David Moore

Nitrogen notes

Above: *The orange-red, blue-green, blue-violet and deep violet shades of the aurora borealis are created as high-energy radiation from the Sun interacts with nitrogen molecules in the upper atmosphere*

Please note that the 'web pages' in this article do not exist on the internet.

GCSE key words
Nitrogen
Fertiliser
Fixation
Radioactivity

Nitrogen is all around us. What do we use nitrogen and its compounds for? Read the 'web pages' and find out!

Colourless, odourless, non-toxic and inert — nitrogen gas is everywhere and we couldn't live without it. Nitrogen makes up 78% of the Earth's atmosphere by volume, equivalent to approximately 4×10^{15} tonnes. It dilutes the oxygen in the atmosphere and therefore slows down respiration in plants and animals. It also slows down burning — fires would be much more fearsome if unreactive nitrogen were not present in the air to slow down the combustion oxidation reactions.

Nitrogen is in Group 5 of the periodic table. It exists in the gas form as diatomic molecules, N_2, bound by a strong covalent triple bond. It is the strength of this bond which accounts for nitrogen's relative stability. A lot of energy, 946 kJ/mol, is needed in order to break the bond and allow the molecule to react. Although nitrogen can be made to react with virtually every other element in the periodic table, high temperatures or a catalyst are usually needed. (Compare the bond strength of nitrogen with that of hydrogen, H_2 454 kJ/mol, or fluorine, F_2 159 kJ/mol.)

In the Earth's crust nitrogen is the 33rd most abundant element, mainly in the form of the minerals saltpetre (KNO_3) and Chile saltpetre ($NaNO_3$). Both are found throughout the world, often in arid areas, or in caverns and caves.

Nitrogen gas was first isolated in 1772 by a British doctor, Daniel Rutherford, although Cavendish, Priestley and Scheele were studying 'burnt or dephlogisticated air' at about the same time. The French chemist Lavoisier proposed that it was an element and named it 'azote' (the lazy one). The importance of nitrogen-containing compounds in the soil was proposed by Justus von Liebig in 1862, at a time when most scientists believed that plants obtained nitrogen directly from the air.

Nitrogen is extracted from the air by the fractional distillation of liquid air. Air is cooled until it liquefies. On warming slightly, nitrogen boils off first at −196 °C, before oxygen at −183 °C.

Compounds of nitrogen are used in fertilisers, dyes, anaesthetics, rocket fuel and explosives.

http://www.liquidnitrogen.catalyst.co.uk

Liquid nitrogen

Liquid nitrogen is used:

- as a coolant — for example in the superconductor industry
- for preserving living cells and tissues, including eggs and sperm for in vitro fertilisation or artificial insemination
- for freezing food; for cooling the container compartments of transport lorries; and even for freeze-branding cattle
- to provide an inert atmosphere: preventing fires when flushing oil pipelines and tanks; preventing oxidation during welding processes; making plate glass; manufacturing silicon chips; in crisp packets to help maintain 'freshness' by excluding oxygen
- in the process of annealing steel, in which heating makes the steel harder

Right: *A researcher removing frozen biological samples from storage in liquid nitrogen*

Tek Image/SPL

http://www.nitrogenfixation.catalyst.co.uk

Nitrogen fixation

Nitrogen **fixation** is the process whereby nitrogen from the air is converted into nitrogen compounds. About 150 million tonnes of nitrogen a year are fixed by bacteria and lightning, and about the same amount by industry.

- Nodules in the roots of **leguminous plants** such as peas, beans and clover contain bacteria called *Rhizobium*. These bacteria combine organic compounds from the plant with nitrogen from the air to produce nitrogen-containing compounds, such as amino acids, proteins and nucleic acids, that the plant needs.
- The high temperature of **lightning** allows nitrogen and oxygen in the air to combine and react, eventually forming nitrogen dioxide. This dissolves in rainwater and is washed into the soil, as a soluble form of nitrogen which plants can use.
- Whenever a crop is harvested, nitrogen-containing compounds are removed from the soil. To replace them, nitrogen-containing **fertilisers** need to be applied to the soil.

Biophoto Associates/SPL

Left: *Red nitrogen-fixing nodules on the roots of a black alder tree. They contain bacteria which take nitrogen from the air*

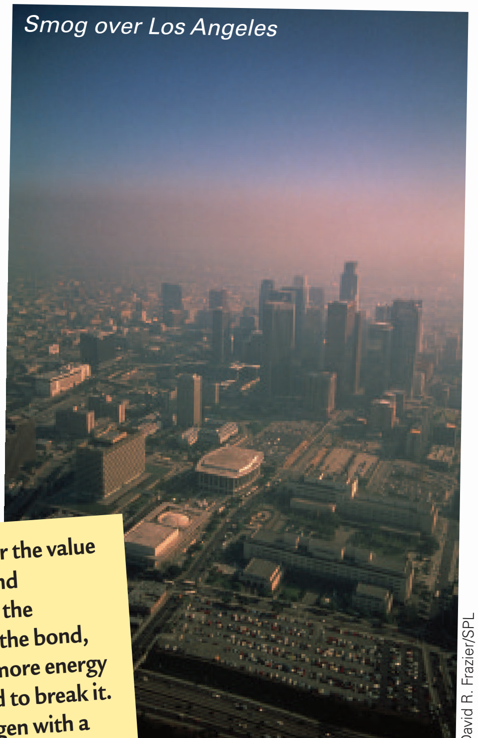
- **What other elements are important in fertilisers?**

- A common starting material for making fertilisers is ammonia, NH_3, which is made by the Haber Process. A mixture of nitrogen (from the air) and hydrogen (either from the petrochemical industry, or by reacting steam with natural gas) is passed over an iron-based catalyst at a temperature of about 450°C at 250 times atmospheric pressure. The gases react to form ammonia in a 17% yield.
- The ammonia can be converted to nitric acid by reacting it with oxygen and water using a catalyst (the Ostwald Process). When the nitric acid is reacted with more ammonia, it makes ammonium nitrate — a widely-used fertiliser commonly known as Nitram.

Recent research has shown that the quantity of nitrogen-containing fertilisers applied to crops between 1980 and 1990 was more than that applied over all previously recorded history. Excessive use of nitrogenous fertiliser may cause problems such as algal blooms in rivers — excess nitrates end up in soil water, groundwater and rivers, and this encourages the rapid growth of algae.

Pekka Parvainen/SPL

http://www.nitrogenatmosphere.catalyst.co.uk



Smog over Los Angeles

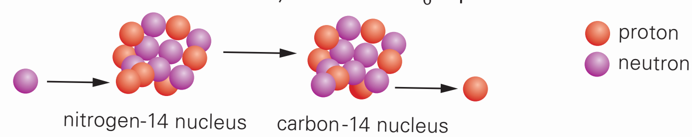
David R. Frazier/SPL

The bigger the value of the bond strength, the stronger the bond, and the more energy is needed to break it. So nitrogen with a strong triple bond is an unreactive gas.

Nitrogen in the atmosphere

Gases in the upper atmosphere are continually bombarded by cosmic rays. The energy of these knocks neutrons from some of the atoms. These neutrons can then knock a proton from the nucleus of some nitrogen atoms. In this way, carbon-14, which is radioactive, is created.

$$^{14}N_7 + n \longrightarrow {}^{14}C_6 + p$$



All living material contains a fixed proportion of this radioactive carbon. When the plant or animal dies, the radioactive carbon present gradually decays, with a half-life of about 5800 years, and is not replaced. The level of radioactive carbon remaining is therefore a measure of the age of the material, and this is the basis for carbon dating.

Nitrogen oxides in the atmosphere can lead to pollution. Smogs are produced when there is a build up of oxides of nitrogen (commonly known as NO_x) in the air in cities. The oxides are mainly produced from the reaction of nitrogen gas and oxygen gas being sparked together electrically within the confines of internal combustion engines.

http://www.nitrogencompounds.catalyst.co.uk

Nitrogen compounds

Some nitrogen compounds:

- **Urea**, $CO(NH_2)_2$, can be made from the reaction of ammonia with carbon dioxide under pressure. It is found in the urine of mammals and is widely used in fertilisers as a source of nitrogen.
- **Azo-compounds** are brightly coloured substances often used as dyes. They contain the –N=N– unit.
- Organic substances which contain the group $-NH_2$ are called **amines**. Two of these, found in rotting meat, are called putrescene, $H_2N(CH_2)_4NH_2$, and cadaverine, $H_2N(CH_2)_5NH_2$, and have appropriately awful smells!
- **Nitrous oxide**, N_2O, often called 'laughing gas', is a colourless gas which, mixed with oxygen, is used as an anaesthetic in dentistry and minor surgery.
- **Hydrazine**, N_2H_4, and compounds derived from it have found some use in the space programme as rocket fuels. The 'flying bombs' and V-2 rockets of the Second World War were powered by hydrazine.
- TNT, **trinitrotoluene**, is an explosive nitrogen compound.

Topfoto

Cut-away diagram of a flying bomb used in the Second World War

- Draw a 'dot and cross' diagram to show the bonding in a nitrogen molecule.

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