GCSE

Edexcel GCSE in Additional Science
Power of the Atom

(Concept approach)

May 2006

Support material

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Scheme of work for Topic 12: Power of the Atom

Introduction

1 This booklet contains a concept-driven scheme of work and some suggested activities for the Edexcel GCSE in Additional Science Unit P2 Topic 12: Power of the Atom.

2 Two schemes of work are available for each topic in separate booklets. One of these booklets contains a scheme of work that is concept-driven ie scientific ideas are presented before their applications are explored. The other booklet contains a scheme of work that is context-driven ie applications of science are presented before the scientific principles used in these applications are explored.

3 Booklets for each GCSE in Additional Science topic are provided free of charge to centres who are offering the Edexcel GCSE suite of Science qualifications via the secure area of the Edexcel website (www.edexcel.org.uk).

4 Although Edexcel owns the copyright for the booklets, they are provided in Word format so that Edexcel centres may customise the schemes if required.

5 Each lesson is designed to last for 50 minutes although the total teaching time is not stated in the specification; teachers may adjust the schemes of work to accommodate the time available in individual centres.

6 Centres are responsible for the overall risk assessment of experimental work undertaken by students.

7 Attention is drawn to the need for safe practice when students carry out laboratory experiments or observe demonstrations. Particular attention is drawn to the possible hazards associated with electrical equipment, the handling of micro-organisms and ionising radiation. Strict aseptic conditions should be used when undertaking practical work. Reference must be made to COSHH regulations and any specific local education authority restrictions.

Relevant advice can be obtained from the following publications:

- *CLEAPSS Laboratory Handbook* (available from CLEAPSS School Science Service, website www.cleapss.org.uk)
- *Control of Substances Hazardous to Health Regulations* (HSE, 2005) ISBN 0717629813
- *Hazcards* (2004 update available from CLEAPSS School Science Service)
- *Topics in Safety, Third Edition* (ASE January, 2001) ISBN 0863573169

Scheme of work for Topic 12: Power of the Atom

LESSON 1: Starting to sparkle							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.16 P2 12.15 P2 12.14	7K: Forces and their effects. 9I: Energy and electricity.	Insulators can be charged by friction when electrons are transferred. Opposite charges are produced on the two materials that are rubbed together. Charged objects attract uncharged objects. Force between charges in terms of attraction and repulsion. Repulsion is the only sure test for charge.	**Practical** Charging by friction — how does this work in terms of separation of charges and transfer of electrons? Testing for charges in terms of attracting uncharged objects. Discuss the sparks that are produced when pulling off a nylon shirt. **Demonstration** Demonstrate the forces between charges using similar rods charged in the same way for repulsion and rods of a different material charged to produce repulsion. **Demonstration** Can you be certain that a charge is positive if it attracts an object which is known to be negative?	Combs, rods, dusters, water from a tap and balloons, attracting your hair. BNFL CD ROM 'Electrifyingly interactive'. Gold Leaf/Braun electroscope if available or balloons.	Explain that insulating and insulated materials can be charged by contact by the transfer of electrons. Explain common electrostatic phenomena in terms of the movement of electrons including shocks and earthing — examples include shocks from car doors, charges on synthetic fibres and lightning. Describe the forces that act between like charges (repulsive) and unlike charges (attractive).		
Homework: Explain, with the aid of diagrams: a) why bicycles are charged before being spray painted b) how exhaust gases from chimneys can be cleaned.							

LESSON 2: A shocking business							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.14 P2 12.17	7K: Forces and their effects. 9I: Energy and electricity.	High voltages and small gaps can produce strong forces and sparks. Thunder and lightning are caused by a spark. An earth wire can make equipment safe. Application of fun science in proper research.	**Demonstration** Describe how the Van de Graaff generator works in terms of electrons and use it to show attraction, repulsion and sparks. Refer to Franklin's experiment and the dangers involved. Find out about 'Georg Wilhelm Richmann kite flying' through a web search. Treat it as part of How Science Works. Was he foolhardy? Was he trying to make a name for himself? Did he just have the courage of his own convictions? **Discussion** Discuss the danger of turning on an electric light in a gas filled room, lightning and lightning conductors, the earthing of fuel tankers to prevent sparks near the fuel and the fact that workers in electronic factories wear an earthed wristband.	Van de Graaff generator. http://science.howstuffworks.com	Explain common electrostatic phenomena in terms of the movement of electrons including shocks and earthing — examples include shocks from car doors, charges on synthetic fibres and lightning. Describe some of the potential dangers and uses of electrostatic charges, such as fuelling aircraft, fingerprinting and laser printing.	ICT: 2.1 2.2 2.3	Do not give shocks to students who have weak hearts! Caution needed: refer to school records on students' health risks or enquire diplomatically of those involved.

LESSON 2: A shocking business (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
			Research How were Van de Graaff generators used to accelerate particles in early nuclear research?				
Homework: Research: a) thunder and lightning and how lightning conductors reduce damage b) why it may be better not to shelter under a tree in a lightning storm — action at points.							

LESSON 3: Hot off the press							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.17 P2. 12.14	7K: Forces and their effects. 9I: Energy and electricity.	There are several aspects of electrostatics used in fingerprinting such as electrostatic lifting of fingerprint patterns and voltage measurements. Why paper is hot when it comes from a photocopier. Examples of electrostatic attraction/repulsion.	**Discussion** Discuss the uses of electrostatic charges such as those arising from the forces of attraction and repulsion. **Demonstration/practical** Show how to dust for fingerprints with chalk and/or carbon dust. This can then be lifted with transparent sticky tape. Electrostatic techniques enables dust to be attracted from tiny gaps/pores etc, which sticky tape cannot attract, so can be used with more materials like fabrics/paper etc. **Research/discussion/written work** Describe the stages of how a photocopier works and ask students to do a sequencing exercise — cut and paste. Students can then research and develop a similar activity for a laser printer.	www.idteck.com/technology/w_fingerprint.jsp has information on fingerprinting. http://members.aol.com/varfee/mastssite/electro.html has information on the electrostatic lifting of dust. http://science.howstuffworks.com also has relevant information.	Describe some of the potential dangers and uses of electrostatic charges, such as fuelling aircraft, fingerprinting and laser printing. Explain common electrostatic phenomena in terms of the movement of electrons including shocks and earthing — examples include shocks from car doors, charges on synthetic fibres and lightning.	ICT: 2.1 2.2 2.3	

LESSON 3: Hot off the press (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
			Discussion Describe some effects of charges in terms of attraction and repulsion such as spray painting a bicycle.				
Homework: Complete all diagrams and descriptions of applications of electrostatics and associated dangers.							

LESSON 4: Nuclear bullets							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.3 P2 12.4		Collision of neutron with U-235 nucleus produces daughter products and more neutrons. The daughter products are radioactive and start a decay series.	**Discussion** Lighting a fire in terms of energy production and the need for a stimulus/trigger in order to set off a fire/explosion. **Written work** With the aid of diagrams, describe the collision of a slow moving neutron with a single Uranium-235 atom to produce more moving neutrons. **Demonstration/practical** Describe the decay process and factors which might affect the relative amounts of products from the decay process.	Video from IoP 'Principles of fission' www.vision learning.com/ library — animates fission. 'Nuclear bullets' from Vision Learning http://michele.usc. edu/java/fission/ nuclear.html — shows neutrons interacting with nuclei. Demonstration 12.4: Decay series. Two burettes/long plastic tubes with exit clips and a beaker, timer.	Describe the fission of U-235 to produce two daughter nuclei and two neutrons. Describe a simple decay series starting from the daughter products of U-235.	C: 2.1 2.2 2.3 N: 2.1 2.2 2.3	

LESSON 4: Nuclear bullets (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
			Model making Make a model using small and large marbles/balls to demonstrate a fission and its products. The marbles/balls might be held loosely together in a nucleus using plasticene. When students fire a separate marble at their nucleus it should split up into its parts. (For higher demand students: introduce nuclear equations.)	Boardworks — radioactive decay. BNFL Free leaflet ‘Beyond U-235: An introduction to the role of the nuclear industry’.			
Homework: a) Find out about the products of radioactive decay and consider briefly the problems created in terms of long-term storage/treatment of radioactive waste. b) Revise atomic numbers etc and answer questions on nuclear equations for fission and radioactive decay etc.							

Scheme of work for Topic 12: Power of the Atom

LESSON 5: Chain reactions for good and evil							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.2 P2 12.6 P2 12.1 P2 12.5		Chain reactions occur in everyday life and can be controlled in a variety of ways. The steady release of energy in a nuclear power station using a model. Use of control rods. Hahn realises how to put Einstein's ideas into practice.	**Demonstration** Demonstrate (or do a practical) on the domino effect to model a simple chain reaction. Consider the spread of an epidemic when one member of a family contracts a disease and gives it to their partner and/or children who then infect others. **Discussion** Explain how this simple chain reaction produces energy at a steady rate — ideal for power production. Discuss people's perception of danger and how a nuclear reactor can be shut down or speeded up with control rods. (Use www.aip.org/history/mod/fission to show that discoverers were real people — How Science Works.)	Activity sheet 12.5: Chain reaction. Dominoes. www.aip.org — Hahn talks. www.aip.org/history/mod/guides.html — teachers' guides (pdf). www.visionlearning.com — applets of chain reactions. Video from IoP ⇒ 'Nuclear power'. www.me.utexas.edu www.aip.org — Einstein talks peace. http://people.howstuffworks.com	Explain the principle of a chain reaction. Explore how scientists use theories to make predictions, including how Einstein suggested the possibility of releasing enormous amounts of energy trapped in an atom from his relation between mass and energy. Explain how the chain reaction is controlled in a nuclear reactor.	C: 2.1 2.2 2.3	

LESSON 5: Chain reactions for good and evil (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
			Consider possibilities that no chain reaction will occur, eg dominoes, like atoms in U-238, may be too far apart.	http://michele.usc.edu — power station applet. BNFL leaflet 'How a nuclear power station works'.	Explain how a chain reaction can be used for both peaceful and destructive purposes.		
Homework: Revise the processes involved in all other types of power stations (fossil fuels, wind hydro, tide, geothermal and wave) and describe the differences between nuclear power stations and these others.							

LESSON 6: Einstein: the bomb and your house							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.9 P2 12.5 P2 12.1		The process and corresponding energy changes involved in a nuclear power station. The 1905 prediction and the 1930s eventual suggestion of a chain reaction to put it into action. Use of the equation $E=mc^2$.	**Discussion** How a generator transfers nuclear energy into electrical energy. **Discussion** Discuss the equation $E=mc^2$ and what each symbol represents. Work out the difference in mass of two protons and two neutrons compared to a helium nucleus. Work out how much energy is then needed to split the nucleus into separate particles. Show Disney video if available. 'Tomorrowland' includes 'Our friend the atom' which includes the famous mousetrap and ping-pong ball depiction of a nuclear reaction.	http://people.howstuffworks.com and www.wikipedia.org has some general information for this topic. www.ida.liu.se/~her/npp/demo.html has a demonstration for controlling a nuclear power plant. www.nei.org discusses the reliability of electricity production. BNFL labmouse CD5.	Describe how thermal energy from the chain reaction is transferred to electrical energy in a nuclear power station. Explain how a chain reaction can be used for both peaceful and destructive purposes. Explore how scientists use theories to make predictions, including how Einstein suggested the possibility of releasing enormous amounts of energy trapped in an atom from his relation between mass and energy.	C: 2.1 2.2 2.3 N: 2.2	

LESSON 6: Einstein: the bomb and your house (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
			Research The products of fission.	www.aip.org/ history/mod — Einstein talks. http://www.ph.unimelb.edu.au/staffresources/lecdem/na1v.htm www.outofthebox.co.nz can provide PowerPoint slides for this topic. ‘Power to learn’ from British Energy features the very useful ‘Nuclear know how’ cartoon. Dominoes. Walt Disney’s ‘Tomorrowland’.			
Homework: Compare in some way (for example using a table, Venn diagram, continuous prose or diamante (see Activity sheet 12.6: Creating a diamante)) the use of fission in power stations and for military purposes.							

LESSON 7: Hand in hand							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.11 P2 12.12 P2 12.1		Idea of density and its measurement. The sun produces its energy using nuclear fusion. From Einstein's equation, the energy released in a star comes from a loss in mass (mention 4000 million kg/s but this is only a very, very small part of the Sun's mass — about 1% per billion years!).	**Practical** Measure the density of a solid and a liquid and discuss that for a gas. Early finishers to find out about the density of ordinary stars, neutron stars, black holes and plasmas. **Discussion** Difficulties of measuring some of these and the uncertainty in data collection to illustrate aspects of How Science Works. **Discussion** What is fusion? What is the problem with producing fusion and how does the high density and temperature help? **Discussion** Fusion — stars use it and we can make bombs with it but why is it difficult to control at the moment?	Blocks of different materials and at least two sizes for one material. Experiment sheet 12.7: Measuring density. http://ippex.pppl.gov www.visionlearning.com/library animates fusion and shows conditions. http://science.howstuffworks.com www.aip.org/history/mod/fission/fission1/01.html Video from IoP 'Nuclear fusion'.	Understand that nuclear fusion requires extremely high temperatures and densities, and relate this to the difficulty of making a practical form of power. Describe how fusion differs from fission and recognise it as the energy source for stars. Explore how scientists use theories to make predictions, including how Einstein suggested the possibility of releasing enormous amounts of energy trapped in an atom from his relation between mass and energy.	C: 2.1 2.2 2.3 N: 2.2 2.3	
Homework: Write a diamante poem for Fission to Fusion and draw a diagram to show how fission and fusion are different. Calculate the density of the Sun and a neutron star from researched data.							

LESSON 8: Keeping us safe							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.8 P2 12.7 P2 12.10		There is a variety of ways of getting your point across. There are advantages and drawbacks to nuclear power generation as with other forms including safety issues and storage problems.	**Communications** Organise a debate, public meeting or a protest (with placards/a petition?) about a proposal to build a nuclear power station nearby. Individuals may prefer to write a letter. Some students could favour the proposal. Discuss situations where different methods are useful such as debates in parliament, council meetings, posters in street demonstrations, or writing a letter of complaint to a planning committee. For example, SATIS (Science And Technology In Society — 1986) activity. **Comparisons** Discuss the small amount of carbon dioxide emissions arising from nuclear power stations.	www.nei.org has information on transportation safety, storage and waste disposal.	Describe the environmental and social impact of a nuclear power station on a locality. Discuss the benefits and drawbacks of nuclear power for generating electricity, including carbon dioxide emissions and safety issues. Explain that the products of nuclear fission are radioactive and discuss the long-term possibilities for storage/disposal of nuclear waste.	C: 2.2 2.3 ICT: 2.1 2.2 2.3	

LESSON 8: Keeping us safe (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
			Contrast this with safety problems. Get students to think about ways of expressing the comparisons, eg as tables, classification charts, and even diamante poems.				
Homework: Finish preparation for presenting your protest about the construction of a nuclear power station in a nearby locality.							

LESSON 9: What do you think?							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
		Emphasise How Science Works aspects of: • 3.6 iii c — presenting information, developing an argument and drawing a conclusion • 3.6 iv a — the use of contemporary scientific and technological developments — benefits, drawbacks and risks	Give (any) presentations that have been produced. **Poster/fact sheet/etc** (Give criteria on which it will be judged by peers.) Emphasise that they are mainly looking at the effects of science on mankind/the environment. Start one each based on: • geography — effects on US of Chernobyl or • science in history/ philosophy/literacy/ poetry/art or • comparison of fission and fusion — equations, amounts of energy/unit mass, products.	Activity sheet 12.9: Poster www.nirex.co.uk www.greenpeace. org.uk BNFL leaflets ‘Energy and the Environment’ and ‘Energy, Electricity, Environment’. Rotblat worked on the atomic bomb which was dropped on Hiroshima to end the Second World War. He received the Nobel prize for peace. The website www.pugwash.org/ award/Rotblatnobel .htm contains his acceptance speech.	How Science Works.	C: 2.1 2.2 2.3 ICT: 2.1 2.2 2.3	

Scheme of work for Topic 12: Power of the Atom

LESSON 9: What do you think? (*continued*)							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
		• 3.6 iv b — how and why decisions about science and technology are made.	or • discussion of waste disposal/treatment • ethics of maintaining a nuclear arsenal.				
Homework: Finish research and poster/fact sheet.							

LESSON 10: Cold fusion							
Spec code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 12.13		How Science Works: • iv c — how uncertainties in scientific knowledge and ideas change over time and validation of new knowledge.	Judge poster/fact sheet on the criteria given in lesson 9. **Research** a) Serendipity b) What is cold fusion and what is the history behind claims for its discovery? **Discussion** a) The benefits cold fusion would bring and the advantages compared to ordinary fusion. b) The processes involved in validating discoveries before they are published (normally) and accepted by other scientists. c) What are the pressures on scientists to publish early?	www.answers.com/ topic/cold-fusion discusses cold fusion. www.loe.org/ shows/segments. htm has a transcript for ‘Cold Fusion: A Heated History’.	Appreciate that new scientific theories, such as ‘cold fusion’, are not accepted until they have been validated by the scientific community.	C: 2.1 2.2 2.3 ICT: 2.1 2.2 2.3	

LESSON 10: Cold fusion (*continued*)		
Homework: Start/finish a limerick and/or finish off any other written work. Compose a limerick — a comic poem — written in five lines and rhyming as: a a b b a, as in the example. Pretend to be a neutron instead of this teacher.		
— **A teacher from Harrow**	There was a young teacher from Harrow Whose nose was too long and too narrow It gave so much trouble That he bent it up double And wheeled it round school in a barrow.	There was a neutron …….. Which/Who ….. ….. ....
Revise this topic for a test.		

Demonstration 12.4: Decay series

What you will learn from this demonstration

In this demonstration you will find out how a decay series works.

What you will know after you see this demonstration

1 That one radioactive material can decay into another that is itself radioactive.

2 That the different substances in the series will be present in different amounts.

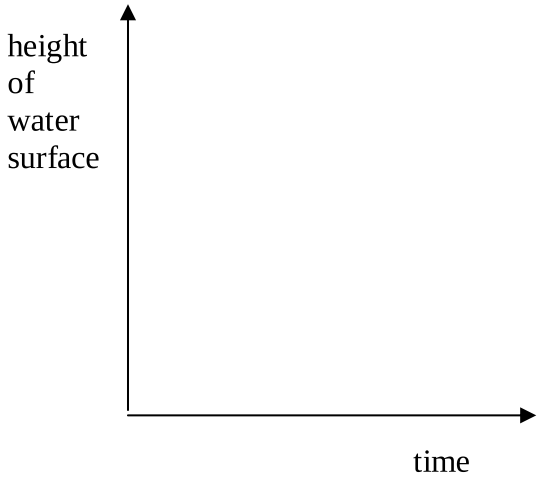
3 That the amounts depend on the half-lives of the substances.

4 That equilibrium may be established.

What you do

1 Do you remember what the graph looks like when water runs out of a long tube?

Sketch it here.



2 Label the diagram below.

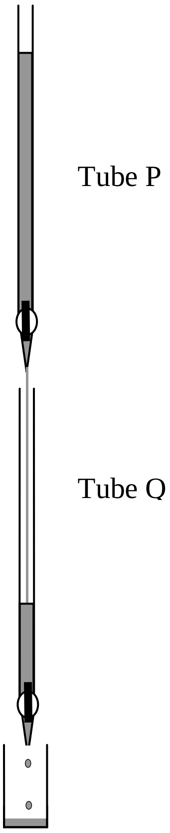


Table of results

	Height of water in:		
Time (s)	tube P (cm)	tube Q (cm)	cylinder (cm)

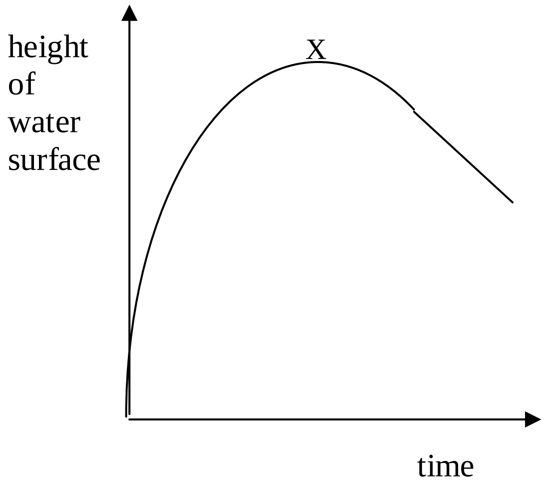
Demonstration 12.4: Decay series

3 What do you expect to happen to the depth of water in tube Q in the first few seconds after starting the experiment?

____

____

4 The graph for tube Q in the first few minutes looked like this.



(i) Describe what happened up to the point X.

____

____

(ii) Explain what is happening at point X on the graph.

____

____

5 Suggest a value for the level in P when the level in Q is:

(i) 10 cm ________________

(ii) 20 cm ________________

6 Plot the data for all three containers on the same axes.

7 Describe what happens to the water surface in the cylinder.

____

8 What would happen to the half-life of the water in P if it was made much wider?

____

Demonstration 12.4: Decay series

9 What would be the effect on the graph for tube Q if:

(i) tube P was replaced by a much wider tube but the same rate of flow was kept

___

(ii) tube P was replaced by a longer tube but the same rate of flow was kept

___

(iii) the same tube was used but the rate of flow was increased?

___

10 What is the half-life of the water in the beaker? How else might you describe such a material?

___

___

Demonstration 12.4: Decay series

Notes for teachers and technicians

Aim

In this demonstration students will find out how a decay series works. If you have enough tubes then this can be done as a class experiment.

Skills, knowledge and understanding

This demonstration will enable students to gain the following skills, and/or knowledge and understanding.

1 One radioactive material can decay into another that is itself radioactive.

2 The different substances in the series will be present in different amounts.

3 The amounts depend on the half-lives of the substances.

4 An equilibrium may be established.

5 Some materials are stable.

6 How combinations of graphs can be interpreted.

Previous skills, knowledge and understanding required

1 Ideas about half-life.

2 What decay graphs look like.

Equipment and chemicals required

1 Two long tubes with narrow tube through a bung in one end (or two burettes).

2 100 ml measuring cylinder.

3 Clock/watch.

Health and safety issues

Care should be taken to ensure the stability of the tubes.

Delivery strategies

- This demonstration could be done as a class practical with groups of four or five students if sufficient equipment is available. Otherwise, students should help you take the readings.
- This is an excellent demonstration for predicting the effects of changing factors.
- Students should have previously done an experiment with a single tube to find its half-life and how to change it.
- In this demonstration, the water from one tube runs into another which in turn lets water run into a third container. This represents one radioactive material decaying into another and then into a third material which is stable.
- The water levels in tube Q and the cylinder are interesting. The water in tube Q is zero initially and gradually increases. But as it increases it starts to run out. As it fills up more, the rate at which it runs out also increases until the two rates are equal (point X). The rate of running out then becomes larger than the in-flow rate and so the level in Q decreases. The level in the cylinder increases all the time since it has no outflow. This is what happens when the radioactive decay chain finishes with an isotope of lead.

Demonstration 12.4: Decay series

Links

1 Links with other GCSE Additional Science topics.

This demonstration is related to:

- P2.11 Radioactivity.

2 Links with Key Stage 3 (KS3)

There are no specific links.

Resources

Multimedia materials, eg Plato learning.

Websites

www.eserc.stonybrook.edu/ProjectJava/Radiation/applet — the time step may be set for 10 years to start with to see the equilibrium. Then move to 100,000 years and see the near equilibrium still then go to 100 million years.

Suggestions for further work

Early finishers could try out some of their own suggestions for different combinations of half-lives with the model or applet.

Activity 12.5: Chain reaction

What you will learn from this activity

In this activity you will find out by means of a model that uses dominoes how a chain reaction works. Each domino in a model represents an atom involved in fission. The decay of one domino is shown by it falling over. You will then compare this model with a nuclear chain reaction and see how power stations and bombs work.

What you will know after you see this activity

1 How a chain reaction works.

2 How fission can be controlled in a power station.

3 How a chain reaction can go out of control and may explode.

What you do

1 Complete these sentences.

In fission a n__________ collides with a n__________ and splits it into two approximately equal parts. These parts are called d_______________ nuclei. Also produced are three n___________.

2 What will happen if one of the neutrons from the first fission meets another uranium nucleus? In the model we are considering here, a domino stands on its end but when it falls over it has undergone fission. Think about 10 dominoes standing on edge in a line near each other, then you knock the end one over.

____

3 Think about testing the idea that the total time for all of the dominoes to fall depends on how far apart they are.

a How will you set up the apparatus?

____

b What will you measure?

____

4 Draw a table to record the five results that your class will take.

Activity 12.5: Chain reaction

5 Plot a graph of the results.

6 Describe what the graph shows about how the total time for all the dominoes to fall depends on how far apart they are.

7 Sketch, on the same axes, what you think the graph would look like if you used dominoes of half the height.

8 Complete these sentences.

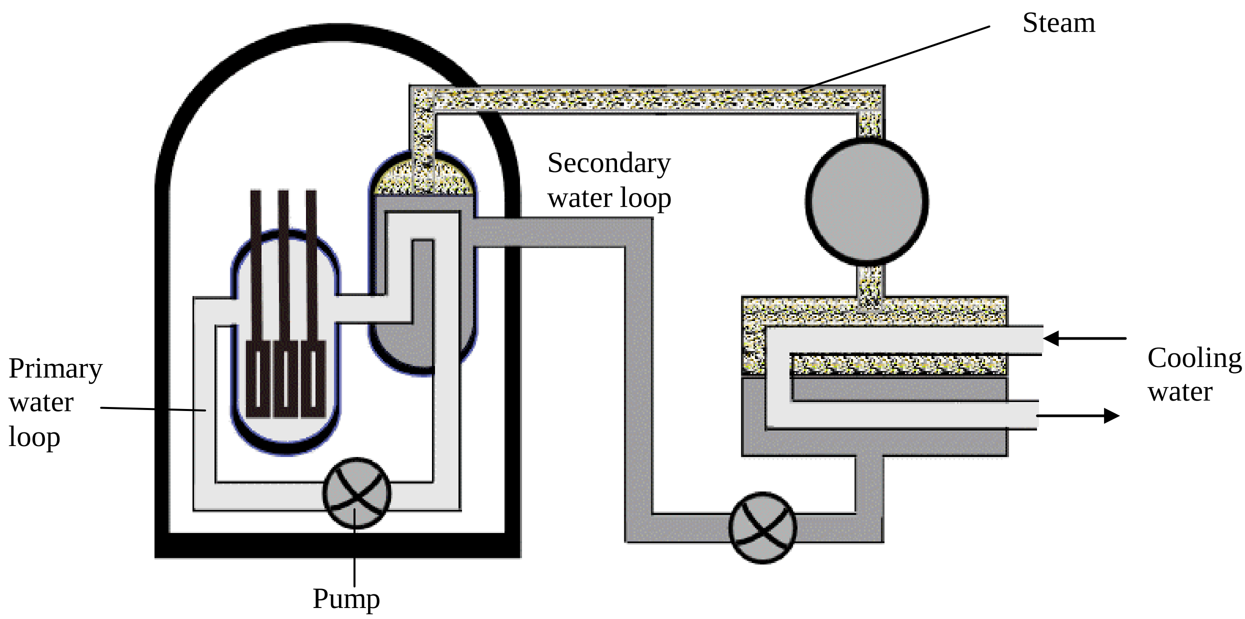
As the dominoes fall, _________________ is transferred. This transfer happens at a steady rate. This is what we want to happen in a p__________ s_______________.

9 If one fission occurs steadily after another, energy is steadily released. This is what happens in a power station. If the situation in question 7 happens, what can you say about the energy released?

____

____

10 Add labels to this diagram of a nuclear reactor using the words in the box below.



control rods	**fuel rods**	**containment building**
turbine	**pump**	

Activity 12.5: Chain reaction

11 Describe two good points about nuclear power stations.

Activity 12.5: Chain reaction

Notes for teachers and technicians

Aim

In this activity students will find out how a chain reaction works by means of a model. Dominoes represent the atoms involved in fission. The decay of one domino is shown by it falling over. The students will then compare this to a nuclear chain reaction and see how power stations and bombs work.

If possible, students could do this as an experiment themselves, maybe in turns while others do the worksheet/try an applet. They will probably need about 20 dominoes.

Skills, knowledge and understanding

This demonstration/experiment will enable students to gain the following skills, and/or knowledge and understanding.

1 How to develop a model.

2 How a chain reaction works.

3 How fission can be controlled in a power station.

4 How a chain reaction can go out of control and explode.

Previous skills, knowledge and understanding required

1 What fission is.

2 The products of fission.

Equipment and chemicals required

1 Several applets can be downloaded from www.visionlearning.com/library to revise fission, and then see chain reactions (a) under control and (b) out of control.

2 A set (or sets) of 20, preferably more, dominoes (or blocks of wood).

3 A stopwatch/clock.

4 Dominoes — these could be small pieces of wood of a rectangular shape (eg 1 cm x 1 cm x 3 or 4 cm) that can be balanced on one end so they stand nearly vertically.

Delivery strategies

- A chain reaction happens when one event produces a similar event in something new, several times over. In this model of a chain reaction, the fall (decay) of one domino causes the next in the sequence to decay. The rate at which it happens depends on how close together the dominoes are and how tall they are. The chain reaction will certainly not work if the distance between them is larger than their height, their thickness is too large (so they are stable/balanced), the disturbance from one to the next is, or becomes, too small, or some are significantly heavier than others.
- Review what happens in fission. Point out that in this model the atom undergoing fission is represented by a domino falling over. Ask students to write down what they think will happen if they make a line of dominoes stand on their side and then you knock one end.
- Get a couple of students to set up 10 dominoes spaced about 1 cm apart. Then, ask someone to tap one of the end ones.
- Relate this to a series of atoms undergoing fission. (The stimulus for the chain reaction with dominoes is gravity whereas in fission it is neutrons from the previous fission.)

Activity 12.5: Chain reaction

- Set up a longer series of dominoes as before. (**Hint**: Every five dominoes or so, miss one out so that the chain does not happen by mistake. The gaps can be filled in just before you start the demonstration.) Time how long it takes from starting the demonstration to the last domino falling.
- Ask students to suggest how to speed up the reaction. They may include things such as putting the dominoes closer together, standing them on their end instead of on their sides or (but don't suggest this yourself yet) letting one domino knock into two or more.
- Ask students to plan an investigation to see how the separation of the dominoes affects the speed of falling.
- Carry out the experiment with four or five different separations. Plot a rough graph.
- Discuss the idea of energy release from fission and then relate the steady release of energy needed in a power station to the steady falling of the dominoes.
- Students complete the activity sheet 12.5.

Links with other GCSE Science topics

This demonstration is related to Unit P2 Topic11: Putting radiation to use.

Resources

- www.visionlearning.com — applets of chain reactions
- www.me.utexas.edu
- IoP video 'Nuclear power'.

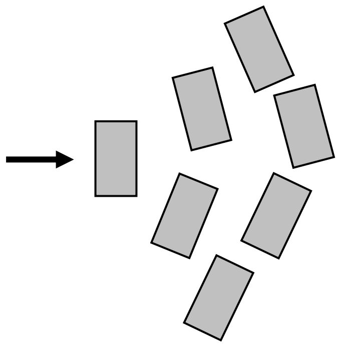
Suggestions for further work

More-able students may think about the idea of using an iron domino so that it does not topple as easily. (This could be U-238, an isotope of uranium which does not undergo fission.) They might also try some form of random placing of the dominoes to see if the arrangement is self-sustaining or not. They can then think about the bomb and perhaps research 'critical size'.

In the next lesson you can extend the model to account for a bomb as a much more rapid, uncontrolled release of energy as follows.

Discuss the effect if one domino hits two dominoes and each of these hits two etc, and show how this leads to a bomb.

Use this diagram to help you explain what happens if one domino is allowed to hit two dominoes.



Activity 12.6: Creating a diamante

Try to create a diamante.

A diamante is a seven-line poem used to go from one thing to its opposite.

- The top three lines are about one aspect
- The bottom three lines are about the other aspect
- But the middle line is where the changeover occurs by using words which both aspects share to some extent.

Example

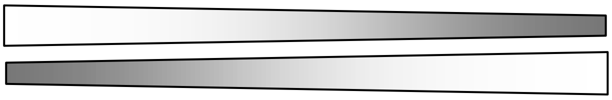
Line 1 – a noun
line 2 – adjective, adjective
line 3 – participle, participle, participle
line 4 – noun, noun, noun, noun
line 5 – participle, participle, participle
line 6 – adjective, adjective
line 7 – noun

Deserts
Parched, sandy
Shimmering, shifting, changing
Stone, sand, cacti, vines, trees
Greening, steaming, clinging
Dripping, dim
Jungles

Alpha particle
positive, heavy
heavily ionising, little deviating, smoke detecting,
quarks, nucleus, radiation, (nucleus), fundamental,
quite penetrating, positively neutralising, easily deflecting,
current, quick
Beta particle

Activity 12.7: Density

Density



1 The title and shapes illustrate changes in density of print. The ink is denser where it is darker.

Complete these sentences.

a A forest is dense when the trees are ______________________________________.

b An object of high density has a lot of material squashed into a _________ volume.

c Density is the amount of material (mass) in each cubic centimetre or cubic metre.

It is calculated by dividing __________ by _____________ .

d A gold ingot has a mass of 19.7 kg and a volume of about 0.001 m^3.

Its density is ____________kg/m^3.

2 Estimate the volume of a 1 kg bag of sugar. __________ cm^3

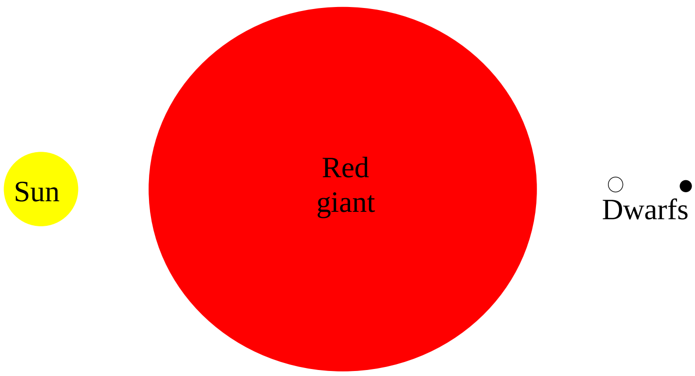
Now estimate the density of the sugar. __________ kg/cm^3

Why is this an estimate not an exact measurement?

____

____

3 The Earth has a mass of 6×10^{24} kg and a volume of 1×10^{21} m^3. The density of the Earth is about _______________________ kg/m^3.



What are the dwarfs called?

Activity 12.7: Density

4 Our Sun has a mass of 2×10^{30} kg and a volume of 1.4×10^{27} m^3. Calculate its density.

____

____

5 A white dwarf star has a mass of 1 × 1030 kg and a density of 1 x 109 kg/m^3. What is its volume?

____

What do you notice about this volume?

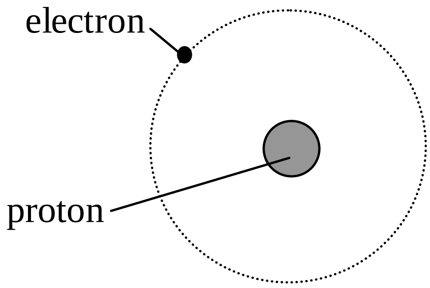
____

6 A neutron star has a density of 1×10^{17} kg/m^3.
Its volume is 4.2×10^{12} m^3.
What is its mass?

____

7 A hydrogen atom consists of an electron in orbit around a proton.
The mass of a hydrogen atom is 1.7×10^{-27} kg.
Its volume is about 6.2×10^{-31} m^3.
Its density is about

________________________ kg/m^3.



8 The mass of the proton is 1.7×10^{-27} kg.
Its volume is about 1×10^{-45} m^3.
The density of a proton is about ________________________ kg/m^3.

What do you notice about this density compared to water?

____

____

____

____

Activity 12.7: Density

Answers

1 (a)…closer together/bigger diameter/thicker.

(b) Small.

(c) mass … density.

(d) 19700 kg/m^3

2 about 1000 cm^3, somewhere between 750 and 1000 cm^3

3 6000 kg/m^3

4 1400 kg/m^3

5 1×10^{21} m^3

This is the same as the volume of the Earth (but 167 thousand times as much mass!).

6 4.2×10^{29} kg

7 2700 kg/m^3

8 1.7×10^{18} kg/m^3

It is 1.7 million, million, million times the density of water!!!

Experiment 12.7: Measuring density

What you will learn from this experiment

In this experiment you will find out that different materials have different densities but all samples of the same material have the same density.

What you will know when you finish this experiment

1 How to find the density of a material.

2 Different materials have different densities.

3 All samples of the same material have the same density.

How you may be assessed

During this experiment you may be assessed on your ability to:

1 collect data

2 present results.

What you do

1 Measure the length, thickness and height of one of the blocks.

2 Calculate the block's volume using volume = length × thickness × height.

3 Measure the mass of the block.

4 Calculate its density.

5 Enter all these values into a suitable table.

6 Repeat steps 1–5 for each block.

7 How does the density of each block compare?

8 Place a 200 cm^3 measuring cylinder on the balance and press 'Tare'.

9 Add 50 cm^3 of water and find its mass.

10 Calculate the density of the water.

11 Place a dry 200 cm^3 measuring cylinder on the balance and press 'Tare'.

12 Add 10 cm^3 of oil and find its mass.

13 Calculate the density of the oil.

14 The value of density calculated for water is more likely to be correct than the value calculated for oil. Why might this be?

Experiment 12.7: Measuring density

Notes for teachers and technicians

Aim

In this experiment students will explore ideas about density. They will look at both very small and very large densities.

Skills, knowledge and understanding

This activity will enable students to gain the following skills, and/or knowledge and understanding.

1 That each element has one constant factor, density, regardless of its mass or volume.

2 Stars have a variety of densities, some of which are comparable to those of the tiniest particles of matter.

Previous skills, knowledge and understanding required

1 Understanding of the meaning of the gradient of a graph.

2 Evaluation activities.

Materials required

1 Rectangular blocks of various materials (with several different sized ones of one material if possible).

2 A 200 cm^3 measuring cylinder.

3 Displacement cans for measuring volumes directly, if desired.

Health and safety issues

No particular health and safety issues.

Delivery strategies

- The activity could be introduced by recalling the stages in the evolution of stars: The same amount of material in a nebula becomes of smaller volume and so the density increases as a star is 'born', then its volume increases as it turns into a red giant etc.
- More-able students can be given more challenging shapes for measuring volume.
- Although not all students will have done all the activities and calculations, make sure that they appreciate the different densities of stars in their various stages. Remind them of the high temperatures inside stars and therefore the high energy and average speed of the particles' movement. These conditions will be referred to later when discussing fusion.
- Activity 12.7: 'Density' contains examples for calculating the density of some objects/materials. The information for some of the later questions involves using information expressed in standard form which will not be accessible to all students, but more able students should be able to cope and hopefully find it interesting.

Experiment 12.7: Measuring density

Assessment strategies

You could use this as an opportunity to assess/improve some students' practical skills:

1 collecting data scores between 1–4 marks: it is not really suitable for the higher-level students as measurements are fairly basic

2 presenting results scores between 1–6 marks.

If you concentrate on a few students you should be able to identify the contribution of each. The assessment criteria are on page 172 of the GCSE in Additional Science specification.

Activity 12.9: Poster

What you will learn from this activity

In this activity you will explore one aspect of fission/fusion in greater depth.

What you will know when you finish this activity

1 A greater amount about your chosen topic.

2 A better understanding of how to communicate information appropriately.

How you may be assessed

You may be assessed on:

1 the visual impact of your poster/fact sheet

2 the amount and accuracy of the science it contains

3 how appropriate the presentation is

4 originality.

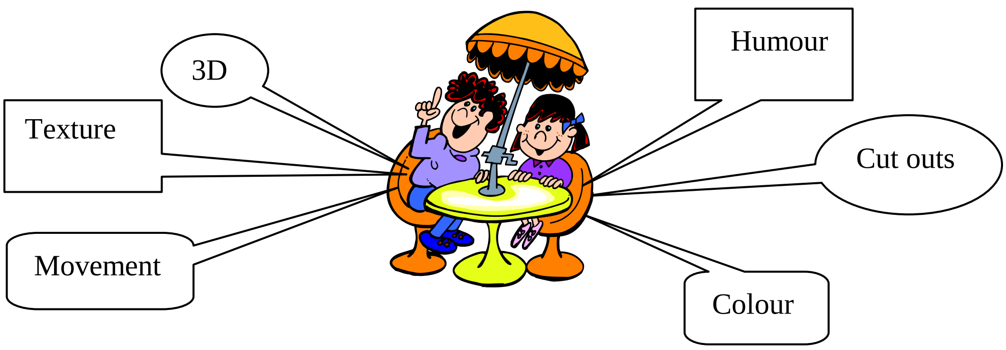
What you do

1 Choose one of the following titles and produce an A3 or A4 poster or fact sheet:

- advertising the advantages of a fusion reactor for a power station rather than a fission reactor
- comparing the good and bad points of fission
- explaining what a chain reaction is
- advertising a photocopier or laser printer
- illustrating the scientific importance of the discovery of fission
- providing an historical account of the development of fission
- 'Ban the bomb'/'Keep Britain nuclear free'.

Research your topic from books and the internet.

2 Presentation: Your poster may convey ideas more clearly and strikingly if you can include some or all of the following.



3 Timing: You have this lesson and your homework to prepare the poster/fact sheet ready for presentation at the next lesson.

Glossary for Topic 12: Power of the Atom

What you do

Complete the glossary for each key word(s).

You will be expected to be able to recall, explain, describe and use the words appropriately.

Key word	Definition
Chain reaction	
Decay series	
Daughter nucleus	
Electrostatic	
Fission	
Fusion	
Insulation	
Nucleus	
Neutron	
Nuclear reactor	
Radioactive	
Thermal energy	

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