulphate? How many tests can you think up to identify either the cation or anion in these two substances?

$(NH_4)_2SO_4$: if heated with sodium hydroxide ammonia will be given off which has a characteristic smell and is basic; a solution in water would give a white precipitate with barium chloride – test for SO_4^{2-}.
NaCl : sodium flame test would identify sodium but remember to use a clean wire as most things are contaminated with sodium; silver nitrate test would give a white precipitate with chloride, soluble in ammonia solution; conc. sulphuric acid on a chloride gives off fumes of hydrogen chloride on heating (CAUTION!).

STOICHIOMETRY 2 Quantities of reactants in preparations

The idea of stoichiometry i.e. definite combining or reacting proportions of elements or compounds as evidenced in chemical equations or formulae for compounds, is basic to chemistry. The mole concept allows us to translate equations or formulae into amounts of actual substances which will react or which will be produced. For example, many instructions for preparations give the masses or volumes required without any relations to stoichiometry. In reality, they are cookery recipes. Surely it is better to start from a chemical equation and to work out what quantities of reactants will be needed to produce a certain yield? This is also one way to avoid the error of adding too much reagent, often a cause of explosions in gas preparations.

e.g. For preparing carbon dioxide we react marble chips and conc. hydrochloric acid, diluting with water to moderate the reaction.

Equation: $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O$
1 mole 2 moles 1 mole

The equation tells us that 1 mole of calcium carbonate i.e. marble chips, reacts with 2 moles hydrochloric acid to give 1 mole of gaseous carbon dioxide.

Conc. hydrochloric acid has a density of 1·18g mL^{-1}, contains 36% by mass of HCl and has a concentration of 12M. (It is very useful to know the concentrations of those laboratory reagents usually available in concentrated solutions in order to make up dilute solutions or work out the number of mL/mol. This information is given in Table 1.)

1 mole HCl is contained in 1000/12 = 83·3mL conc. HCl, and 2 moles in 166·6mL

1 mole $CaCO_3$ weighs 40·0 + 12·0 + 48·0 = 100g
Therefore 100g $CaCO_3$ should react completely with 167 mL conc. HCl to give ~22·4L (1 Mole) of gaseous CO_2, or about 40 gas-jars full of gas.

Having decided what volume of gas we want to produce, the appropriate quantities of reactants can easily be calculated. Apart from improving understanding and minimizing the risks of accidents, this procedure will also ensure less wastage of chemicals.

If dilute hydrochloric acid were used (2M HCl), how much acid would be needed to produce 4·5L of gas? 4·5L is ¼ of a mole and thus we would need 100/4 = 25g CaCO3 and 2/4 = 0·5 moles HCl i.e. 250 mL, since 1L contains 2 moles. The large volume of dilute acid that would be needed explains why conc. acid is used.

N.B. Use a tap-funnel to control addition of acid and use marble chips rather than powdered calcium carbonate to reduce the rate of gas production. Gas is produced faster when the solid particles are smaller and have a greater surface area. Most explosions are caused because gas is produced too quickly to get out of the apparatus.

Table 1	Substance	Concentration
	Glacial ethanoic acid (glacial acetic acid)	~17M
	Conc. ammonia solution (0·88o)	~16M
	Conc. hydrochloric acid solution	~12M
	Conc. nitric acid solution	~16M
	Fuming nitric acid solution	~24M
	Conc. phosphoric (V) acid solution (orthophosphoric acid)	~15M
	Conc. sulphuric acid solution	~18M

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l, l or L: a question of clarity
Did you know that the internationally accepted symbol for the litre is now L, not l or l but L? This is to avoid confusion in typing since l is often used for 'one' as well. L, cL and mL are easier to type and it is clear what is meant.

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Test for carbon dioxide: a new twist

It is quite common to use the limewater test to show the occurrence of CO2 in exhaled air and that it is the same gas produced by adding acid to limestone. The reaction involved is of course the precipitation of the sparingly soluble calcium carbonate from a solution of calcium ions.

$Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O$

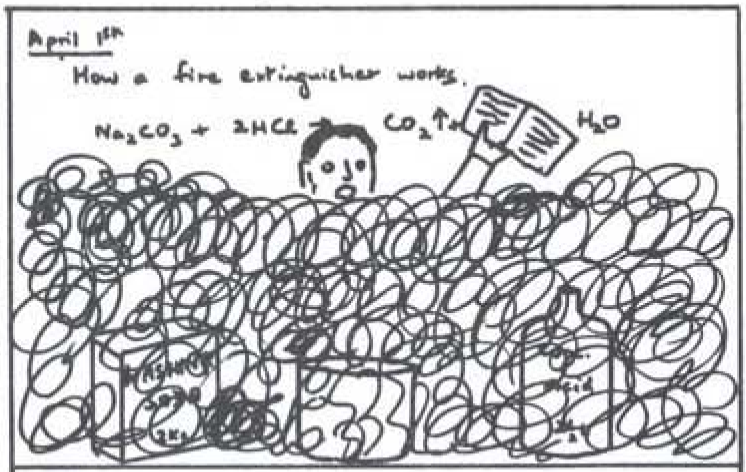
What happens if you keep on passing CO_2 through the cloudy limewater? (Try this next time you do this test.) You and your class may be surprised to find that the solution goes clear again! Why?

Carbon dioxide is the acid anhydride of a dibasic acid: carbonic acid. Thus it forms two series of salts: carbonates and hydrogen carbonates. When excess CO_2 is passed through a suspension of calcium carbonate it redissolves due to the formation of the soluble calcium hydrogencarbonate.

$CaCO_3(s) + CO_2(g) + H_2O \longrightarrow Ca(HCO_3)_2(aq)$

Heating this solution will drive off CO_2 and reverse the reaction. Calcium hydrogen carbonate is only known in solution and cannot be isolated as a solid.

A cautionary tale



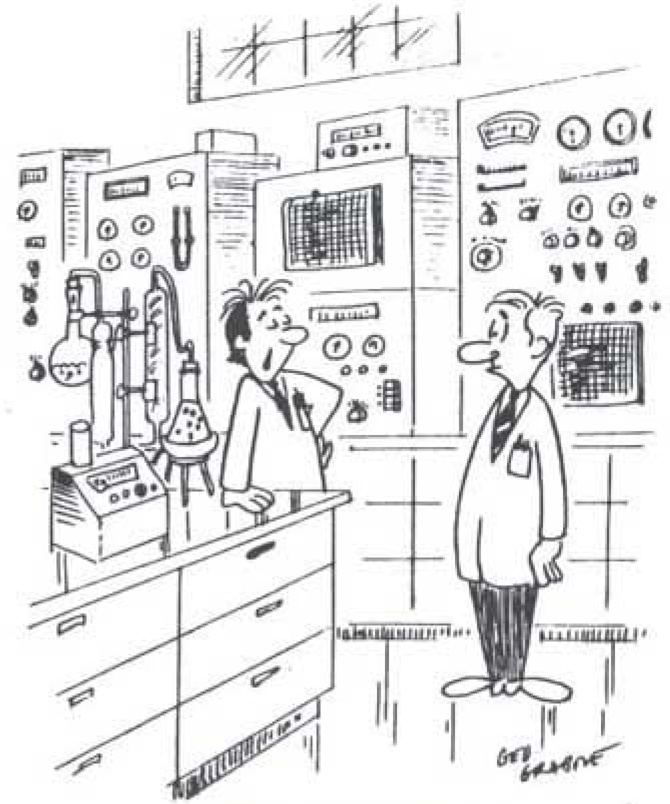
"Help ! I'm sure it said add 2kg of washing soda to a bottle of acid. What went wrong?"

How much gas did he produce? Work it out and see p.17

Chemical Education

Teaching science at school

“But after all, the main reason for teaching some branch of physical science is to be found in considering the sort of processes by which the truths of such science are investigated, and the faculties of mind which are exercised in the course of physical investigations. In the first place a student of any branch of natural history or science must learn to observe carefully, to use his eyes and to know the difference between facts which are abnormal and facts which are typical. Then he must come into actual contact with realities, must handle objects, must try experiments, must question matter and nature closely, must invent new forms of test, must watch and wait until he is quite sure he has hold of the true answer. And when he has observed the phenomena, he has to reason from them inductively, and pass from particular facts to the general laws which underlie and comprehend them.”
Lectures on Teaching, Sir Joshua Fitch, CUP (1898) quoted by Norman Booth in S.S.R. 61 (214), Sept. 1979



"Test tube! . . . .What's a test tube?"

Reprinted from CHEMTECH Jan. 1980

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STRUCTURES RELATED TO DIAMOND

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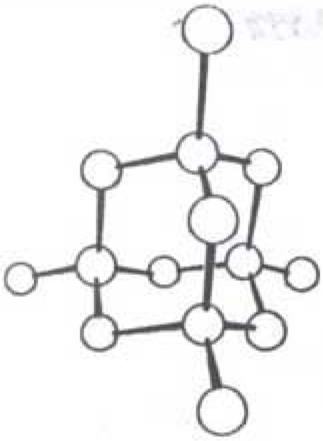
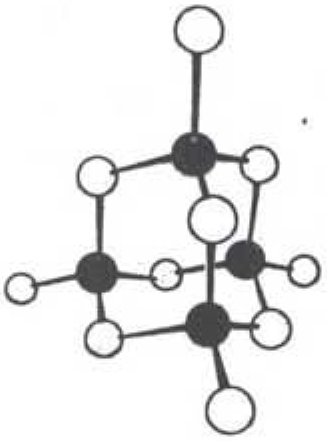
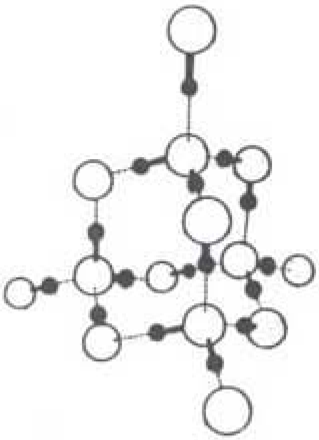


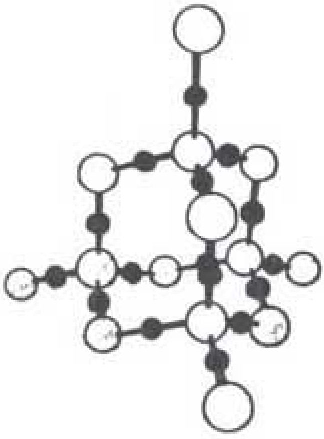
A. The diamond structure (also for silicon, germanium and α-tin.)



B. Cubic boron nitride, cubic silicon nitride or zinc blende



C. Ice (solid water)



D. One form of silicon dioxide (β - cristobalite)

How many allotropes of carbon?

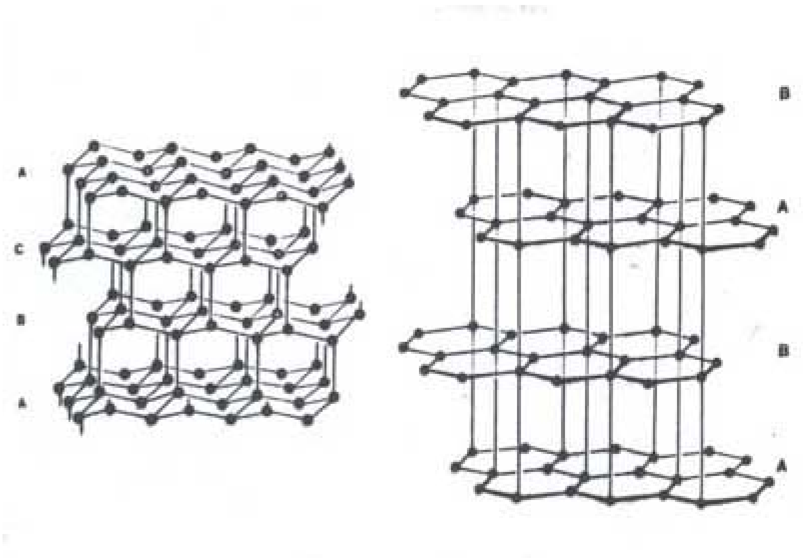
This question is not as easy to answer as it appears from the content of Inter-Cert. Science courses. Allotropes are different forms of the same element, having different structures i.e. arrangements of atoms. If a single crystal is powdered it is the same substance, with the same structure. Each tiny grain of solid is a small crystal. Sticking the powder together by heating and pressing i.e. sintering, leaves the basic structure unchanged.

Most forms of carbon often classed as allotropes e.g. coal, coke, soot, carbon black, charcoal, etc. are really impure forms of graphite, with varying degrees of crystallinity. Glassy carbon can be made which is completely amorphous and hexagonal diamonds have been made and found in meteorites, which are a metallic-type of carbon.

The only really definite answer to the question above, is that carbon occurs as two common allotropes when pure: diamond and graphite.

Diamonds have been known since biblical times:
“The sin of Judah is written with a pen of iron and with the point of a diamond.”
Jer.17:1

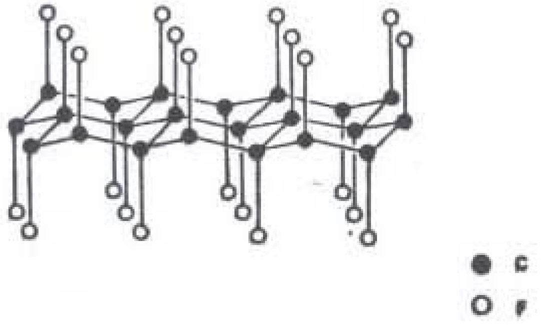
Diamond and Graphite structures



Diamond and graphite are the main forms of carbon i.e. they are allotropes. Their crystal structures are radically different as the diagrams above show and results in very marked differences in physical and chemical properties.

Diamonds are transparent, colourless (when pure), hard, brittle, electrical insulators, good conductors of heat (!) and chemically resistant. Each carbon is linked to four others arranged tetrahedrally and can be described as sp^3 hybridised. One could think of it as the ultimate branched hydrocarbon – but without any hydrogen. It was only in 1797 that Tennant established that diamond was another form of carbon. Its rigid structure, strong bonds and lack of hydrogen means that although it will burn in oxygen it does not catch fire readily (just as it is harder to ignite the harder forms of coal with high carbon content e.g. anthracite or coke).

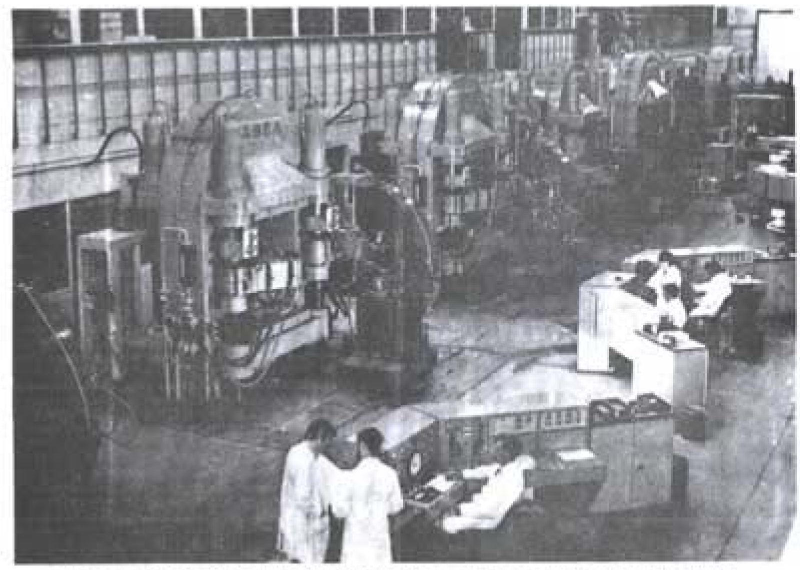
Graphite, on the other hand, is black, soft, a good electrical conductor along the layers, and is chemically quite reactive to form compounds known as lamellar or intercalation compounds. One good example is carbon monofluoride, (CF)n, shown below which is used as a lubricant. The layers of carbon atoms in graphite lie flat, and the bonding is sp^2, i.e. each sheet is a super-aromatic molecule, with delocalised pi-electrons. It is these delocalised electrons that can carry an electric current along the layers but not at right-angles to them. Graphite thus has different properties in different directions and is said to be anisotropic. The layers are held together very weakly by interaction between the pi-electron clouds. The layers thus slide easily over each other making graphite a good lubricant and it feels soapy. Because the bonding is weak reactive atoms or molecules can get in and attack the pi-electrons forming the lamellar compounds. Graphite is more stable than diamond and when carbon compounds are heated heating graphitization occurs at 2000-2500ºC. Carbon fibres are orientated single crystals of graphite made by heating stretched polymer fibres and are very strong and light.



Carbon monofluoride

Chemistry in Ireland: 2

DE BEERS INDUSTRIAL DIAMOND DIVISION (IRELAND) LTD



The photograph above shows the row of 10000 ton presses at De Beers, Shannon. These presses are operated round the clock, producing a range of grades of industrial diamonds. De Beers is the world's leading supplier of synthetic and natural industrial diamonds and has other synthetic diamond plants in Sweden and South Africa. The Shannon factory was opened in 1960.

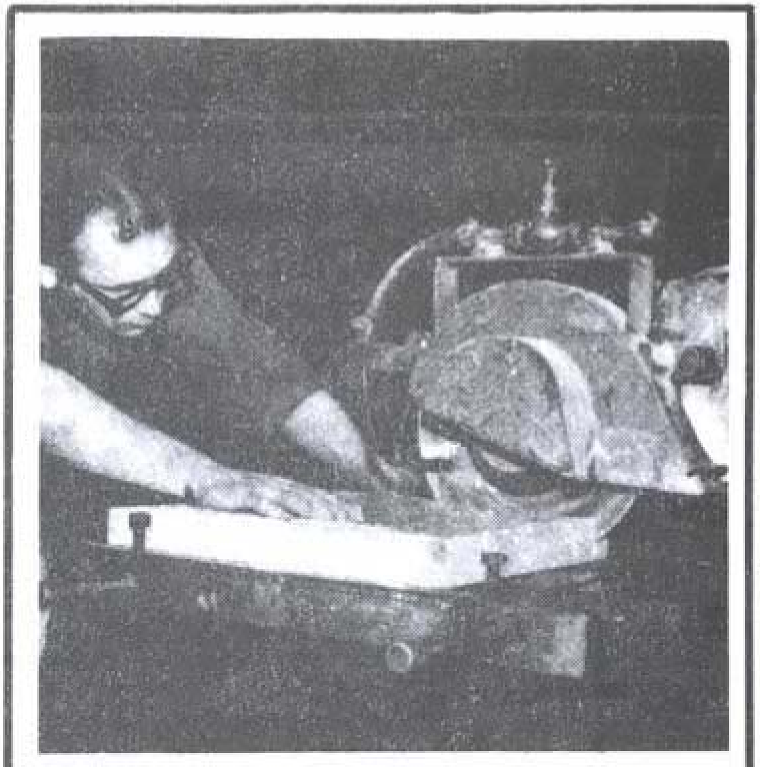
The photograph above shows the row of 10000 ton presses at De Beers, Shannon. These presses are operated round the clock, producing a range of grades of industrial diamonds. De Beers is the world’s leading supplier of synthetic and natural industrial diamonds and has other synthetic diamond plants in Sweden and South Africa. The Shannon factory was opened in 1960.

One of Ireland’s most unusual and exotic examples of industrial chemistry, and one of the oldest of the new chemical industries, is the De Beers industrial diamond plant located at Shannon, Co.Clare. De Beers Industrial Diamond Division (Ireland) Ltd. was one of the first companies to use the Shannon Free Airport Industrial Estate and opened up in 1960. It is the mid-west’s major exporter to date and one of Ireland’s top companies, employing nearly 700 people. The plant was set up by the South African-based De Beer’s group only a few years after the discovery of a method of synthesising diamonds, one of nature’s most elusive and most treasured materials.

Natural diamonds are found only in certain geological formations known as diamond pipes or in alluvial deposits. Africa is the main source of natural diamond, but South America and more recently Australia are also important. More than half the natural diamonds are indispensable to modern technology and industry. Around 80 million carats of industrial diamonds (1 carat = 0·2g) are consumed by industry each year and are used in a myriad industries. Diamonds have been known from antiquity both as gemstones and as cutting and engraving tools. Although large pieces of diamond are often found the majority of the mined material is mainly low-grade diamond, and 1000 tons of material have to be processed to produce 1 oz (28·4g) of diamond. The expanding demand for industrial diamonds after the 1940’s could not keep pace with the production, and synthetic diamonds came at the right time to fill the need. The first reproducible process for producing synthetic diamonds was announced by a group from General Electric in the U.S.A. in 1955, and De Beers achieved their own synthesis, by a very similar method, in 1959. This success led directly to the setting up of the Shannon plant. De Beers also has synthetic diamond plants in South Africa and in Sweden.

“A diamond is a letter to us from the depths.”
Charles Frank

As gemstones it is the characteristic ‘fire’ of diamonds when cut and polished, due to their high refractive index, that makes them attractive. Industrially it is the hardness of diamond that makes it useful. Diamond is the hardest material known and consequently it can be used to cut, engrave or polish any other material. The hardness of diamond falls in the range 9000-15000kg mm-2; the next hardest material is cubic boron nitride (4400kg mm-2), followed by boron carbide (2800kg mm-2) and silicon carbide (2500kg mm-2). The hardness is measured by the force required to indent the surface. Diamonds are thus used for grinding, polishing, cutting, engraving and drilling hard materials such as ceramics, glass, metals etc.



A diamond-impregnated blade saws through 15½"x 2" hard refractory material in 20 s.

A diamond-impregnated blade saws through 15½” x 2” hard refractory material in 20s.

How diamonds are made

Scientists have long sought a means of transforming the black, low-valued form of carbon, graphite, into its transparent, hard, valuable allotrope, diamond. This was the modern alchemist’s dream and much more realistic than the older one of transforming lead to gold, since it involved only a change in crystal structure of the same element. The philosopher’s stone turned out to be transition metals acting as a solvent and catalyst, at high temperatures and pressures. The 10000 ton presses at Shannon, shown above, symbolise the success of this venture – a marriage of high technology and painstaking scientific research. Earlier attempts to make diamonds, associated with the names of Hannay (1880) and Moissan (1894), were not reproducible and whether either of them achieved success is doubtful. Recent studies indicate that Hannay may fortuitously have hit on the right conditions in some of his experiments, which were extremely dangerous. Not only was the technology for reaching high pressures and temperatures unavailable, but the scientific basis for making the transformation was not understood either. Until the phase diagram for carbon was determined (see Figure) it was not possible to choose the optimum conditions for diamond synthesis. A phase diagram describes the thermodynamics of system and shows the stability of different phases as the pressure and temperature are altered. Even when the correct thermodynamic conditions are satisfied nothing may happen if the reaction is too slow. The conversion of diamond to graphite or vice-versa is slow except at elevated temperatures or using a catalyst. The first successful, reproducible diamond synthesis announced in 1955 by Bundy et al. used nickel as a metallic solvent for carbon and as a catalyst, to achieve the synthesis at reasonable pressures (60000 atm.) and temperatures (1000-1400ºC). This is the basis of synthetic diamond production at Shannon, except that cobalt is used as the solvent/catalyst. A graphite sample is sandwiched between two layers of cobalt in a cylindrical die.

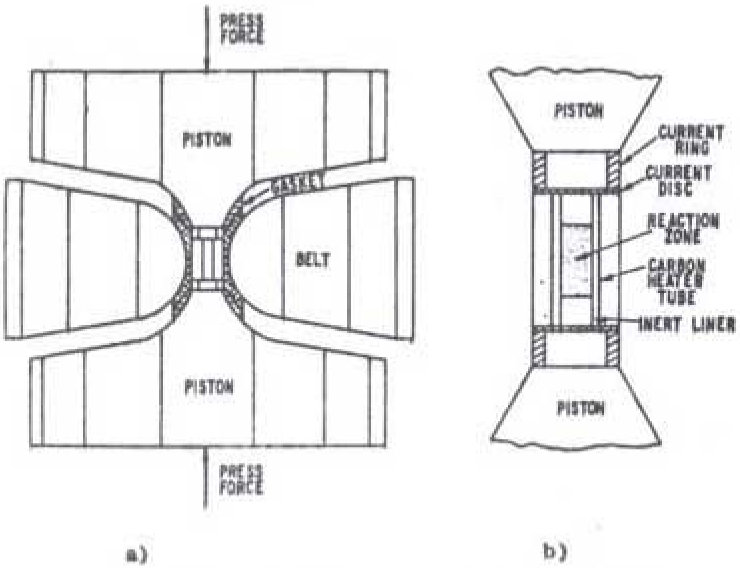
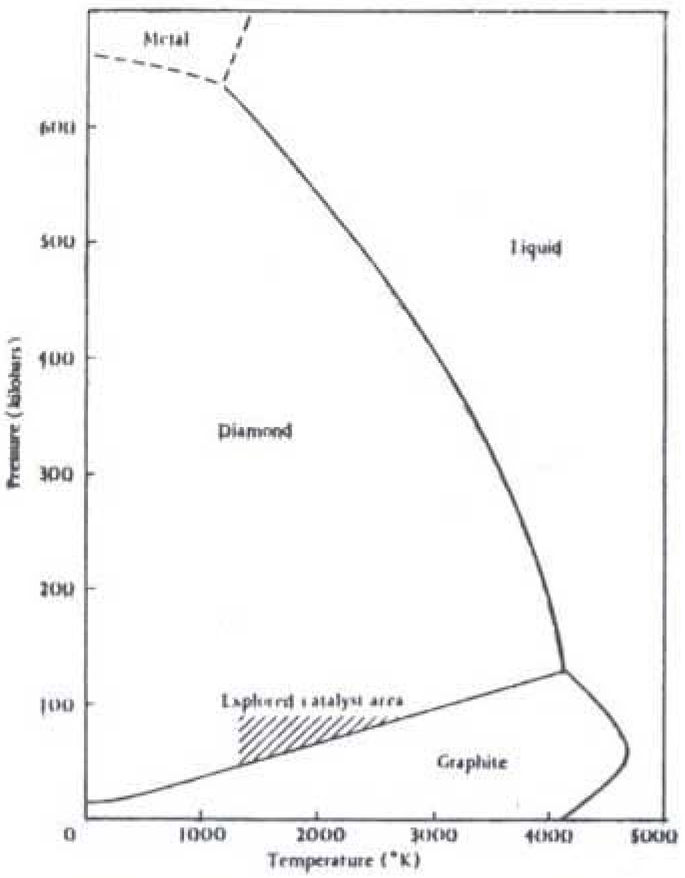


Diagram showing a) the press and b) a close-up of the reaction chamber (from Bundy et al.,1973)

The phase diagram of carbon. The shaded region is the catalyst/solvent area.

Diagram showing a) the press and b) a close-up of the reaction chamber (from Bundy et al., 1973) p.15

This is squeezed in a large press to about 60000 atm. and then heated electrically to around 1400ºC. The shaded area on the phase diagram is the region where diamond synthesis occurs. The metal melts and starts to dissolve the graphite. Under these conditions the metal becomes saturated with graphite and supersaturated with diamond, which is more stable than graphite at this point. Diamond thus starts to crystallise out, more graphite dissolves, and in a few minutes the process is complete and most of the graphite has been converted to small diamonds. The diamonds produced are small because of the rapid nucleation. By varying the conditions it is possible to control this nucleation rate to produce diamonds of different sizes and to some extent, different shapes. The whole process is now computer-controlled to produce the desired grades of synthetic diamonds. The reaction mass is cooled and reduced to room pressure and temperature in a controlled way. The mass of metal, diamonds and unreacted graphite is broken up and the metal is dissolved away in acid to leave the carbon, from which the diamonds are separated and sorted. It is the use of the metal as a solvent/catalyst that makes the process economically viable, since the required conditions (P and T) are readily attainable. The product can compete with natural diamond in cost and has advantages in that the size and shape of the product can be controlled.



The phase diagram of carbon. The shaded region is the catalyst/solvent area.

DIAMOND VERSUS GRAPHITE: which is most stable?

Both graphite and diamond exist at room temperature and pressure and so both are stable in that sense of the word. In chemical terms stability usually refers to thermodynamic stability i.e. is the substance stable with respect to other substances at the conditions chosen? In fact, diamond is the less stable form of carbon. It is denser than graphite (3·51g mL-1 versus 2·22 g mL-1) and the change from diamond to graphite would have a standard free energy change of –2·88kJ mol-1. This means that diamond should spontaneously change to graphite. It does not in practice because the activation energy for the process is so high. Graphite is more disordered than diamond and so graphite becomes more stable with respect to diamond as the temperature is raised. If diamond is heated in the absence of air (to prevent it burning to CO2!) above 800ºC it converts to graphite. There is a large increase in volume and the crystal explodes. This is shown dramatically in the film ‘Carbon’

The phase diagram for carbon shows the regions where diamond, graphite and liquid are stable. Diamond and graphite are at equilibrium along the line separating the two phases (corresponding to a zero free energy change). The larger the free energy change favouring the formation of diamond from graphite i.e. during the synthesis process, the smaller the diamonds will be. Large diamonds can be grown by choosing conditions just on the equilibrium line to ensure slow growth and gem-sized diamonds have been grown in this way starting from diamond seed crystals: unfortunately they cost more than the natural stones and have more chemical impurities. Gem-sized stones were grown for the first time in 1971, again by a team from General Electric.

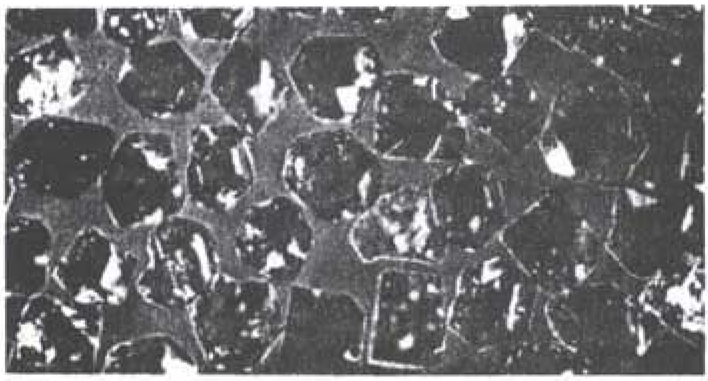
The natural process for diamond growth, which can produce very large stones, is still not fully understood but it is likely that they grew very slowly under stable conditions. In nature diamonds can grow over thousands or millions of years with a slow addition of carbon, under very stable conditions due to the large mass of material surrounding the growing diamonds. The largest natural diamond found so far, the Cullinan, weighed 3106 carats (621·2g) before cutting. The most famous diamond mine is the Premier Mine at Pretoria, S.Africa which left the biggest man-made hole in the world, known locally as the Big Hole, almost 800 ft. deep. It is a diamond pipe and was mined for 43 years, to a total depth of nearly 4000 ft.: 25 million tons of earth were removed and yielded about 3 tons of diamonds.

Diamonds from almost anything!

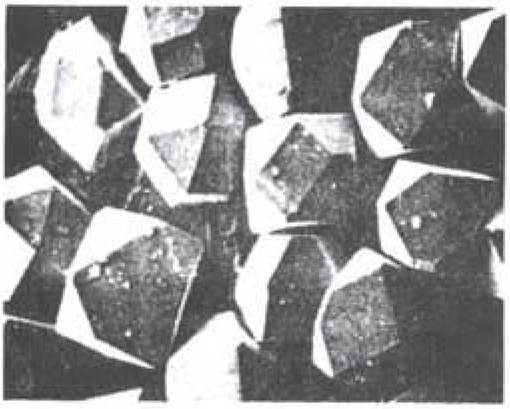
Commercial graphite is the usual starting material for the synthesis of diamond by the catalyst/solvent process. But one can load the reaction cell with any carbon-containing material: wood, coal, tar, peanut butter etc. and still form diamonds from the carbon liberated from these materials at high temperatures and pressures.

Many grades of diamonds are made for different uses.

Synthetic diamonds are usually yellow-green due to the presence of isolated nitrogen atoms in the diamond crystals. Different grades are produced by De Beers for different end-uses, and various sizes are available within each grade. The figures below show the shapes of different grades of synthetic diamonds (these pictures are in colour in the originals from De Beers). For example, SDA diamonds are used for diamond saws; the crystals are typically 0·3-0·4mm in diameter and strong and tough, because the crystals are blocky and regular in shape, based on cubo-octahedrons. MDA grades are designed to bond well to metal; they have good thermal stability and high strength. RDA grades are long and irregular in shape, are more friable i.e. break off more easily, and are used in resin-bonded grinding and cutting wheels; they have sizes in the range 0·14-0·17mm in diameter. Metal-coated diamonds are produced which bond better to metal and also gives better thermal properties. A new product is SYNDITER which consists of a sintered, polycrystalline block of diamond i.e. many small diamonds fused together at the edges to form a solid mass. This can be used to make lathe tools for machining very hard components: instead of just a coating of diamond, which most wheels, drills etc. have, a SYNDITE tool is solid diamond.



SDA grit types have a blocky, regular particle shape with a predominance of single cubo-octahedral crystals, the ideal crystal form for maximum strength and wear resistance.



The blockiness and symmetry of SDA is well illustrated in this electron microscope picture.

SDA grit types have a blocky, regular particle shape with a predominance of single cubo-octahedral crystals, the ideal crystal form for maximum strength and wear resistance.

Cubic boron nitride – another synthetic abrasive

Boron and nitrogen are the elements on either side of carbon in the Periodic Table. Boron and nitrogen can combine to form a compound boron nitride, BN, which is isoelectronic with carbon i.e. the same average number of electrons per atom. There are two forms of boron nitride: a hexagonal form and a cubic form which is formed under pressure from the hexagonal form, in a similar way to the formation of diamond from graphite. Cubic boron nitride is amber in colour, it is the second hardest substance after diamond, and it is isostructural with diamond i.e. they have the same pattern of atoms (see p.13).

De Beers make Amber Boron Nitride using a similar process to that used for synthetic diamond (boron nitride has a similar phase diagram to carbon) and it is marketed as a grinding abrasive for steel.

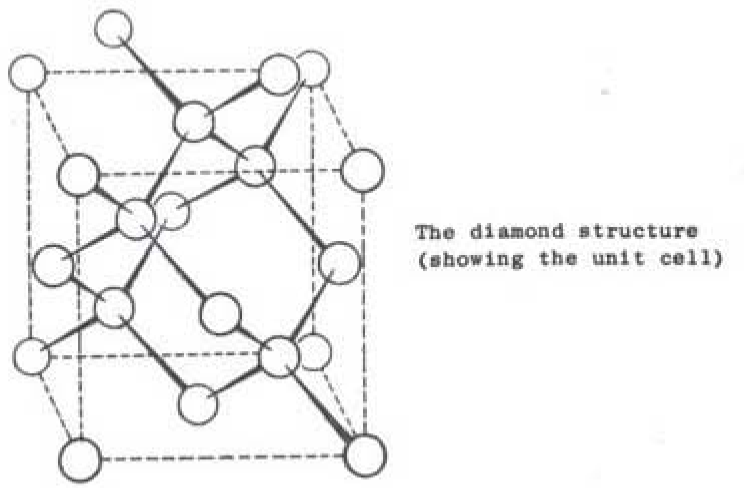
Cubic boron nitride, known as borazon, is made by subjecting the hexagonal form to 60000 atm. and 1500ºC, with a catalyst of lithium or magnesium nitride.

"In this age of mechanical progress, industrial diamonds have achieved the status of a strategic material for which there is no substitute."
Sir Ernest Oppenheimer (1947)

Why is diamond hard?

The great strength and hardness of diamond is due to the strong, rigid, symmetrical tetrahedral bonding between the carbon atoms. Each carbon is linked to four other carbons, arranged tetrahedrally around it, by a strong single

C-C bond.



The diamond structure (showing the unit cell)

Each carbon in the structure is thus linked by a strong network of C-C bonds to every other atom. A piece of diamond is a single crystal i.e. the piece is one, giant molecule. Such structures are known as giant molecule or giant network structures. They are very strong because all the atoms are linked to each other and it is thus very difficult to break off pieces from the solid i.e. diamond is hard. The diamond structure is the most stable structure known because the bonding extends symmetrically in all directions forming a three-dimensional network. Other substances with the same structure are expected to be hard as well. This is found to be true with cubic boron nitride and silicon carbide, both isoelectronic and isostructural with diamond. They are not as hard as diamond because the covalent bond holding the structures together i.e. the B-N and Si-C bonds, respectively, are weaker than the C-C bond. In line with this, the m.p.'s of the solids are also less than that of diamond, see table below.

Compound	m.p./ºC	Bond	strength/kJ mol-1
Diamond	3527	C-C	356
Graphite	3652*		
Boron nitride	3027*	B-N	?
Silicon carbide	2727*	Si-C	285
Silicon dioxide	1713	Si-O	368

*sublimes

The silicon atoms in one form of silicon dioxide are also arranged in the diamond structure, with oxygen atoms between each pair of silicons. Ice also has a structure based on the diamond structure, with the oxygen atoms being held together by the fairly weak hydrogen bonds. The figures on p.13 show the relationship between the various structures.

"Pliny the Elder (A.D. 23-79) in his highly unreliable Natural History gives directions for distinguishing a natural diamond. It should be put, he says on a blacksmith's anvil and smitten with a heavy hammer as hard as possible; if it breaks it is not a true diamond. It is likely that a good many valuable stones were destroyed in this way because Pliny was muddling up hardness and toughness. Diamond is the hardest of all substances and the hardness of diamond is useful when one wants to cut or scratch or grind materials and this is its main industrial use. But diamond, like other hard precious stones, is quite brittle so that, even if one could get it cheaply in large pieces it would not be a very useful structural substance."
J.E.Gordon
The New Science of Strong Materials
Penguin Books, 1968, p.98

General Electric are due to open up a synthetic diamond plant in Dublin shortly, with a £47 million investment and producing 700 jobs. Ireland will then be a world leader in synthetic diamond production, with both De Beers and G.E.

Bacteria that eat copper

Avoca mine is the only copper mine operating in the E.E.C. and is financially marginal due to the low grade ores involved. A copper eating bacteria, thiobacillus ferro-oxidans, is being studied as the vital element in a new method of mining low grade ores: microbiological leaching. The ore deposit at Avoca is estimated at over 40 million tons which would yield 200,000 tons of copper. The use of this relatively new method is being investigated at Avoca by IIRS, in collaboration with other EEC countries.

Copper has been mined at Avoca for many centuries and the rich lodes are mostly exhausted. Water running from the old workings at East Avoca is quite acid and contains high levels of dissolved copper, iron and zinc – a reason for the lack of fish in the Avoca river. (Copper occurs in sulphide minerals with iron, zinc and lead and the ore at Avoca contains 0·45% copper, 0·25% lead and 0·39% zinc). In the USA about 20-25% of copper production is obtained by leaching of old mining residues. The copper can then be recovered by cementation i.e. adding a more reactive metal (usually scrap iron) which displaces copper from solution. (This is easily demonstrated in the laboratory by adding an iron nail to dilute copper (II) sulphate solution).

Concentration of low grade ores by the traditional methods of grinding, froth flotation and smelting is very expensive. Microbiological leaching offers a potentially much cheaper method: it involves blasting the rock and then leaching with dilute sulphuric acid in the presence of thiobacillus ferro-oxidane. The rate of dissolution is slow with acid alone and the bacillus produces iron (III) sulphate which helps dissolve the copper minerals, and increase the concentration of copper and other metals in the leaching solution. After cementation of the ‘pregnant liquor’, as this solution is known, the copper metal concentrate is much purer (50-80%) than that produced by flotation (18-22%), which separates copper (II) sulphide particles rather than copper metal. This reduces the energy required and hence the costs of producing pure copper. The recovery of other metals present with copper i.e. lead, zinc, silver and gold, will also be investigated.

The project which started in 1979 will take four years and success would make Avoca mine a highly profitable venture once more, and produce much needed foreign exchange.

Refs. “Leaching low-grade copper ores at Avoca”, Colin Burton, “Technology Ireland”, October 1979, 30-32.

P.S. Does your school subscribe to “Technology Ireland”? If not, then you ought to see that it does: it is very useful for keeping up with applications of science and technology in Ireland.

“It is not unusual to find a chemistry graduate who, though knowing his subject very well, knows little about the relative significance or volume produced of many of the compounds he has studied. For all he knows they are all of equal significance and value to society. He has no sense of the history of his subject or the way history has shaped it or how chemistry has profoundly affected civilisation. It is not unusual for this same chemistry graduate to join the teaching profession. School, college and university chemistry courses must each contribute to the alleviation of this sort of situation.”
Will Hughes
“Chemistry: pure vs. applied” in New movements in the study and teaching of chemistry, ed. D.J.Daniels, Temple Smith, London, 1975.

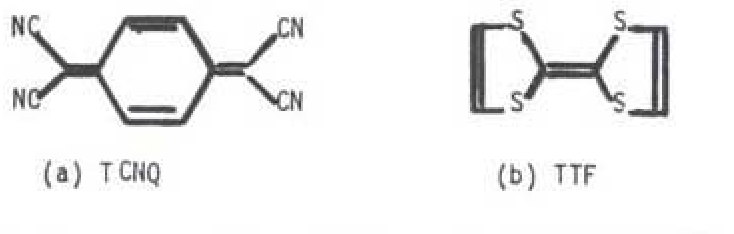
How much gas?

2kg of washing soda ($Na_2CO_3.7H_2O$ = 232g mol^{-1}) would contain 2000/232 = 8·6 moles.
2½L of conc. hydrochloric acid (12M) would contain 30 moles of acid.
From the equation 1 mole sodium carbonate reacts with 2 moles of acid to give carbon dioxide gas (1 mole). Thus the acid is present in excess and all the washing soda would be consumed. 8·6 moles of gas would be produced or approx. 8·6 x 22·4L = 193L of gas. Quite a volume to be produced all at once on

the front bench!

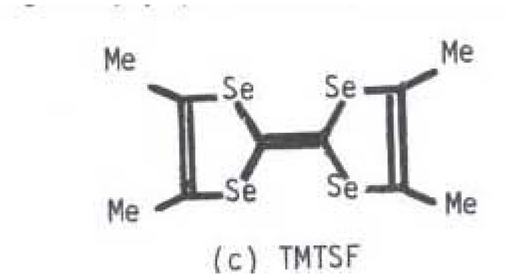
Frontiers of Chemistry
ORGANIC METALS: MATERIALS FOR THE FUTURE?

One of the accepted truths of chemistry is that electrical conductivity is a good guide to the type of bonding in a solid. Covalent or molecular solids are insulators in the solid and liquid states; ionic solids are insulators but conduct ionically when molten; metallic solids conduct electronically when solid or liquid. Modern advances in the electrochemistry of solids have upturned two of these assumptions: a large number of ionic compounds are now classified as ‘superionic’ conductors as they conduct in the solid state and are important materials for developing new types of battery. These materials will be discussed in the next issue. Secondly, quite a number of organic materials have been synthesised which are electronic conductors, and they have been called ‘organic metals’ or ‘synthetic metals’, and we shall discuss these here. Most organic compounds are insulators, though some are semi-conductors. One notable exception is graphite (p.13) which is a good 2-dimensional, planar electronic conductor. Graphite is used to make electrodes for dry batteries and for the electro-extraction of metals. However, organic complexes with high electronic conductivity have been known for some years now and their discovery in 1960 sparked off a new area of research. The new conductors are 1-dimensional or ‘chainar’ conductors, electrons being conducted through delocalised pi-electron orbitals extending along the chains. One example if the charge-transfer complex TTF-TCNQ. It is a complex formed from TCNQ (7,7,8,8, tetracyano p-quinodimethane, Figure (a)), the compound which started the gold-rush for new organic conductors in 1960, and TTF (tetrathiofulvene, Figure (b)).


(a) TCNQ
(b) TTF

Figures (a) and (b), p.18

TCNQ is a planar, symmetric, electron-poor molecules that easily gains one or two electrons to form an anion. TTF is a planar, symmetric, electron-rich compound and readily loses electrons to form a cation. A 1:1 compound of the two forms a charge-transfer complex where electrons are transferred from TTF to TCNQ: the extra electrons on the TCNQ molecules are in pi-orbitals which overlap to form a delocalised ‘conduction band’ through the crystal. In the crystal the planar molecules are stacked like pancakes, TTF and TCNQ forming different but neighbouring stacks within the crystal. Conductivity can only occur in one direction in the crystal and the electrical properties are thus anisotropic. (Isotropic means the same in all directions, as in a metal.) TTF-TCNQ has conductivities ranging from 100-1000(ohm.cm)-1; copper for comparison has a conductivity of 105(ohm.cm)-1. Chemists have been ringing the changes on these molecules by adding and removing substituents, changing S for Se etc. e.g. TMTSF is shown in Figure (c) (tetramethyl-tetraselanafulvalene).


(c) TMTSF

Figure, p.18
(c) TMTSF

It is this ability of the chemist to tailor organic molecules to specification, known as ‘molecular engineering’, which explains the interest in organic conductors. This method has been used to great success in the pharmaceutical industry and the hope is that the organic chemists can produce molecules with the optimum electrical properties.

A range of compounds has already been made ranging from insulators, through semi-conductors to organic metals. On cooling the organic conductors their resistance decreases like true metals, but unfortunately change to an insulating state around 50 K. As conductors these materials are inferior to graphite but one additional reason for the intense interest in them is the possibility they hold for an organic super-conductor operating at temperatures of 20K or above. Recently (Dec.1979) D.Jerome and co-workers announced that they had observed superconductivity in (TMTSF)2PF6 (ditetramethyl-tetraselenafulvalene – hexafluorophosphate), at 12000 atm and below 1K. Although this seems a rather esoteric discovery, it has excited great interest among solid state chemists and physicists and industrialists. A superconductor is a material whose


(d) trans-poly(acetylene)

Figure (d), p.18

electrical conductivity and magnetic resistivity drop to zero below a certain critical temperature. This means that there is no resistance to the passage of electric current, thus no power losses and no resistive heating. High currents can thus be passed and the main use of superconducting coils is to produce very high-field electromagnets. These are used, for example, in high-frequency n.m.r. spectrometers, in fusion research etc. The coils are made from metals or alloys which become superconducting when cooled with liquid helium e.g. niobium or niobium-titanium. The discovery of organic super-conductors (which was predicted from theory in 1955) shows that the phenomenon is not restricted to metals but can exist in synthetic conductors built from organic molecules. The aim is to produce superconductors that operate around 20K (liquid hydrogen temperatures) and ultimately up to room temperature. Organic superconductivity itself was considered an impossible dream 20 years ago and has now been established: the scientists active in this field of research are now dreaming of the future… As D.Jerome says “One can hardly doubt that the whole field of organic conductors will have an exciting future.”

CONDUCTION IN SOLIDS

A material may be an insulator (high resistance) or a conductor (low resistance). A conductor may be an electronic conductor (electrons carry the current e.g. a metal) or an ionic conductor (ions carry the current e.g. a molten salt, an electrolyte solution or superionic conductor).

An electronic conductor may either be a metallic conductor (resistance drops with decreasing temperature, electrons carry the current) or a semi-conductor (resistance increases as temperature decreases; current carried by electrons, n-type, or by electron-holes, p-type). Microprocessors are based on silicon microchips which are n- or p-type semi-conductors, depending on the nature of the impurities added as dopants. A dopant is a material added, usually in small amounts, to modify the electrical properties of a material. The process is known as doping.

Ionic conduction is thermally activated like semi-conduction i.e. conductivity increases with increasing temperature, whereas metals show the opposite behaviour.

Superconduction is exhibited by a few materials (metals, alloys and now organic materials). In this the materials behave like metals down to a critical temperature, at which a transition occurs and resistance drops to zero.

CONDUCTING POLYMERS

Perhaps of even greater technological significance is the work going on into conducting polymers. A recent review of a conference on this subject said “The stakes and the scientist’s spirits are high in this rapidly evolving field of synthetic metals”. The advantages of producing conducting polymers lie in their good mechanical properties (strength, ease of film-forming), ease and diversity of chemical synthesis, the vast potential for molecular engineering in polymers, availability of processing and production techniques, and their relative cheapness. The two best-known conducting polymers are poly(thiazyl) (polysulphur nitride), (SN)n, and poly(ethene) (poly(acetylene)), (C2H2)n. Both these materials are linear polymers and pi-electrons are delocalised along the chains. Poly(acetylene) can be thought of as a 1-D version of graphite (see Figure (d)). Doping these materials with halogens (bromine or iodine) or with compounds such as AsF5, produces large increases of conductivity e.g. from 10-5-10-6 (ohm.cm)-1 undoped to 10-1000 (ohm.cm)-1 doped. Other polymers such as poly(pyrrole) and poly(p-phenylene sulphide) are also under study, the latter polymer already being commerically produced. A promising new battery has been patented by its inventor Alan McDiarmid (U. of Pennsylvania), made from doped poly(acetylene), which he describes as a sheet of plastic between two strips of celluloid sticky tape. The materials are still under development but seem to offer much more promise of application than the materials such as TTF-TCNQ, although these are vital in the development of our theoretical understanding of what has been described as “the fastest-growing field there is”. We are certainly going to be hearing more about organic metals in the future.

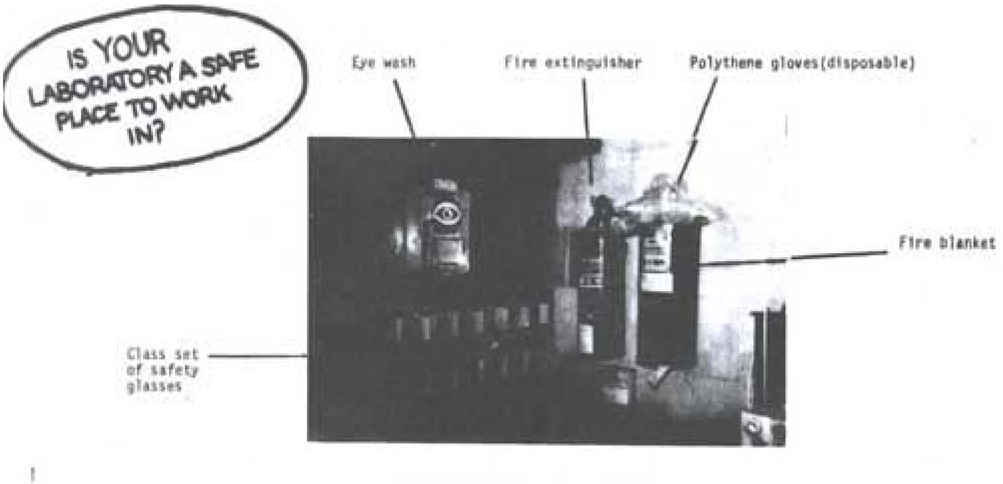
References:

*“Organic superconductors”, D.Jerome, M.Ribault and K.Bechgaard, New Scientist 10/7/80, 104-107
“One-dimensional materials astir with activity”, J.H.Krieger, C&EN, 4/7/77, 14-17
“Conductive polymers”, J.Mort, Science, 208, 23/5/80, 819-825
“Synthetic metals generate widespread excitement”, news item in Chemistry and Industry, 6/9/80. 674
* recommended as most readable and accessible.

Safety

SAFETY IN THE LABORATORY – are these items in your laboratory?

IS YOUR LABORATORY A SAFE PLACE TO WORK IN?



<u>SAFETY CHECKLIST:</u> use it to evaluate your lab.

<u>Safety equipment: Does your laboratory have the following?</u>

1. Fire extinguishers – what types? Suitable for solvent fires?
2. Fire blanket and fire bucket (containing sand)
3. Eye washes or facilities for washing out eyes quickly
4. Protective clothing for handling chemical spills (face mask, safety visor, thick rubber gloves, rubber boots, apron etc.)
5. Eye protection for each pupil doing experiments i.e. safety goggles or spectacles
6. Safety screen for demonstration experiments
7. Do pupils wear protective clothing – aprons or coats?
8. Do you have a step-ladder for reaching high shelves?
9. First aid kit.

<u>Chemical hazards – are you aware of them and how to deal with accidents?</u>

1. Does the laboratory/school have a reference book detailing chemical hazards and how to deal with them?
2. Do you know the common hazards associated with chemicals? When setting up an experiment involving chemicals do you think of possible hazards and try to minimise risks?
3. Are all chemicals properly labelled, stored safely and used sensibly? Are bottles labelled indicating any major hazards e.g. flammable, toxic, caustic or corrosive etc.
4. Do you handle or prepare chemicals with harmful vapours in a fume cupboard?
5. If you use it, can you deal with a mercury spillage?
6. Do you dispose of chemical wastes safely? How do you deal with flammable liquids or solid wastes?
7. Do you use minimum amounts of hazardous materials and use dilute solutions where possible?
8. Is eye protection worn by use and your pupils whenever chemicals are being used?

<u>Is your laboratory designed for safety?</u>

1. Does it have at least two exits in case of fire or chemical spillage?
2. Is the fume cupboard (hood) working? Are there enough fume cupboards for your needs?
3. Is the ventilation in the laboratory adequate?
4. Are your benches arranged to allow easy movement and to avoid any blind alleys in case of fire?
5. Can the electrical power and gas supply be cut off at a master switch for each laboratory? Are these switches/taps easily accessible and labelled?
6. Are chemicals stored safely e.g. flammable substance separate from oxidising agents? Conc. acids and large bottles at floor level? Poisons locked away?

7. Are all electrical points and apparatus properly earthed and regularly checked?
8. Do your sinks work properly and is there a good supply of water?
9. Can you see what everyone is doing in the laboratory from the front?

Mechanical hazards etc.

1. If you have gas cylinders are they properly secured and do they have correct reducing valves?
2. Is glassware stored safely so that it cannot fall or be knocked accidentally?
3. Are there any obstructions in the gangways, or anything sticking out to catch pupils in the face?
4. Is all broken glassware either discarded or repaired? Does all glass tubing used have fire-polished ends?
5. Has asbestos been banished from your laboratory? In wire gauzes, mats etc.
6. Do you check bunsen tubing regularly and replace worn or perished rubber tubing?

This list is just a guide to some areas where safety is important. Make sure you buy and read a suitable book on laboratory safety (particularly chemical hazards) or one on laboratory organisation containing safety information (see issue 1, p.17, May 1980).

Some teachers use safety as an excuse for not doing practical work at school. If we took that argument seriously none of us would venture on the roads, particularly in a car, and many of us would have to change our diets considerably! The school laboratory can be a safe working place even with large amounts of practical work – but we, the teachers, must be safety conscious and must be informed so as to prevent hazards, and ensure safe working conditions. It can be done and requires only a commitment to safe practical work. Start today by making sure you become safety conscious.

Are you bored by Bohr – then read on:

“They once used atoms by Bohr
For structure and bonding and more,
But now that we want ‘em
To learn it by quantum
They find it much more of a chore.”
J.W.Hill

“There once was a Dane named Niels Bohr
In whose theory we once set great store
But it proved to be wrong
And it didn’t last long
So why teach it in school any more?”
P.E.Childs

Humour in class (so what’s funny about chemistry?)

Chemistry teacher: “Now what do you know about nitrates?”
Pupil: “Well, er – oh, yes! They’re much cheaper than day rates.”
(Ask a silly question – get a silly answer.)

****

Pupil: “But I don’t think my work deserves an absolute zero.”
Teacher: “Neither do I. But that’s the lowest mark I can give.”

****

Teacher: “This is a very good textbook. Use it wisely and it’ll do half your work for you.”
Pupil: “Good. I’ll take two of them.”

****

Chemical Graffiti:
Observed in a Smithfield Market pub loo:
“Mercury comes from Hg wells” (I.T. 24/9/80)