Jules Prosser

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What is chemistry?

Chemistry has close links to Biology, Physics, Geology and many other subjects. In this article, Jules Prosser explores what chemistry is about and what makes it distinctive from the other sciences and looks at some of the areas in which chemists work.

Chemistry is what chemists do. It's the study of the nature, properties and composition of matter, and as such links together biology, physics and maths. Chemistry is roughly split into fields of *organic*, which is the chemistry of carbon containing compounds, *inorganic*, looking at the other elements of the periodic table and their compounds and *physical* chemistry which investigates reactions for their precise atomic changes. These have their own specialist areas including *biochemistry* (study of molecules and their interactions in living systems), *synthetic organic* (making molecules – which my job relies on), *analytical* (determining exactly what is present in a sample and in what amounts), *computational, polymer,* and many, many more. Chemistry is constantly evolving and as new discoveries are made, new areas of work open up.

Working as a chemist involves using carefully measured quantities of chemicals.

Key words
chemistry
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drug

What use is chemistry?

Plastics and metals clearly shape the world around us, and chemistry is at the heart of their development. Around 1000 BC iron and copper working started in Europe. Chemists developed the refining process, which today produces 1800 million tonnes of pig iron a year (see Box 1).

Box 1
Obtaining iron: the blast furnace

A workman at a blast furnace in the Czech Republic

Iron ore comprises haematite and magnetite, both iron oxides. These are fed into a blast furnace which is heated by a hot air stream. Carbon in the form of coke is added, which reacts with oxygen from the heated air to form carbon monoxide. The carbon monoxide in turn reacts with the iron oxides to give carbon dioxide and iron.

$$C + O_2 \rightarrow CO_2$$
$$C + CO_2 \rightarrow 2\,CO$$
$$3\,CO + Fe_2O_3 \rightarrow 3\,CO_2 + 2\,Fe$$

The iron formed this way contains about 4–5 % carbon with other impurities such as magnesium and phosphorus. It is relatively brittle and is used to cast items such as lamp posts. Modern construction needs steel, which is an iron / carbon alloy containing between 0.4–2 % carbon. Carbon prevents weakening movements in the iron crystal lattice, and so varying the carbon content allows chemists to produce a metal with the required properties, such as strength or ductility.

Plastics are polymers that come from the joining of many small reactive molecules. Natural polymers such as latex have been traditionally used by native tribes in South America, but the first example of a commercially exploited synthetic plastic was Bakelite, patented in 1909 and designed for mechanical parts and as an electrical insulating material. It was quickly found that additives (see Box 2) changed the properties of the plastic and allowed additional uses. Cheap, strong and easy to manufacture, it started a wave of experimentation that resulted in the large variety of plastics we use today.

Synthetic plastics have a wide range of everyday uses.

Chemistry starts at the sub-atomic scale. Medical imaging, from X-rays to the latest 3D scanning techniques, make use of radiation and so require a deep chemical understanding of both the radioactive materials and their effects on living organisms.

Atomic knowledge can also be used offensively; in 1945, 2 atomic bombs were dropped on Japan to end the Second World War. These bombs worked through nuclear fission, which is the splitting of atoms to release huge amounts of energy. Whilst nuclear research for weapons continues, nuclear power now makes up around 20% of the UK's energy production. Nuclear power generation relies on chemists being able to initiate and then control the rate of the reaction.

What of chemistry now and when I want a job?

Chemistry and medicine are very strongly linked. From the first healers who used natural remedies, chemistry has developed into a huge pharmaceuticals industry (see Box 3). This is where I work as a synthetic organic chemist, making molecules to be tested against a disease. My job has changed since I graduated, with more automation coming in, but there is still a high demand for chemists in this industry. We also need to continue to explore molecules from nature looking for new therapeutics (active ingredients in a drug or medicine) and to synthesise these to prove the structure and to provide enough material for testing.

This boy uses a 'puffer' to ensure that he receives the correct dose from his asthma inhaler.

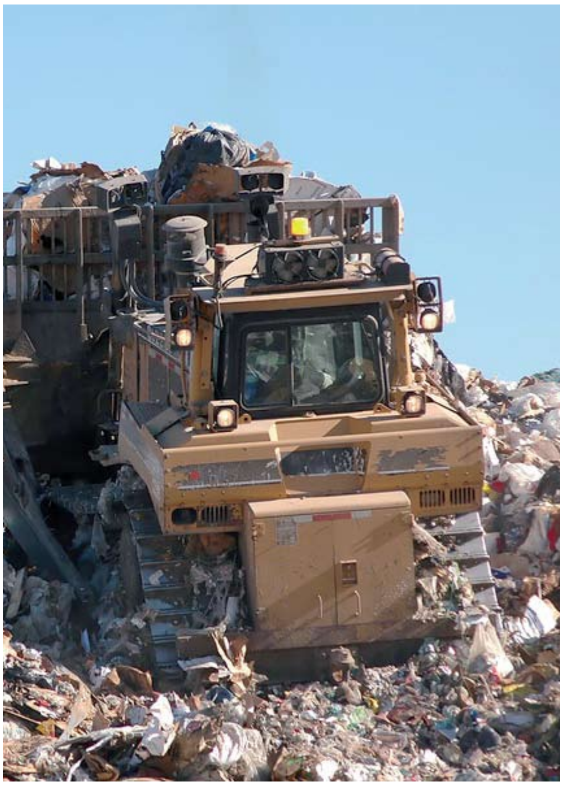
Currently many drugs are tested on animals. This is controversial in itself, but also far from ideal for biological reasons – tests on animals may not provide a reliable model when applied to humans. Testing on isolated human cells does not provide information on the effects on other parts of the body. Computational chemists are currently attempting to make a 'virtual human' which can model drug effects on all parts of a body, and even allow for existing complaints (for example a heart condition).

Box 2 Additives in plastics

Different types of plastics are formed from different materials. The same plastic can be made to have different properties by controlling the reaction conditions (temperature, pressure, time) used to make them and by use of additives, including plasticisers, flame retardants, pigments, and conductive additives. Antibacterials such as triclosan can be added to plastics that contact food.

Nanotechnology is another rapidly expanding area of chemistry. Working on a nanoscale (10^{-9} m or millionths of a millimetre) requires new diagnostic and imaging tools. Scanning Electron Microscopy uses a carbon nanotube attached to a very fine tip to pass electrical current over the surface of a material, giving its topography on a nanoscale. Many other techniques are being developed.

Our population is growing and the pressure on the Earth for raw materials and space is increasing. Environmental chemists need to ways to satisfy rising energy demands, develop alternative fuels, and protect existing populations from their waste. Recycling is twofold; there is the drive to recycle current waste, and here chemistry is needed to help solve the economic problems of recycling; and there is the reclamation of materials dumped in landfill at a time when recycling was economically unviable. Currently, most councils in the UK recycle four types of plastics; large amounts of potentially useful hydrocarbons are still buried in landfill or incinerated.



Useful resources are increasingly being extracted from landfill sites.

Box 3
How do you make a drug?

People in the Philippines take the drug albendazole as part of a public health campaign. This drug provides protection against the infectious disease filariasis which is carried by parasitic worms.

Often drugs start from existing treatments or naturally occurring molecules with the desired biological effect. Chemists then make a large number of similar molecules, looking for the correct pharmacokinetic properties – strength of the biological effect, take-up in the blood stream (bioavailability) and how long the effects last (half life). When a molecule is discovered that shows the desired properties a synthetic route to make many kilos of it is needed, usually differing from the original route used to make small amounts for initial testing. Assuming it gets this far, the molecule then goes into healthy volunteers for safety checks, into patients to prove it works, and finally (hopefully) is approved for sale as a medicine.

Chemistry is a subject with deep roots in all the sciences, constantly evolving to meet new needs in society, healthcare, materials sciences, fuels and food. For me, it's a day to day struggle to find a new drug, often frustrating but with potentially huge rewards.

Jules Prosser *graduated 6 years ago from Warwick University and now works for Pfizer as a research organic chemist making molecules to be tested for antiviral activity.*

Look here!

This website has information about how nuclear power is generated:
www.eon-uk.com/EnergyExperience/343.htm

A previous issue of Catalyst had more information about making new medicines:
www.sep.org.uk/catalyst/articles catalyst_19_1_363.pdf

The Royal Society of Chemistry website has further details about careers in chemistry, help with revision and games:
http://rsc.org/Education/SchoolStudents/index.asp