PUPIL RESEARCHER INITIATIVE

Radiation Carriers

Pupil Research Brief

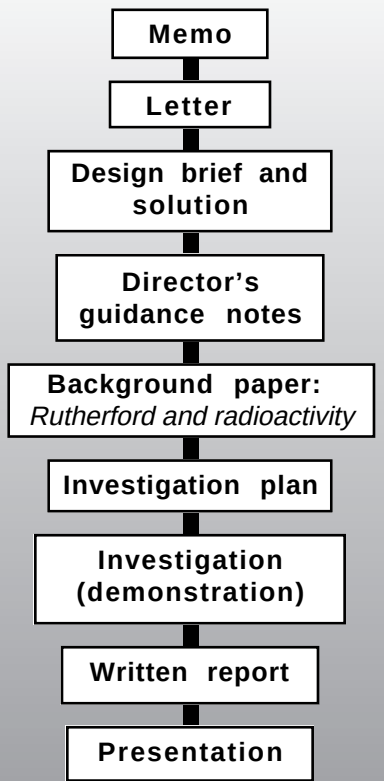
Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ atoms have a small central nucleus, made up of protons and neutrons, around which there are electrons
- ❑ some substances give out radiation all the time
- ❑ these substances are called radioactive
- ❑ alpha (α) radiation consists of helium nuclei and is easily absorbed by a few centimetres of air or a thin sheet of paper
- ❑ beta (β) radiation consists of electrons emitted from the nuclei of atoms and is absorbed by a few millimetres of metal
- ❑ for each electron emitted, a neutron in the nucleus becomes a proton
- ❑ gamma (γ) radiation is very short wavelength electromagnetic radiation and is very penetrating and requires many centimetres of lead or metres of concrete to absorb most of it
- ❑ there are radioactive substances all around us in the ground, in the air, in building materials, in food, and arriving from space
- ❑ radiation from these sources is known as background radiation
- ❑ the relative masses of protons, neutrons and electrons and their relative electric charges

	Mass	Charge
proton	1	+1
neutron	1	0
electron	negligible	-1

Route through the Brief



Introduction

This Brief focuses on the section of the science syllabus which covers ionising radiation. Radiation Carriers is based on a scenario which reflects the close relationship which exists between many hospitals (and National Health Trusts) and universities.

In the Brief pupils take on the role of research students in a university department. The teacher is the team leader and Radiological Protection Officer. The Chief Scientific Officer of a National Health Trust has asked the department to evaluate a design which has been commissioned by the Trust from a commercial design company. The design is for a carrying container for radioactive sources used for medical purposes. The pupils plan an investigation, which is then carried out by the teacher (acting as the Radiological Protection Officer). The investigation tests the materials suggested for making the carrying container to see if α-particles, β-particles or γ rays can be stopped from leaking out. They are asked to assess the suitability of other materials than those specified in the design to see if they will work better. The pupils then carry out a safety analysis (risk

assessment) of the proposed method. Following the investigation, pupils write a report which can be presented to the whole group. The reports should make recommendations to the Trust for improvements in the design of the carrying container. Each presentation undergoes peer review by other pupils, reflecting practice in the research community.

Experimental and investigative skills

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

Prior knowledge

Before attempting this Brief pupils should have had an introduction to the topic of radioactivity, ways of detecting radiation and the symbolic representation of radioactive isotopes.

Running the Brief

Pupil grouping

Pupils could work in a number of groupings during this Brief. Suggestions are :

Initial briefing	-	whole class; teacher briefly introduces topic and sets the context for the activity
Memo, letter and design brief	-	whole class; teacher in role of team leader introduces tasks
Guidance notes and background paper	-	small groups of 2 - 4 pupils
Investigation plan and safety analysis	-	small groups of 2 - 4 pupils
Presentations and peer review	-	whole class plenary; small groups making presentations
Investigations (carried out by teacher)	-	whole class or with smaller groups
Proposals for the design of the carrier	-	small groups of 2 - 4 pupils
Communication	-	compilation of reports in small groups or individually if used for assessment purposes

Timing

The Brief should take about 3 hours of classroom time.

Activities

The teacher should issue the pupils with the **Study Guide** which provides pupils with a summary of what they should produce as they work through the Brief. It can also act as a checklist for pupils to monitor their own progress. Pupils are issued with the **memo** and **letter**. The **team leader** (teacher) then goes through the memo and the letter from Margaret Spencer of the St Hildegard Health Trust to set the scene and outline the work the **research students** (pupils) have to do. The pupils should be issued with the **design brief** from *Feynman Design Consultants*. This gives the consultant's suggested solution to the problem facing the Trust - carrying radioactive sources safely from one building to another, sometimes over long distances. There can be some discussion about flaws in the design at this point. The **Guidance notes** and the **background paper** *Rutherford and radioactivity* can then be given out and the students can be organised into small groups of two to four. Each group has to produce an investigation plan to :

- determine the types and thicknesses of materials that will prevent penetration by the different radiations
- set out a safety analysis of the proposed practical work

Pupils may need some guidance in finding the thickness of one sheet of thin card when planning the investigation to find the thickness needed to reduce the count-rate of each type of radiation. The graph of count rate per minute against thickness works very well for β-particles using aluminium. The graph for α-particles and card is likely to be much less clear. When the proposals for the investigation have been completed, a spokesperson from each group gives a summary of their plan during a whole class plenary session. Each plan can therefore undergo peer review. The best plans are then carried out by the **Radiological Protection Officer** (teacher) who can reject or alter any experimental procedure suggested by the pupils which is unsafe. Pupils' safety analyses (risk assessments) should have shown up any of the potential safety problems.

Once the selected experiments have been carried out, pupils can then write a report of the findings and go on to include proposals for improving the Feynman *Design Consultant*'s design or to propose their own design. They may conclude that there should be different carriers for each type of radioactivity.

Teachers' Notes continued

Investigation details

The investigation(s) carried out will vary slightly from class to class. Essentially there will be some measurements of the radiation levels reaching a G-M tube. This should be done with no barrier between the radioactive source and the tube and then with a range of thickness of card and aluminium interposed. The sources need to be a set distance away from the tube, but not so far as to seriously decrease the count-rate provided by the α - source. Alpha rays are easily stopped by a few centimetres of air. Pupils are likely to request lead to be used for the γ - source. If pupils plot a graph of count-rate against thickness of material they should get a reasonable graph for β - particles and aluminium. The graph will be an exponential decay curve. By extrapolating the graph they should find the thickness required to get the count-rate down to the background count. Alternatively, they can do this experimentally if a range of aluminium sheets of different thicknesses are available, or aluminium blocks from materials kits.

The experiment with the α - source and card is likely to produce a very rapid decrease in count-rate with increased thickness. In this case, they could determine the thickness of card required to reduce the count-rate to the background count by experiment, rather than by extrapolation of a graph.

The γ - source will require lead to reduce the count-rate significantly. In this case very thick pieces of lead will be required.

Pupils should note the comment in the paper *Rutherford and Radioactivity* about Geiger-Müller tubes being only 1% efficient at best in detecting γ - rays and they should scale up the count-rates for γ - sources accordingly.

Using IT. A radioactive count rate sensor could be used for the investigation. A spreadsheet could be used to produce graphs from the results and to calculate the thickness of material needed to make the carrying container.

Technical details

The equipment required for this Brief will include :

- standard radioactive sources
- Geiger-Müller tubes or radioactive count rate sensor
- electronic counter or ratemeter
- card
- aluminium foil
- different thicknesses of aluminium sheet or aluminium blocks
- different thicknesses of lead sheet
- clamp stands
- metre rules or micrometers for measuring the thickness of card and foil

Pupils are not allowed to use radioactive sources and so all investigations need to be carried out by the teacher. Radioactive sources should not be touched, but handled with tweezers. They should not be looked at or pointed at others and they should be returned to their lead-lined boxes immediately after use.

Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

In England, Wales and Northern Ireland
All activities with radioactive sources come under Administrative Memorandum 1/92 and the Local Rules applicable to the individual school.

This means that **no pupils in Key Stage 4 may handle the sources**. Only teachers, working under the Local Rules, may handle the sources.

This Brief requires pupils to carry out a risk assessment. As such it can be seen to support the teaching and learning of the section of the programme of study for Key Stage 4 relating to Health and Safety and included in all GCSE syllabuses.

In Scotland
Refer to Scottish Education Department (now SOED) Circular 1166 (issued 1988) "Procedures for use of ionising radiations in educational establishments"

Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales, Northern Ireland Curriculum)

P	Planning	O	Obtaining evidence
A	Analysing evidence	E	Evaluating evidence

Pupils will plan, but not carry out, an investigation into which materials and/or what thickness of a particular material are needed for a carrier for radioactive sources. It will be carried out by the teacher. Pupils could analyse and evaluate the evidence produced by the investigation. Their plan could be used to assess **Skill Area P**. The suggested investigations must be very well planned by the pupils so that it can be carried out by the teacher. **Skill Area O** is unlikely to provide evidence for

assessment as the practical work is not carried out by the pupils. For **Skill Area A,** in order to reach high mark ranges, consideration will have to be given to errors. For high marks in **Skill Area E**, pupil evaluations will need to address the suitability of procedures and improvements in reliability of evidence.

Scottish syllabus coverage

Standard Grade Physics - *Health Physics*

Further pupil research opportunities

Pupils can find out about the effects of exposure to ionising radiation. They can find out how radioactive materials are used in hospitals and discover how scientists who work with radioactivity have their exposure to radioactivity monitored.