Classic chemistry experiments

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The Royal Society of Chemistry
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Classic chemistry experiments

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Foreword

Chemistry is an experimental subject, and what can be more stimulating than carrying out a laboratory experiment where the results are memorable either by their visual nature or by their tying together of theory.

This collection of 100 chemistry experiments has been developed with the help and support of teachers throughout the United Kingdom. It is designed for both the experienced teacher of chemistry and for those whose first subject is not chemistry in the hope that they can communicate the excitement and wonder of the subject to their students so that they will also be captured by the subject and want to take it further.

Professor Tony Ledwith CBE PhD DSC CChem FRSC FRS
President, The Royal Society of Chemistry

Introduction

Since the introduction of the National Curriculum in England, Wales and Northern Ireland, much emphasis has been given to investigative practical work. The importance of other laboratory activities has recently become somewhat neglected. However there are many reasons for students to do class experiments.

- They allow students to apply their knowledge and understanding to what they experience, developing basic skills such as selecting and using equipment, and learning various techniques such as measuring temperature and pH.
- They often illustrate a concept or process, so students gain first-hand experience before further discussion or analysis.
- They can also be the starting point for investigations. They encourage students to ask questions and make predictions. These often arise directly from their observations.
- They extend the scope of the curriculum and can be done in chemistry or science clubs.

Furthermore, students often find experimental work stimulating, motivating and enjoyable.

The ideas for the experiments in this book have come from a variety of sources. Some may be original, but most have been collected from school chemistry departments and from the literature. Many of the ideas have come from more than one source.

Some of the experiments may be unfamiliar, others are classics. I have attempted to cover the range of experiments that would be familiar to most experienced chemistry teachers. These will be useful to new teachers and to scientists from other disciplines who are teaching chemistry, as well as to experienced subject specialists.

All of the experiments have been tested at the University of Sussex Institute of Education. They have subsequently been trialled in school where they have worked in a classroom setting. Although these experiments are reliable, teachers should try them out before using them with their students.

Kevin Hutchings

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How to use this book

It is often said that when a schoolteacher writes a worksheet they reinvent the wheel; it has probably already been written elsewhere. However, most teachers would argue that their own worksheets are the most effective; they are targeted at their own classes and tailored to their own teaching style. In an attempt to address these issues, this publication allows the worksheet text and diagrams to be modified. This enables teachers to take the basic concept for the experiment, then adapt the worksheet to their own classroom needs. This should also help with another problem, where different equipment is used in the school to that stated in the resource. This normally requires the familiar explanation

'the worksheet says use a … but we're going to use'.

From experience, this can cause exasperation for some students and confusion in less able classes. With the resource downloadable from the Internet, teachers can adapt and differentiate them as required.

There are many opportunities for customising and differentiating the student worksheets. These are really only limited by the creativity of the teacher.

For example:

▼ diagrams can be re-sized. Labels can be removed from the diagrams. Labels can be given on separate sheets. Students can then cut out and stick or copy onto their own sheet;

▼ methods can be adapted, either made into smaller steps or removed completely. This provides an opportunity for students to design their own methods. The methods can be organised into a flow diagram. This allows students to organise and sort the stages before starting the practical work. Individual steps in the procedure can be obscured so that students can then fill in the gaps. There are many possibilities for directed activities related to text (DARTs);

▼ the equipment list can be added from the teacher's guide to help students organise the apparatus; and

▼ questions can be removed, either completely or as appropriate. For example, this is common when using experiments with younger ages, when questions requiring the use of chemical formula may be too advanced.

To illustrate just a few possibilities, a number of variations of the first experiment have been included in the next section.

Adapting the worksheets – examples

Teacher's notes

The following examples show how the worksheets might be adapted.

This particular worksheet has been written for a mixed ability class of 11–12 year old students.

The examples are:

Version A
This is written in the same style as the rest of this publication.

Version B
This represents one possibility for use with less able students.

Version C
This uses unlabelled diagrams to reinforce the names of chemical apparatus.

Version D
This includes a problem solving, sequencing exercise.

Version E
This represents a more student directed approach.

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Separating a sand and salt mixture

Topic

Separation techniques.

Timing

45 min.

Description

In this experiment students use simple processes to separate sand and salt.

Apparatus and equipment (per group)

- 250 cm^3 Beaker
- Filter funnel and paper
- Evaporating dish
- Tripod
- Bunsen burner
- Gauze
- Glass rod for stirring.

Chemicals (per group)

- A mixture of salt and sand (about 20 per cent salt).

Teaching tips

It can be effective to show the separate sand and salt to the whole class. Mix them at the front of the class, then use this as an introduction to a class discussion about how to separate them.

Background theory

The principles of filtration, evaporation, and the dissolving process.

Safety

Wear eye protection.

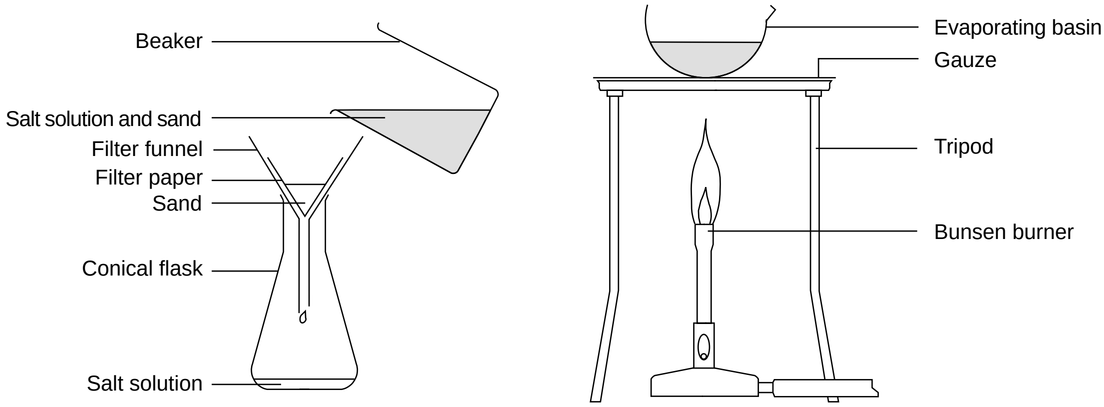
Answers

1. To dissolve the salt in water.
2. The sand is filtered out into the filter paper; the filtrate is salt solution.
3. To remove the majority of the water.

Separating a sand and salt mixture (Version A)

Introduction

In this experiment simple processes are used to separate salt from a sand and salt mixture.



What to do

1. Mix about 5 g of the mixture with 50 cm^3 of water in a 250 cm^3 beaker. Stir gently.
2. Filter the mixture into a conical flask and pour the filtrate into an evaporating basin.
3. Heat the salt solution gently until it starts to ‘spit’. **Care:** do not to get too close.
4. Turn off the Bunsen burner and let the damp salt dry.

Safety

Wear eye protection.

Questions

1. Why is the salt, sand and water mixture stirred and heated in step 1?
2. What happens when this mixture is filtered in step 2?
3. Why is the salt heated in step 3?

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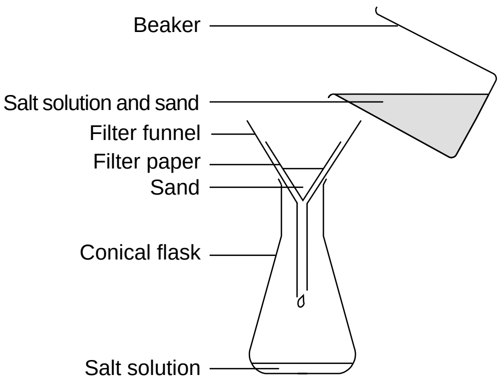
Separating a sand and salt mixture (Version B)

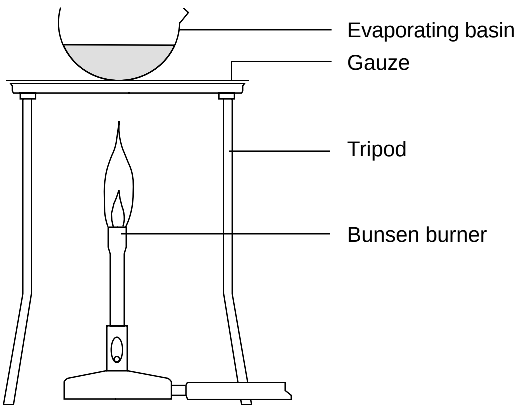
Introduction

In this experiment simple processes are used to separate salt from a sand and salt mixture.

Stage 1



Stage 2



Safety

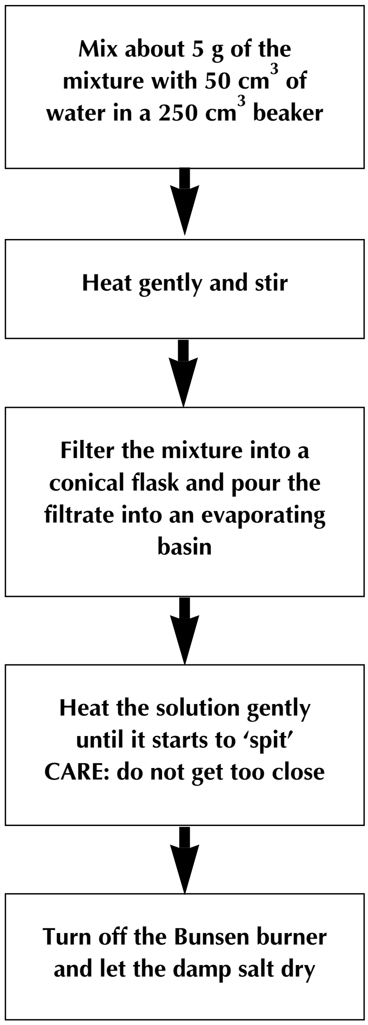
Wear eye protection.

What to do

Collect the following :

- 250 cm^3 Beaker
- Filter funnel and paper
- Evaporating dish
- Tripod

- Bunsen burner
- Gauze
- Glass rod for stirring
- Salt and sand mixture (about 5 g)
- Eye protection.



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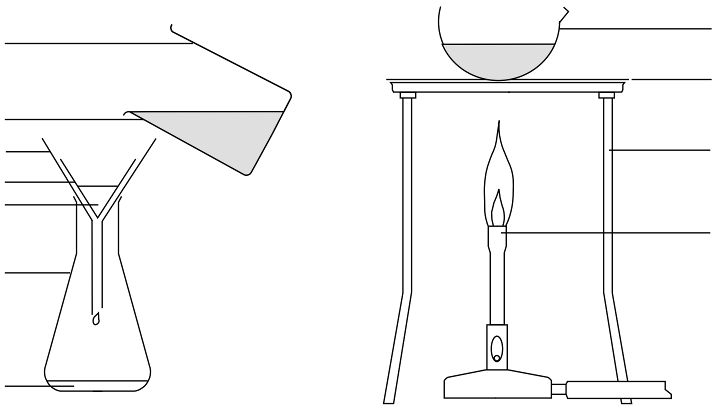
Separating a sand and salt mixture (Version C)

Introduction

In this experiment simple processes are used to separate salt from a sand and salt mixture.

Add the following labels to the diagram:

Bunsen burner, Salt solution, Conical flask, Filter funnel, Filter paper, Evaporating basin, Beaker, Sand, Salt solution and sand, Gauze, Tripod.



What to do

1. Mix about 5 g of the mixture with 50 cm^3 of water in a 250 cm^3 beaker. Stir gently.
2. Filter the mixture into a conical flask and pour the filtrate into an evaporating basin.
3. Heat the salt solution gently until it starts to 'spit'. **Care:** do not get too close.
4. Turn off the Bunsen burner and let the damp salt dry.

Safety

Wear eye protection.

Questions

1. Why is the salt, sand and water mixture stirred and heated in step 1?
2. What happens when this mixture is filtered in the step 2?
3. Why is the salt heated in step 3?

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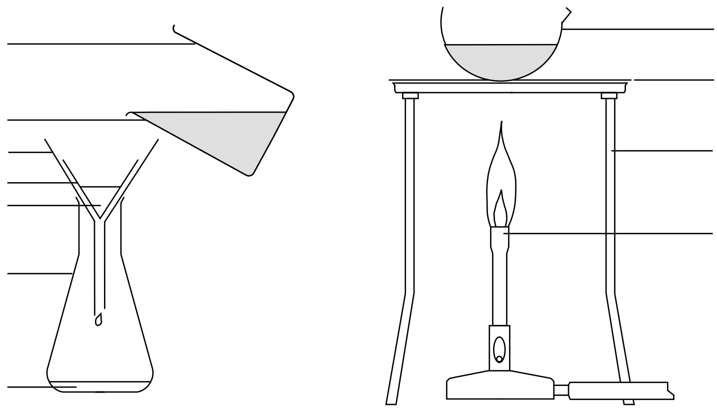
Separating a sand and salt mixture (Version D)

Introduction

In this experiment simple processes are used to separate salt from a sand and salt mixture.

Add the following labels to the diagram:

Bunsen burner, Salt solution, Conical flask, Filter funnel, Filter paper, Evaporating basin, Beaker, Sand, Salt solution and sand, Gauze, Tripod.



What to do

1. Arrange these instructions into the correct order.
2. Check the accuracy with your teacher before starting the practical work.

Filter the mixture into a conical flask and pour the filtrate into an evaporating basin

Wear eye protection

Heat the solution gently until it starts to 'spit' CARE: do not get too close

Turn off the Bunsen burner and let the damp salt dry

Heat gently and stir

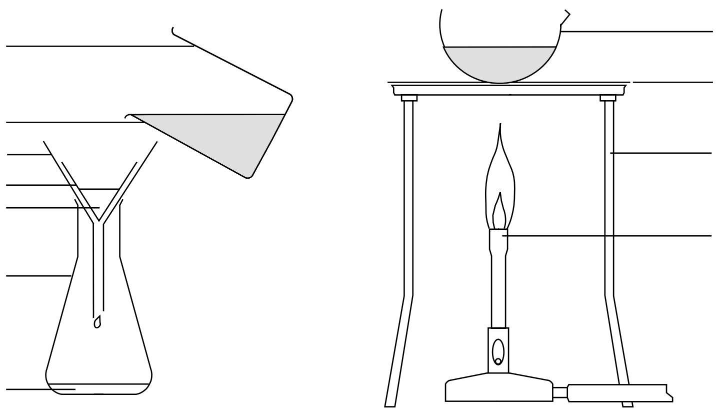
Mix about 5 g of the mixture with 50 cm^3 of water in a 250 cm^3 beaker

Separation of a sand and salt mixture (Version E)

Introduction

In this experiment, simple processes will be used to separate salt from a sand and salt mixture.

Add labels to the diagram

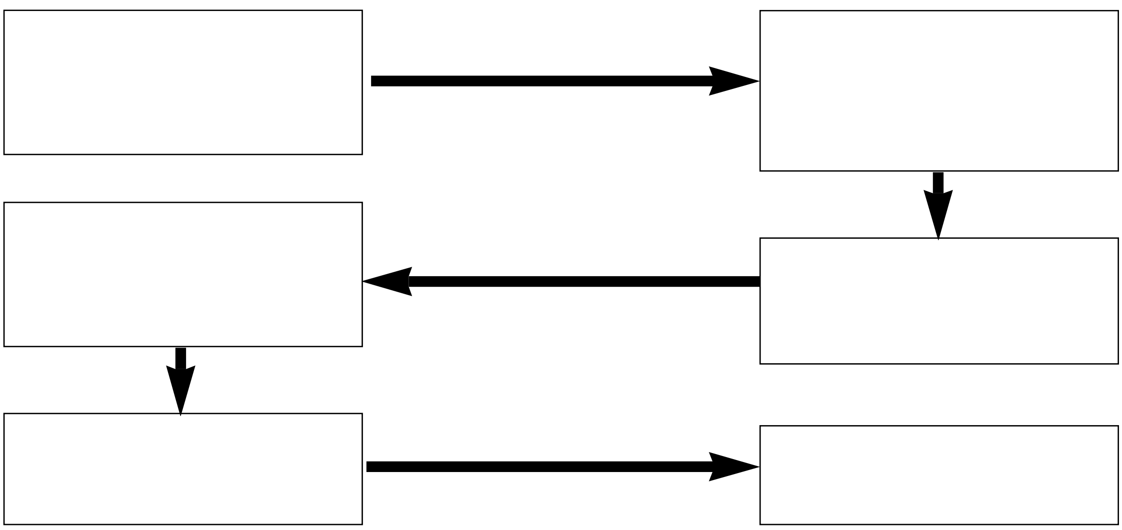


Safety

Wear eye protection.

What to do

1. Use the diagram as a guide. Complete the flow chart with a safe procedure to separate the sand and salt mixture.
2. Check with your teacher before starting the practical work.



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The role of information and communication technology (ICT)

Information and communication technology can be valuable in many of these classic chemistry experiments. In particular, there are sensors that measure say, temperature as a computer displays their readings on a screen. In essence the computer provides a running record of the experiment which helps students to appreciate what is happening and how fast it is happening. For example, adding a temperature sensor to the flask in an acid-base titration shows clearly that there is a point where adding further acid no longer produces heat of neutralisation. Or used in a cooling curve, a temperature sensor shows the expected temperature plateau during a change of state, while a second temperature sensor shows the change in the environment. In this latter example, students see that the environment actually gains heat while the cooling material is apparently ‘doing nothing’.

Data logging technology offers some other benefits – the software usually has graph analysis tools so that rates of change can be calculated while even the smallest computer screens offer a large digital display for demonstrations. It also finds uses in longer term experiments – for example it will happily take readings overnight during the fermentation of yeast.

With or without technology, it is good practice to ask students to predict the kind of graph they expect to see.

Throughout this set of experiments, the teaching tips suggest uses of data logging sensors where, like the above examples, it can add value to the experience. Schools that have the most modest data logging system will find opportunities to use it profitably here. While few schools will have class sets of such technology, a teacher demonstration (before or after they do the experiment) can still aid students’ understanding. Those with data handling software may want to use it wherever graphs need to be drawn.

Using this publication on the web

The student worksheets may be downloaded from http://www.chemsoc.org/classic_exp as .pdf files and as Word files that can be adapted by teachers.

Disclaimer: The Royal Society of Chemistry accepts no responsibility for any occurrence as a result of teachers modifying the worksheets. Teachers should use their professional judgement and carry out appropriate risk assessments based on the modified worksheets.

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List of experiments

1. Separating a sand and salt mixture
2. Viscosity
3. Rate of evaporation
4. Chromatography of leaves
5. The energetics of freezing
6. Accumulator
7. Electricity from chemicals
8. Iron in breakfast cereal
9. Unsaturation in fats and oils
10. The pH scale
11. Preparation and properties of oxygen
12. Identifying polymers
13. Energy values of food
14. A compound from two elements
15. Chemistry and electricity
16. Combustion
17. Determining relative atomic mass
18. Reaction of a Group 7 element (iodine with zinc)
19. Reactions of halogens
20. Sublimation of air freshener
21. Testing the pH of oxides
22. Exothermic or endothermic?
23. Water expands when it freezes
24. Chemical properties of the transition metals - the copper envelope
25. Reactivity of Group 2 metals
26. Melting and freezing
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31. Competition for oxygen
32. Making a crystal garden
33. Extracting metal with charcoal
34. Migration of ions
35. Reduction of iron oxide by carbon
36. Experiments with particles
37. Particles in motion?
38. Making a pH indicator
39. Reaction between a metal oxide and dilute acid
40. Disappearing ink
41. Testing for enzymes
42. Testing the hardness of water
43. A chemical test for water
44. Forming glass
45. Thermometric titration
46. Forming metal crystals
47. Forming a salt which is insoluble in water
48. Titrating sodium hydroxide with hydrochloric acid
49. The properties of ammonia
50. Causes of rusting
51. Reactions of calcium carbonate
52. To find the formula of hydrated copper(II) sulfate

53. Heating copper(II) sulfate
54. The oxidation of hydrogen
55. Investigating the reactivity of aluminium
56. An oscillating reaction
57. Chocolate and egg
58. Catalysis
59. Cartesian diver
60. Neutralisation of indigestion tablets
61. Mass conservation
62. Metals and acids
63. Solid mixtures – a lead and tin solder
64. The effect of temperature on reaction rate
65. The effect of concentration on reaction rate
66. The effect of heat on metal carbonates
67. Change in mass when magnesium burns
68. The volume of 1 mole of hydrogen gas
69. How much air is used during rusting?
70. Making a photographic print
71. 'Smarties' chromatography
72. The decomposition of magnesium silicide
73. An example of chemiluminescence
74. Colorimetric determination of copper ore
75. Glue from milk
76. Rubber band
77. Polymer slime
78. The properties of ethanoic acid
79. The properties of alcohols
80. Testing salts for anions and cations
81. Quantitative electrolysis
82. Electrolysis of solutions
83. An oxidation and reduction reaction
84. Heats of reaction (exothermic or endothermic reactions)
85. Comparing the heat energy produced by combustion of various alcohols
86. Fermentation
87. Microbes, milk and enzymes
88. The properties of the transition metals and their compounds
89. Halogen compounds
90. Finding the formula of an oxide of copper
91. Making a fertiliser
92. Electrolysis of copper(II) sulfate solution
93. Producing a foam
94. Getting metals from rocks
95. Addition polymerisation
96. Cracking hydrocarbons
97. Displacement reactions between metals and their salts
98. The effect of temperature on solubility
99. Purification of an impure solid
100. Chemicals from seawater

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List of experiments by categories

Here the experiments are listed by categories. There are also suggestions for the place of each experiment within the curriculum. These should not be taken as prescriptive. There are very few experiments that could not cross this somewhat artificial pre-14 and post-14 boundary. Teachers can adapt the experiments according to the needs of their students and there are many that can be revisited at various times within the curriculum.

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Experiment No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Curriculum Pre-14	✔	✔	✔	✔	✔		✔	✔		✔	✔	✔	✔	✔	✔	✔				✔
Post-14				✔	✔	✔	✔		✔	✔		✔	✔		✔		✔	✔	✔	✔
Periodicity																		✔	✔	
Acids and bases						✔	✔			✔					✔		✔		✔	
Physical properties	✔	✔	✔	✔	✔			✔				✔		✔	✔					✔
Particulate nature of matter		✔	✔		✔										✔					✔
Chemical analysis				✔				✔	✔		✔	✔								
Formation of compounds													✔	✔		✔		✔	✔	
Mixtures and separations	✔			✔				✔				✔		✔						✔
Energy					✔	✔	✔						✔		✔	✔				
Organic chemistry				✔					✔			✔	✔			✔				
Rates of reaction																				

Experiment No	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Curriculum Pre-14	✔		✔	✔	✔		✔	✔		✔		✔	✔		✔	✔	✔	✔		✔
Post-14	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔		✔		✔	
Periodicity				✔	✔							✔								
Acids and bases	✔									✔								✔	✔	✔
Physical properties			✔			✔	✔	✔		✔		✔		✔			✔			
Particulate nature of matter			✔			✔	✔			✔				✔		✔	✔			
Chemical analysis														✔				✔		
Formation of compounds				✔	✔				✔	✔	✔		✔	✔	✔				✔	
Mixtures and separations								✔						✔						
Energy		✔	✔			✔														
Organic chemistry																				
Rates of reaction									✔											

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Experiment No	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Curriculum Pre-14	✔	✔	✔			✔	✔			✔	✔		✔	✔	✔	✔	✔		✔	
Post-14	✔			✔	✔	✔	✔	✔	✔			✔	✔	✔		✔		✔		✔
Periodicity						✔									✔			✔		
Acids and bases					✔			✔	✔		✔									✔
Physical properties	✔					✔			✔		✔	✔	✔			✔	✔		✔	
Particulate nature of matter						✔							✔				✔		✔	
Chemical analysis	✔	✔	✔	✔	✔			✔	✔			✔								✔
Formation of compounds		✔		✔	✔		✔		✔	✔	✔	✔	✔	✔	✔			✔		
Mixtures and separations																				
Energy					✔									✔						
Organic chemistry																				
Rates of reaction															✔	✔		✔		

Experiment No	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Curriculum Pre-14	✔	✔	✔		✔		✔	✔	✔	✔	✔		✔	✔	✔		✔			✔
Post-14		✔	✔	✔	✔	✔		✔		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
Periodicity																				
Acids and bases		✔		✔		✔		✔									✔	✔		
Physical properties			✔							✔	✔	✔	✔	✔	✔	✔	✔			
Particulate nature of matter	✔		✔	✔		✔	✔	✔								✔				
Chemical analysis								✔	✔					✔						✔
Formation of compounds	✔	✔		✔	✔	✔	✔		✔	✔		✔	✔	✔	✔		✔	✔	✔	
Mixtures and separations			✔								✔			✔	✔					
Energy										✔		✔	✔			✔				
Organic chemistry															✔		✔	✔	✔	
Rates of reaction				✔		✔														

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Experiment No	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Curriculum *Pre-14*		✔	✔				✔					✔	✔	✔				✔	✔	✔
Post-14	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔	✔	✔	✔	✔		
Periodicity								✔	✔											
Acids and bases											✔									
Physical properties	✔	✔						✔	✔			✔	✔	✔				✔	✔	✔
Particulate nature of matter	✔	✔	✔									✔	✔					✔	✔	✔
Chemical analysis	✔							✔	✔	✔										
Formation of compounds			✔	✔		✔	✔	✔	✔	✔	✔			✔			✔			
Mixtures and separations														✔					✔	✔
Energy	✔	✔		✔	✔															
Organic chemistry					✔	✔	✔								✔	✔				
Rates of reaction							✔													

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Health and safety

The purpose of this book is to give examples of good practice in hands-on chemistry teaching. We believe that all the activities can be carried out safely in schools. The hazards have been identified and any risks from them reduced to insignificant levels by the adoption of suitable control measures. However, we also think it is worth explaining the strategies we have adopted to reduce the risks in this way.

Regulations[1] made under the Health and Safety at Work *etc* Act 1974 require a risk assessment to be carried out before hazardous chemicals are used or made, or a hazardous procedure is carried out. Risk assessment is your employer's responsibility. The task of assessing risk in particular situations may well be delegated by the employer to the head of science/chemistry, who will be expected to operate within the employer's guidelines. Following guidance from the Health and Safety Executive most education employers have adopted various nationally available texts as the basis for their model risk assessments. Those commonly used include the following:

Safeguards in the School Laboratory, 10th edition, ASE, 1996
Topics in Safety, 2nd edition, ASE, 1988
Hazcards, CLEAPSS[2], 1998 (or 1995)
Laboratory Handbook, CLEAPSS[2], 1997
Safety in Science Education, DfEE, HMSO, 1996
Hazardous Chemicals Manual, SSERC[2], 1997.

If your employer has adopted one or more of these publications, you should follow the guidance given there, subject only to a need to check and consider whether minor modification is needed to deal with the special situation in your class/school. We believe that all the activities in this book are compatible with the model risk assessments listed above. However, teachers must still verify that what is proposed does conform with any code of practice produced by their employer. You also need to consider your local circumstances. Is your fume cupboard reliable? Are your students reliable?

Risk assessment involves answering two questions:

- how likely is it that something will go wrong? and
- how serious would it be if it did go wrong?

Hydrogen has been exploding (see Experiment 54) ever since people started teaching chemistry – and long may it continue to do so! But the explosions must be carried out in a controlled way, so as to avoid injury, and unintended explosions must be avoided. You need to be reasonably sure that no student will attempt to light the hydrogen at the delivery tube, because there is a risk that the 'hydrogen' is in fact an explosive mixture of hydrogen and air.

How likely it is that something will go wrong depends on who is doing it and what sort of training and experience they have had. You would obviously not ask 11 year old students to heat concentrated sulfuric acid with sodium bromide, because their inexperience and lack of practical skills makes a serious accident all too likely. By the time they reach post-16 they should have acquired the skills and maturity to carry it out safely. In most of the publications listed above there are suggestions as to whether an activity should be a teacher demonstration only, or could be done by students of various ages. Your employer will probably expect you to follow this guidance. This means, for example, that the Addition polymerisation (Experiment 95) should normally only be done as a teacher demonstration or by post-16 students. Perhaps with well-motivated and able students it might be done pre-16, but any deviation from the model risk assessment needs discussion and a written justification beforehand. More commonly, teachers will conclude that an activity which is, in principle, permissible is really not suitable for their students.

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Teachers tend to think of eye protection as the main control measure to prevent injury. In fact, personal protective equipment, such as goggles or safety spectacles, is meant to protect from the unexpected. If you expect a problem, more stringent controls are needed. A range of control measures may be adopted, the following being the most common. Use:

- a less hazardous (substitute) chemical;
- as small a quantity as possible;
- as low a concentration as possible;
- a fume cupboard; and
- safety screens (more than one is usually needed, to protect both teacher and students).

The importance of lower concentrations is not always appreciated, but the following table, showing the hazard classification of a range of common solutions, should make the point.

ammonia (aqueous)	irritant if ≥ 3 M	corrosive if ≥ 6 M
sodium hydroxide	irritant if ≥ 0.05 M	corrosive if ≥ 0.5 M
ethanoic (acetic) acid	irritant if ≥ 1.5 M	corrosive if ≥ 4 M
hydrochloric acid	irritant if ≥ 2 M	corrosive if ≥ 6.5 M
nitric acid	irritant if ≥ 0.1 M	corrosive if ≥ 0.5 M
sulfuric acid	irritant if ≥ 0.5 M	corrosive if ≥ 1.5 M
barium chloride	hamrful if ≥ 0.02 M	toxic if ≥ 0.2 M (or if solid)
copper(II) sulfate	harmful if ≥ 1 M (or if solid)	
copper(II) chloride	harmful if ≥ 0.15 M	toxic if ≥ 1.4 M (or if solid)
iron(II) sulfate	harmful if ≥ 1 M	
iron(III) sulfate	harmful if ≥ 0.75 M	
lead nitrate	harmful if ≥ 0.001 M	toxic if ≥ 0.01 M
potassium dichromate	toxic if ≥ 0.003 M	very toxic if ≥ 0.2 M (or if solid)
silver nitrate	irritant if ≥ 0.2 M	corrosive if ≥ 0.5 M (or if solid)
bromine water	harmful & irritant if ≥	0.0006 M (0.1 per cent toxic & corrosive if ≥ 0.06 (1 per cent) very toxic & corrosive if ≥ 0.42 M (7 per cent) (non aqueous or saturated aqueous solution)

Throughout this book, we make frequent reference to the need to wear eye protection. Undoubtedly, chemical splash goggles, to the European Standard EN 166 3 give the best protection but students are often reluctant to wear goggles. Safety spectacles give less protection, but may be adequate if nothing which is classed as corrosive or toxic is in use. Reference to the above table will show, therefore, that if sodium hydroxide is in use, it should be more dilute than 0.5 M.

Science as carried out in schools is very safe. Do not believe the myths and rumours that various chemcials or procedures are banned. That is very rarely true, although you may well have to take various safety precautions. Chemistry can be – and should be – fun. It must also be safe.The two are not incompatible.

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[1]The COSHH Regulations and the Management of Health and Safety at Work Regulations.
[2]Note that CLEAPSS and SSERC publications are available only to members.
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