PUPIL
RESEARCHER
INITIATIVE

Radiation Carriers

Setting the Scene

You will be working as a member of a radioactivity research team. You have been asked to plan an investigation to test the design of a container that can carry radioactive materials used in hospitals. The investigation will be carried out by the Radiological Protection Officer.

Pupil Research Brief

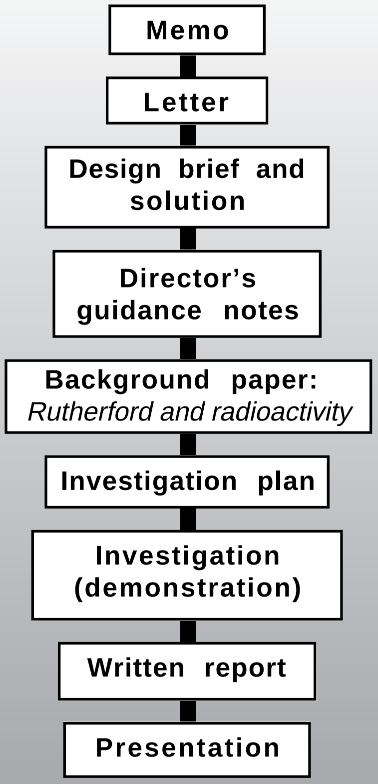
Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ☐ 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



Outcome Checklist

You will produce a written report of your findings, which will be presented to the rest of the research team in a peer review. A set of director's guidance notes guide you through the Brief. You should make sure you produce the following items as you work through the Brief.

Director's guidance notes

- ☐ investigation plan
- ☐ risk assessment
- ☐ written report
- ☐ presentation

Radford University

Materials Research Institute

Memo

From Chris Hunter, Director of Research Programmes

To Radioactivity Research Team

Date

I had an interesting conversation with Margaret Spencer, Chief Scientific Officer of the St Hildegard Health Trust yesterday. The Trust needs a small research project carrying out, and I thought that as new members of the research staff you would be interested in doing it.

The Trust asked *Feynman Design Consultants* to come up with a design for a small carrying container, suitable for carrying radioactive material between different hospitals. Margaret is not sure whether the design would be suitable, and she has asked us to carry out some investigations to check it out. I have copied the letter she sent me, and the Feynman Design Brief.

We need to carry out some work to test the design. I have written some notes, which are attached to this memo, along with a paper I usually give our new researchers to read. It summarises the background knowledge about radiation you will need before you start on any research project.

You will need to work closely with the Radiological Protection Officer (RPO) on this project. Some of the practical procedures you will need to use can only be carried out by the RPO. Therefore, you must make sure your investigation plan is self-explanatory, since the RPO has to carry it out.

When you have completed the investigation into whether the carrying container is suitable for its purpose (see the design company's Design Brief for details of this) I would like to see your reports. I will then get in touch with Margaret and inform her of the outcome of the work. We may be required to make a presentation of our findings to the Board of Trustees - so be prepared!

Documents enclosed

1. Letter from Margaret Spencer

2. Design Brief from *Feynman Design Consultants*

3. My guidance notes

4. The *Rutherford and Radioactivity* paper

St. Hildegard Health Trust
Becquerel House
Sievert Road
Radford

Chris Hunter
Director of Research Programmes
Materials Research Institute
Radford University
Radford

Dear Chris,

This letter follows our telephone conversation during which we discussed a small research project we need doing. As you will probably already know there are times when it is necessary for low level radioactive sources, including α, β and γ emitters, to be transported between the hospitals in our group. Feynman Design Consultants have produced a design brief for a carrying container. We would like your advice on whether or not such a container is suitable for the purpose.

I have my doubts about the safety of their proposed solution, particularly its suitability for carrying γ emitters, but they maintain that they have tested the prototype using an appropriate radioactive source.

In order to resolve this difference of opinion the Board of Trustees of the Hospital Trust have asked me to commission you to carry out an independent study to test the suitability of the Feynman design solution. I know it is short notice, but it would be really helpful if you could report to the next meeting of the Board which is in two week's time.

Enclosed with this letter is a copy of the design brief and the proposed design solution.

Yours sincerely,

Margaret Spencer

Margaret Spencer

Feynman Design Consultants

Design Solutions for Health Professionals

Design brief

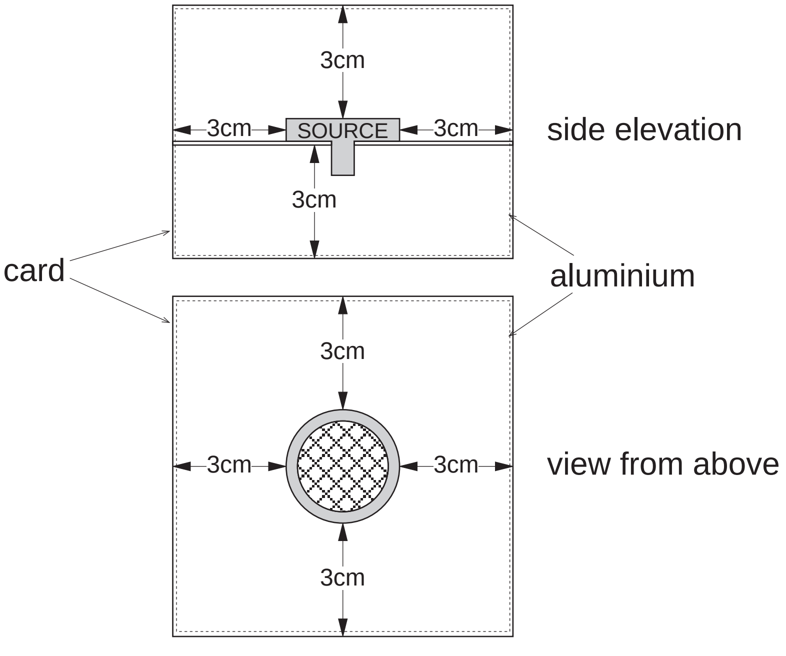
The St Hildegard Health Trust needs to transport small, low level sources of radiation between the hospitals in the group. The need is for a small, robust and cheap container which can allow these sources to be transported safely. The criterion for safe transportation is that the level of activity measured outside the container should not exceed that of the background radiation. The background radiation is the naturally occurring radioactivity in rocks, building materials and food, as well as cosmic rays from space. There may also be some 'radioactive fall-out' from nuclear tests and accidents like the Chernobyl disaster - the radioactivity lingers for many years after these events have occurred.

The container should be able to be carried inside a locked carrying case and therefore should not exceed overall dimensions of 10cm x10cm x10cm. Each container will be used to carry only one source.

Design solution

Following extensive testing using a Po 218 source it was found that the container itself should be made from card of thickness 0.01cm, lined with aluminium foil of thickness 0.005cm. The source is positioned at the centre of the container with an overall clearance of 3cm between the source and the wall of the container. (See figure below)

Figure 1. Proposed radioactive source container



Using this construction it was found that the level of radiation detected outside the container holding the Po 218 source did not exceed the normal background count.

The container itself is light, strong and durable.

Radford University

Materials Research Institute

Guidance notes on St Hildegard Project

Chris Hunter, Director of Research Programmes

You will have read the attached design brief. Your task will be to **draw up a plan** to investigate the properties of a range of materials for their suitability for use in 'packaging' the different radioactive sources which need to be transported. The sources which are used contain the following isotopes:

Americium 241, Plutonium 239, Strontium 90, Cobalt 60 and Radium 226.

As you will see from the attached table taken from the data book the radioactive emissions from these sources vary considerably when compared with the Polonium source tested in the Feynman Design Consultants' report.

Table 1.

Source	Radiation
Americium 241	α; low energy γ which can usually be ignored
Cobalt 60	γ; low energy β particles
Plutonium 239	α; low energy γ which can usually be ignored
Polonium 218	α
Radium	α; β; γ
Strontium 90	β

TASK - The properties of ionising radiations

Background literature

Your first task will be to identify the properties of each type of radiation. To help you I have summarised some of the findings made by Ernest Rutherford in 1903 *(Phil. Mag. S.6. Vol. 5. No. 26. Feb. 1903)*. I always suggest that new research students read this paper, or at least my summary of key points. It explains very clearly some of the earliest experiments on types of radioactivity. A copy is attached. It would be a good idea to read it now, before you go any further. Then you should follow the instructions set out below in parts 1 and 2. As new students you will be working with the department's Radiological Protection Officer, **who will carry out the tests you suggest in your investigation plan.**

Part 1 Producing an investigation plan

I would like you to draw up a plan for an investigation to verify the figures given by Rutherford for the penetrating power of the three types of radiation; α, β and γ. Since the design brief uses both aluminium and card I suggest that you plan a comparative study on these two materials which enables the measurement of the degree of absorption for different thicknesses of material for each type of radiation. You will have to check your plan for safety (see Part 2 below) before it is passed to the Radiological Protection Officer, who will conduct the investigation. The results of the investigation will enable you to judge the suitability of the Feynman Design Consultants' container.

I suggest that you present your results graphically. A graph of count-rate against thickness for each material will allow you to extend the graph to find the thickness you will need to get the counts per minute down to the background count. This way you don't have to find the thickness experimentally.

You should also offer suggestions for improving the container design, including the possible use of materials other than card and aluminium. I'm not convinced that **one** container will meet the requirements of the St. Hildegard Health Trust, but I need reliable data from you to support any recommendations this Institute makes to the Trust

Practical note

Before performing any practical work you must produce a research outline which will include the following information:

☐ a statement of your research method, which should be in two parts: the first part should say what you are trying to find out and the second part what you are going to do

☐ a list of apparatus you require saying why you selected that apparatus

☐ a suggested form in which the experimental results should be presented

Part 2 Radiological protection

Important safety note

This practical investigation will involve the use of a range of equipment and materials which are potentially hazardous. In planning this investigation it is very important that a full safety analysis is conducted and checked with the Radiological Protection Officer **before** any practical work is undertaken. **In particular you must identify which aspects of this work can only be conducted by the RPO.** Your safety analysis should contain a clear statement of the health and safety hazards associated with each of the ionising radiations. Check with the RPO for sources of information for this safety analysis.

Presentation of findings

Following your investigation and report writing, we will have a presentation session where each group working on the project can report its findings. We will do this either by poster display, or oral presentation of reports (with visual aids - using OHPs or flip charts). This will allow us to carry out a peer review. We can then present a report to St Hildegard's Board of Trustees.

Criteria for peer review

1. Has the purpose of the investigation been made clear?

2. Is the science correct? Are there any points that need to be corrected or made clear?

3. Have the plans for the practical work been correctly drawn up? Do they need to be improved, and if so, in what way?

4. Are the results clearly presented? Do they support the conclusions and recommendations made by the research team?

Rutherford and radioactivity

Summarised by Professor C. Hunter

In 1903 Ernest Rutherford reported on work he had been doing on the radiation given out by the radioactive element Radium. He reported that "radium gives out three distinct types of radiation.

(1) The α rays, which are very easily absorbed by thin layers of matter, and which give rise to the greater portion of the ionization observed under the usual experimental conditions.

(2) The β rays, which consist of negatively charged particles projected with high velocity, and which are similar in all respects to cathode rays produced in a vacuum-tube.

(3) The γ rays, which are not deflected a magnetic field, and which are of a very penetrating character." (Rutherford, 1903)[1]

Of course we now know that these three types of radiation are very different. They all come from the nucleus of an atom but they are different because they are the result of different processes.

An α particle is made up from **two neutrons and two protons** just like a helium nucleus. So it is quite a large, heavy particle which will cause a lot of ionization when it bumps into other atoms because it has a charge of +2.

We also know that Rutherford was right in saying that β particles are like cathode rays because they are **electrons.** This means that β particles are small and light (roughly 1/2000th the mass of a proton) with a charge of -1. They are fast moving electrons which are produced when a neutron decays to become a proton.

---

[1] The magnetic and electric deviation of the easily absorbed rays from Radium *Phil. Mag.* S.6. Vol.5. No. 26. Feb. 1903.

continued

Gamma rays are high energy packets of short wavelength electromagnetic waves which are emitted from the nucleus when other changes, such as α or β particle emission, are taking place.

When Rutherford did his work he was interested in how penetrating each of these radiations was. Rutherford measured the thickness of aluminium required for the intensity of the radiations to fall by half and got the results shown below:

Radiation	**Aluminium**
α rays	0.0005
β rays	0.05
γ rays	8 cm

These thicknesses are usually called half value-thicknesses.

Check one of the data books for the figures for lead.

Historical note

The Geiger-counter was invented by Hans Geiger, who was an assistant to Ernest Rutherford. The detector was later modified by Geiger and W. Müller, which is why it is properly called the **Geiger-Müller tube**. Geiger-counters are very efficient at detecting and counting α and β radiation, but for γ rays they are no more than 1% efficient. So, if you use a G-M tube for detecting γ rays you should multiply the count by 100 to get a more accurate result.