

HUMANS AND THE ENVIRONMENT

Nitrogen is a vital element in the promotion of leaf and stalk growth in plants. Farmers who grow cereal crops need a nitrogen rich soil with a pH of about 7. The air is a rich source of nitrogen (approximately 78%) However it has poor solubility in water.

Why would this be a problem for most plants?

Nitrogen needs to be converted into a soluble form which plants can use. To do this the nitrogen in the air needs to undergo a chemical reaction with oxygen in air-to form nitrogen dioxide.

Write a balanced chemical equation for the reaction between nitrogen and oxygen.

Nitrogen dioxide will dissolve in water to form a dilute nitric acid solution. Write a balanced equation for the reaction of nitrogen dioxide with water.

Thus nitrogen can fall in rain water in a soluble form as nitrate ions NO_3^- .

Under normal conditions, nitrogen atoms are very reactive but nitrogen molecules are relatively unreactive and won't react with oxygen in air. Why?

Nitrogen atoms are $^{14}_7\text{N}$ work out the electron arrangement of a nitrogen atom.

What do nitrogen atoms need to do to attain a noble gas arrangement?

Nitrogen gas consists of N_2 molecules, how can each atom in the molecule attain a noble gas arrangement.

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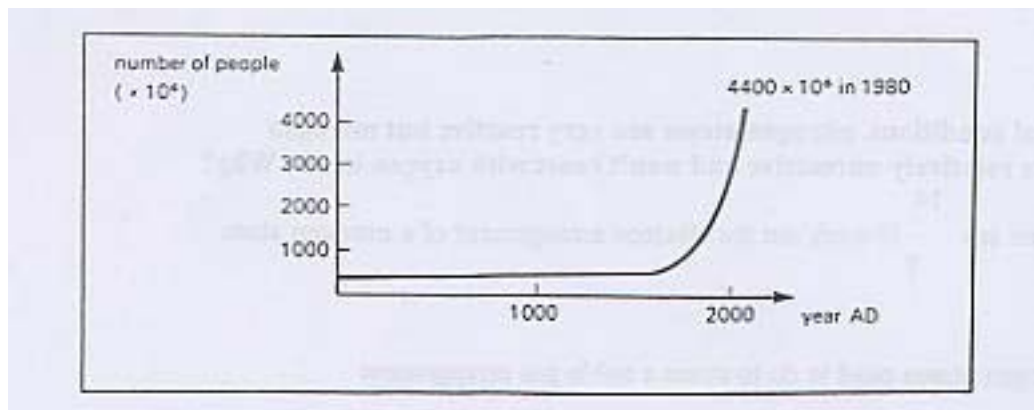
Illustrate the covalent bonding in nitrogen showing only the outer electron shells of atoms.

Why, under normal conditions, are nitrogen molecules unreactive?

What natural occurrence could provide enough energy to break bonds in nitrogen?

Nitrogen is naturally present in soils due to natural processes and can have nitrogen reserves as much as 5000kg per hectare. A lot of this is in the form of insoluble nitrogen substances caused by the decay of organic matter (manure, dead plants, animals). Under the right conditions of aeration (allowing air (oxygen), moisture to get to soil and it being exposed to warmer temperatures) allows microbes to oxidise these to soluble nitrates

Below is a graph which shows the world population trend:



What does this imply for farmers growing cereal crops and what conclusions can you draw about natural processes as a means of supplying the requisite amount of nitrogen for the soil in the form of nitrate ions?

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As a result farmers need to put artificial fertilizers onto the soil. These fertilizers can be compounds of nitrogen such as ammonium nitrate, ammonium sulphate or urea, although fertilizers containing phosphorus and potassium are also important particularly for root and germination. Fertilizers containing nitrogen all are soluble in water to different degrees and some contain a greater percentage of nitrogen than others.

The percentage of nitrogen in a fertilizer can be calculated from its molecular formula:

For example the percentage of nitrogen in ammonia could be worked out as:

NH_3 (RAM of N =14, H =1)

therefore RAM of ammonia = 17

% Nitrogen in ammonia = $14/17 \times 100 = 88\%$

Calculate the percentage by mass of nitrogen in ammonium nitrate, NH_4NO_3 and Ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$ use your periodic table to help you.

These values are quoted on the bags of fertilizer so that the farmer can see which is richer in nitrogen
Which of these two fertilizers is richer in nitrogen?

Look at the following statements:

- The percentage of nitrogen in ammonia is 88% by mass.
- Ammonia is a gas and an irritant. It is highly soluble in water. Ammonia is highly alkaline.
- Salts of ammonia are fertilizers as well, some examples are Ammonium nitrate NH_4NO_3 , and Ammonium Sulphate $(\text{NH}_4)_2\text{SO}_4$.
- Both of these are highly soluble in water, they are slightly acidic when dissolved in water.
- Ammonium nitrate is explosive when heated strongly.
- Ammonium salts are cheap to make.
- Urea: $\text{CO}(\text{NH}_2)_2$ is only slightly soluble in water it is also a fertilizer.
- Farmers can be prosecuted for polluting natural water bodies such as rivers.
- Farmers apply different fertilizers in different seasons.
- Fertilizers need to be safe to handle.
- Most plants favour soils which are near neutral in pH.

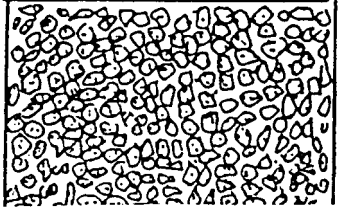

Problems with over-use of fertilizers

Fertilizers need to be soluble if they are to get through the root systems of plants.

How can soil type and solubility cause problems?

SOILS

Look at the following diagrams of soil particulates

<p>A clay soil has snail particles and not much air is trapped between the particles. Clays tend to hold onto water and drain very slowly.</p>	
<p>A sandy soil has large particles with large pockets of air. Sandy soils do not hold water and drain very easily. (Intensive working of soil allows it to become aerated)</p>	

Comment on the advantages and disadvantages of each soil type, the use of fertilizers on these soils, and **how** a farmer could employ the advantages of each type of soil

SOLUBILITY

Below shows the solubility of three nitrogenous fertilizers. These are all quite soluble compounds because they are **ionic**.

FERTILIZER	FORMULA	SOLOUBILITY G/1000g water at 20C
Ammonium nitrate	NH_4NO_3	2000
Ammonium sulphate	$(\text{NH}_4)_3\text{SO}_4$	800
Ammonium phosphate	$(\text{NH}_4)_3\text{PO}_4$	250

Which of these fertilizers might you spread on soils during winter months? Explain your answer

Covalent molecules are not so soluble. The bigger the covalent molecule, the less soluble the compound. In addition the presence of C=O groups (with carbon forming two covalent bonds to oxygen) and O-H groups (oxygen forming one covalent bond with hydrogen) in a covalent molecule will increase its solubility in water.

If you wanted to design a nitrogenous fertilizer 'molecule' what properties would you want it to have? (Bear in mind what has been said about fertilizers so far)

So, what type(s) of chemical bonding would be present in this molecule to meet these properties?

From this, what elements would you need in your molecule?

Use some molecular models to try and come up with a design for your own nitrogenous fertilizer molecule. You will need to recall your covalent bonding and ionic bonding to do this.

Write out what the formula for your molecule would be.

Theoretical chemists in companies such as ICI design molecules using complex computer programs which involve a lot of quantum mechanics (mathematics of the atom). They then ask their research chemists to prepare the fertilizer, in the lab on a small scale. They then will analyse it to check its composition. From this they can work out an **empirical formula**. The technique they use is called **ATOMIC ABSORPTION SPECTROSCOPY**

This is a technique whereby the percentage by mass of each element in a compound can be determined and from this the **empirical formula**

An empirical formula is the simplest ratio in moles of each element in the compound.
To work it out is simple:

The **percentage by mass** of an element tells you the number of grams of that element in 100g of the compound.

This is then divided by the **mass of 1 mole of that element** (this is a 6×10^{23} atom of that element) and is simply the atomic mass in grams.

This answer tells you **the number of moles of that element in the compound** and by comparing it with the number of moles of other elements, the formula can be found.

For example, atomic absorption tells you that the following elements are present in a compound in the following percentages by mass:

CARBON=20% HYDROGEN = 6.67% NITROGEN = 46.67% OXYGEN = 26.67%

In 100g of the fertilizer there will therefore be: 20g of carbon, 6.67g of hydrogen, 46.67g of nitrogen and 26.67g of oxygen.

1 mole of carbon atoms = 12g, therefore number of moles of carbon = $20/12 = 1.67$

1 mole of hydrogen atoms = 1g, therefore number of moles of hydrogen = $6.67/1=6.67$

1 mole of nitrogen atoms = 14g, therefore number of moles of nitrogen = $46.67/14 = 3.26$

1 mole of oxygen atoms = 16g, therefore number of moles of oxygen = $26.67/16 = 1.66$

Ratio of moles = 1.67C: 6.67 H: 3.26N: 1.66O

Divide each by the smallest: 1C: 4H: 2 N: 1O

Empirical formula: $\text{CH}_4\text{N}_2\text{O}$

This is the simplest ratio of moles of each of the elements in the fertilizer.

Rivers and other water bodies

Eutrophication

a) Rivers and lakes are habitats for many different species of animals and plants. Animals need oxygen to live. Bacteria feed upon carbon containing substances. Algae and other plant life are carbon based life forms. When the bacteria feed they use up dissolved oxygen in the water. Provided with the necessary nutrients, algae grow rapidly and will cover the surface of the water, forming an algal bloom, this prevents sunlight getting to plants underneath the surface

Different organisms can act as indicators of the above effects since different organisms have different oxygen tolerances. As a result a **Biotic Index** can be plotted based on the sampling of organisms in a water body, which will be an indicator of dissolved oxygen and therefore of the degree eutrophication

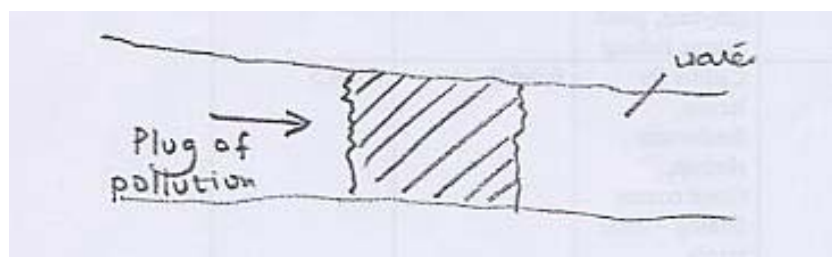
Typical Biotic index

STATE OF WATER	ANIMALS PRESENT	VOLUME OF OXYGEN: cm ³ /litre of water at 5C	VOLUME OF OXYGEN: cm ³ /litre of water at 20C
Clean, unpolluted	Stonefly nymph, mayfly nymph, salmon, trout, grayling, good coarse fishing.	6.5-9.0	4.5-6.0
Doubtful	Caddis fly larvae, freshwater shrimp, good coarse fishing – trout rarely	6.0-6.5	4.0-4.5
Poor	Water louse, 'blood worm' (midge larvae), leech, roach, gudgeon, moderate to poor fishing	3.5-6.0	2.5-4.0
Grossly Polluted	Sludge worm, rat-tailed maggot, no fish life	0-3.5	0-2.5

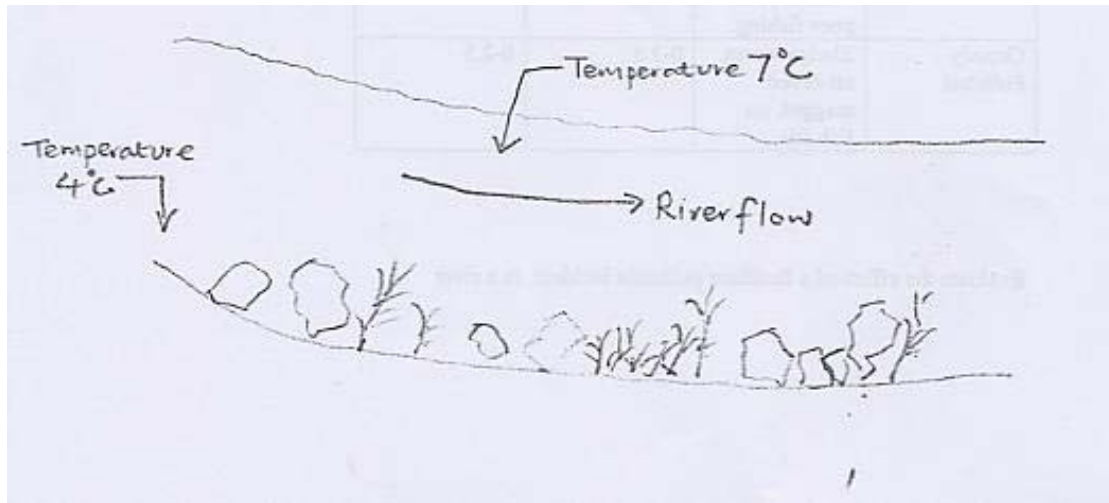
Evaluate the effect of a fertilizer pollution incident in a river.

River Pollution

If sewage or carbon containing matter is added to a river or lake, once again, bacteria will feed upon this matter. The overall effect is the same as above except that it will be more immediate. Rivers are flowing systems. When pollution enters a river the pollution it is not diluted by the river water but acts as a plug of substance which travels with the river.



The effects upon aquatic life due to **de-oxygenation** can vary from almost immediate to more extended periods of time, depending upon the heaviness of the pollution. The extent of the pollution can be monitored via the Biotic index. The plug of pollution will be carried and its profile will be affected by the speed of flow in the river. Below shows a river cross section



Evaluate and **explain** the different contributions of the factors labelled in (the diagram upon river speed and flow profiles and the possible effects upon a plug of pollution

Nitrates (NO_3) are converted into nitrites by bacteria in the small intestines of humans. A chemical called haemoglobin in blood carries oxygen around the body by chemically bonding to oxygen. Nitrites bond more strongly to haemoglobin than oxygen does.

How and why might the over-use of nitrate fertilizers such as ammonium nitrate pose a problem to the health of babies and the development of the 'blue-baby' syndrome?

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Research scientists at the Rothamsted Experimental Station in Hertfordshire found that when fertilizer is given in the correct dosage to a crop, it does not cause nitrate pollution, but that rivers and other water bodies fed by groundwater coming from these intensively farmed soils could still have increasing nitrate dosages.

Why?