

# Development of the model of the atom

## Mark Scheme



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1. The model of the atom hasn't always looked the way it does today. It has been an incredible scientific journey that has led to our modern understanding of matter.

For each of the following questions **circle** the letter of the correct answer.

- a) Which of the following best describes the '**plum pudding**' model of the atom?

|                                        |                      |
|----------------------------------------|----------------------|
| <b>B – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

- b) In the alpha particle scattering experiment, most of the alpha particles passed straight through the gold foil without changing direction. What did this observation prove?

|                                        |                      |
|----------------------------------------|----------------------|
| <b>A – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

- c) How did Niels Bohr adapt the nuclear model of the atom?

|                                        |                      |
|----------------------------------------|----------------------|
| <b>C – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

- d) Which scientist provided the experimental evidence to prove the existence of neutrons within the nucleus?

|                                        |                      |
|----------------------------------------|----------------------|
| <b>D – is the only correct answer.</b> | <b>1 mark</b>        |
|                                        | <b>Total: 1 mark</b> |

(Total for Question 1 is 4 marks)

2. Over the last 200 years, the scientific model of the atom has changed significantly as new evidence has been discovered.

- a) Before the nuclear model was accepted, scientists believed in the '**plum pudding**' model.

Describe the plum pudding model of the atom.

|                                                                            |                |
|----------------------------------------------------------------------------|----------------|
| A description to include the following:                                    |                |
| <b>Structure:</b> A ball / sphere of positive charge.                      | 1 mark         |
| <b>Electrons:</b> With negative electrons embedded / spread throughout it. | 1 mark         |
| <b>Reject:</b> protons. (protons had not been discovered yet).             |                |
|                                                                            | Total: 2 marks |

- b) In 1909, Ernest Rutherford's team conducted the alpha particle scattering experiment.  
They fired a beam of alpha particles at a very thin piece of gold foil.

During the experiment, they observed that approximately **1 in every 8000** alpha particles bounced straight back towards the source.

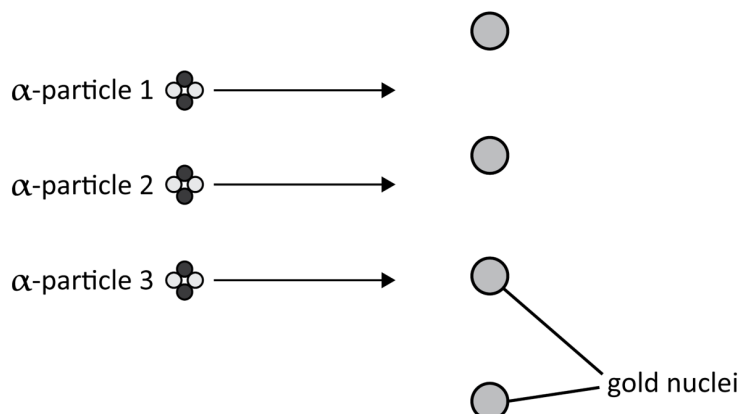
If the radioactive source emitted  $3.2 \times 10^6$  alpha particles during a test, calculate the expected number of alpha particles that would bounce straight back.

|                                                      |                |
|------------------------------------------------------|----------------|
| $3.2 \times 10^6 \div 8000$ or $3,200,000 \div 8000$ | 1 mark         |
| Final answer: 400                                    | 1 mark         |
|                                                      | Total: 2 marks |

(Total for Question 2 is 4 marks)

3. In 1909, Hans Geiger and Ernest Marsden conducted an experiment by firing  $\alpha$ -particles at a thin sheet of gold foil.

The figure below shows three of the alpha particles being fired at a layer of the gold foil. Also shown are the paths of the three  $\alpha$ -particles directed at the foil.



- a) State the result of the experiment that shows that an atom consists of a very tiny, charged core, containing almost all the mass of the atom.

|                                                                   |                |
|-------------------------------------------------------------------|----------------|
| A very small number / fraction / 1 in 8000                        | 1 mark         |
| bounced straight back / were deflected through very large angles. | 1 mark         |
|                                                                   | Total: 2 marks |

- b) Give the sign of the charge on this core.

|              |               |
|--------------|---------------|
| Positive / + | 1 mark        |
|              | Total: 1 mark |

- c) State what particle occupies the space between these charged cores.

|             |               |
|-------------|---------------|
| Electron(s) | 1 mark        |
|             | Total: 1 mark |

- d) Some of the alpha particles fired at the gold foil were reflected back.  
Why did this occur?

|                                                                                                        |                |
|--------------------------------------------------------------------------------------------------------|----------------|
| <b>Mass:</b> they hit the nucleus, which contains most of the mass / is very heavy/dense.              | 1 mark         |
| <b>Charge:</b> Both the alpha particle and the nucleus are positively charged, so they strongly repel. | 1 mark         |
|                                                                                                        | Total: 2 marks |

e) Our understanding of atomic structure has changed over time.

Compare the structure of the **plum pudding** model with the **current** (nuclear) **model** of the atom.

|                                                                                                                                                                                             |                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Any <b>four</b> valid comparisons from:                                                                                                                                                     |                       |
| <b>Charge:</b> In the plum pudding model, positive charge is spread evenly throughout, whereas in the current model, the positive charge is concentrated in the centre (the nucleus).       |                       |
| <b>Mass:</b> In the plum pudding model, mass is spread evenly throughout, whereas in the current model, the mass is concentrated in the central nucleus.                                    |                       |
| <b>Electrons:</b> In the plum pudding model, electrons are randomly embedded/scattered, whereas in the current model, electrons orbit at specific distances / in shells / in energy levels. |                       |
| <b>Empty space:</b> The plum pudding model is a solid mass / has no empty space, whereas the current model is mostly empty space.                                                           |                       |
| <b>Nucleus contents:</b> The plum pudding model does not contain protons or neutrons, whereas the current model has a nucleus containing protons and neutrons.                              |                       |
|                                                                                                                                                                                             | <b>Total: 4 marks</b> |

(Total for Question 3 is 10 marks)

4. In the early 1900s, scientists believed the atom was a plum pudding. By 1932, this had been completely replaced by the modern nuclear model. Describe how the model of the atom was developed.

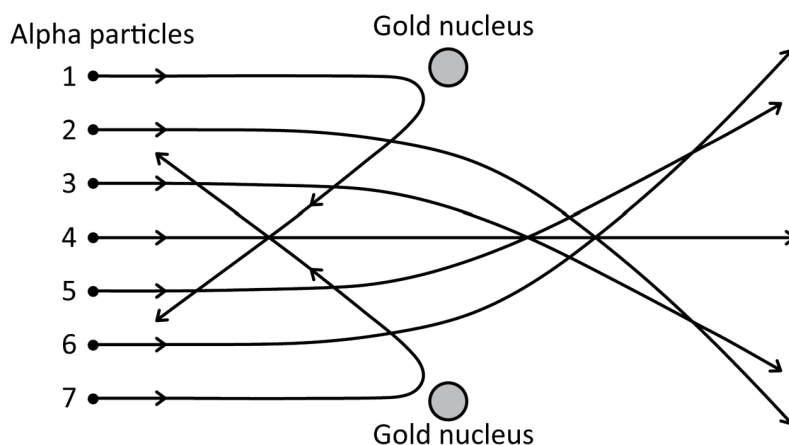
| Marking guidance |       |                                                                                                                                                                                                                                                   |
|------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Level            | Marks | Descriptor                                                                                                                                                                                                                                        |
| Level 1          | 1 - 2 | Simple, isolated statements are made.<br>The student correctly links a scientist to a model or discovery (e.g., "J.J. Thomson made the plum pudding model") but provides no further explanation.                                                  |
| Level 2          | 3 - 4 | A partially complete description.<br>The student correctly explains the contributions of 2 or 3 scientists, OR describes several models but with some scientific inaccuracy, missing details, or out of chronological order.                      |
| Level 3          | 5 - 6 | A detailed, logically sequenced chronological description.<br>The student correctly explains the discoveries and changing models across most of the timeline (must cover at least 4 key scientists/stages, including Rutherford's nuclear model). |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                |
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| Indicative content:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                |
| <p><b>1. Democritus / Ancient Greeks:</b></p> <ul style="list-style-type: none"> <li>Suggested that all matter is made of tiny, indivisible particles called atoms.</li> </ul> <p><b>2. John Dalton:</b></p> <ul style="list-style-type: none"> <li>Described atoms as solid spheres that could not be divided into smaller parts.</li> <li>Suggested that different types of spheres make up different elements.</li> </ul> <p><b>3. J.J. Thomson:</b></p> <ul style="list-style-type: none"> <li>Discovered the first subatomic particle: the negative electron.</li> <li>This proved atoms could be divided.</li> <li>He proposed the 'plum pudding' model: a ball/sphere of positive charge with negative electrons embedded randomly inside it.</li> </ul> <p><b>4. Ernest Rutherford (The Nuclear model):</b></p> <ul style="list-style-type: none"> <li>Directed the alpha particle scattering experiment (firing alpha particles at gold foil).</li> <li>Because some particles were deflected or bounced back, he concluded that the mass and positive charge of the atom were concentrated in a tiny central nucleus.</li> <li>Because most particles passed straight through, he concluded the atom was mostly empty space.</li> <li>This replaced the plum pudding model with the nuclear model.</li> </ul> <p><b>5. Niels Bohr (energy levels):</b></p> <ul style="list-style-type: none"> <li>Adapted Rutherford's nuclear model.</li> <li>Suggested that electrons do not just randomly orbit the nucleus, but orbit at specific distances / in fixed energy levels (shells).</li> <li>His theoretical calculations matched experimental observations of light given off by atoms.</li> </ul> <p><b>6. James Chadwick (The neutron):</b></p> <ul style="list-style-type: none"> <li>Conducted experiments roughly 20 years after the nucleus was accepted.</li> <li>Provided the experimental evidence to prove the existence of neutral subatomic particles called neutrons within the nucleus.</li> </ul> |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Total: 6 marks |

(Total for Question 4 is 6 marks)

5. The nucleus was discovered by Geiger and Marsden using an alpha particle scattering experiment. In this experiment alpha particles were fired at a very thin sheet of gold foil.

The figure below shows a part of the experiment in action.



- a) Explain why alpha particle 1 takes the path shown in the figure above.

|                                                                                                             |                |
|-------------------------------------------------------------------------------------------------------------|----------------|
| An explanation to include:                                                                                  |                |
| <b>Charge:</b> The alpha particle and the gold nucleus are both positively charged (so they repel).         | 1 mark         |
| <b>Position/Mass:</b> The alpha particle hits the nucleus head-on / gets very close to the massive nucleus. | 1 mark         |
|                                                                                                             | Total: 2 marks |

- b) Explain why the path of alpha particle 2 is more tightly curved than the path of alpha particle 3.

|                                                                                            |                |
|--------------------------------------------------------------------------------------------|----------------|
| An explanation to include:                                                                 |                |
| <b>Distance:</b> Alpha particle 2 passes much closer to the nucleus than alpha particle 3. | 1 mark         |
| <b>Force:</b> Therefore it experiences a stronger (electrostatic) force of repulsion.      | 1 mark         |
|                                                                                            | Total: 2 marks |

- c) Describe how the Bohr model of the atom is different from the modern nuclear model of the atom?

|                                                                                                                                           |                |
|-------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| A description to include:                                                                                                                 |                |
| <b>Neutrons:</b> The modern nuclear model includes neutrons in the nucleus.                                                               | 1 mark         |
| <b>Protons:</b> The modern model shows the nucleus is made up of protons and neutrons (rather than just a generic ball of positive mass). | 1 mark         |
|                                                                                                                                           | Total: 2 marks |

(Total for Question 5 is 6 marks)