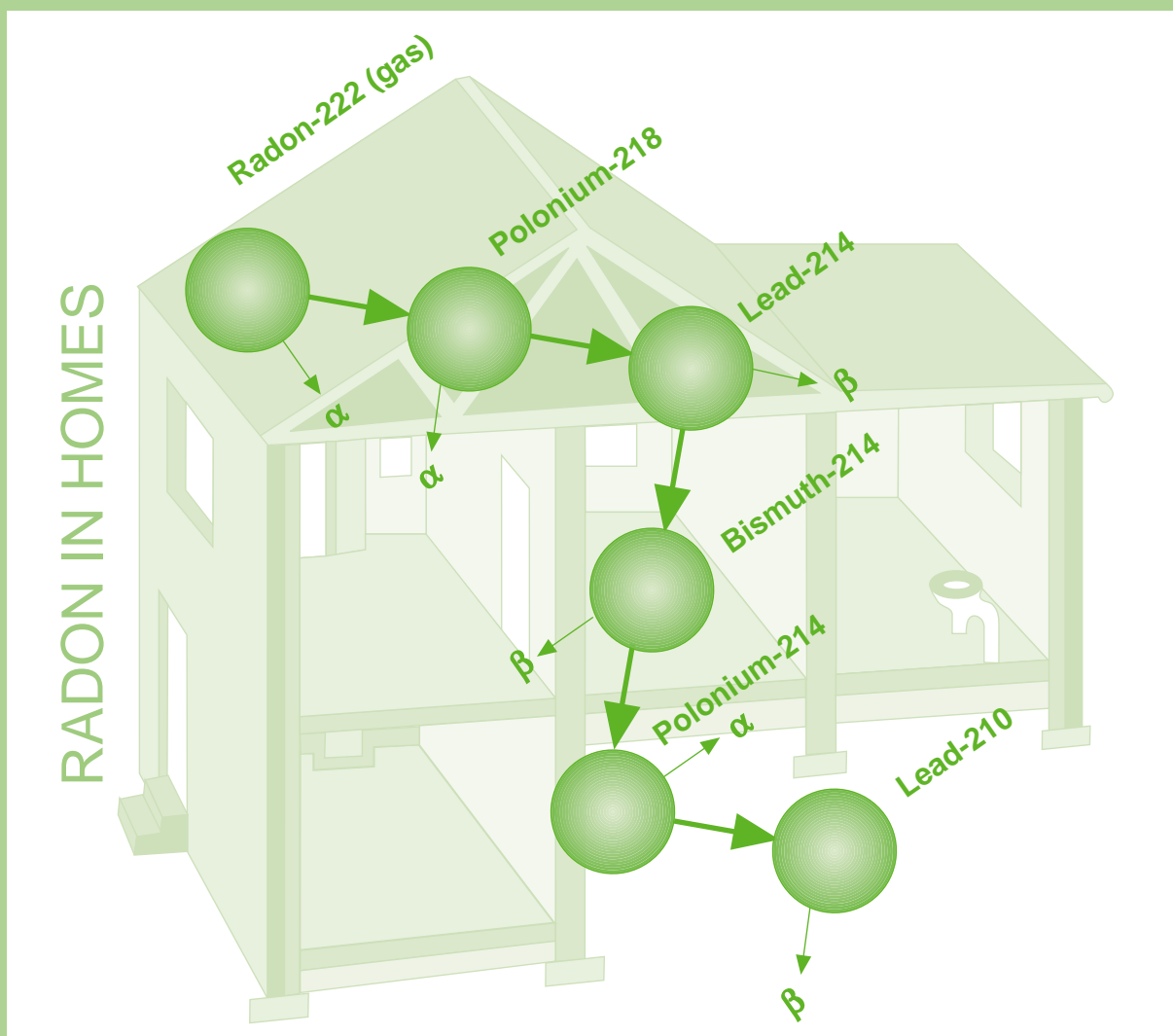


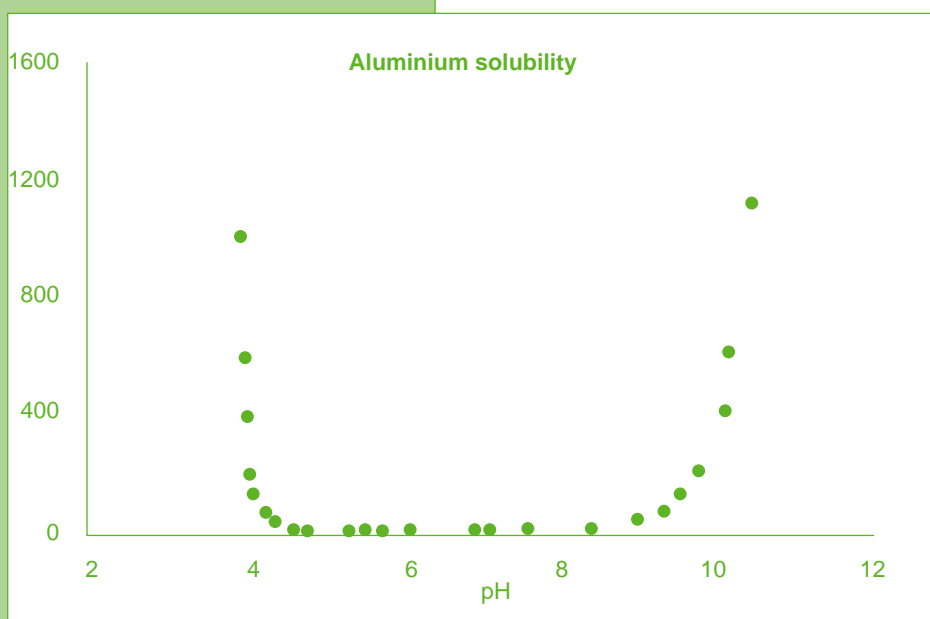
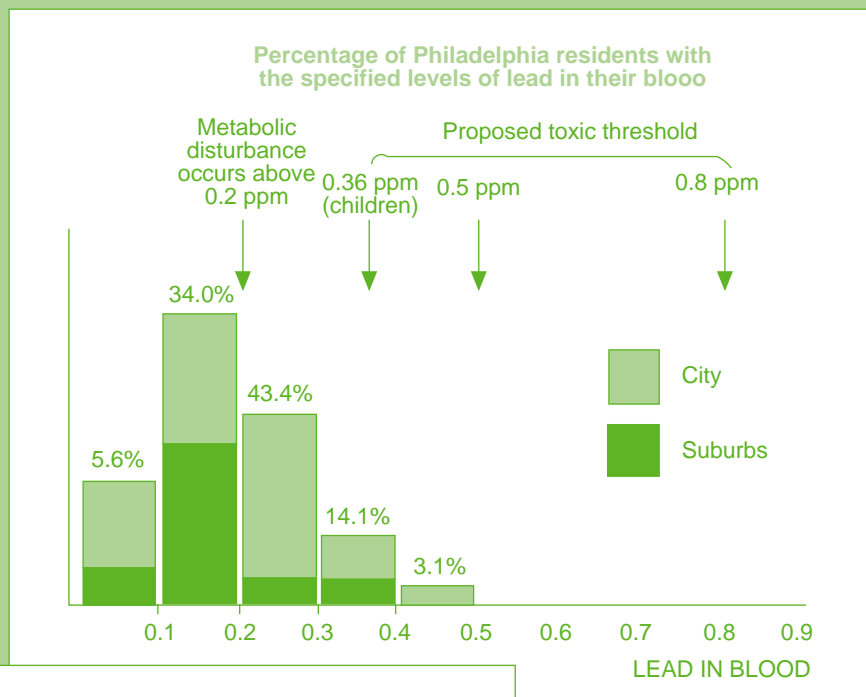
Chemistry and the Environment



Curriculum materials on
environmental chemistry



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Increased interest in the environment has highlighted the practical importance of chemistry. This book contains 26 activities aimed at students who have studied science up to the age of 16. The activities are grouped into three themes that emphasize the value of chemical knowledge and techniques to society:

- air quality
- water quality
- radon

The book includes information on experiments, data interpretation exercises and stimulus material that can support both field and laboratory work. The activities are designed to be used together, but can also work as free standing tasks. However they are used, the activities provide extra material for teachers on topics of fundamental importance to environmental issues.

Chemistry and the Environment

Compiled by Justin Dillon, Rod Watson and Canan Tosunoglu

Centre for Educational Studies, King's College, London

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Introduction

The increased concern for, and interest in, the environment has highlighted the role of chemists and the value of chemical knowledge and techniques to society. This pack is aimed at developing knowledge and techniques in students who have studied science up to the age of 16. The activities will support work outside the laboratory either in the immediate environment or further afield. Some of the material goes beyond the bounds of some post-16 syllabuses: we make no apology for this. We believe that the topics looked at here are fundamentally important to citizens of the present and the future.

The pack contains 26 activities: experiments, data interpretation exercises and stimulus material that is relevant to chemistry and the environment. The activities are grouped into three themes: air quality; water quality; and radon.

The activities are designed to be used together and as free standing tasks to supplement existing resources.



The activities

RISK ASSESSMENT

IT IS VITAL THAT A RISK ASSESSMENT IS COMPLETED FOR ANY PRACTICAL EXERCISE DESCRIBED HERE THAT IS TO BE ATTEMPTED.

The following is a list of the activities included in this pack. They include data analysis, comprehension exercises, and practical activities. Students should realise that in some cases they will have to use other sources of reference to find the answers to the problems raised – eg a data book.

1. Air quality

This group of activities enables students to develop an understanding of the chemistry of acid rain. Students can collect and analyse a sample of rain water for nitrate(V), sulphate(VI) and pH. They can work out the approximate proportion of the acidity due to SO_2 and NO_x pollution. Some of the analytical methods can also be used to test for water quality.

- 1.1 Acid rain: the background
- 1.2 Sulphur(IV) oxide, SO_2
- 1.3 Acid rain and tree damage
- 1.4 Investigating rain
 - (a) Monitoring acid rain
 - (b) pH determination
 - (c) Nitrate(V) determination
 - (d) Sulphate(VI) determination
- 1.5 From Siberia to suburbia
- 1.6 Lead
 - (a) Sources of lead pollution
 - (b) Lead in the blood
 - (c) Lead determination

2. Water quality

Water quality has become an area of intense interest in the past few years. By using this group of activities, students can analyse water samples for lead, aluminium, and oxygen; and these activities can be supplemented by using the nitrate(V), sulphate(VI), and pH activities from the air quality theme.

- 2.1 The response of water to carbon dioxide
- 2.2 Aluminium in the water supply
- 2.3 Oxygen in water
- 2.4 Aluminium and Alzheimer's disease
- 2.5 Aluminium determination

3. Radon

This group of activities focuses on the indoor radon problem. The element radon, a noble gas, accounts for the death of thousands of people in the world each year. Interest in the problems posed by radon in the environment is relatively recent and is still growing. An understanding of the problems requires knowledge from chemistry, physics, biology, geology and geochemistry.

Factors affecting the distribution of radon such as the distribution of minerals in the UK, house construction and climatic influences, are considered. Students detect

radon in the home using a solid state detector and approximate concentrations of the gas are calculated.

Note that ideally, activities 3.4b and 3.5 should be done before activity 3.6.

- 3.1 Radon and leukaemia
- 3.2 What is radon?
- 3.3 Why is radon dangerous?
- 3.4 Radon in the UK
 - (a) Radon, health and homes
 - (b) Where in the country is radon found?
- 3.5 Geochemistry
- 3.6 Factors affecting the emission of radon
- 3.7 Where in the home is radon found?
- 3.8 How much radon is there?
 - (a) Detecting radon
 - (b) Interpreting the results



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Addresses of organisations mentioned in the text

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Institution of Environmental Health Officers, Chadwick House, 48 Rushworth Street, London SE1 0QT;
National Radiological Protection Board, Chilton, Didcot, Oxon OX11 0RQ;
Persore Mouldings, Trading Estate, Persore, Worcestershire WR10 2DH;
United Kingdom Atomic Energy Authority Education Service, Room 9a, Building 354W, Harwell Laboratory, Oxfordshire OX11 0RA.

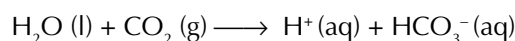
1. Air quality

Activity 1.1 Acid rain: the background

Acid rain is used loosely to describe both acidic gases in the atmosphere and, more precisely, rain, mist or snow containing acid compounds of sulphur and nitrogen. Two main gases contribute to the formation of acid rain: sulphur(IV) oxide (SO_2), produced by burning fossil fuels which contain sulphur, such as coal and oil; and oxides of nitrogen (NO_x), which are formed when anything is burnt. The formation of acids from these gases and the way in which they move through the atmosphere are also affected by other pollutants, including ozone. The main sources of sulphur dioxide and oxides of nitrogen are power stations which burn fossil fuels, other large industrial combustion plants and motor vehicles.

This Common Inheritance, Britain's Environmental Strategy

The extract comes from the government's white paper on the environment. The Earth's atmosphere contains about 0.03 per cent of carbon dioxide, some of which dissolves in water to form an acidic solution of pH 5.6.



However, rain water with a pH around 3 is not uncommon. More typical data is shown in table 1, which compares rain water compositions from similar sites in inland Scandinavia during the 1950s and 1970s. Data from a similar site in the US is also included.

Site	pH	H^+	SO_4^{2-}	NO_3^-	HCO_3^-
Scandinavia (1956)	5.4	4	15	0	6
Scandinavia (1974)	4.3	50	26	26	0
North-eastern US (1974)	3.9	126	55	50	0

Table 1 Comparison of rain water composition for three sites in mmol dm^{-3} ie $10^{-6} \text{ mol dm}^{-3}$

Questions

- Why has the acidity of Scandinavian rain water increased so significantly in the period 1956-74?
- What have been the greatest effects of the increased acidity of rain water in Scandinavia?
- Use the data given below to explain why the HCO_3^- concentration in Scandinavia (1974) and north-eastern US (1974) was zero:

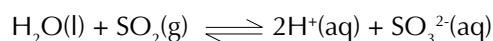


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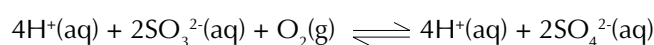
Acid or ion	Equilibrium	K_a /mol dm ⁻³
Sulphuric(VI) acid	$\text{H}_2\text{SO}_4 \rightleftharpoons \text{H}^+ + \text{HSO}_4^-$	very large
Nitric(V) acid	$\text{HNO}_3 \rightleftharpoons \text{H}^+ + \text{NO}_3^-$	40
Hydrogensulphate(VI) ion	$\text{HSO}_4^- \rightleftharpoons \text{H}^+ + \text{SO}_4^{2-}$	1.0×10^{-2}
Carbonic acid	$\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$	2.0×10^{-4}
Carbon dioxide/water	$\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$	4.5×10^{-7}
Hydrogencarbonate ion	$\text{HCO}_3^- \rightleftharpoons \text{H}^+ + \text{CO}_3^{2-}$	4.8×10^{-11}

Activity 1.2 Sulphur(IV) oxide, SO₂

Sulphur(IV) oxide, SO₂, is formed by the combustion of sulphur compounds in coal and oil. Sulphur(IV) oxide reacts with water to form a weak acid, sulphuric(IV) acid (pK_a = 1.8):



Sulphur compounds can react with other atmospheric gases to form compounds with higher oxidation states, whose solutions are more acidic. Sulphuric(IV) acid can be oxidised in the atmosphere to sulphuric(VI) acid, H₂SO₄, a strong acid:



On a global basis, the amount of sulphur(IV) oxide released by human activity has increased rapidly over the past 100 years. In 1985 the total release of sulphur (as SO₂) from human activity was 90 million tonnes as compared with an estimated natural global release of 70 million tonnes of sulphur per year. In some countries, emissions from power stations are being reduced by flue-gas desulphurisation systems. The results of this have yet to be seen in the global figures for sulphur(IV) oxide emissions, as Fig. 1 illustrates.

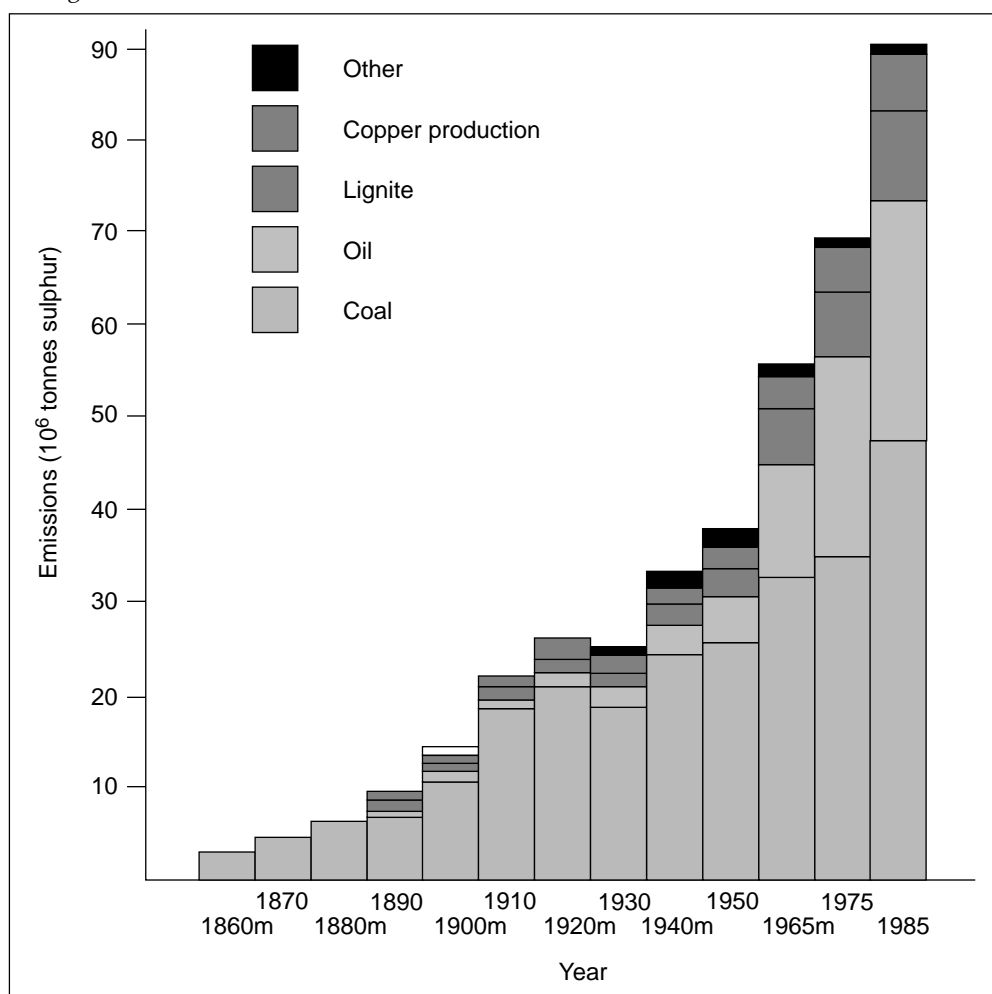


Figure 1 Global sulphur dioxide emissions (excluding natural sources)



In the decade 1974 to 1984 emissions of sulphur(IV) oxide fell by about 30 per cent in the UK, and this is shown by the decrease in concentrations of sulphur(IV) oxide in the air in London. Concentrations also fell in most major European cities over a similar period. *Figure 2* shows the concentration of sulphur(IV) oxide in some major European cities in recent years.

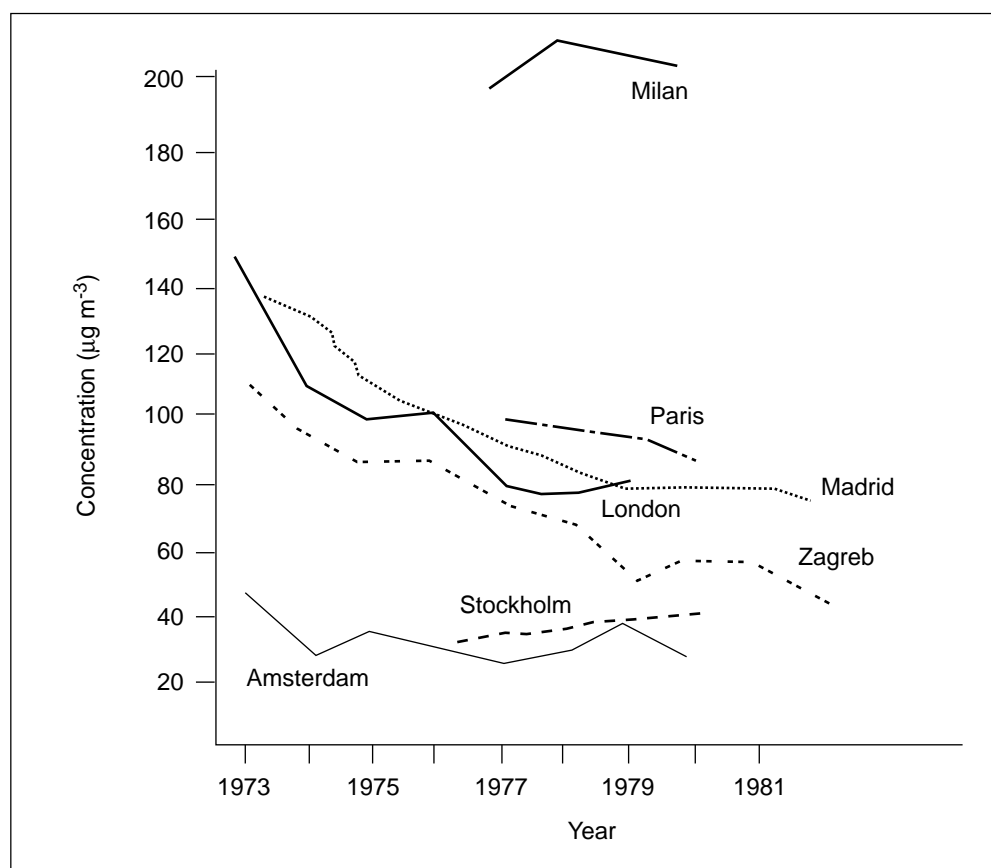


Figure 2 Concentration of SO₂ in some major European cities

The guide-line range suggested by the World Health Organisation, to limit human health effects of SO₂ in urban areas, is 40–60 g m⁻³.

Question

- (i) Are there any parts of Europe where pollution from sulphur(IV) oxide is significantly lower or higher than other parts of Europe? If so, can you suggest any reasons why these differences might exist?

Activity 1.3 Acid rain and tree damage

In recent years there have been reports from all over Europe of widespread damage to trees. The damage is not confined to other countries. *Figure 1* summarises the damage to a range of tree species surveyed in Britain in 1987.

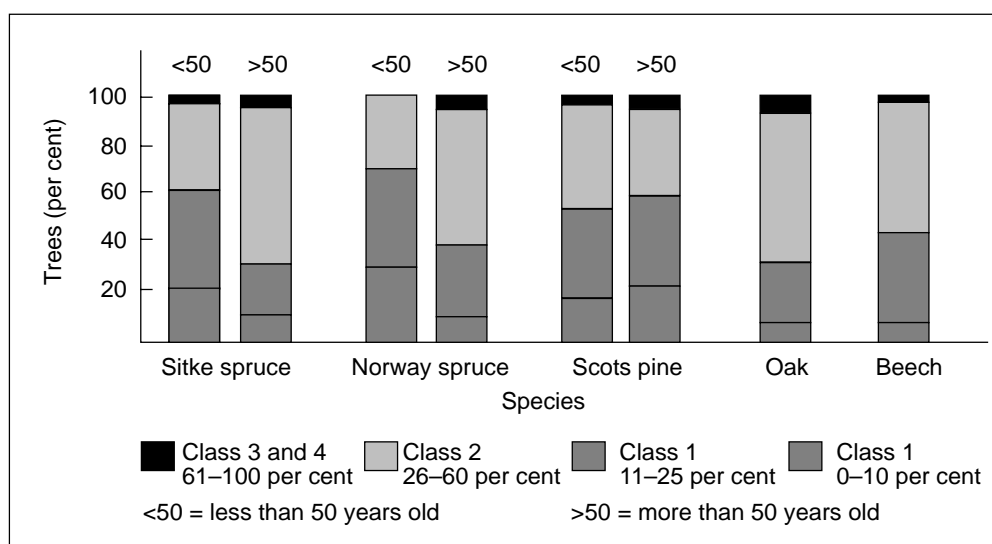


Figure 1 Distribution of crown thinning for five tree species surveyed in Britain in 1987 by the Forestry Commission (Class 4 is the most damaged)

There is general agreement that the damage is widespread but there is much discussion about the causes. One possible factor is that acid rain leaches aluminium out of the soil and that this change in the soil chemistry damages the trees. Harmless substances in the soil such as aluminium silicate dissolve in the acidic solution. This can disturb the soil chemistry and impair root growth.

Investigating the effect of pH on the amount of aluminium ions leached from the soil

Design an experiment to investigate the effectiveness of acid rain in leaching aluminium ions out of soil. You could investigate:

- ▼ the effect of different acids (acid rain contains sulphuric(VI) and nitric(V) acids);
- ▼ the effect of different concentrations of the acids; and
- ▼ the effect on different types of soil.

You can assume that strips are available to test for aluminium ions.



Activity 1.4 Investigating rain

Activity 1.4a Monitoring acid rain

It is possible to detect the extent of acidification of the rain water and to find out something about the nature of the acidification. To do this, a relatively simple analysis of rain water is made and weather data recorded. Three chemical analyses: measuring of pH, sulphate(VI) ion concentration and nitrate(V) ion concentration enable you to learn more about the nature of the pollution.

Aims

It is important at the beginning of the experiment to decide the questions that you would like to try to answer. Formulating your questions at the beginning will help you to decide what data you need to collect and where from. Some *possible* questions are:

- ▼ What is the origin of any pollution detected?
- ▼ What weather conditions are associated with high levels of pollution?
- ▼ What types of rainfall are associated with high levels of acidity?

Setting up the experiment

Select a suitable collection vessel and measure the surface area open to the rain (you will need this to calculate the total amount of acid deposited each day). To avoid contamination by splashing, fix your container to a post, about 1.5 m from the ground, well away from buildings and trees.

At the same time every day, the collection vessel should be lined with a clean plastic bag and any rain *etc* measured and analysed. Avoid handling the inside of the bag when putting it in your collection vessel by wearing a second plastic bag over your hand as a glove. The bag should be changed each day, even if it does not rain, as dry deposition can deposit acids in the bag too. You should also note down any contaminants that you find in the bag – *eg* bird droppings!

Collecting data

A recording table is provided. You may, however, wish to devise your own if you wish to answer different questions. For example, atmospheric pressure, which is related to cyclonic and anticyclonic weather is not included on the form. As well as collecting local weather data, it is useful to contact the meteorological office to obtain a better picture of where the air masses affecting the rain originated.



Activity 1.4b pH determination

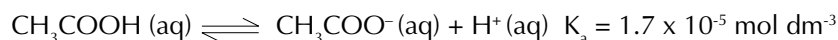
To measure the pH of the rain water you can use short range indicator paper with increments of 0.3 pH units between pH 2.0 and pH 7.0. This paper is accurate to within about 0.3 pH units. Theoretically, pH meters are more accurate but the electrodes can deteriorate with use. Each time you measure the pH of the rain water you need to:

- 1 convert your pH reading into the hydrogen ion concentration;
- 2 estimate the error in your pH readings. Your teacher may provide you with buffer solutions of a pH unknown to you, for you to test; and
- 3 work out the error in your hydrogen ion concentrations from the error in the pH readings.

Recently, in a rainstorm at Pitlochry in Scotland, a pH of 2.4 was recorded. This was claimed to be more acidic than vinegar.

Question

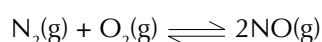
- (i) Is rain water with a pH of 2.4, really as acidic as vinegar? Remember, pH is calculated from the hydrogen ion concentration of a solution. This is not necessarily the same as the concentration of acid present. In a weak acid only a small proportion of the acid will be ionised to form H^+ . The equation showing the dissociation of ethanoic acid is:



- (a) Calculate the hydrogen ion concentration of a solution of vinegar which has a pH of 2.4.
- (b) Calculate the concentration of a solution of ethanoic acid that would have a pH of 2.4.
- (c) What volume of $0.1 \text{ mol dm}^{-3} \text{ NaOH(aq)}$ would be required to neutralise 100 cm^3 of the vinegar?
- (d) Assuming that the acid rain consists entirely of a mixture of strong acids such as nitric(V) acid or sulphuric(VI) acid, what volume of $0.1 \text{ mol dm}^{-3} \text{ NaOH(aq)}$ would be required to neutralise 100 cm^3 of the acid rain?
- (e) Comment on the statement 'rain water with a pH of 2.4, is as acidic as vinegar'.

Activity 1.4c Nitrate(V) determination

The spark temperatures in car engines can exceed $2000 \text{ }^\circ\text{C}$, and at these temperatures, some atmospheric nitrogen can combine with oxygen to form nitrogen(II) oxide, NO:

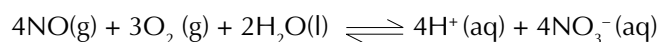


Up to 0.4 per cent of the exhaust gases from an accelerating motor car can consist of nitrogen(II) oxide. Industrial processes involving the combustion of fossil fuels are also sources of nitrogen oxides.

Nitrogen oxides can react with other atmospheric gases to form compounds with higher oxidation states, whose solutions contribute to acid rain. There are a number



of steps involved, and other chemicals such as ozone and certain peroxides are produced and consumed. However, the net results are relatively easy to describe. Nitrogen(II) oxide can be converted into nitric(V) acid, HNO_3 , a strong acid:



About 30 per cent of the acidity in acid rain consists of nitric(V) acid. The figure varies from place to place depending on the source of the acid rain, but as a general trend the proportion of nitric(V) acid in acid rain is increasing. It is estimated that non-natural emissions now account for about half the global total. In industrialised countries, vehicle emissions constitute the greatest individual source, other sources are nitrogenous fertilisers and industrial processes.

Nitrate(V) ion concentrations can be measured using a Merckoquant nitrate test strip. Concentrations as low as 10 mg dm^{-3} can be detected. First the strip reduces nitrate(V) ions to nitrate(III) (nitrite) ions. In the presence of an acid buffer the nitrate(III) is converted to nitric(III) acid which diazotizes an aromatic amine in the strip. This couples with N-(1-naphthyl) ethylenediamine to form a red-violet azo dye.

Questions

- (i) What is the concentration of 10 mg dm^{-3} of nitrate(V) ions in mol dm^{-3} ?
- (ii) Work out the nitrate(V) ion concentration of your sample in mol dm^{-3} .
- (iii) If you have done activity 1.4d what proportion of the acidity of the rain is due to nitric(V) acid? Comment on your answer in the light of the introduction.

Activity 1.4d Sulphate(VI) determination

This technique compares the cloudiness of a mixture of rain water and barium chloride solution with mixtures of solutions containing known concentrations of sulphate(VI) ions.

- 1 Immediately before you do your test on the rain water, place 2 cm^3 of 1 mol dm^{-3} barium chloride solution in each of five clean test-tubes. Make up five comparator tubes by adding equal volumes of 0.01, 0.005, 0.001, 0.0005, and $0.0001 \text{ mol dm}^{-3}$ solutions of sodium sulphate(VI) to the different tubes. Shake each tube.
- 2 Add equal volumes of the barium chloride and the rain water together. If no precipitate appears immediately, stopper the tube and wait a few minutes before making the comparison.
- 3 Match your rain water tube with a comparator tube. If you are unsure whether there is a precipitate, compare the tube with one containing water. Estimate the sulphate(VI) ion concentration.

This test enables you to detect the presence of the sulphate(VI) ion and to estimate its concentration. The solubility product of barium sulphate is $1.0 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$ and so at equilibrium there will be a precipitate down to concentrations of about $10^{-8} \text{ mol dm}^{-3}$ sulphate(VI). Equilibrium is not reached immediately. During trials of this activity, the following observations were made:



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Concentration	Immediate observations	Observations after 5 minutes
$10^{-2} \text{ mol dm}^{-3}$	cloudy/milky	milky ppt beginning to settle
$10^{-3} \text{ mol dm}^{-3}$	cloudy	cloudy
$10^{-4} \text{ mol dm}^{-3}$	no effect	very faint cloudiness

Table 1

Questions

- (i) What concentration of hydrogen ions would have to be present with the sulphate(VI) to make sulphuric(VI) acid?
- (ii) If you have done activities 1.4b and 1.4c on this sample, how does your answer to question (i) compare with the answers for hydrogen ion concentration in activity 1.4b and nitrate ion concentration in activity 1.4c?

Activity 1.5 From Siberia to suburbia

The data shown on the record sheet, headed 'Camberley data 1991', were collected in January and February of 1991. Use the information given below, together with the record sheet, to answer the questions.

Camberley is a town in Surrey situated about 55 kilometres west-south-west of London. The data collection period started with about two weeks during which there was an anticyclone over the British Isles with almost stationary air sitting over the country. This air mass was slowly replaced by very cold air from Siberia, which started arriving over south east England on 5th February. This cold air brought snow and slowly pushed back weather fronts which had been starting to come into the west of the British Isles. The winds from 7th February until 11th February were very light and somewhat variable giving rise to an almost stationary air mass over south east England again. On 12th February slightly less cold air from the north west arrived carrying first snow and later rain. Warmer air arrived with a weather front from the south west on 20th February, and it rained heavily during the next two days. The wind direction stayed south westerly for about two weeks to be replaced by a strong wind from the south on 5th March. This wind betrayed its Saharan origins by the brown dust that was deposited with the rain.



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CAMBERLEY DATA 1991

Date			Wind direction	Wind strength	Weather data	Rain type	Contaminant	Daily pH (to 1 dp)	Daily vol (cm ³)
Year	Month	Day							
1991	1	22	NE	B	F	–	–	–	–
	1	23	–	A	F	–	–	–	–
	1	24	–	A	F	–	–	–	–
	1	25	–	A	F	–	–	–	–
	1	26	NE	B	BF	E	–	2.9	1.0
	1	27	–	A	AF	E	–	3.0	0.3
	1	28	–	A	AF	E	–	3.6	0.01
	1	29	–	A	AF	E	–	3.2	0.01
	1	30	–	A	AF	B	–	3.0	0.1
	1	31	NE	B	ADF	BD	–	3.0	3.1
	2	1	–	A	AF	BD	–	3.5	3.4
	2	2	N	B	F	–	–	–	–
	2	3	–	A	FG	–	–	–	–
	2	4	E	B	FG	–	–	–	–
	2	5	SE	B	AFG	D	–	6.0	0.1
	2	6	E	B	AF	D	–	5.0	1.9
	2	7	NE	B	CDF	D	–	3.5	17.7
	2	8	NE	B	AF	D	–	3.2	6.8
	2	9	NE	B	AF	D	–	3.2	2.1
	2	10	N	B	AF	D	–	3.2	0.7
	2	11	NW	B	E	–	–	–	–
	2	12	NW	B	AFG	AD	C	3.8	32.3
	2	13	NW	B	AF	D	–	4.3	0.5
	2	14	W	B	DE	A	–	4.3	14.6
	2	15	W	B	AF	B	–	2.5	0.1
	2	16	NW	B	E	–	–	–	–
	2	17	NE	B	EF	–	–	–	–

Key

Wind direction: N North; S South; E East; W West; NE North east; SE South east; SW South west; NW North west

Wind strength: A None; B Light; C High

Weather data: A Showers; B Intermittent rain; C Continuous rain; D Night rain; E Clear sky; F Overcast; G Bright spells

Rain type: A Heavy; B Light; C Hail; D Snow; E Mist; F Thunder

Contaminant: A None; B Insect; C Dust; D Plant material; E Droppings



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Questions

- (i) The data on the record sheet can be divided into distinct patterns according to the origin of the air mass.
- (a) Draw a graph to show how the pH changed with time.
 - (b) Divide the data into different weather periods and suggest an explanation for the pH of the rain or snow in that period.
- (ii) Is there any apparent relationship in the data between rain type and pH?
- (iii) Compare the following days: 7th, 8th and 14th February. On which of these days was most acid deposited in the rain?
- (iv) The rain collector had a collecting area of 125 cm^2 .
- (a) Calculate the mass of hydrogen ions that fell on a square kilometre on 8th February.
 - (b) If all of the acidity had been associated with sulphuric(VI) acid, what mass of sulphuric(VI) acid would have fallen per square kilometre?

Activity 1.6 Lead

Activity 1.6a Sources of lead pollution

Although lead (Pb) is toxic to living organisms, it is widely used by humans and dispersed throughout the environment. Inorganic lead (Pb^{2+}) is a general metabolic poison and enzyme inhibitor (like most of the other heavy metals). Young children are particularly affected and can suffer mental retardation and semi-permanent brain damage.

One of the most insidious effects of inorganic lead is its ability to replace calcium in bones and remain there to form a semi-permanent reservoir for long term release well after the initial absorption.

Organic lead, as tetraethyl lead (TEL) or tetramethyl lead (TML), is even more poisonous than inorganic lead. TEL and TML, called lead alkyls and used as anti-knock additives in petrol, have been added to most gasoline supplies since 1923. The amount added at present to petroleum spirit ranges from 44-88 mg of TEL per litre. During driving, 25-75 per cent of this lead is emitted into the atmosphere, depending on driving conditions. Although most of this lead is ultimately deposited on the ground, appreciable concentrations can enter the air.

Figure 1 shows the amount of lead detected in dated layers of snow in the Greenland ice cap. There has been some debate about the validity of this evidence!

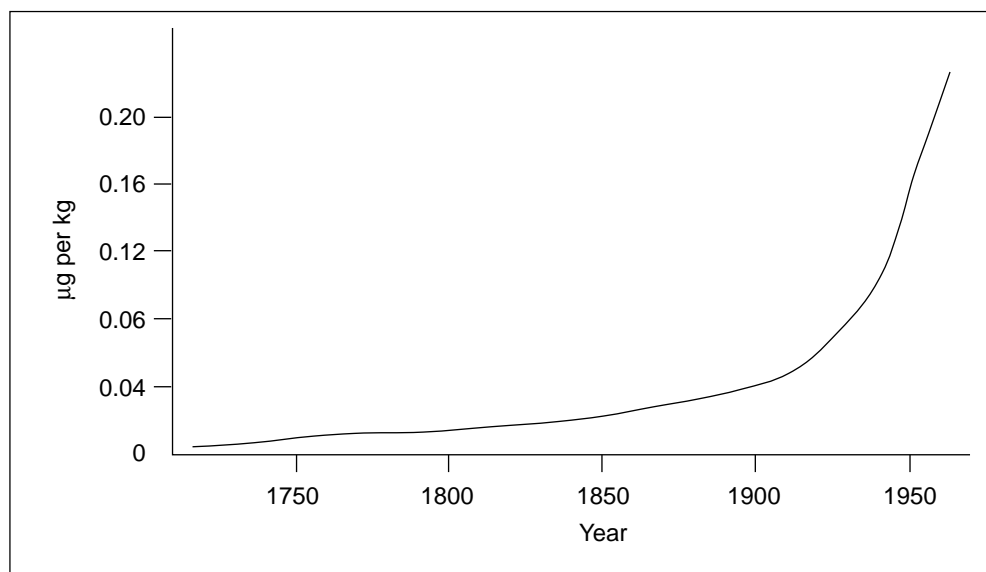


Figure 1 Lead content of snow layers in Northern Greenland

Questions

- (i) Explain the shape of the graph.
- (ii) What changes have resulted in a reduction in the amount of lead emitted by motor vehicles?



Activity 1.6b Lead in the blood

Anaemia is a characteristic toxic effect resulting from lead levels of around 50 μg per 100 cm^3 of blood in adults, and approximately 40 μg per 100 cm^3 blood in iron deficient children. Brain dysfunction can occur at 60–70 μg per 100 cm^3 blood in adults. Concern has been raised that blood-lead levels as low as 10 μg per 100 cm^3 may cause neurological damage in some children. The amount of lead in the blood of different groups varies considerably. Table 1 shows some data collected during various studies.

Country	Area	Group	Age ^a	Number*	1975	1976	1977	1978	1979	1980
Japan	Tokyo	Urban	5–12 ^b	18–48	–	11.5	6.9	5.8	7.8	6.5
Japan	Tokyo	Suburban	–	16–57	–	7.2	5.8	6.6	6.0	5.0
Japan	Tokyo	Urban	12–18 ^b	19–78	8.8	7.6	6.7	7.7	–	7.1
Japan	Tokyo	Suburban	–	20–84	7.1	–	5.1	5.8	–	5.4
Country	Area	Group	Age ^a	Number*	1976	1984	1985	1986	1987	
UK	National	Traffic police	Adult	172–248 ^b	–	11.3	11.0	8.7	8.8	
UK	National	Population exposed to traffic	Adult	384–413 ^b 433–467 ^c	–	12.7 9.8	12.0 8.9	10.7 8.0	9.7 7.5	
UK	National	Rural and suburban	Adult	151–192 ^b 178–210 ^c	–	10.9 8.0	10.5 7.7	10.0 7.2	9.0 6.9	
UK	National	Urban child	6–7	885–988	–	9.9	9.2	7.6	7.3	
Wales	–	Rural	45.8 ^d	13	16.7	11.2	–	–	–	
Wales	–	Old mining area	52.3 ^d	23	18.2	13.7	–	–	–	

* Ranges are quoted when studies were done over a number of years
^a In μg per 100 cm^3 blood
^b Males only
^c Females only
^d Mean age

Table 1 Human blood-lead concentrations in selected countries^a

Questions

- (i) What reasons can you think of to explain the differences between the blood-lead levels in the urban and suburban groups?
- (ii) What could explain the relatively sharp decrease in the figures from 1976 to 1987 for Japan?
- (iii) What could explain the different blood-lead concentration of male and female groups?
- (iv) Why do you think the results for 6–7 year old children are higher than those of adults? Why is this significant?
- (v) What explanation can you think of for the results from Wales?

Activity 1.6c Lead determination

In this activity soil or water samples are analysed for lead by using a complexing agent called dithizone (diphenylthiocarbazone – $C_6H_5-N=N-CS-NH-NH-C_6H_5$). Dithizone forms a complex with metal ions such that if the metal ion is M^{2+} and dithizone is dith, the complex formula is $[M(dith)]^{2+}$. The complex is orange-coloured lead dithizonate which, like dithizone, is soluble in organic solvents.

The complexation of the dithizone with other heavy metal ions is avoided by the addition to the soil of a buffer solution and one additional reagent, tetren, before shaking with the dithizone solution. The degree of orange colour in the organic layer is then matched against those obtained using known concentrations of lead ions to give an estimate of the amount of lead.

Solutions are made up so that approximately 6 ppm of metal ion in solution is totally complexed by an equivalence of dithizone solution to water. If less than 6 ppm is present then some green uncomplexed dithizone remains giving a colour intermediate between green and red.

Procedure

- 1 Place 5 cm^3 of water to be tested or one level spatula full of soil (about 2 g) in 5 cm^3 of distilled water in a test-tube.
- 2 Add 5 cm^3 of the buffer solution followed by one drop of Tetren.
- 3 Add 5 cm^3 of dithizone solution (which sinks). The tube is then corked and shaken vigorously for about 15 s.
- 4 After allowing the two layers to separate, match the colour of the solvent layer against the results obtained for known concentrations of lead nitrate solution.

To enable the colour of the solvent layer to be seen, for soil samples, it is frequently necessary to filter the mixture. The coloured layer either comes through as the filtrate or can be decanted out of the top of the filter funnel into a clean tube. Alternatively, if too much soil is present, it can be decanted into a second filter funnel.



2. Water quality

Activity 2.1 The response of water to carbon dioxide

Natural water from different sources responds to carbon dioxide in different ways. In one experiment 50 cm³ of water from each of the following three sources was used: a pond in Finland; the River Thames in London and London snow.

A pH probe was connected to a computer and placed in the water sample being investigated. The experimenter introduced carbon dioxide into the water by passing a steady stream of the gas through a straw for one minute.

The graph shows the effect of carbon dioxide on the pH of water from the three different sources.

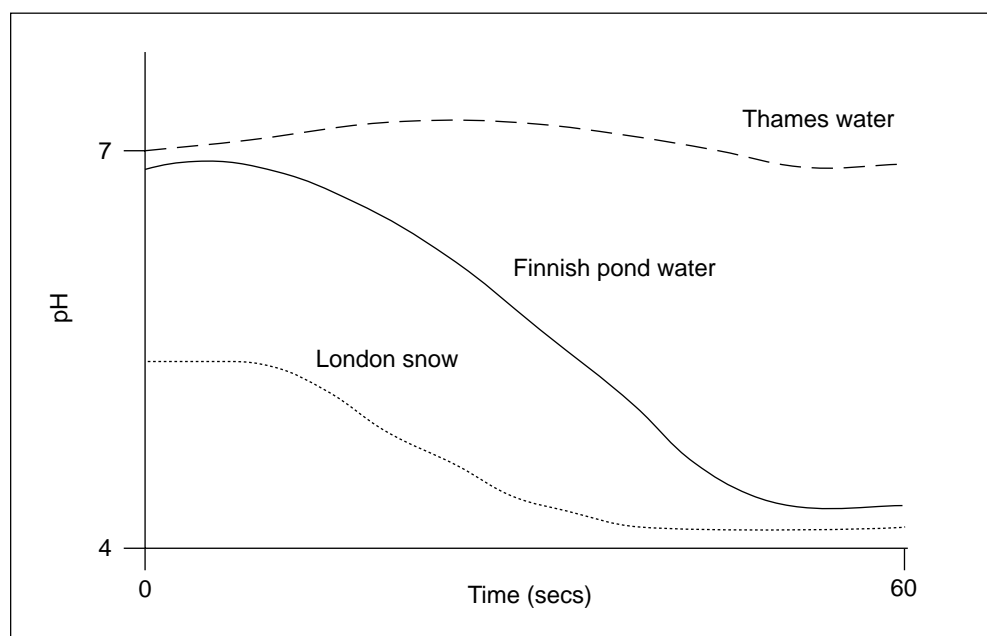


Figure 1 Response of water samples to carbon dioxide

Questions

- (i) From the graph, what is the difference between the original samples of London snow water and Finnish pond water?
- (ii) The carbon dioxide was added at a constant rate, but the plots for the London snow water and the Finnish pond water are not linear. Why is this?
- (iii) Do you expect the changes in the London snow water and the Finnish pond water to be due to biological or chemical effects? Explain your answer.
- (iv) On addition of carbon dioxide, an acidic oxide, the pH of Thames water would be expected to fall, yet it appears to rise initially. Can you suggest a simple explanation for this?

Activity 2.2 Aluminium in the water supply

The purpose of this activity is to introduce you to the topic of water and pollution.

Chemical cocktail in water 'still harmful'

A leading scientist has warned that 20,000 people whose water supply was seriously polluted by chemicals may suffer long term health problems. He has accused South West Water of taking no interest in the medical implications of the incident, which he claims it has sought to cover up.

Dr Neil Ward, one of Britain's top toxicologists, has investigated the 'cocktail of chemical events' that followed the accidental dumping of 20 tons of toxic aluminium sulphate in the water supply serving the Camelford area of north Cornwall in July.

It was six weeks before the truth of the incident, which made people and animals violently sick and led to the death of up to 60,000 fish, was admitted by the water authority after immediate assurances that there was no danger to the public. Last month *'The Observer'* detailed how the authority tried to keep the accident secret.

Dr Ward, a senior lecturer in metal toxicology at Surrey University, whose report was independently commissioned and based on data available to South West Water, claims that the authority has ignored the 'vast effects on both the environment and the residents living within the area'.

Describing the incident 'as a major ecological disaster, the likes of which have not been recorded in Britain before', Dr Ward says: 'It will be going on for a very long period of time. There are still chemical events happening in the water.'

His conclusions are based on the effects of chemicals introduced into the water system after the initial incident in an attempt to neutralise the highly toxic aluminium sulphate. These reacted with water pipes, introducing high levels of lead, copper and zinc into drinking supplies, with potentially harmful results for unborn children and infants especially.

The Department of the Environment has ruled out a full independent inquiry, saying it is satisfied with the thoroughness of the water authority's own report on the incident. The authority would make no further comment.

So far more than 100 local residents, many of whom became ill and had their hair turn deep green after the incident, are seeking damages against the water authority for negligence.

The authority has promised homes in the area a 10 percent reduction on the water rates.

The Observer,
13th November 1988

Questions

- (i) Why is aluminium sulphate(VI) used by water suppliers?
- (ii) What are the possible sources of lead, copper, and zinc in drinking water?
- (iii) What were the effects of this incident on the environment?
- (iv) What type of substance could be added to the water supply to remove the aluminium sulphate(VI) from solution? List some examples. Try to find out what a water board would do if the public supply was contaminated with aluminium sulphate(VI) again.



Activity 2.3 Oxygen in water

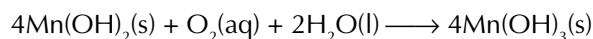
The amount of dissolved oxygen in water is important for the life in it. Oxygen has a low solubility in water and varies with the temperature. For example, at 15°C the maximum concentration is about 10 ppm. In this activity you will be measuring the amount of dissolved oxygen by using either a titrimetric method (the Winkler analysis) or an oxygen electrode.

Sampling

Water samples are especially subject to changes in chemical composition owing to chemical reactions or microbiological changes. It is better to analyse samples immediately after collection if possible. Each water sample that you use should be labelled with the place and depth at which it was taken.

The Winkler method

In this method of analysis, dissolved oxygen oxidises iodide to iodine which is then titrated with thiosulphate solution. Manganese salts are used as intermediates to make the reaction of the oxygen fast and quantitative:



The manganese(III) hydroxide dissolves when concentrated sulphuric acid is added, and the iodide is oxidised to iodine.

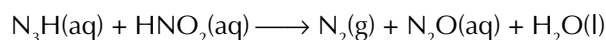
Questions

- (i) Write a balanced equation for the reaction of manganese(III) hydroxide with iodide ions in the presence of acid.

The iodine is then reduced by the thiosulphate.

- (ii) Write a balanced equation for this reduction.

Interference by nitrate(III) (nitrite) might occur in some samples but can be overcome if a small amount of sodium azide is added to the alkaline potassium iodide solution. The nitrate(III) reacts on acidification:



Safety precautions

- ▼ Do not get any of the reagents on your skin or in your eyes.
- ▼ Wash your hands after doing the test.
- ▼ Be particularly careful with the alkaline potassium iodide solution as it is very corrosive.

Procedure

- 1 Fill two 250 cm³ glass-stoppered bottles with a water sample until there is no more air inside. Do the Winkler analysis on one sample immediately and keep the other bottle in a dark place for 5 days at approximately 20 °C.

A little of the sample to be analysed will need to be discarded so that there is sufficient room in the bottle for the reagents to be added (see below).

- 2 Add 1 cm³ of a 3 mol dm⁻³ solution of manganese(II) sulphate to the sample using a pipette.
- 3 Add 1 cm³ of alkaline potassium iodide solution, insert the stopper and then mix the contents thoroughly.
- 4 Repeat the mixing procedure after a few minutes then let the precipitate settle. *Carefully* add 1 cm³ of concentrated sulphuric acid.
- 5 Insert the stopper immediately and carefully mix until the precipitate disappears.
- 6 Allow the solution to stand for 5 minutes and then withdraw 100 cm³ of the solution into a conical flask.
- 7 Add a 0.025 mol dm⁻³ solution of sodium thiosulphate from a burette until the yellow colour nearly disappears.
- 8 Add 1 cm³ of starch solution and continue adding the thiosulphate solution until the blue colour disappears.
- 9 Record the volume of thiosulphate solution used (disregard any return of the blue colour) – 1.00 cm³ is equivalent to 0.2 mg of dissolved oxygen in the 100.0 cm³ portion titrated.
- 10 Repeat the test with the water that has been stored in the dark for five days.

It is oxidised organic matter in the water that uses oxygen. The difference between the two measurements you have recorded is the five-day biological oxygen demand (BOD₅), measured in parts per million. A five-day BOD of 7 ppm, for instance, means that 7 mg of oxygen were consumed by 1 dm³ of the contaminated water over a period of five days. Water in rivers, lakes and canals with a BOD₅ of not more than 3 ppm is defined by the National Water Council as *Class 1A Good Quality*.



Activity 2.4 Aluminium and Alzheimer's disease

In this activity you will be looking at an extract from a scientific paper about an area of controversy in science at the moment: the possibility of a link between aluminium ions in drinking water and Alzheimer's disease.

Aluminium is wide-spread in the environment and we all swallow several milligrams each day. Much of the aluminium in the diet is insoluble and is not readily taken up from the gastrointestinal tract. However, because the aluminium in drinking water is either dissolved or easily brought into solution at gastric pH it might be absorbed more easily. Aluminium in water is mainly derived from treatment processes. Water from upland catchments tends to have a brown tinge from its contact with peat and aluminium sulphate is used as a coagulant to remove this colour. Although treatment plants are operated to remove most of the added aluminium, some passes into the water supply. Residual concentrations of aluminium in drinking water vary widely between areas; this allowed us to examine a possible relation between exposure to aluminium and the development of Alzheimer's disease by an epidemiological survey.

...

The survey showed a positive relation between the rates of Alzheimer's disease and the concentrations of the aluminium in drinking water. Rates in county districts where aluminium

concentrations are greater than 0.11 mg l^{-1} were 1.5 times higher in districts where the aluminium concentration was below 0.01 mg l^{-1} . When the analysis was restricted to cases under the age of 65 years the association was stronger; the rates of the disease in districts with the highest aluminium concentrations were 1.7 times greater than those in districts with the lowest concentrations. There was no evidence of a relation between aluminium and late-onset epilepsy. We think that these results point towards a casual relationship between aluminium and Alzheimer's disease. However, interpretation of a survey of this sort must be tentative, not least because of the many things other than the concentration of aluminium in water, that differ between areas. Studies at the unit are currently underway to establish the relation between exposure to aluminium and the development of Alzheimer's disease in individuals rather than in populations and to assess the risk from other environmental sources of aluminium.

Alzheimer's disease and aluminium in drinking water,
Dr C N Martyn, MRC News

Questions

- (i) What is Alzheimer's disease?
- (ii) What are the major dietary and medicinal sources of aluminium?
- (iii) What is the evidence suggesting that aluminium may be a contributory factor in the development of Alzheimer's disease?

Activity 2.5 Aluminium determination

Aluminium ions can be determined by using a test strip. Aluminium ions are converted by alkali into aluminate, which forms a red colour lake with the ammonium salt of aurin tricarboxylic acid on bathing in ethanoic acid. In the process, interfering ions are removed, which means that the test is highly sensitive and largely immune to interference.

The test strips are initially coloured red. The colour to be compared with the scale is not produced until the analysis has been done in accordance with the directions for use.

If the concentration lies at or above the upper value of the colour scale, the sample solution must be diluted to bring the concentration within the most sensitive range of the colour scale. When calculating the concentration, however, the dilution factor must be taken into account.

Preparation of samples

Water samples are used directly but soil samples need to be prepared. One gram of soil is placed in a test tube with 10 cm³ of distilled water and the mixture is shaken for 30 sec. After the precipitate has settled, 5 cm³ of the solution is transferred to another test tube.

Safety precautions

- ▼ Do not get any of the reagents on your skin or in your eyes.
- ▼ Do not touch the reaction zone of the test strip.
- ▼ Wash your hands after doing the test.

Procedure

- 1 Rinse the measuring vessel with the solution to be tested and fill it to the 5 cm³ mark.
- 2 Adjust the pH to 13 by adding Reagent 1 dropwise and filter off any precipitate which forms.
- 3 Briefly immerse the reaction zone in the solution. Shake off excess liquid.
- 4 Apply 1 drop of Reagent 2 to the reaction zone, distribute evenly, allow to react for 1 min.
- 5 Shake off any excess reagent and compare with the colour scale.



3. Radon

Activity 3.1 Radon and leukaemia

The following report looks at links between radon and leukaemia, an area of growing concern. This first appeared in *New Scientist* magazine, London, the weekly review of science and technology.

Linear link found between radon exposure and leukaemia

Radon, the naturally occurring radioactive gas, may be an important cause of leukaemia, cancers of the kidney and the skin, and a number of cancers in children. Researchers at the University of Bristol have found a close linear correlation between radon exposure and certain cancers in 15 countries.

Scientists already recognise radon as a significant cause of lung cancer. According to physicists in Bristol, led by Denis Henshaw, the gas is also responsible for up to 12 per cent of cases of myeloid (*bone marrow*) leukaemia in Britain and up to a quarter of all cases of myeloid leukaemia world-wide.

To confirm the correlation that the international data appeared to show, the Bristol team considered regions of Canada in detail. Here, data on the incidence of cancer and data on radon levels were available for identical geographical areas. The results showed a highly significant correlation between radon and acute myeloid leukaemia for all age groups.

In Britain, radon is believed to cause up to 2500 deaths from lung cancer each year. Most of the alpha radiation from the gas is released in the respiratory tract, and scientists had until now assumed that the lungs bore the brunt of most of the damage associated with radon. It

now appears that the link between radon and other cancers could be due to other mechanisms as well.

One is the tendency of radon to concentrate in fat cells within bone marrow. Alpha radiation from these cells may initiate leukaemia by damaging primitive blood cells in the surrounding tissue. An additional source of radiation may be so-called "radon daughters" – the breakdown products of the gas – which are normally mixed with radon in room air.

The Bristol team has attempted to calculate the proportion of leukaemia due to radon and the proportion due to other types of natural background radiation. Their analysis, published in the current issue of *The Lancet*, suggests that alpha radiation is far more likely to cause leukaemia than has previously been appreciated (vol 335, p1008).

The conventional "quality factor" of the alpha particle with respect to gamma radiation is 20: broadly speaking this means that alpha radiation is 20 times as damaging to tissues as gamma radiation. The Bristol team calculates the real quality factor of alpha radiation is likely to be greater than 20, and may be as high as 180. The team says that findings may explain some of the clusters of leukaemia observed in Britain and say their observations warrant urgent investigation.

Questions

- (i) Which cancers is radon thought to be an 'important cause of'; and which cancer has radon already been recognised as a 'significant cause of'?
- (ii) What new ideas are described and how do they explain the increased concern about the dangers of radon?
- (iii) Explain what is meant by the term 'quality factor' and say why the researchers are saying that it should be changed significantly?

Activity 3.2 What is radon?

The purpose of this activity is to look at what exactly we mean by radon, where it comes from and how we can detect it.

Q What is radon?

A Not as simple a question as it seems. The element radon has three naturally occurring isotopes, ^{222}Rn (usually referred to as radon), ^{220}Rn (usually referred to as thoron), and ^{219}Rn (known as actinon, and of little significance). They are found in the environment as gases.

Q Where do they come from?

A Radon is produced during the decay of ^{238}U . Thoron is produced during the decay of ^{232}Th . Both ^{238}U and ^{232}Th are naturally occurring elements found throughout the world in very small amounts. They are radioactive and break down into other elements.

Q Are radon and thoron radioactive too?

A Yes, radon has a half-life of 3.8 days whereas thoron has a half-life of 55 seconds.

Q What happens to radon and thoron when they are produced?

A Radon produced in the soil diffuses into the air and some may move a considerable distance before decaying. Thoron produced in the soil has little chance of moving far before decaying, though it is still dangerous in high concentrations.

Questions

- (i) Explain the difference between ^{222}Rn and ^{220}Rn in terms of their atomic structure. Would you expect them to behave chemically in the same way as each other or not? Why?
- (ii) Explain what is meant by the term 'half-life'.
- (iii) Why do you think thoron is less of a problem than radon?
- (iv) Using a book of data, explain how uranium 'turns into' radon and how thorium 'turns into' thoron. Can you think of a better way of describing the process than 'turns into'?



Activity 3.3 Why is radon dangerous?

Radon, its daughter elements, and to a lesser extent, thoron are breathed in and enter the respiratory tract. As the atoms decay they emit alpha particles which, because they are inside the body, can cause much more damage than alpha particles emitted by radon and thoron outside the body.

Alpha particles cause more damage to cells than beta particles. This is because they have twice the charge, are far more massive, and are moving relatively slowly. Thus, they are more likely to hit other atoms.

The term 'quality factor' is used to indicate the relative danger of different types of ionising radiation to cells.

Type	Quality factor
Alpha	20
Beta	1
Gamma	1
X-ray	1

Table 1 The quality factor of different types of radiation

Alpha particles can chemically change DNA and also ionise water molecules in the body to form free radicals that are highly reactive species which can also damage cells.

The consequences of the cell damage may be passed onto offspring and can result in the cancerous growth of cells.

Questions

- (i) Why are alpha particles inside the body more likely to cause damage than those outside the body?
- (ii) What does radon break down into? Why is this particularly dangerous? Which organs are most at risk from radon?
- (iii) What is meant by 'ionisation' and how could alpha particles cause it?
- (iv) What are free radicals, and why are they so reactive?

Activity 3.4 Radon in the UK

Activity 3.4a Radon, health and homes

The purpose of this activity is to explain what radon is and where it originates. It starts with an extract from the government's white paper on the environment, *This Common Inheritance*.

Radon is a naturally occurring radioactive gas produced from the radioactive decay of uranium, found in small quantities everywhere, but especially in areas of granite rock. Radon disperses quickly in the open, but can accumulate inside buildings. These accumulations can cause damage to the lungs and increase the risk of lung cancer. Recent estimates suggest that as many as one in twenty lung cancer cases in Britain might be caused by exposure to radon in the home.

The Government recommended action to reduce radon in homes in 1987, and set an action level above which precautionary measures were recommended. In view of the latest research on radiation dangers, the Government announced in January 1990 that the action level should be halved, to an

annual average concentration of 200 becquerels per cubic metre. The National Radiological Protection Board (NRPB), which advises Government on radiation protection standards in Britain, calculates that radon and thoron (a form of radon) contribute 51% of the average annual radiation dose to the British population. Britain's action level is lower than those proposed elsewhere in the European Community and it is ahead in its programme of research and surveys.

The Government is pursuing urgently research into the methods of reducing radon entry into existing houses, or of removing it once it has entered. This can be done in three main ways. In most cases for best results a combination of two or more techniques may be needed...

Questions

- (i) By using a geological map of the UK, identify the places that you would predict have higher than average radon levels.
- (ii) What action has the government taken recently and why?
- (iii) What further action could be taken to reduce radon levels in homes?
- (iv) What is the role of the NRPB?

Activity 3.4b Where in the country is radon found?

In activity 3.4a you read that:

Radon is a naturally occurring radioactive gas produced from the radioactive decay of uranium found in small quantities everywhere, but especially in areas of granite rock.

The National Radiological Protection Board (NRPB) has published survey findings indicating the location of radon in the environment. This map shows the indoor radon concentrations throughout the UK as the shading of 10 km squares in the Ordnance Survey grids. Approximately 10,000 homes are included.

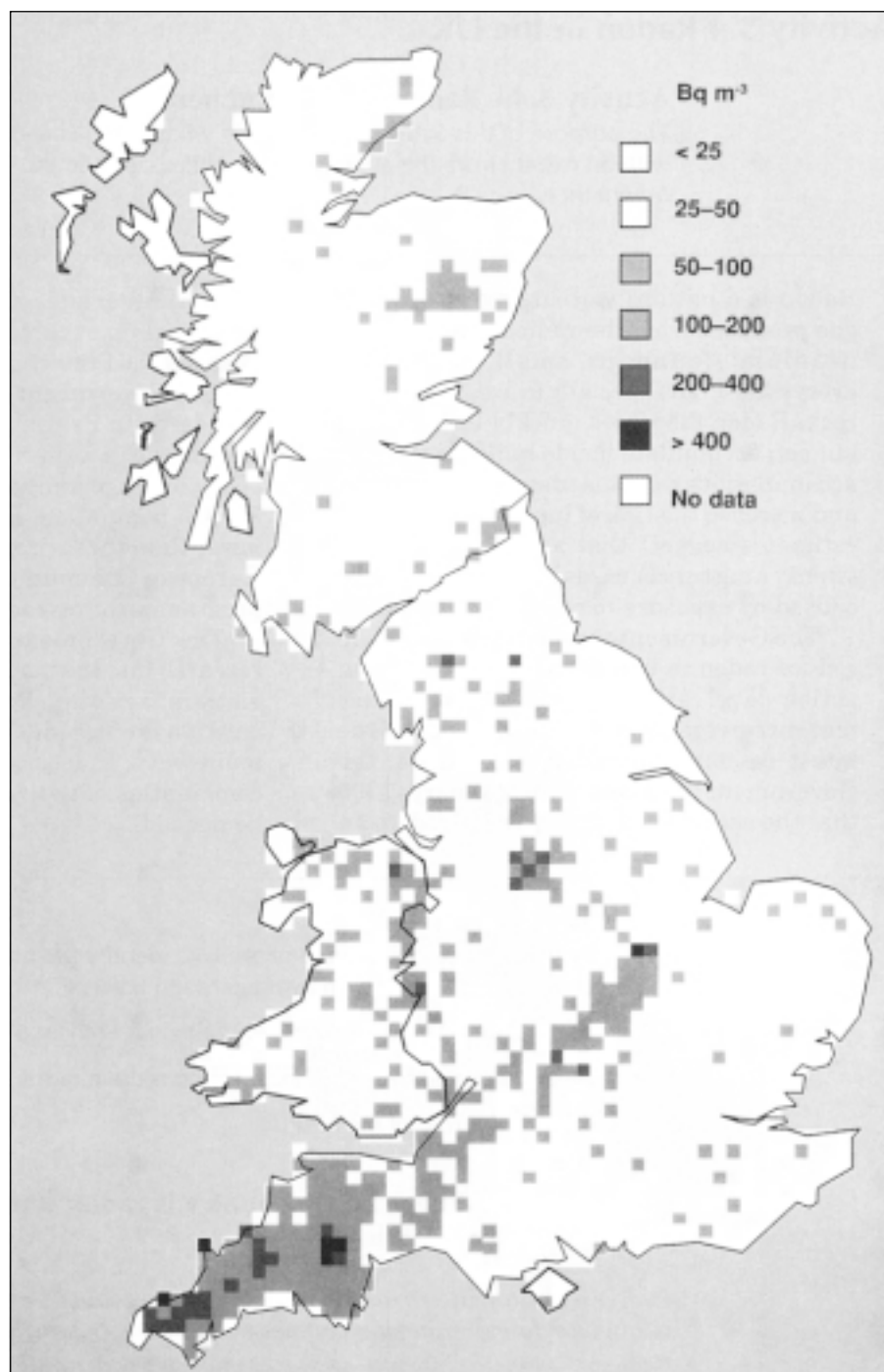


Figure 1 Indoor radon concentrations
(Figure supplied by courtesy of the NRPB)

Question

- (i) In activity 3.4a you made predictions about radon levels. Compare your predictions with the map above. Try to explain any differences between this data and your prediction.

Activity 3.5 Geochemistry

This activity uses mineralogical data to explain the distribution of radon in different parts of the UK. Use the data provided and a data book to answer the questions.

Almost all of the natural radioactivity caused by minerals in the ground is due to the presence of three elements: uranium, thorium and potassium. Uranium has two radioisotopes (^{235}U and ^{238}U), thorium is monoisotopic (^{232}Th) and potassium has several isotopes, of which only one is radioactive (^{40}K).

Questions

- (i) The contribution of ^{235}U is usually discounted? Why?

	S W England		North Wales		Scotland
	Granite B	Granite C	Granite	Rhyolite	Granite
K ₂ O per cent	4.69	5.2	4.19	3.2	4.1
Th ppm	14	6	29	16	40
U ppm	20	11	6	2	8.6

Table 1 Analytical data for some typical radioactive granites

- (ii) By using the information in Table 1, in which rocks would you expect to find the highest level of alpha radioactivity? Explain your answer.

	S W England		North Wales		Scotland
	Granite B	Granite C	Granite	Rhyolite	Granite
Uraninite	90	75	–	–	–
Zircon	2	5	10	8	8
Monazite	4	9	80	80	25
Apatite	4	11	10	12	4
Thorite	0	0	0	0	30
Fe oxides	–	–	–	–	32

Table 2 The percentage of the uranium in different minerals found in the same samples as Table 1.

The mineral, uraninite (UO_2) has a low surface area to weight ratio. It is relatively easily broken down by weathering.

- (iii) Weathered granite from the south west of England can produce more ^{222}Rn than unweathered granite. Explain this phenomenon.
- (iv) Uraninite has been significant in the history of chemistry. The Curies used it, but what for?



Activity 3.6 Factors affecting the emission of radon

In this activity you will be looking at the factors that affect the rate of emission of radon from rocks and soils. This information will help to explain your results and those from other surveys.

Geological factors

In activities 3.4b and 3.5 you saw that most of the radioactivity from geological sources comes from uranium minerals. Uranium minerals are common in some forms of granite. However there are other types of rock that contain significant amounts of uranium. In particular, samples of some metalliferous veins, certain hydrocarbon deposits and some sedimentary rocks containing phosphate minerals all contain uranium.

The weather

Questions

- (i) How do you think the weather might affect the rate of emission of radon from the ground?

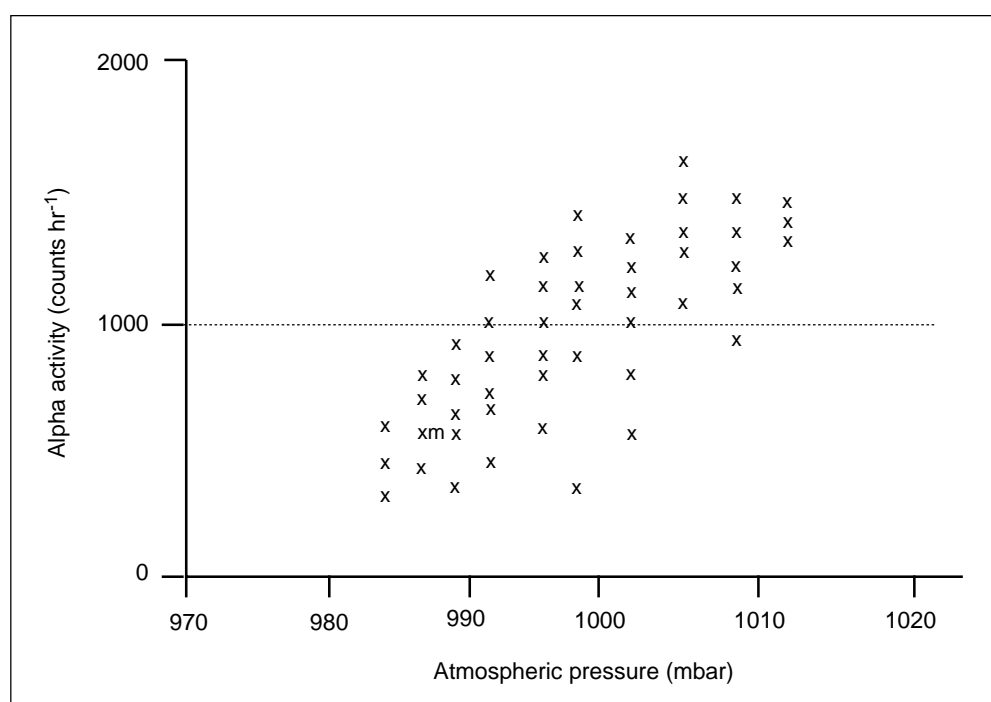


Figure 1 Alpha activity in the ground versus atmospheric pressure, Kingswood, Devon

- (ii) What interpretation can you provide for the data in *Fig. 1*?

In clay soils or soils rich in organic material the dominant influence on radon emission is thought to be the moisture content of the ground.

- (iii) Where does the moisture come from and why these soil types in particular?

Activity 3.7 Where in the home is radon found?

In this activity you will be thinking about how the choice of materials and the design of a house can affect the radon concentration. This will help you to design your own experiment later and to explain data from other surveys.

In the UK there are many different house designs and methods of construction. Some of the differences explain the differences in radon concentrations found by nationwide surveys. An understanding of the design and construction of houses will also help you to think about what to do to reduce radon concentrations, and theoretically, reduce the risk of contracting lung cancer.

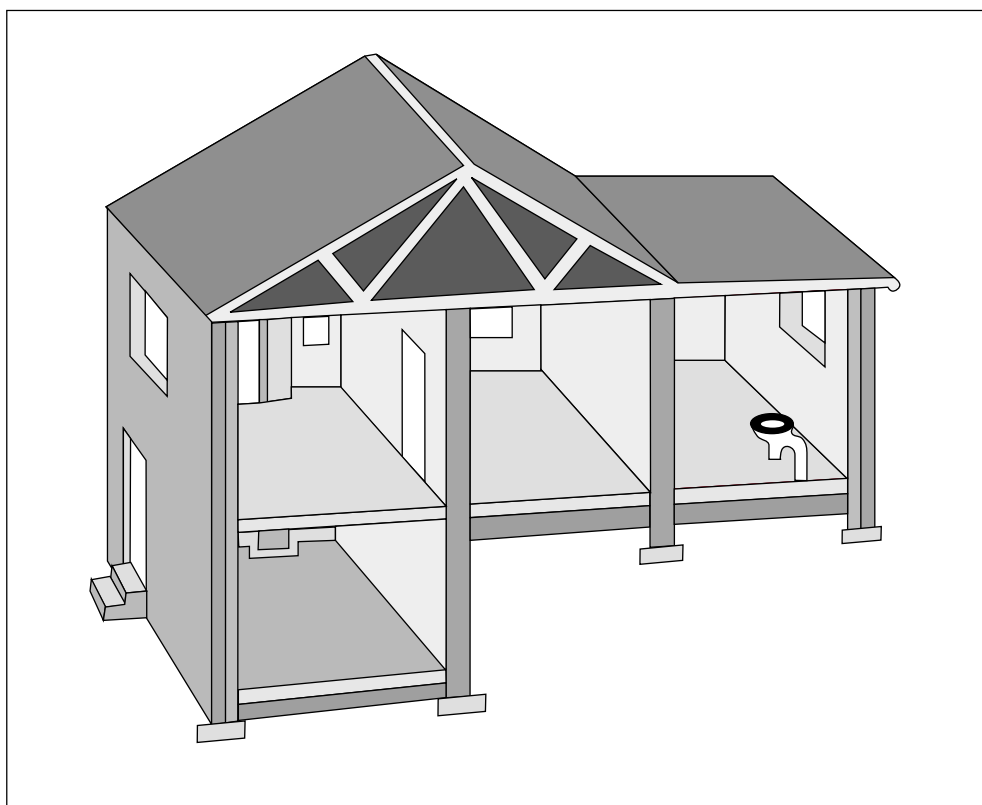


Figure 1 One typical house design

Questions

- (i) In what ways could radon get into the house from outside?
- (ii) What other sources of radon could there be apart from the rocks and soil that are below the house?
- (iii) How could the radon concentration in a house be lowered?



Activity 3.8 How much radon is there?

Activity 3.8a Detecting radon

In this activity you will be monitoring the occurrence of radon in your home. You will be using a plastic detector known as CR-39. The plastic detector is left in an area for some weeks. Alpha particles associated with the presence of radon produce tracks in the plastic which become visible through a microscope after etching. As it decays, each radon atom emits an alpha particle which penetrates the CR-39 (the plastic detector) forming a track which after etching is seen clearly under a microscope.

The first thing to do is to decide where you are going to put the CR-39. You should have some ideas if you have done activity 3.7.

Preparing the CR-39

Handle the CR-39 as little as possible and only by the edges. Use pieces approximately 10 mm x 20 mm. Remove the foil wrapping and cut the CR-39 into the required sized pieces. This is done by scoring with a scalpel or similar sharp edge and then holding the marked surface along the edge of a table and tapping it sharply. Remove the plastic layer covering the CR-39 just before placing it in the soil or in the container.

Identifying the CR-39

Give each piece of CR-39 an identification mark, so that you will recognise it later, by scratching each piece in one corner with something sharp.

Positioning the CR-39

Attach the CR-39 to the inside bottom of a polystyrene cup, using Blu-tac, as shown in *Fig. 1*. Make sure that you touch the CR-39 as little as possible. Cover the open end with Cling film and fix firmly with a rubber band. Place the cups on the floor or on a shelf in the sampling points that you have selected.

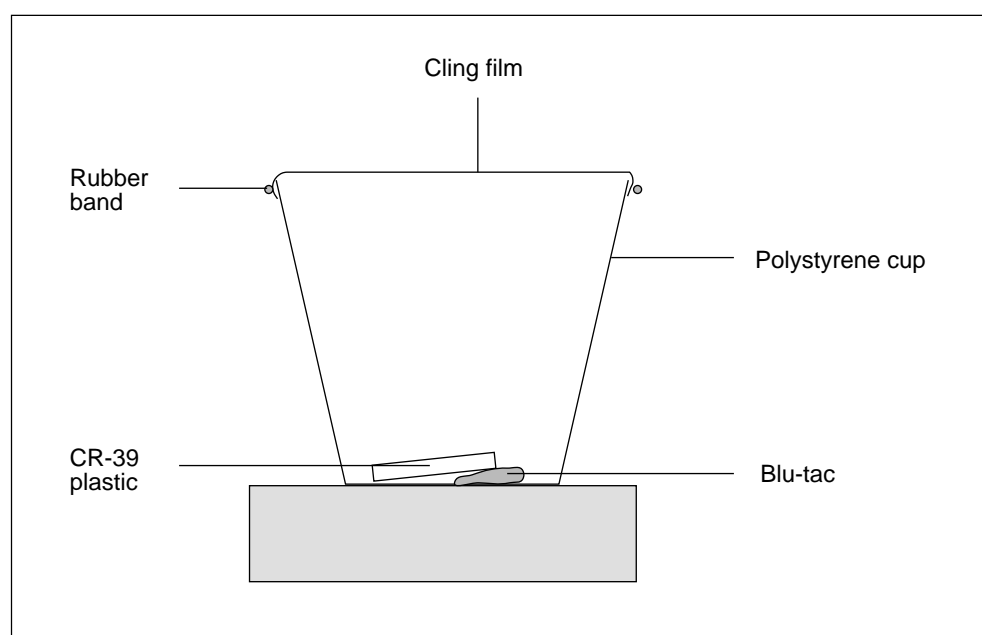


Figure 1 Radon detection apparatus

After about four weeks collect the pieces of CR-39, cover them with metal foil, and secure them in a plastic bag. Hand them to your teacher for etching. **This procedure involves using a highly corrosive solution (6.25 mol dm⁻³ sodium hydroxide solution) and should therefore be done by a suitably qualified teacher or technician.**

Counting the tracks



Figure 2 Alpha particle tracks visible in etched CR-39 (x 400)

For the counting, work in pairs so that you can check one another's results. Use a microscope with a magnification of x100 – x200. Take counts at three different parts of each piece CR-39 chosen at random. Now get your partner to take a further three readings on your CR-39, again at random. This will enable you to work out an average value. Repeat this procedure with each piece of CR-39. Find the radius of the field of view using a graticule or a clear plastic ruler or by using 4 mm squares made from graph paper. For each piece of CR-39 work out the average counts per cm² – call this Z.

Calibration

Radioactivity is measured in standard units called Becquerels (1 Becquerel = 1 disintegration per second). To convert the count of the number of tracks on your piece of plastic into a reading in Becquerels per cubic metre of air, a calibration exercise has been done: pieces of the plastic were exposed to alpha radiation of a known strength and the number of tracks counted. This is then used to produce the conversion factors in the calculation below.

The activity concentration = $((5.3 \pm 0.5) \times Z)/n$ Bq m⁻³
where n = the number of days that the CR-39 was exposed

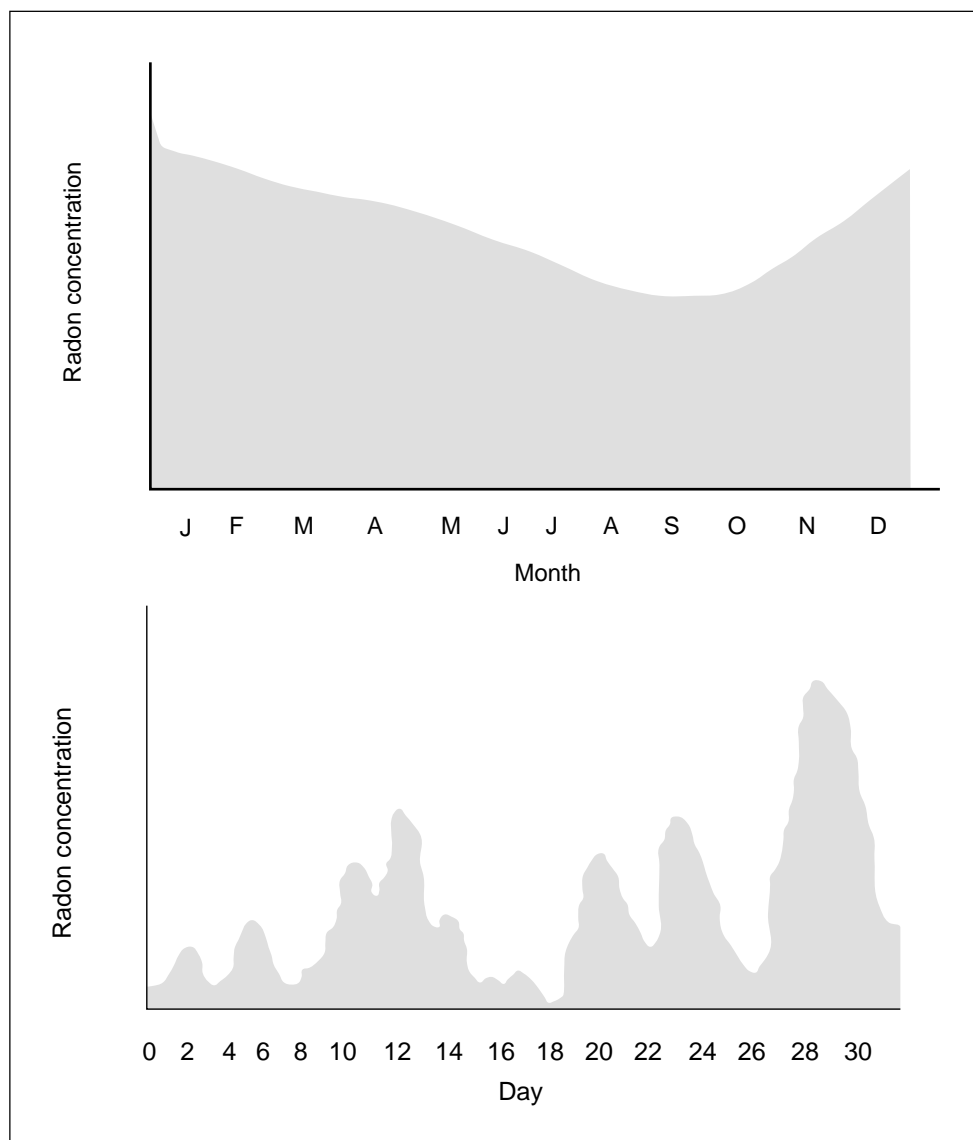
Now calculate the activity concentration for each of your samples.



Activity 3.8b Interpreting the results

This activity is designed to make you think about the limitations of the experiment that you have done in activity 3.8a. You were trying to measure the amount of radon present in your home. What affects the concentration of radon in the home?

Here is some data provided by the National Radiological Protection Board (NRPB) based on measurements taken in peoples' homes.



Questions

- (i) Explain the shape of the monthly radon distribution graph.
- (ii) Explain the shape of the daily radon distribution graph.
- (iii) Predict what a graph of radon concentration for one day would look like. Explain your reasoning.

Teachers' guide to the activities

1. Air quality

Activity 1.1 Acid rain: the background

This is an introductory activity designed to show the level of variation between different samples of rain. An understanding of dissociation is required to answer the question.

Source: HMSO, 1990 & Longhurst *et al*, 1987.

Answers to questions:

- (i) Emissions of sulphur(IV) oxide and nitrogen oxides have increased as consumption of fossil fuels has increased. The wind systems of the industrial Western countries take much of the pollution to Scandinavia, where a lot of it falls in the form of acid rain.
- (ii) The most immediately obvious effects have been the deforestation of vast areas of Scandinavia, and the killing of the fish populations in the surface water system.
- (iii) Carbonic acid is a weak acid. Sulphuric (VI) acid is a strong acid and completely dissociated. The high $[H^+(aq)]$ suppresses the dissociation of the two reactions that produce $HCO_3^-(aq)$.

Activity 1.2 Sulphur(IV) oxide, SO_2

This activity gives a simplified introduction to the chemistry of acid rain and, in particular, the contribution of sulphur(IV) oxide (sulphur dioxide).

Answer to question:

- (i) Amsterdam and Stockholm have lower levels: Milan has a very high level. The reasons are complicated and factors include geographical location, local industry and prevailing wind direction.

Sources:

Figure 1: Monitoring and Assessment Research Centre, 1987, p7.

Figure 2: Monitoring and Assessment Research Centre, 1987, p8.

Activity 1.3 Acid rain and tree damage

What causes tree damage is still very much an area of scientific debate. This open-ended exercise is suggested, in which students can test hypotheses about the effect of pH on aluminium leaching. Strips to test for aluminium are available, see activity 2.5. These are semi-quantitative.

Source: Forestry Commission, 1987 and Innes & Boswell, 1987.

See also: Raiswell *et al*, 1980; Openshaw, 1987; Review group on acid rain, Warren Spring Laboratory, 1987; Wellburn A, 1988; Gill & Gill, 1989.



Activity 1.4 Investigating rain

Activity 1.4a Monitoring acid rain

This experiment involves the collection and analysis of rain (and other precipitation). Students should formulate their own hypotheses which they should then attempt to test. A 30-day collection period should be used. Data from previous years, collected by schools, is available on the National Environmental Database (NED) which is available on the computer network, Campus 2000. The NED pack of teaching materials (Watson et al, 1990) is available from the Association for Science Education, College Lane, Hatfield, Herts, AL10 9AA; price (1993) £25.

Activity 1.4b pH determination

This activity is designed to challenge the misconceptions about acid rain and acidity. To help the students to assess the errors in the pH measurements, three buffer solutions of known pH should be supplied to students as unknowns. This activity enables students to see that errors are magnified numerically by converting pH to hydrogen ion concentration.

Answer to question (i):

(a) $\text{pH} = 2.4$

therefore, $[\text{H}^+(\text{aq})] = \text{antilog } -2.4$

$= 4.0 \times 10^{-3} \text{ mol dm}^{-3}$

(b)
$$K_a = \frac{[\text{CH}_3\text{COO}^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{CH}_3\text{COOH}(\text{aq})]}$$

we know that $[\text{H}^+(\text{aq})] = 4.0 \times 10^{-3} \text{ mol dm}^{-3}$

therefore, $[\text{CH}_3\text{COO}^-(\text{aq})] = 4.0 \times 10^{-3} \text{ mol dm}^{-3}$

so, $1.7 \times 10^{-5} = \frac{4.0 \times 10^{-3} \times 4.0 \times 10^{-3}}{[\text{CH}_3\text{COOH}(\text{aq})]}$

therefore,

$$[\text{CH}_3\text{COOH}(\text{aq})] = \frac{(4.0 \times 10^{-3})^2}{1.7 \times 10^{-5}} = 9.4 \times 10^{-1} \text{ mol dm}^{-3}$$

(c) Number of moles of ethanoic acid in 100 cm^3

$= 9.4 \times 10^{-1} \times \frac{100}{1000} = 9.4 \times 10^{-2}$

if the volume of sodium hydroxide solution required for neutralisation is V ,

$$\frac{0.1 \times V}{1000} = 9.4 \times 10^{-2}$$

$\Rightarrow V = 940 \text{ cm}^3$

(d) Number of moles of H^+ in 100 cm^3 of rain water =

$$4.0 \times 10^{-3} \times \frac{100}{1000} = 4.0 \times 10^{-4}$$



if the volume of sodium hydroxide solution required for neutralisation is V ,

$$\frac{0.1 \times V}{1000} = 4.0 \times 10^{-4}$$

$$\Rightarrow V = 4.0 \text{ cm}^3$$

- (e) The purpose of this question is to challenge what the student sees as an acid. If acidity is measured as pH *ie* $\text{pH} = -\log_{10} [\text{H}^+(\text{aq})]$, then yes, rain water with $\text{pH} = 2.4$ is as acidic as vinegar with a pH of 2.4. However, if acidity is taken as a measure of the total amount of acid contained in a solution, then as rain water contains strong acids that are effectively fully dissociated, vinegar of the same pH will (as a weak acid) contain more acid.

Activity 1.4c Nitrate(V) determination

Nitrate test strips are used to analyse a sample of water. Nitrate testing strips are available from BDH Laboratory Supplies: Merckoquant nitrate test strips. Graduations: 0-10-30-60-100-250-500 mg l^{-1} (ppm). The approximate cost of one test is 15p (1992).

The outer reaction zone of the test strip contains a reducing agent that reduces nitrate(V) to nitrate(III) (nitrite). In the presence of an acid buffer, the nitrate(III) is then converted to nitric(III) (nitrous) acid which diazotizes an aromatic amine (sulphanilic acid). Coupling with *N*-[1-naphthyl] ethylenediamine produces a red-violet azo dye.

Test strips are also available for detecting nitrate(III) (from BDH) but we have been unable to detect the presence of it in the rain collected in our trials. It is unlikely that the nitrate(V) ion concentration will produce a result in which nitric(V) acid accounts for 30 per cent of the total acidity. The experiment is not accurate enough.

Answers to questions:

- (i) $[\text{NO}_3^-(\text{aq})] = 10 \text{ mg dm}^{-3} = \frac{10}{1000} \times \frac{1}{62}$
- $$= 1.6 \times 10^{-4} \text{ mol dm}^{-3}$$
- (ii) $[\text{NO}_3^-(\text{aq})] \text{ in sample} = \text{reading} \times 1.6 \times 10^{-5}$
- (iii) Convert pH to $[\text{H}^+(\text{aq})]$ and calculate the difference between (ii) and (iii). It is possible for $[\text{NO}_3^-(\text{aq})]$ to exceed $[\text{H}^+(\text{aq})]$ because the measurement techniques are inaccurate.

Activity 1.4d Sulphate(VI) determination

This activity is designed to see if sulphate(VI) can be detected in rain water. It is possible to estimate the concentration of any sulphate detected.

The semi-quantitative nature of the activities means that the total hydrogen ion concentrations are unlikely to correlate with the nitrate(V) and sulphate(VI) ion concentrations, but the activities do give the students opportunities to work on experimental errors. More sensitive techniques would also fail to correlate because small quantities of other acids, such as hydrochloric acid, are also present in acid rain.

Test strips are available for detecting sulphate(VI) and sulphate(IV) ions. The sulphate(VI) strips are not sensitive enough for this activity. We have been unable to detect the presence of sulphate(IV) ion in the acid rain collected in our trials.

**Answers to questions:**

- (i) $[\text{H}^+(\text{aq})] = 2 \times [\text{SO}_4^{2-}(\text{aq})]$
- (ii) $[\text{SO}_4^{2-}(\text{aq})]$ has been found empirically to be approximately equal to $[\text{NO}_3^-(\text{aq})]$ (see activity 1.4c). This will not necessarily be the case in your area.

Activity 1.5 From Siberia to suburbia

This is a data analysis exercise that enables students to develop their understanding of the nature of acid rain.

Answers to questions:

- (i) This question gives students a chance to explore the wide range of factors that may affect the acidity of rain.
- (ii) There is no significant correlation between rain type and pH.
- (iii)

Date	pH	$[\text{H}^+(\text{aq})]$ (mol dm^{-3})	Volume of rain (cm^3)	Number of moles ($[\text{H}^+(\text{aq})]$)
Feb 7	3.5	3.2×10^{-4}	17.7	5.6×10^{-6}
Feb 8	3.2	6.3×10^{-4}	6.8	4.3×10^{-6}
Feb 14	4.3	5.0×10^{-5}	14.6	7.3×10^{-7}

Most acid was deposited on 7th February.

- (iv)
- (a) 448 g
- (b) 21.95 kg

Activity 1.6 Lead**Activity 1.6a Sources of lead pollution**

This activity gives a brief introduction to the chemistry of lead in the environment.

Answers to questions:

- (i) Up to 1750, the lead content of the ice was $20 \mu\text{g}$ per tonne. As a result of the Industrial Revolution this value had increased to $50 \mu\text{g}$ per tonne by 1860. Since World War II, with the explosion of automobile ownership, the level climbed spectacularly to $120 \mu\text{g}$ per tonne in 1950 and to $210 \mu\text{g}$ per tonne by 1965. The sharp increase since ca 1940 is attributed mainly to combustion of lead alkyls in gasoline.
- (ii)
- (a) Catalytic converters were introduced to reduce emissions of CO/NO_x , but these are poisoned by lead. Thus, lead-free petrol has to be used in cars with these converters.

- (b) Changes in tax levels have been used to encourage drivers to use lead-free petrol if they can.
- (c) Lean-burn engines have been developed to minimise the amount of petrol burned.

Source: Murozumi *et al*, 1969; Price, 1983.

Activity 1.6b Lead in the blood

Data from various sources is used to show the variation in blood-lead levels. The questions are designed to show the links between body chemistry and the environment.

Answers to questions:

- (i) Higher levels of lead in towns and cities could be due to car exhaust, lead in dust from industry and lead in paint.
- (ii) A change in the law relating to emissions leading to a change in consumption.
- (iii) Different metabolisms? Different patterns of work – more people commute in cars.
- (iv) Children may spend more time outside. Children may ingest more dust from their fingers. Children are particularly at risk from the effects of lead due to the greater sensitivity of the developing nervous system and their greater intake and uptake per unit body weight.
- (v) Closure of lead workings? Gradual excretion of lead from the body?

Source: Monitoring and Assessment Research Centre, 1987, p 202; Elsom, 1987, p 51.

Activity 1.6c Lead determination

Lead ions are detected in a sample of water or soil by using a chelating agent which forms a coloured complex.

Required reagents:

Dithizone (Diphenylthiocarbazon) solution – dissolve 0.5 g of dithizone powder in 250 cm³ of 1,1,1-trichloroethane to make a stock solution. The solution is light sensitive and should be stored in a dark bottle covered in aluminium foil to minimise decomposition. The working solution is made up freshly as required by diluting the stock solution with the solvent by a factor of one in 50. This too should be stored in foil covered bottles.

Buffer solution

Dissolve 10.0 g of citric acid (2-hydroxy-1,2,3-propanetricarboxylic acid) (Analar) and 2.0 g of hydroxylamine hydrochloride (NH₂OH.HCl) (Analar) in 200 cm³ of distilled water. Add 1–2 cm³ of a 0.04 per cent solution of the indicator thymol blue in ethanol and then add concentrated ammonia solution (Aristar) until the indicator just turns blue (pH 8.9). Approximately 8 cm³ are needed.

Shake the solution in a separating funnel with 10 cm³ portions of dithizone working solution to remove all traces of lead before making it up to 250 cm³ with distilled water. This scrubbing process is complete when the dithizone solution remains dark green. Three portions are usually sufficient. Any dithizone that enters the aqueous layer during the scrubbing process gives it a yellow colour that can be reduced by shaking with 10 cm³ portions of solvent. This process is usually repeated



until the buffer gives a satisfactory colour with a standard 2 ppm lead solution. Up to 10 portions may be needed.

Tetren (tetraethylene pentamine) solution

Make up 25 cm³ of tetraethylene pentamine (Tetren) to 250 cm³ with distilled water.

Standard lead solutions

0.64 g of lead nitrate, Pb(NO₃)₂ is dissolved in 1 dm³ of distilled water. Five, 10 and 50 cm³ of this solution are made up to 1 dm³ to give solutions having concentrations 2, 4 and 20 ppm respectively. Students can practice the water analysis test and compare the concentration of samples they have analysed.

Source: Sanderson, 1988 and 1989; Sanderson and Newton, 1986.

2. Water quality

Activity 2.1 The response of water to carbon dioxide

This is a puzzle involving some interesting experimental data. This activity would be much more meaningful if the students were answering similar questions using data they had collected, using water that had been collected from a variety of sources.

Answers to questions:

- (i) The London snow water is clearly more acidic than the Finnish water.
- (ii) Carbon dioxide dissolves in water to form a weak acid.

$$\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$$

As more gas dissolves the concentration of the acid becomes greater and a smaller proportion of it is dissociated, hence the typical pH curve of a weak acid.
- (iii) Students may put forward a number of possible explanations. The reaction is likely to be chemical because of the speed with which the carbon dioxide affects the pH (biological changes would need longer to take effect). Many of the students' ideas could be tested directly by using qualitative analysis or by considering simple chemical changes.
- (iv) The rise in the pH of the Thames water when the carbon dioxide is first added may be due to experimental error.

Activity 2.2 Aluminium in the water supply

This activity uses a newspaper article about the 'Camelford incident' in which drinking water supplies were accidentally contaminated with aluminium sulphate(VI).

Answers to questions:

- (i) Aluminium sulphate is added as a flocculant to remove some impurities.
- (ii) The water pipes.
- (iii) People and animals were violently sick and up to 60,000 fish died.
- (iv) Bases, such as calcium oxide and calcium hydroxide.



In a real-life situation, if the water supply was contaminated and had not yet been passed on to the consumers, the most likely course of action would be to redirect the contaminated water to a reservoir. The aluminium sulphate(VI) would slowly sink to the bottom as it flocculated with suspended particles. Once sufficient had settled the water could be returned to the system.

Source: *The Observer*, 13th November, 1988.

Activity 2.3 Oxygen in water

To measure the dissolved oxygen content of a water sample students can either use an oxygen electrode or a titrimetric analysis. Ideally, the analysis should be done as soon as possible after the water sample has been collected.

Required reagents:

Manganese(II) sulphate solution (3.0 mol dm⁻³).

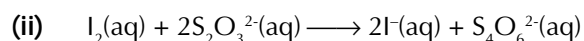
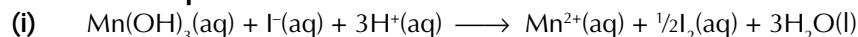
Alkaline potassium iodide solution (dissolve 50 g of sodium hydroxide and 15 g of potassium iodide in distilled water to make 100 cm³ of solution. **Warning: this solution is caustic**). Sodium azide can be added to this solution to reduce the interference from nitrite. Use 5 g of sodium azide per dm³.

Sodium thiosulphate solution (0.025 mol dm⁻³).

Starch indicator.

Concentrated sulphuric(VI) acid (safety precautions must be observed).

Answers to questions:



Source: Hammil, 1980; Marr and Cresser, 1983; Mackereth *et al*, 1978; Department of the Environment/Welsh Office, 1987.

Details of the experimental procedure are to be found in Dee Snell, 1972.

Activity 2.4 Aluminium and Alzheimer's disease

An area of controversy in science, at the moment, is the possibility of a link between aluminium and Alzheimer's disease. In this activity an article written by a scientist provides the stimulus.

Answers to questions:

- (i) Alzheimer's disease is a form of senile dementia. It is a progressive disorder of cognitive and intellectual function.
- (ii) Many foodstuffs and some medications contain aluminium, as do some toothpastes.
- (iii) Rates of Alzheimer's disease in county districts where aluminium concentrations are greater than 0.11 mg l⁻¹ were 1.5 times higher in districts where the aluminium concentration was below 0.01 mg l⁻¹. When the analysis was restricted to cases under the age of 65 years the association was stronger; the rates of the disease in districts with the highest aluminium concentrations were 1.7 times greater than those in districts with the lowest concentrations.

Source: Martyn, 1989. See also: Cowburn *et al*, 1990.

Activity 2.5 Aluminium determination

Aluminium in drinking water has become an important topic and in this activity



aluminium ions are detected by using a test kit. It is important to realise that this is a complicated topic and one where there is considerable debate amongst scientists about some of the effects of aluminium in the body.

The aluminium test kit is available from BDH Laboratory Supplies: Merckoquant aluminium test strips and reagents. Graduations: 0-10-25-50-100-250 mg l⁻¹ (ppm). The approximate cost of one test is 20p (1992).

3. Radon

Activity 3.1 Radon and leukaemia

As an introductory activity a *New Scientist* article from 1990 is used which reports research into possible links between radon and leukaemia. It should be pointed out to students that, at the time of writing, the conclusions are not widely accepted, and do not agree with results from detailed studies of miners exposed to radon.

Answers to questions:

- (i) Leukaemia, cancers of the kidney and the skin, and a number of cancers in children. Specifically up to 12 per cent of cases of myeloid leukaemia in Britain and up to a quarter of all cases of myeloid leukaemia worldwide. Scientists already recognise radon as a significant cause of lung cancer.
- (ii) The report mentions the tendency of radon to concentrate in fat cells within bone marrow. Alpha radiation from these cells may initiate leukaemia by damaging primitive blood cells in the surrounding tissue. An additional source of radiation may be radon daughters – the breakdown products of the gas – which are normally mixed with radon in room air. The Bristol team has attempted to calculate the proportion of leukaemia due to radon and the proportion due to other types of natural background radiation. Their analysis suggests that alpha radiation is far more likely to cause leukaemia than has previously been appreciated.
- (iii) Alpha radiation is estimated to be 20 times as damaging to tissues as gamma radiation. The Bristol team calculates the real quality factor of alpha radiation is likely to be greater than 20, and may be as high as 180, therefore, alpha particles may be more damaging than first thought. The findings may explain some of the clusters of leukaemia observed in Britain.

Source: Read, 1990.

Activity 3.2 What is radon?

Information about radon is given which the students use as a basis for developing their understanding of the radiochemical processes involved in the decay of uranium in soil and rocks and in the formation of radioactive particles from radon.

Answers to questions:

- (i) ²²²Rn has two more neutrons. Both isotopes have the same chemical properties.
- (ii) The half-life is the time for half of a radioactive sample to decay.
- (iii) Thoron's half-life is much shorter than that of radon. Consequently radon is present in the environment for longer and can migrate further.

For an overview of the topic see Phillips & Simpson, 1990.

See also: Sutton, 1988 and NRPB 1989a, 1989b.

Activity 3.3 Why is radon dangerous?

The effects of different types of radioactivity are considered using the idea of Quality factor mentioned in this activity. This activity is used for revision of ionisation and free radicals.

- (i) See text.
- (ii) See text.
- (iii) Alpha particles are charged helium nuclei ${}^4_2\text{He}^{2+}$, so can cause ionisation by taking electrons from other particles eg water.
- (iv) Free radicals are species with unpaired electrons. Radicals are reactive because they tend to join up the unpaired electrons usually by forming a chemical bond.

Source: NRPB, 1989b.

Activity 3.4 Radon in the UK

Activity 3.4a Radon, health and homes

The government's white paper on the environment is used to introduce ideas about the geological distribution of radon in the UK. Students will need access to a geological map of the UK. Students predict the likely distribution of radon levels by using the information that high levels are associated with granites.

Answers to questions:

- (ii) See text.
- (iii) The government announced in January 1990 that the action level should be halved, to an annual average concentration of 200 bq m^{-3} . The government is pursuing urgently research into the methods of reducing radon entry into existing houses, or of removing it once it has entered.
- (iv) The NRPB provides advice to the government on radiological safety.

Source: HMSO, 1990.

Activity 3.4b Where in the country is radon found?

The students predictions about the distribution of high radon levels from activity 3.4a are compared with data from surveys done in homes.

Answer to question:

- (i) Differences are due to the fact that there is more than one type of granite. Some granites contain more uranium than others.

Source: NRPB, 1990a, p 22.

Activity 3.5 Geochemistry

Using data about the elemental and mineral content of rock samples, students should develop a deeper understanding about the relationship between geology and radon concentrations.

**Answers to questions:**

- (i) It forms little Radon during its radioactive decay
- (ii) Weathering breaks down the uraninite thus increasing the surface area and exposing daughter elements of ^{238}U and increasing the likelihood of radon escaping from the mineral.
- (iv) Uraninite was the source of radium which the Curies used in their experiments at the turn of the century.

Source: Ball, 1988 (both tables).

Activity 3.6 Factors affecting the emission of radon**Answers to questions:**

- (i) When the air pressure is high, radon is literally pumped back into the ground. Radon is particularly soluble in water (see a data book), and moisture in the soil will dissolve radon, thus reducing the amount that leaves the ground.
- (ii) The effect of air pressure on radon concentrations is explored using data from the Dartmoor experiments which were done by the British Geological Survey. As atmospheric pressure increases the alpha activity in the ground increases (see answer to (i) above). Radon is forced not only back into the ground, but also into houses. A possible explanation of this is that the air pressure outside is greater than the pressure inside the house, and radon flows inside with the air, through cracks. The same argument explains why houses are often draughty.
- (iii) Water is bound in the structure of some types of clay, and water can be produced by the decomposition of organic material. The presence of water is important in dissolving radon from the atmosphere (see (i) above).

Source: Ball, 1988; Ball *et al*, 1991.

Activity 3.7 Where in the home is radon found?

The problem of radon in the home has solutions some of which are explored in this activity. Designers of new homes can obtain information from the NRPB about ways of reducing radon concentrations.

Answers to questions:

- (i) Through cracks in floors and walls; joints; gaps around service pipes; cavities in walls *etc.* This is a diffusion effect; it happens because the pressure inside a house is sometimes less than that outside (partly due to warm air rising inside the house). The effect is greatest when there is a large temperature difference between inside the house and outside.
- (ii) From the building materials themselves (particularly in Devon and Cornwall).
- (iii) Installing extractor fans in rooms or below rooms; opening windows periodically *etc.*

Source: Ball, 1988; Gerusky T M., 1987; Institute of Environmental Health Officers, 1988; NRPB, 1990b.

See also: Scottish Schools Science Equipment Centre, 1988; Brookins, 1990.

Activity 3.8 How much radon is there?

Activity 3.8a Detecting radon

Nouryset 200 (diethylene glycol bis-allyl carbonate), sometimes known as CR-39, is a transparent plastic material which, when exposed to alpha radiation and etched in strong alkali solution, can be used to indicate the amount of radon in the environment if left at sampling points in the home for a minimum of four weeks. It must be stressed that the experiment has many sources of error and the results should not be taken as particularly accurate. However, if a student's result is significantly higher than the rest of the class, it should be repeated.

Background to the experiment

Fleischer *et al* (1981) report using a polystyrene cup containing a solid state alpha particle detector in their measurements of radon levels in energy efficient homes. This work was based on that reported some years previously (Fleischer *et al*, 1975). The experimental method was developed further in Bristol. A teaching pack was distributed by the Institute of Physics to its affiliated schools (IOP, 1988), and a national survey followed using 170 schools as sampling points throughout Britain. The results were processed in Bristol (Camplin *et al*, 1988).

Radon will diffuse through the cling film but not through polystyrene. Some yoghurt pots are thought to be more transparent to radon than others which is why we have decided to standardise on polystyrene.

CR-39 is available in sheet form from Pershore Mouldings, Trading Estate, Pershore, Worcestershire WR10 2DH.

Etching the CR-39

Place some 6.25 mol dm⁻³ sodium hydroxide solution into boiling-tubes and support it in a water bath using a clamp. You will need one boiling-tube for each piece of CR-39. Heat the water bath until the water is boiling and the temperature of the sodium hydroxide solution is stable at 98 °C. Carefully lower the CR-39 into the sodium hydroxide solution. Leave it there for one hour at 98 °C. Remove the CR-39 carefully and rinse well with distilled water.

Counting the tracks

Students will need access to a microscope with a magnification of x100 or x200.

Nuclear radiation is measured in Sieverts, Sv. The Sievert is used to express the biological equivalent of an absorbed dose of nuclear radiation. It is the SI unit, replacing the rem.

For a good explanation of the units used see Cole, 1988.

Activity 3.8b Interpreting the results

Seasonal and daily variations affect the experimental results as can be seen from studying the data provided. Sampling over four weeks makes the results more reliable but a variation of approximately 2.6 to 3.0 times the level in winter as in summer has been reported (Institution of Environmental Health Officers, 1988).

Answers to questions:

- (i) Air pressure affects the radon concentration as does air temperature. In winter there are usually less windows open and draughts are often kept to a minimum. This is the reverse of what happens in the summer. Consequently radon is more likely to escape from houses in the summer.



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- (ii) Daily differences are due to the pattern of activity in the house and to changes in the air pressure. Notice how radon concentrations build up relatively quickly.
- (iii) During periods when the house is unoccupied or when people are asleep, radon concentrations will increase. When people are coming or going, draughts reduce the concentration quickly.

Source: NRPB, 1990b.