Nuclear medicine

Curriculum links

| KS3 Physics NC | • Particle model |
| KS3 Working Scientifically NC | • Analysis and evaluation – present observations and data using appropriate methods, including tables and graphs. |
| GCSE Physics NC | • Atomic structure – explain the concept of half-life and how this is related to the random nature of radioactive decay. |
| AQA GCSE | 4.4.2.1 Radioactive decay and nuclear radiation 4.4.2.3 Half-lives and the random nature of radioactive decay |
| OCR GW GCSE | P6.1d Recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays P6.1j Explain the concept of half-life and how this is related to the random nature of radioactive decay |

Outcomes table

<table>
<thead>
<tr>
<th>Band</th>
<th>Outcome</th>
<th>Checkpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing</td>
<td>• Match some radioactivity key words to their definitions.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>• Answer simple questions about half-life data.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Plot data on given graph axes.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>• With help, identify key points in a piece of text.</td>
<td>1–5</td>
</tr>
<tr>
<td>Secure</td>
<td>• Correctly match radioactivity key words to their definitions.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>• Analyse half-life data and, with help, draw a conclusion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Label graph axes with help, then independently plot data and draw a line of best fit.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>• Identify key points in a piece of text.</td>
<td>1–5</td>
</tr>
<tr>
<td>Extending</td>
<td>• Write definitions for radioactivity key words.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Interpret half-life data and independently draw a conclusion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Independently draw and label graph axes, plot data, and draw a line of best fit.</td>
<td>1</td>
</tr>
</tbody>
</table>

Maths/Literacy/Key words

<table>
<thead>
<tr>
<th>Maths</th>
<th>In Main 1, students plot and interpret a graph.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literacy</td>
<td>For homework, students write a job advertisement for a nuclear medicine technician.</td>
</tr>
<tr>
<td>Key words</td>
<td>radiation, radioactive substance, activity, radioactive decay, half-life, count rate</td>
</tr>
</tbody>
</table>
# Lesson plan: Physics

### Starter

**What is radioactivity? (10 min)**
Display a gamma camera image of the kidneys (search for *gamma camera image kidneys*). Tell students that a nuclear medicine technologist uses radioactive substances and a special gamma camera to produce images of the body, such as the one shown. These images help doctors to diagnose diseases, such as kidney disease. Students then work through the activity sheet.

**Radioactivity definitions (10 min)**
Tell students that a nuclear medicine technologist uses radioactive substances and special cameras to produce images of the body that doctors can use to help diagnose diseases. Students then work through the activity sheet in which they match radioactivity key words with their definitions.

### Main

**Modelling radioactive decay (25 min)**
Students follow instructions on the practical sheet to model radioactive decay. The practical involves throwing pasta shells onto the table. Those that land one way up represent atoms that decay, and are removed. Students repeat the process, recording the number of ‘decays’ in each turn, and display their results on a graph. They then follow instructions on the practical sheet to explain how the model represents the random nature of radioactive decay.

**Different half-lives (10 min)**
Display the data below, and ask students the question – ‘Which substance has the shortest half-life?’. Students then make up three questions about the data before working in pairs to answer each other’s questions. This activity makes the point that half-life values vary considerably.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-14</td>
<td>5730 years</td>
</tr>
<tr>
<td>Fluorine-18</td>
<td>110 minutes</td>
</tr>
<tr>
<td>Iodine-131</td>
<td>8 days</td>
</tr>
<tr>
<td>Lithium-11</td>
<td>9 seconds</td>
</tr>
<tr>
<td>Technetium-99</td>
<td>6 hours</td>
</tr>
</tbody>
</table>

### Plenary

**Choosing half-lives (10 min)**
Tell students that to make images (like that in Starter 1), the patient first swallows, or is injected with, a radioactive substance. The substance travels to body organs and emits radiation. Special devices detect the radiation and produce an image. The radioactive substance must have a half-life that is long enough to allow time for the image to be made, but short enough to minimise damage. Students then study the data in the table from Main 2 to select a substance with a suitable half-life. Technetium-99 is most commonly used in diagnosis.

### Homework

**Nuclear medicine technologist**
Students use the internet to find out more about the work of a nuclear medicine technician, using the web site of the British Nuclear Medicine Society, for example. They then make a job advertisement for the role. This should include the knowledge, skills, and qualities required.
Modelling radioactive decay

Setting the scene

In this practical you will model radioactive decay to help to explain why the activity of a radioactive substance decreases over time.

Aims

In this activity, you will:

- model radioactivity decay to help explain why the activity of a radioactive substance decreases over time.

You will be working scientifically to:

- present observations and data using appropriate methods, including tables and graphs.

You will be using numeracy skills to:

- plot data on a graph, and draw a line of best fit.

Safety

- Do not eat the pasta shells, or put them in your mouth.

Equipment and Materials

- 100 pasta shells
- A plastic tray

Method

1 Count out 100 pasta shells
2 Throw all the pasta shells, in handfuls, into the plastic tray (as if you were throwing dice).
3 Remove the pasta shells that land like ‘boats’.
4 Count the number of shells that you removed. Record this number in your results table. Then place the removed pasta shells to one side.
5 Remove the remaining pasta shells in the tray. Then throw them back into the tray again.
6 Remove the pasta shells that land like ‘boats’.
7 Count the number of shells that you removed. Record this number in your results table. Then place the removed pasta shells to one side.
8 Repeat steps 5–7 until you have filled in all the rows of your results table.
Healthcare Science
Practical sheet: Physics

Results

<table>
<thead>
<tr>
<th>Turn</th>
<th>Number of pasta shells removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Questions

1. On a piece of graph paper, draw a set of axes and plot your results. Put the ‘number of pasta shells’ removed on the y-axis and ‘turn’ on the x-axis. On the graph, the number of pasta shells removed represents activity, or count rate, and the turn number represents time. (4 marks)

2. a. Draw a smooth curve on your graph to show your line of best fit. (1 mark)
   
   b. Describe the shape of your line of best fit. (2 marks)

3. Complete the sentences below by circling the correct bold word in each pair.

   In the experiment, each pasta shell represented an atom. The pasta shells that landed like boats represented atoms that decay by giving out radiation/light. Once an atom has decayed, it is stable/unstable. It is no longer available to decay. We modelled this by adding/removing the pasta shells that landed as boats. The greater the number of pasta shells that landed like boats, the greater/smaller the activity, or count rate.

   There were a large number of atoms (pasta shells) at the start so many atoms were available to decay. The activity was high/low. As more atoms became stable, fewer/more atoms were available to decay. This explains why the activity of a radioactive substance increases/decreases over time.

   Radioactive decay is a regular/random process, which means you cannot predict which atoms that will decay at a given time. (8 marks)
Extension

4 Compare the pasta model of radioactive decay used in the experiment to the real process of radioactive decay. In your answer, include one similarity between the model and the real process, and one difference.

5 The line graph you drew of your results models how the activity, or count rate, of a radioactive substance changes over time.

a Explain why the data you collected, and shown in your results table, should actually have been plotted using a bar chart and not a line graph.

b Suggest one advantage of plotting the data you collected on a line graph rather than a bar chart.
Modelling radioactive decay

Aims
In this activity, students will:

- model radioactivity decay to help explain why the activity of a radioactive substance decreases over time.

Students will be working scientifically to:

- present observations and data using appropriate methods, including tables and graphs.

Students will be using numeracy skills to:

- plot data on a graph, and draw a line of best fit.

Teacher notes

- For Main 1, the practical is straightforward, but you might like to demonstrate how to throw the pasta shells, in handfuls, into the plastic tray so that they all land in the tray and can easily be counted.
- Position each student group in a clearly defined area, or separate desks/lab benches, to make sure that pasta shells from different groups do not get confused.
- Students could work in groups of three. Each student can then have two turns at throwing the pasta shells into the tray.
- Remind students to throw the pasta shells carefully.
- A support sheet is available for this practical in which students are provided with a set of axes on which to plot the data they collect.

Answers

Main practical

Sample results

<table>
<thead>
<tr>
<th>Turn</th>
<th>Number of pasta shells removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>
Questions

1  Correctly drawn and labelled x-axis (1); correctly drawn and labelled y-axis; three data points plotted correctly (1); all data points plotted correctly (1). (4 marks)

(Support sheet)
Three data points plotted correctly (1); all data points plotted correctly (1). (2 marks)

2  a  Line of best fit drawn correctly (1 mark)
   b  The curve/line of best fit sloped steeply downwards at first (1); it then becomes almost level/horizontal (1). (2 marks)

3  In order: radiation (1); stable (1); removing (1); greater (1); high (1); fewer (1); decreases (1); random (1). (8 marks)

Extension

4  Allow one mark for any acceptable similarity: e.g. radioactive decay and throwing the pasta shells are both random processes. Allow one mark for any acceptable difference: e.g. in the real situation it is not possible to remove the atoms that have decayed from the substance. (2 marks)

5  a  The independent variable/turn and the dependent variable/number of pasta shells removed are both discrete variables (1). A line graph should only be used when the independent variable and the dependent variable are both continuous data (1). (2 marks)
   b  It is easier to see the shape of the graph. (1 mark)

Starter 1 activity sheet – answers

1  These atoms break down, in a process known as decay. (1 mark)
2  A substance that gives out radiation is radioactive. (1 mark)
3  Uranium (1); plutonium (1) (2 marks)
4  Some radioactive substances can be used to diagnose and treat diseases. (1 mark)
5  Iodine (1 mark)

Starter 2 activity sheet – answers

Radiation – energy in the form of particles or waves that are given out by a radioactive substance (1)
Radioactive substance – something that gives out radiation (1)
Count rate – the amount of radiation given out in one second (1)
Half-life – the time taken for the count rate to halve (1)
Unstable atom – an atom that can break down by itself (1)
Activity – the amount of radiation given out in one second (1)
Radioactive decay – the breakdown of an atom by giving out radiation (1) (7 marks)
Technician notes

Safety
- Remind students that they should not eat the pasta shells, or put them in their mouths.
- Tell student to throw the pasta shells into the plastic tray with care so that they do not land on the floor where they may trip someone over.

Equipment and materials
Per student group
- 100 pasta shells (conchiglie or conchigliette). This number of pasta shells typically has a mass of around 130 g.
- A plastic tray – large enough to throw the pasta shells into.
Modelling radioactive decay

Setting the scene

In this practical you will model radioactive decay to help to explain why the activity of a radioactive substance decreases over time.

Aims

In this activity, you will:

• model radioactivity decay to help explain why the activity of a radioactive substance decreases over time.

You will be working scientifically to:

• present observations and data using appropriate methods, including tables and graphs.

You will be using numeracy skills to:

• plot data on a graph, and draw a line of best fit.

Safety

• Do not eat the pasta shells, or put them in your mouth.

Equipment and Materials

• 100 pasta shells
• A plastic tray

Method

1 Count out 100 pasta shells
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Results

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<tbody>
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<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Questions

1. Using the axes provided below, plot your results. On the graph, the number of pasta shells removed (y-axis) represents activity, or count rate, and turn (x-axis) represents time. (2 marks)
2 a Draw a smooth curve on your graph to show your line of best fit. (1 mark)

b Describe the shape of your line of best fit.

3 Complete the sentences below by circling the correct bold word in each pair.

In the experiment, each pasta shell represented an atom. The pasta shells that landed like boats represented atoms that decay by giving out radiation/light. Once an atom has decayed, it is stable/unstable. It is no longer available to decay. We modelled this by adding/removing the pasta shells that landed as boats. The greater the number of pasta shells that landed like boats, the greater/smaller the activity, or count rate.

At the start, there were many atoms (pasta shells); so many atoms were available to decay. The activity was high/low. As more atoms became stable, fewer/more atoms were available to decay. This explains why the activity of a radioactive substance increases/decreases over time.

Radioactive decay is a regular/random process, which means you cannot predict which atoms that will decay at a given time. (8 marks)
What is radioactivity?
In this activity you will learn some key information about radioactive substances.

Task
Read the information in the box, and then answer the questions below.

Some types of radioactive substances can be used to diagnose and treat diseases. What are radioactive substances?

Most atoms are stable. This means they do not break down by themselves. However, some atoms are unstable. These atoms break down, in a process known as decay. When an atom decays, it gives out energy called radiation. This radiation can be in the form of particles or waves.

A substance that gives out radiation is radioactive. The elements uranium and plutonium are examples of radioactive substances. Some elements have some atoms that are radioactive and some atoms that are not. One example is iodine. Iodine-131 is radioactive, but iodine-127 is not.

A radioactive substance gives out radiation randomly. The amount of radiation given out in one second is called the activity, or count rate. The time taken for a radioactive substance’s count rate to halve is called the half-life. Different substances have different half-lives.

1. In blue, underline one sentence that describes what an unstable atom is. (1 mark)
2. In black, underline the sentence that defines a radioactive substance. (1 mark)
3. In pencil, underline the names of two types of radioactive elements. (2 marks)
4. In green, underline the sentence that describes how radioactive substances can be used in a hospital. (1 mark)
5. In red, underline the name of one substance that has types of both radioactive and non-radioactive atoms. (1 mark)
Radioactivity definitions

In this activity you will learn the definitions of some key words relating to radioactivity.

Task
Read the information in the box below.

Some types of radioactive substances can be used to diagnose and treat diseases. What are radioactive substances?

Most atoms are stable. This means they do not break down by themselves. However, some atoms are unstable. These atoms break down, in a process known as decay. When an atom decays, it gives out energy called radiation. This radiation can be in the form of particles or waves.

A substance that gives out radiation is radioactive. The elements uranium and plutonium are examples of radioactive substances. Some elements have some atoms that are radioactive and some atoms that are not. One example is iodine. Iodine-131 is radioactive, but iodine-127 is not.

A radioactive substance gives out radiation randomly. The amount of radiation given out in one second is called the activity, or count rate. The time taken for a radioactive substance’s count rate to halve is called the half-life. Different substances have different half-lives.

Draw one line to match each word to its definition. You will need to use one definition twice.

<table>
<thead>
<tr>
<th>radiation</th>
<th>something that gives out radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>radioactive substance</td>
<td>the amount of radiation given out in one second</td>
</tr>
<tr>
<td>count rate</td>
<td>the time taken for the count rate to halve</td>
</tr>
<tr>
<td>half-life</td>
<td>an atom that can break down by itself</td>
</tr>
<tr>
<td>unstable atom</td>
<td>energy in the form of particles or waves that are given out by a radioactive substance</td>
</tr>
<tr>
<td>activity</td>
<td>the breakdown of an atom by giving out radiation</td>
</tr>
<tr>
<td>radioactive decay</td>
<td></td>
</tr>
</tbody>
</table>

(6 marks)