Chemists in a social and historical context

Chemists are real people, living in the real world

Written by Dorothy Warren
RSC School Teacher Fellow 1999–2000

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How to use this resource

At the start of the 21st century secondary education yet again underwent changes. These included the introduction of new curricula at all levels in England, Wales and Scotland and the Northern Ireland National Curriculum undergoing review. With more emphasis on cross curricula topics such as health, safety and risk, citizenship, education for sustainable development, key skills, literacy, numeracy and ICT, chemistry teachers must not only become more flexible and adaptable in their teaching approaches, but keep up to date with current scientific thinking. The major change to the science 11–16 curricula of England and Wales was the introduction of 'ideas and evidence in science', as part of Scientific Enquiry. This is similar to the 'developing informed attitudes' in the Scottish 5–14 Environmental studies, and is summarised in Figure 1.

In this series of resources, I have attempted to address the above challenges facing teachers, by providing:

- A wide range of teaching and learning activities, linking many of the cross-curricular themes to chemistry. Using a range of learning styles is an important teaching strategy because it ensures that no students are disadvantaged by always using approaches that do not suit them.
- Up-to-date background information for teachers on subjects such as global warming and Green Chemistry. In the world of climate change, air pollution and sustainable development resource material soon becomes dated as new data and scientific ideas emerge. To overcome this problem, the resources have been linked to relevant websites, making them only a click away from obtaining, for example, the latest UK ozone data or design of fuel cell.
- Resources to enable ideas and evidence in science to be taught within normal chemistry or science lessons. There is a need to combine experimental work with alternative strategies, if some of the concerns shown in Figure 1, such as social or political factors, are to be taught. This can be done for example, by looking at the way in which scientists past and present have carried out their work and how external factors such a political climate, war and public opinion, have impinged on it.
- Activities that will enhance student's investigative skills.

These activities are intended to make students think about how they carry out investigations and to encourage them to realise that science is not a black and white subject. The true nature of science is very creative, full of uncertainties and data interpretation can and does lead to controversy and sometimes public outcry. Some of the experiments and activities will be very familiar, but the context in which they are embedded provide opportunities for meeting other requirements of the curriculum. Other activities are original and will have to be tried out and carefully thought through before being used in the classroom. Student activities have been trialled in a wide range of schools and where appropriate, subsequently modified in response to the feedback received.

Dorothy Warren

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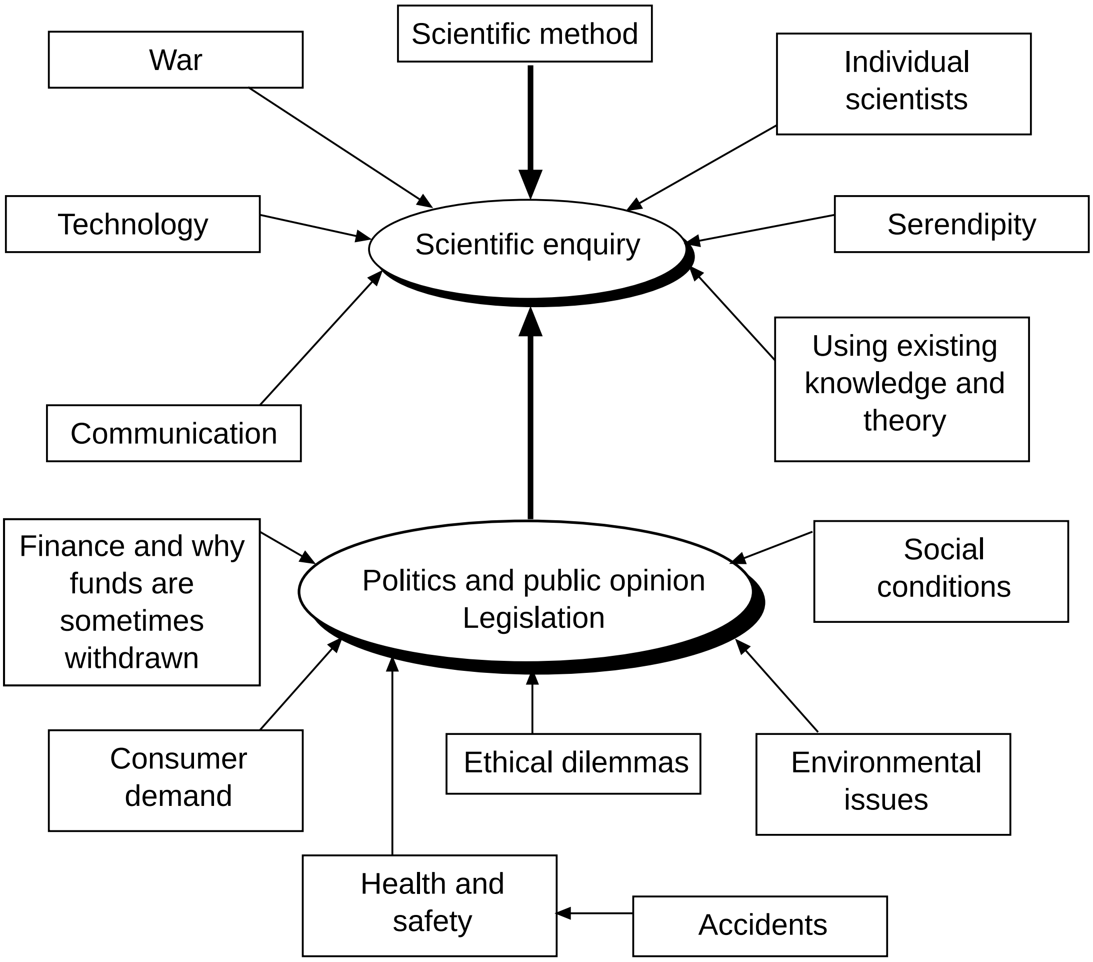

Figure 1 The factors influencing the nature of scientific ideas– scientific enquiry and the advancement of science

Maximising the potential use of this resource

It is hoped that this resource will be widely used in schools throughout the United Kingdom. However, as every teacher knows, difficulties can be experienced when using published material. No single worksheet can cater for the needs of every student in every class, let alone every student in every school. Therefore many teachers like to produce their own worksheets, tailored to meet the needs of their own students. It was not very surprising when feedback from trial schools requested differentiated worksheets to allow access to students of different abilities. In an attempt to address these issues and concerns, this publication allows the worksheet text and some diagrams to be modified. All the student worksheets can be downloaded in Word format, from the Internet via the LearnNet website, **http://www.chemsoc.org/networks/learnnet/ideas-evidence.htm** .This means that the teacher can take the basic concepts of the activity, and then adapt the worksheet to meet the needs of their own students. Towards the end of the teachers' notes for most activities there are some suggestions as to how the resource can be adapted to meet the needs of students of different abilities. There are also some examples of differentiated worksheets included in the resource.

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It is not envisaged that teachers will use every activity from each piece of work with an individual class, but rather pick and choose what is appropriate. For example some activities use high level concepts and are designed to stretch the most able student and should not be used unchanged with less able students *eg* **The atom detectives** and **What happens when things burn?**

Activities that involve researching for secondary information on the Internet contain hyperlinks to appropriate websites. To minimise the mechanical typing of the URLs and possible subsequent errors, the students can be given the worksheet in electronic form and asked to type in their answers. The websites are then only a click away.

Appropriate secondary information has been included in the teachers' notes for use in class when the Internet or ICT room is unavailable.

Unfortunately, from time to time website addresses do change. At the time of publication all the addresses were correct and the date that the site was last accessed is given in brackets. To minimise the frustration experienced when this happens, it is advisable to check the links before the lesson. If you find that a site has moved, please email both **LearnNet@rsc.org** and **education@rsc.org** giving full details so that the link can be updated on the worksheets on the web in the future.

Strategies for differentiated teaching

All students require differentiated teaching and it is not just an issue for those students with special educational needs. The following definition by Lewis[1] has been found to be quite useful.

'Differentiation is the process of adjusting teaching to meet the needs of individual students.'

Differentiation is a complex issue and is very hard to get right. It can be involved in every stage of the lesson *ie* during planning (differentiation by task), at the end of the activity (differentiation by outcome) and ongoing during the activity. Often teachers modify the activity during the lesson in response to feedback from the class. Differentiation does not only rely on appropriate curriculum material but is also concerned with maximizing learning. Student involvement and motivation effect the learning experience and should be considered and taken into account. It is therefore not surprising that differentiation is one of the areas of classroom teaching where teachers often feel under-confident. Most strategies for differentiated lessons are just applying good teaching practice *eg* varying the pace of the lesson, providing suitable resources and varying the amount and nature of teacher intervention and time.[2] Rather than just providing several examples of differentiated activities from the same worksheet, a list of strategies for differentiated teaching is presented, with some examples of how they can be used in the classroom. The examples can be found at the appropriate places in the text.

1. Using a range of teaching styles

A class is made up of different personalities, who probably have preferred learning styles. Using a range of teaching approaches makes it more likely that all students will be able to respond to the science that is being taught. The following examples have been included and can be found at the appropriate place in the resource.

Example What happens when things burn?
Approach 1 – Working in groups and reporting back to the whole class
Approach 2 – A thinking skills lesson

2. Varying the method of presentation or recording
Giving the students some choice about how they do their work. There are many opportunities given throughout the resource.

3. Taking the pupil's ideas into account
Provide opportunities for students to contribute their own ideas to the lesson. For example when setting up an investigation allow different students the freedom to chose which variables they are going to investigate. The use of concept cartoons provides an ideal opportunity for students to discuss different scientific concepts (see D. Warren, *The nature of science*, London: Royal Society of Chemistry, 2001.)

4. Preparing suitable questions in advance
Class discussions are important in motivation, exploring ideas, assessment *etc*. Having a list of questions of different levels prepared in advance can help to push the class.

5. Adjusting the level of scientific skills required
Example – Using symbol equations or word equations

6. Adjusting the level of linguistic skills required
Example Norman Rillieux – Sparkling white crystals of sugar
Sheet 1 – a high reading age
Sheet 2 – a low reading age

Teachers may like to check the readability of their materials and of the texts they use. Guidance on this and on the readability of a range of current texts may be found at **http://www.timetabler.com/contents.html** (accessed June 2001).

7. Adjusting the level of demand on the student
Example
What happens when things burn? – both approaches are for the more able student. Burning theories is much easier to understand and less demanding on students.

References

1. A. Lewis, *British Journal of Special Education*, 1992, **19**, 24–7.
2. S. Naylor, B. Keogh, *School Science Review*, 1995, **77(279)**, 106–110.

How scientists communicate their ideas

Effective communication is crucial to the advancement of science and technology. All around the globe there are groups of research scientists and engineers, in universities and in industry, working on similar scientific and technological projects. Communication between these groups not only gives the scientist new ideas for further investigations, but helps in the evaluation of data. Results from different groups will either help to confirm or reject a set of experimental data. Communication is vital when a company wants to sell a new product. Depending on the product the buyer will want to understand how it works and how to maintain it. Several of the employees will have to learn how to use the product, and respond quickly to changing technology and circumstances. Therefore the manufacturers must be able to communicate the science to prospective buyers.

Scientists communicate in a number of ways including:

- Publication in research journals
- Presenting papers at scientific conferences
- Poster presentations at conferences
- Book reviews by other scientists
- Publication on the Internet
- Sales brochures
- Advertising flyers
- Television documentaries

Publication in research journals
The article is written. The article must have an abstract, which is a short summary.

It is submitted to a journal.

The article is refereed by other scientists, working in a similar area. This is to check that the work is correct and original.

The article may be returned to the author to make changes.

The article is accepted and published by the journal.

The article is published.

Presenting papers at scientific conferences
Conference organisers invite scientists to speak on specific topics and projects.

An abstract is submitted to and accepted by the conference organisers.

The conference programme is organised and the speakers notified.

The scientist gives their talks, usually aided by slides, which contain the main points.

There is usually time for questions after the talk.

The written paper is given to the conference organisers.

All the papers are published in the conference proceedings. This is usually a book.

Poster presentations at conferences
An abstract is submitted to and accepted by the conference organisers.

The conference programme is organised and the poster people notified.

During the poster session the authors stand by the posters ready to answer any questions, as the delegates read the posters.

Written papers may then be published in the conference proceedings.

Book reviews
Other scientists in the same field often review new books. The reviews are then published in scientific magazines and journals. The review offers a critical summary of the book. The idea of the review is to give possible readers an idea of the contents and whether it is suitable for the intended purpose.

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Publishing on the Internet
This is the easiest way to publish. Anyone can create their own web page and publish their own work. In this case the work is not refereed or checked by other people.

However, a lot of the information published on the Internet is linked to reputable organisations. In this case the articles will have been checked before they are published. Much of the information published on the Internet is targeted at the general public, and therefore the scientific ideas are presented in a comprehensible way. There are often chat pages so people can communicate their views and ask questions or request further information. The power of the Internet is that there is the opportunity to get immediate feedback to a comment or question.

Sales brochures
The information must be presented in an attractive and concise manner. After all you are trying to sell something. There should be a balance between technical information and operating instructions!

Advertising flyers
This must be written with the target audience in mind.

The information must be concise as there is limited space. The format must be attractive and should include pictures as well as writing. The flyer should also be quite cheap to produce.

Teaching students to communicate ideas in science

Students can be taught effective communication skills:

- By encouraging communication between students and a range of audiences in classrooms
- By encouraging them to investigate like 'real scientists' by reporting their findings for checking and testing by others, and participating in two-way communication. (Communicating between groups, classes, partner schools, schools abroad perhaps via the Internet.)
- By setting investigations in a social context which offers the opportunity to communicate the project outside of the classroom. These work best when there is local interest.

When presenting investigative work to an audience, the student should consider the following:

- Who will be in the audience?
- What information does the audience need to know *eg* method, results and recommendations?
- How to present the information in an interesting and professional way *eg* should graphs be hand drawn or done on the computer?
- That the information offered convinces the audience that their investigation was valid and reliable.
- Poster presentations or display boards should be concise, since the space is limited.
- When speaking to audiences remain calm, speak clearly and slowly and try to be enthusiastic. Make sure that information on slides and OHTs can be read from the back of the room.

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When writing a report of the findings of a scientific investigation for others to check and test, the emphasis should be on clarity. Another person is going to carry out the same investigation. The only information available is what is written in the report.

The report could be written under the following headings:

- Introduction
- Scientific knowledge
- Planning
- Table of results
- Graphs
- Conclusions
- Evaluation
- Recommendations

Further background information

R. Feasy, J. Siraj-Blatchford, *Key Skills: Communication in Science*, Durham: The University of Durham / Tyneside TEC Limited, 1998.

Curriculum coverage

Curriculum links to activities in this resource are detailed at **http://www.chemsoc.org/networks/learnnet/social-hist.htm**

Curriculum links to activities in other resources in this series are detailed at

http://www.chemsoc.org/networks/learnnet/ideas-evidence.htm

Health and safety

All the activities in this book 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 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 employers 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. These commonly include the following:

Safeguards in the School Laboratory, 11th edition, ASE, 2001

Topics in Safety, 3rd Edition, ASE, 2001

Hazcards, CLEAPSS, 1998 (or 1995)

Laboratory Handbook, CLEAPSS, 1997

Safety in Science Education, DfEE, HMSO, 1996

Hazardous Chemicals – a manual for science education, SSERC, 1997 (paper).

Hazardous Chemicals – an interactive manual for science education, SSERC, 1998 (CD-ROM)

If your employer has adopted more than one 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, teacher 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?
- How serious would it be if it did go wrong?

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. 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.

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 mol dm^{-3}	corrosive if ≥ 6 mol dm^{-3}
Sodium hydroxide	irritant if ≥ 0.05 mol dm^{-3}	corrosive if ≥ 0.5 mol dm^{-3}
Ethanoic (acetic) acid	irritant if ≥ 1.5 mol dm^{-3}	corrosive if ≥ 4 mol dm^{-3}

Throughout this resource, 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 (M = mol dm^{-3}).

CLEAPSS Student Safety Sheets

In several of the student activities CLEAPSS student safety sheets are referred to and recommended for use in the activities. In other activities extracts from the CLEAPSS sheets have been reproduced with kind permission of Dr Peter Borrows, Director of the CLEAPSS School Science Service at Brunel University.

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- Teachers should note the following points about the CLEAPSS Student Safety Sheets:
- Only extracts from fuller student safety sheets have been reproduced.
- Only a few examples from a much longer series of sheets have been reproduced.
- The full series is only available to member or associate members of the CLEAPSS School Science Service.
- At the time of writing, every LEA in England, Wales and Northern Ireland (except Middlesbrough) is a member, hence all their schools are members, as are the vast majority of independent schools, incorporated colleges and teacher training establishments and overseas establishments.
- Members should already have copies of the sheets in their schools.
- Members who cannot find their sheets and non-members interested in joining should contact the CLEAPSS School Science Service at Brunel University, Uxbridge, UB8 3PH; tel. 01895 251496; fax. 01895 814372; email science@cleapss.org.uk or visit the website **http://www.cleapss.org.uk** (accessed June 2001).
- In Scotland all education authorities, many independent schools, colleges and universities are members of the Scottish Schools Equipment Resource Centre (SSERC). Contact SSERC at St Mary's Building, 23 Holyrood Road, Edinburgh, EH8 8AE; tel. 0131 558 8180, fax 0131 558 8191, email sts@sserc.org.uk or visit the website **http://www.sserc.org.uk** (accessed June 2001).

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Using the resource on an Intranet

If your school or college has an Intranet you may wish to download the material in part or in whole to the Intranet to facilitate easy links for students. Alternatively you could use some of the web references given to design an interactive worksheet. Instructions for this are given below.

Designing an interactive worksheet
These instructions are for Microsoft Word.

- First you need to do some research on the Internet to find the relevant sites related to the topic and note down the website addresses, or use the sites already known and available from the resource.
- Choose an appropriate font, size and colour for your text.
- Type in the title of the page.
- Save this page as an HTML file in order to make the page 'live'.
- Type in the instructions and questions that you want the students to read.
- Type in the web page address (url). Always begin http://www (this will automatically make the page a hyperlink to the website you have typed and the text will turn blue).

Now you can make your work look more like a web page by placing lines, graphics, scrolling text and backgrounds in it.

- To place a horizontal line on your page, put the cursor where you would like the line to be, then click on insert, go to horizontal line, choose a line and click on OK.
- To add a background to your page, click on format, go to background, then fill effects option, choose an effect and click on OK.
- To add a picture to your work, place the cursor where you would like the picture to be, then click on insert, go to picture and clip art option. Choose a suitable picture for your work and click on OK. The picture size can be altered by moving the edges in or out or the picture can be moved to another place by dragging it over.
- To place scrolling text in your work, you need to highlight the words, click on insert, go to scrolling text, choose background colour, the speed of the scroll and press OK. (If you are going to print this work out, the scrolling text will not print out).

  Your work is now beginning to look like an interactive web page.
- When you are satisfied with the final product, click on file, go to web page preview and this will show you what your page looks like. (You cannot alter your page through the web page preview screen; you will have to go back to Word).
- Remember to do a spell check on your work, *ie* click on the ABC icon on the top of toolbar.
- Test out your page.

Now you are ready to use the page with students.

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Introduction

Chemistry has a human face. The aim of this book is to present chemists as real people and not stereotypical 'mad scientists' whose lives are completely dominated by science. It may only take a couple of minutes of a lesson to present the class with a bit of personal background information which could, for some students, add interest to the lesson. The history of chemistry is full of serendipitous tales. The influence of World War II played a major role in the development of plastics, which otherwise may not have been produced on a commercial scale. In other parts of the world science was held back, simply because the scientists were coloured and this was socially unacceptable. In the early days of chemistry, there were few woman chemists as this too was deemed to be unacceptable. The womans' place was in the home and certainly not in the laboratory carrying out experiments. The social context of the time must be understood to explain why the majority of the early chemists appear to be white middle-class or upper-class gentlemen. Many of the scientific projects had to be funded by the chemists themselves, so they already had to be wealthy or have a very good income. At times science was just the hobby, before it took over. This is not to say that there were no scholarships available. In fact, there are a number of very distinguished scientists such as Ernest Rutherford and John Jacob Berzelius who came from very humble backgrounds.

Today we live in a very different world, where people should be accepted regardless of race or gender. Science is taught in all schools and young people of today are encouraged to develop an interest in the subject. There is more money available to carry out research, although some would say not enough, as we go on living in the scientific and technological age.

Running throughout this series of books written by Dorothy Warren, there are many references to different scientists. The scientists are always introduced within the context of their work at the most appropriate place; for example John Lind is found in **The nature of science** book, Alice Hamilton in the **Health, safety and risk** book, Mario Molina in the **Climate change** book and the aluminium pioneers in the **Green Chemistry** book. In this resource, the focus is twofold, namely providing strategies for teaching about people in chemistry and an introduction to some of the chemists who played a role in the development of major ideas in chemistry, *eg* theories about the atom and burning. Roy Plunkett and the discovery of Teflon has been included as an example of serendipity, Harry Kroto and buckminsterfullerene as an example of a living chemist and Norbert Rillieux as an example of a successful chemical engineer, despite being an African-American living in the 19th century.

One of the problems for busy teachers is having a readily available source of background information about different scientists. There are many Internet sites that will provide a wealth of biographical information, photographs and scientific information. The three web sites listed here are worth a visit.

1. The British Society for the History of Science (BSHS) website **http://www.man.ac.uk/Science_Engineering/CHSTM/bshs/** (accessed June 2001). This site links into several other useful sites. It also provides a discussion forum for teachers as well as useful contacts such as actors willing to do scientific performances in schools.

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2. The Nobel Foundation site at **http://www.nobel.se** (accessed June 2001) lists all the Nobel Laureates with photographs, biographical and scientific background information.
3. This week in the history of chemistry **http://webserver.lemoyne.edu/faculty/giunta/week.html** (accessed June 2001) can be accessed to provide information for any week of the year.
4. European Network for Chemistry, Millennium Project, has a site listing 100 distinguished European chemists from the chemical revolution to the 21st century. **http://www.chemsoc.org/networks/enc/fecs/100chemists.htm** (accessed June 2001).
5. Chemsoc timeline is a linear based exploration of key events in the history of science with a particular emphasis on chemistry. **http://www.chemsoc.org/timeline** (accessed June 2001).

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The atom detectives

Teachers' notes

Objectives

- To understand how the model of the atom has developed over time.
- To learn about some of the chemists involved in developing the model of the atom.
- To be able to apply today's accepted model of the atom and draw diagrams to represent the atoms of the first 40 elements of the periodic table.

Outline

This section looks at how the model of the atom has developed over the last 200 years. It explores how scientists work together to develop new ideas and how new theories may, at first, give rise to controversy. It shows how technological advances can lead to the development of new theories and ideas.

Teaching topics

This material is intended to be used with more able students between the ages of 14 and 16 or post-16 students, when teaching about atomic structure and the Periodic Table. Understanding the arrangements of subatomic particles in the atom is a high level concept. In this activity, you can see how the ideas developed as scientific method and instrumentation developed and other areas of science unfolded. Look at the student worksheets before reading the detailed notes below.

Background information

Since 5 BC, people have been curious to find out more about different materials and substances. The theory of Democritus said 'Substances are different because homogenous particles have different sizes and shapes and cannot be cut'. This was just the start of many more theories that would be put forward and then rejected over the next 2000 years. Many of the early theories of matter were not based upon experiments. As scientists began to study the relationship between physical phenomena such as electricity and magnetism they began to develop different models about atomic structure.

Sources of information

The atomic structure timeline at
http://www.watertown.k12.wi.us/hs/teachers/buescher/atomtime.asp
(accessed June 2001).

The timeline has twenty-two entries, starting in the Greek era and finishing in 1932 with James Chadwick. By clicking on the scientist's name, personal background information and portraits can be accessed. A short summary of their contribution to atomic structure is included with some hot links leading to further information.

Teaching tips

This section is ideal for group work leading to a wall display featuring the history of the atom. There are five student worksheets each featuring a scientist who made a significant contribution to the development atomic theory.

- Dalton
- Berzelius
- Thomson

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- Rutherford
- Bohr.

The sixth student worksheet is an information sheet, bringing the theory up-to-date.

Following an introduction to the lesson, the class could be divided into groups of 4 or 5 students. Each group could work through one of the worksheets. To make the sheets more durable, they could be photocopied onto card and laminated. The activities at the bottom of the sheet could be carried out and presented as a poster, on a large piece of paper. The group should also include some background information about the scientists and what they did.

You will need to tell the class whether you expect models or diagrams of the atoms, or if they have a free choice. In order to answer all the questions some groups will have to communicate with others.

At the start of the next lesson, each group could present their posters, in chronological order, to the rest of the class, highlighting the major aspects of the theory, which could be summarised.
Eg 1 Berzelius' relative atomic masses are used today. Berzelius introduced chemical symbols.
Eg 2 Thomson discovered that the negatively charged electron was part of the atom. It was 1/1840 the mass of the positively charged particles.

The rest of the lesson could be spent with everyone working on the sheet **Modelling the atom today**. You should go through the lithium example with the class and maybe do one of the other examples with the class. The information for completing question 1 will have been covered in the poster presentations and may already be available. The rest of the sheet could be completed as homework.

Note: Throughout this material, the term mass has been used unless the accepted terminology of weigh or weight is more appropriate. Teachers may wish to draw attention to the difference between mass and weight.

Resources

- Student worksheets
  - – John Dalton
  - – John Jacob Berzelius
  - – Joseph John Thomson
  - – Ernest Rutherford
  - – Niels Bohr
  - – Present day models of the atom
  - – Modelling the atom today

Timing

2 hours plus homework

Opportunities for using ICT

- Using the Internet to find out more about the atom detectives.
- Word processing and drawing packages to make posters.

Opportunities for using key skills

- Working together in groups.
- Communication between groups.
- Presentation of work to the class.

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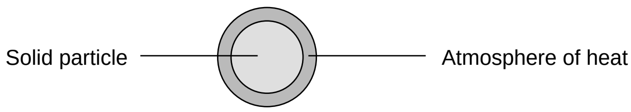
Answers

John Dalton

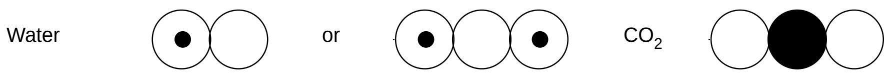
1.



2. A molecule of ice had less heat surrounding the particle than a molecule of water.

3. He guessed!

4.



Dalton thought that the water molecule only consisted of one O and one H atom, so either molecule may be accepted.

John Jacob Berzelius

1.

Element	Symbol	Relative atomic mass
Chlorine	Cl	35.5
Copper	Cu	63.5
Hydrogen	H	1.0
Lead	Pb	207.2
Nitrogen	N	14.0
Oxygen	O	16.0
Potassium	K	39.1
Silver	Ag	107.9
Sulfur	S	32.1

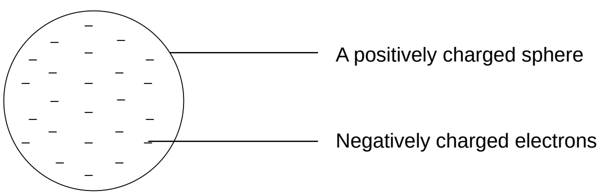
2. Berzelius because his 1826 values are very close to the ones that are used today.

3. He was able to work out the number of atoms in each molecule.

4. Berzelius believed that atoms were held together by electrostatic attraction. He thought that some atoms were positively charged and others were negatively charged.

Joseph John Thomson

1.



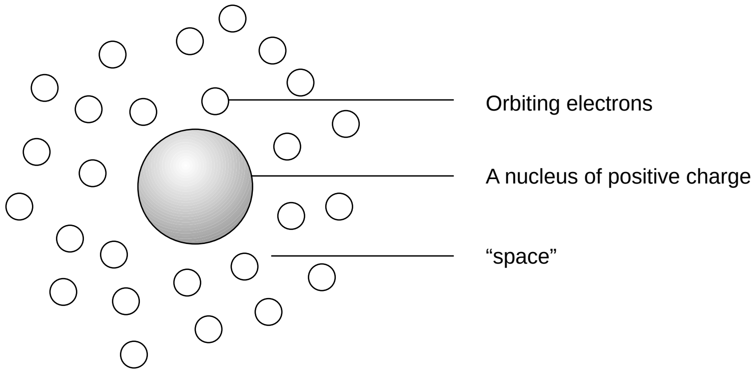
The plum pudding model

2. Thomson's model of the atom contained negative particles of electricity (which he called electrons) embedded in a solid sphere of positive charge. Daltons' atom was a solid particle, surrounded by an atmosphere of heat.

3. A very sensitive camera.

Ernest Rutherford

1.



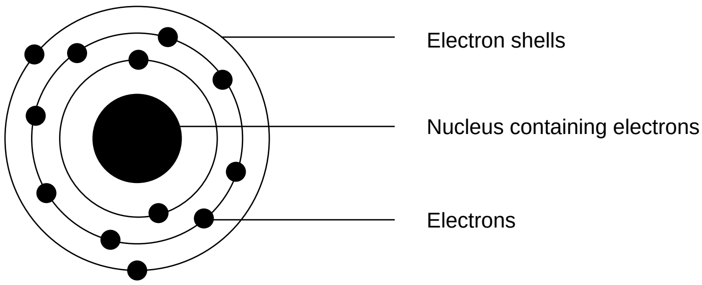
2. The main difference between the two models is that the Thomson model has a solid sphere with negative charges whereas the Rutherford model has a small solid nucleus, some 'space' and then orbiting electrons, which are separate particles.

3. Rutherford carried out his experiments in the dark so that he could observe the glow left behind by the radiation and see where the particles went.

4. Rutherford noticed that some of the positively charged radiation bounced back from the atom in the same direction. Rutherford concluded that this must be due to another positive force repelling the positive radiation. This large positive force must come from the centre of the atom.

Niels Bohr

1.



2. In the Bohr atom the electrons are arranged in definite shells whereas in the Rutherford model, the electrons just orbit the nucleus. They are free to go wherever they like.

3. Bohr's model of the atom was based on theoretical calculations and a good imagination. Although his model could explain atomic spectra, it was based on incomplete data. It was thought that the model could not be used to explain the reactivity of the elements. Many chemists preferred Lewis' model because it was based on real experimental chemical data. The Lewis model could be used to explain the reactivity of the elements. However, it could not be used to explain the hydrogen spectrum.

RS•C

Modelling the atom today

1.

Particles	**Charge**	**Relative Mass**
Protons	**positive (+)**	1
Neutrons	neutral	**1**
Electrons	**negative (–)**	**1/1840**

2.

Element	**Mass No.**	**Atomic No.**	**No. of protons**	**No. of neutrons**	**No. of electrons**
Hydrogen	1	1	**1**	**0**	**1**
Carbon	**12**	**6**	6	6	**6**
Neon	20	**10**	10	**10**	10
Aluminium	**27**	13	**13**	14	**13**
Potassium	39	19	**19**	**20**	**19**

3. Nucleus containing correct number of protons and neutrons (see table), electrons arranged in shells 2,8,8,18 *etc*.

John Dalton

John Dalton
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John Dalton (1766–1844)

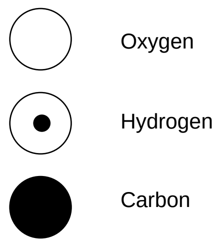
He was the son of an English weaver from Eaglesfield in Cumbria. When he wasn't carrying out investigations, he was probably teaching at the Presbyterian college in Manchester. In 1807, John Dalton was the first person to use the word **atom** to describe the smallest particle of any element.

What did Dalton do?

Dalton studied gases and discovered that elements combine with other elements to make compounds. He had to guess how many atoms joined together to make the compound. He was able to calculate the relative weights of particles using data from his own observations and measurements. Individual particles were too small to weigh. He had to make some assumptions to explain his observations *eg* the atmosphere of heat surrounding the solid particle was used to explain why some elements were solids and some gases. Solid compounds had less heat than gaseous ones.

Dalton's atomic theory of matter, 1807

1. All matter is made up of tiny particles called atoms.
2. Each atom is a solid particle with no spaces, surrounded by an atmosphere of heat.
3. Atoms cannot be made or destroyed.
4. Atoms of the same elements are alike with the same mass, colour *etc*.
5. Atoms of different elements have different masses, colours *etc*.
6. Atoms can join to form larger particles in compounds.



Dalton's symbols

Things to do

1. Make a model or draw a diagram of Dalton's atom.
2. How did Dalton explain the different between a molecule of ice and a molecule of water?
3. How did Dalton known how many atoms were in a molecule?
4. Using Dalton's symbols, write down the formulae of water and carbon dioxide.

John Jacob Berzelius

John Jacob Berzelius
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John Jacob Berzelius (1779–1848)

Berzelius was an orphan from Sweden, brought up by a mean stepfather. He worked on his farm and lived in a room which was also the potato store. His stepfather made sure that the potatoes did not freeze during winter, so at least this meant that Berzelius kept warm too. From high school, he went on to university where he became interested in experimental chemistry.

What did Berzelius do?

Berzelius heard about Dalton's theory and set about making his own relative atomic weight measurements. But, from previous experiments carried out by Humphrey Davy, he knew how many atoms were in the compounds. He knew that when electricity was passed through water, twice as much hydrogen was collected at the negative terminal than oxygen at the positive terminal. So he concluded that water was made from two atoms of hydrogen and one of oxygen.

Berzelius' atomic theory

1. All atoms are spherical.
2. All atoms are the same size.
3. Atoms have different weights.
4. Atoms joined together in fixed proportions, by an electrochemical reaction. Some atoms are positive and others are negative.

Dalton could not accept Berzelius' electrochemical combination, but at the same time could not explain why atoms joined together in fixed proportions.

Elements	Dalton's atomic weights 1808	Berzelius' atomic weights 1826
Chlorine	unknown	35.41
Copper	56	63.00
Hydrogen	1	1.00
Lead	95	207.12
Nitrogen	5	14.05
Oxygen	7	16.00
Potassium	unknown	39.19
Silver	100	108.12
Sulfur	13	32.18

Chemical symbols

Berzelius thought that chemical symbols should be letters. He took the first letter of the Latin name of each element. When the letters were the same, he used both the first letter and the next different letter. Berzelius' symbols are used in today's Periodic Table.

Things to do

1. Look up, in a modern data book, the relative atomic masses and the symbols of the elements listed in the above table. Put your answers in a table.
2. Who do you think had the best method for calculating the relative weights of atoms, Dalton or Berzelius?
3. What do you think was the key to the successful calculations?
4. How did Berzelius think that atoms joined together to make compounds?

Joseph John (JJ) Thomson

Joseph John Thomson
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Joseph John Thomson 1856–1940

Thomson was born near Manchester. His ambition was to be an engineer but instead he was awarded a scholarship in chemistry. The scholarship was in memory of John Dalton. At the age of 28, Thomson became professor at the Cavendish Laboratory, Cambridge University.

What did Thomson do?

In 1897 Thomson discovered the electron, while he was investigating the conductivity of electricity by gases at very low pressures. After collecting data for twenty years, Thomson was convinced that electrons were negative particles of electricity. He even measured the mass of the electron.

However, he still needed more evidence to convince the scientific world, so he asked Wilson to try and take a photograph of an electron. It took him until 1911 to build a suitable camera, which was sealed in a glass chamber in which electrons could be produced. The experiment was successfully carried out and the electron was photographed.

JJ Thomson was worried about telling the world his new theory of the atom, because until now the atom was thought of as a single solid particle.

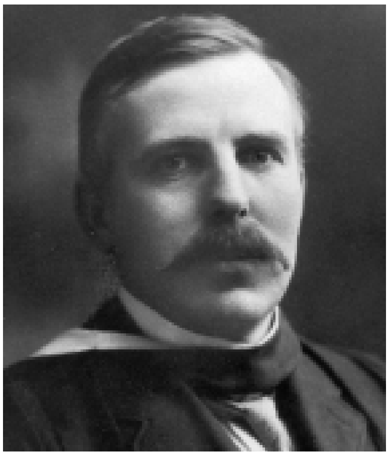
Thomson's model of atomic structure – 1899

- Atoms consisted of rings of negative electrons embedded in a sphere of positive charge (the plum pudding model).
- The positive and negative charges balance to make the atom neutral.
- The mass of the atom was due to the nucleus.
- The mass of an electron was 1/1840 of the mass of hydrogen, the lightest atom.
- There were 1840 electrons in an atom of hydrogen.

Things to do

1. Make a model or draw a diagram of JJ Thomson's model of the atom.
2. What is the main difference between this new model and Dalton's model?
3. What advances in technology made it possible for Thomson to successfully complete his investigations?

Ernest Rutherford



Ernest Rutherford
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Ernest Rutherford (1871–1937)

Rutherford was born near the village of Nelson, New Zealand. His father was an odd-job man and simple farmer. Rutherford obtained an honours degree in mathematics and science from the University of New Zealand before gaining a scholarship that took him to work with JJ Thomson at the Cavandish laboratory in Cambridge.

What did Rutherford do?

Rutherford studied radioactive atoms and found that they were not stable. By this time a lot was understood about radiation. Rutherford carried out his investigation in the dark. He used positively charged radiation to bombard the atom and watched to see where the radiation particle went. The radiation always left a glow. The glow showed that most particles went straight through the atom, some were slightly deflected, while others bounced back in the same direction.

After doing many calculations, Rutherford concluded that the radiation could only come back if that atom had a hard positively charged core at the centre of the atom. He called this the nucleus. If the atom was 100 m, the size of a football pitch, the nucleus would be the size of a pea placed in the centre of the pitch.

Rutherford's model of atomic theory

1. The atom consists mainly of space.
2. The mass of the atom is concentrated in the nucleus, which is a small core at the centre of the atom.
3. The nucleus has positive charges.
4. Electrons move around the nucleus like planets orbiting the sun.
5. The atom is neutral as it has the same number of positive charges and negatively charged electrons.

Things to do

1. Make a model or draw a diagram of Rutherford's atom.
2. What was the main difference between Rutherford's model of the atom and Thomson's model?
3. Why did Rutherford carry out his experiments in the dark?
4. What evidence do you think lead Rutherford to conclude that the atom had a positively charged nucleus?

Niels Bohr

Niels Bohr
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Niels Bohr (1885–1962)

Niels Bohr was born into a scientific family. His father was a professor of physiology and his brother a distinguished mathematician. After obtaining his Ph.D. from the University of Copenhagen, Denmark, he accepted an invitation to work with Rutherford, at Cambridge.

Bohr was very intelligent and had an amazing imagination. He was not afraid to build on the idea of Max Plank, that energy came in little packets called quanta, and apply this to Rutherford's model of the atom.

What helped Bohr?

Bohr based his investigation on Max Plank's idea. He imagined the electron orbiting the nucleus unless it was disturbed by some outside force, when it jumped to a different energy level. A packet of energy was either gained or lost.

Bohr's model of the atom (1922)

1. Most of the mass of an atom is in the central nucleus that contains protons.
2. The electrons are arranged in definite shells or energy levels and orbit the nucleus.
3. The electron shells are a long way from the nucleus.
4. When one shell is full a new shell is started. This is called the electronic configuration.
5. Atoms with full shells are not very reactive.
6. Electrons determine the reactivity of the atom.

Chemists not happy

While Bohr's model of the atom could explain the spectrum of the hydrogen atom, chemists didn't think it would explain the reactivity of the other chemical elements. His theory was based on incomplete physical data and mathematical calculations. Many chemists favoured Lewis' theory. The American's octet theory was based on real chemical data. Lewis proposed that the fixed nucleus was surrounded by cubic shaped electron shells. The electrons were fixed in the corner positions.

Things to do

1. Make a model or draw a diagram of Bohr's atom.
2. What is the main difference between Bohr's model of the atom and Rutherford's model?
3. Suggest why some chemists preferred Lewis' model of the atom to Bohr's.