

Development of the model of the atom

Mark Scheme



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1. Our understanding of atomic structure has evolved significantly over time, with each new model being developed to explain new experimental evidence.

- a) J.J. Thomson's 'plum pudding' model was the first to include a sub-atomic particle.

What was the particle that Thomson had discovered.

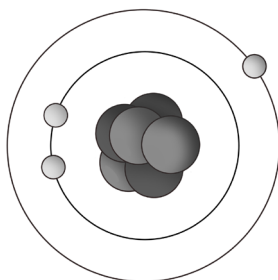
D – is the only correct answer.	(1)
	Total: 1 mark

- b) When the model of the atom was developed, scientists reviewed the work of other scientists.

Why is it important for scientists to review the work of other scientists?

A – is the only correct answer.	(1)
	Total: 1 mark

- c) The figure below of an atom shows that electrons occupy different shells around the nucleus.



Who put forward this atomic model?

D – is the only correct answer.	(1)
	Total: 1 mark

- d) Ernest Rutherford's alpha particle scattering experiment provided evidence for a new model of the atom. What was the main conclusion from this experiment?

D – is the only correct answer.	(1)
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. Our understanding of the atom has changed over time as new evidence has become available.
- a) J. J. Thomson proposed the 'plum pudding' model of the atom. This model was later disproved by the alpha particle scattering experiment.

Explain how the results of the alpha particle scattering experiment showed that the 'plum pudding' model was incorrect.

An explanation to include any three of the following:	
- Most alpha particles passed straight through the foil. - Which showed the atom is mostly empty space. (So) the mass / positive charge is concentrated in the centre / nucleus. - Some alpha particles were deflected / reflected (through large angles). (Whereas) the 'plum pudding' model suggested mass / charge was spread out. Allow references to the plum pudding model being a solid sphere of positive charge.	
	Total: 3 marks

- b) Niels Bohr adapted the new nuclear model.

Describe the main improvement that Bohr made to the model of the atom.

A description to include:	
Electrons orbit the nucleus at specific distances.	(1)
Allow electrons can only exist in fixed orbits.	
(Suggested that) electrons orbit in energy levels / shells.	(1)
Do not accept protons / neutrons in shells.	
	Total: 2 marks

- c) The model of the atom was later completed by the discovery of a final subatomic particle.

Name the scientist who discovered the neutron and explain why this discovery was important.

<u>James Chadwick.</u>	(1)
(Provided evidence to support) the existence of isotopes.	(1)
	Total: 2 marks

(Total for Question 2 is 7 marks)

3. Before the discovery of the nucleus, one popular scientific theory was the 'plum pudding' model of the atom. This model is illustrated in the figure below.

The plum pudding model had to account for the fact that atoms are electrically neutral despite containing negatively charged electrons.

- a) Describe the charge of the 'pudding' part of the atom in this model.

Any two from	
(The 'pudding' has a) positive charge.	(1)
(Which is) spread throughout (the atom).	(1)
(Which is) equal in amount to the (total) negative charge.	(1)
	Total: 2 marks

- b) Describe these unexpected results and explain the conclusion about the structure of the atom that was drawn from them.

A description to include two of the following:	
- Some alpha particles) were deflected / reflected (through large angles). (Some alpha particles) bounced back. (Which showed that) the atom has a concentrated centre / nucleus. (Which showed that) the mass / positive charge is concentrated in a small space.	
	Total: 2 marks

- c) Describe **one** feature of the experimental method that helped to ensure the conclusions were scientifically valid.

Any one of the following:	
The experiment was carried out in a vacuum.	(1)
The gold foil used was very thin (only a few atoms thick).	(1)
	Total: 1 mark

- d) Describe the structure of an atom according to the modern nuclear model.

Marks will be awarded for a clear, well-organised answer that uses specialist terms correctly.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	The response makes valid points (e.g., stating protons are positive) but is disjointed or very brief. Not all particles are discussed, or there are significant errors in positions or properties.
Level 2	3 - 4	The description is mostly relevant but may lack some detail or structure. All three particles are named, but there may be an omission regarding a specific property (e.g., missing one mass or position) or a minor inaccuracy.
Level 3	5 - 6	The description is relevant and coherent, providing a detailed structure of the atom. All three subatomic particles are identified with their correct positions, relative masses, and relative charges. There are no significant errors.

General Structure • The atom has a central nucleus. • The nucleus is very small compared to the size of the atom. • The atom is mostly empty space. Subatomic Particles & Positions • Protons are found in the nucleus. • Neutrons are found in the nucleus. • Electrons are found in shells (or energy levels) orbiting the nucleus. Relative Masses • Proton relative mass = 1 • Neutron relative mass = 1 • Electron relative mass = very small / negligible / (approx 1/2000) Relative Charges • Proton relative charge = +1 (positive) • Neutron relative charge = 0 (neutral) • Electron relative charge = -1 (negative) Additional Credit (for full coherence) • The number of protons equals the number of electrons (making the atom electrically neutral). • Most of the mass of the atom is concentrated in the nucleus.	
	Total: 6 marks

(Total for Question 3 is 11 marks)

4. The modern nuclear model of the atom replaced earlier ideas, such as J.J. Thomson's 'plum pudding' model.

a) Contrast the modern nuclear model with the 'plum pudding' model by describing **two** key differences.

Any two from:	
• Nuclear model mass is concentrated at the centre / nucleus whereas plum pudding model mass is spread out. • Nuclear model is mostly empty space whereas plum pudding model is a 'solid' mass. • Nuclear model positive charge is only in the nucleus whereas plum pudding model positive charge is spread throughout. • Nuclear model electrons orbit the nucleus / are in shells whereas plum pudding model electrons are embedded in the positive charge.	
	Total: 2 marks

Before a scientist's work, like Rutherford's on the atomic model, can be published, it must be peer-reviewed.

b) Describe the process of peer review.

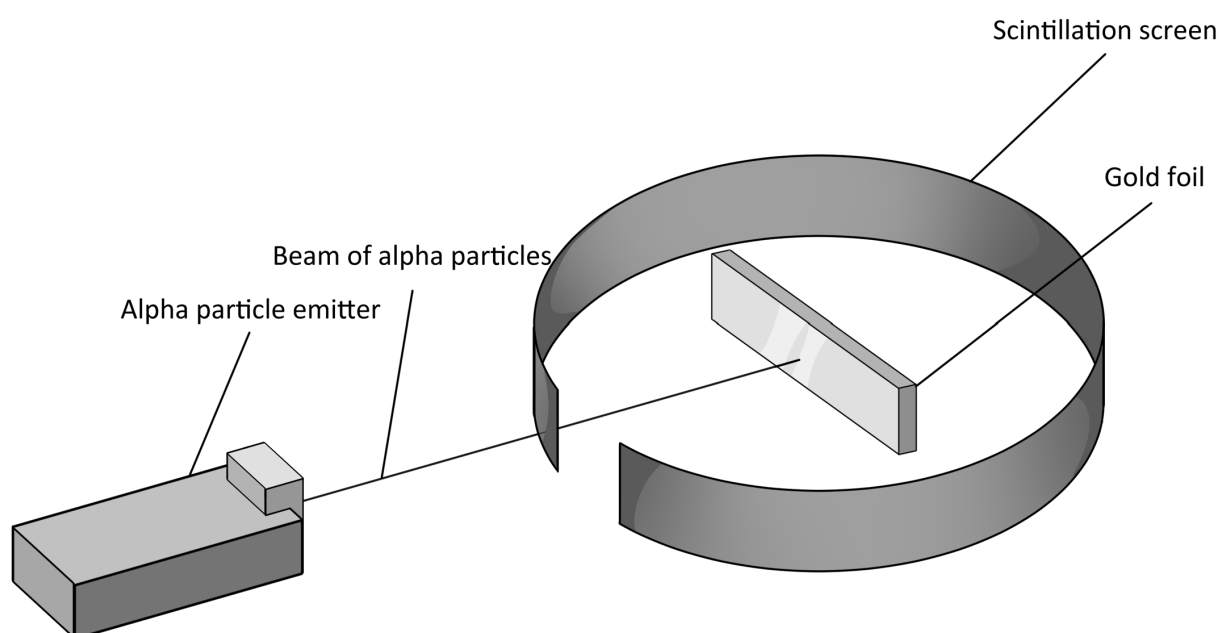
Other scientists / experts (in the same field) check the results / work.	(1)
To check if the results are valid / accurate / original	(1)
	Total: 2 marks

c) Describe the particle that Chadwick discovered and explain how it completed our understanding of the nucleus.

A description to include:	
(Discovered the) neutron.	(1)
(Which has) no charge / is neutral.	(1)
(This explained) the existence of isotopes / the extra mass in the nucleus.	(1)
	Total: 3 marks

(Total for Question 4 is 7 marks)

5. The figure below shows the setup for the alpha particle scattering experiment.



a) This experiment was designed to test the 'plum pudding' model.

Based on the plum pudding model, what path were the alpha particles expected to take after hitting the gold foil? Explain your answer.

An explanation to include:	
(Expected to) pass straight through the foil or be deflected very slightly.	(1)
(Expected to be) deflected very slightly.	(1)
Because the positive charge was thought to be spread out / distributed evenly (throughout the atom)	(1)
	Total: 2 marks

- b) The actual results of the experiment were surprising.

State **two** observations that did not match the predictions of the plum pudding model.

Any two from:	
- Some alpha particles were deflected / scattered through large angles. - A (very) small number of alpha particles were reflected / bounced back. - Fewer alpha particles passed straight through than expected.	
	Total: 2 marks

- c) Rutherford's new 'nuclear model' was a major breakthrough, but it was not perfect.

Describe **one** problem with the nuclear model that was later addressed by Niels Bohr.

(Electrons orbiting the nucleus would) lose energy / emit electromagnetic radiation.	(1)
(Causing them to) spiral into the nucleus / causing the atom to collapse.	(1)
	Total: 2 marks

- d) Explain in detail how the observations from the alpha scattering experiment led to the development of the nuclear model of the atom.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements of valid observations or conclusions are made, but they are not linked effectively (e.g., listing results without explaining what they prove).
Level 2	3 - 4	The explanation links observations to conclusions, but may lack detail or fail to cover all three aspects. For example, linking deflection to charge and empty space, but omitting mass concentration. The logic is generally sound.
Level 3	5 - 6	A detailed and coherent explanation that clearly links the specific observations from the experiment to the corresponding conclusions about the nuclear model. All three main conclusions (empty space, charged nucleus, concentrated mass) are addressed.

Indicative content:	
Observation: Most alpha particles passed straight through the gold foil. Conclusion: This showed that the atom is mainly empty space. Observation: Some alpha particles were deflected (through large angles). Conclusion: This showed that the centre of the atom must have a positive charge (to repel the positive alpha particles). Observation: A very small number of alpha particles were reflected / bounced straight back. Conclusion: This showed that the mass of the atom is concentrated in the centre (nucleus). Conclusion: This showed that the nucleus is extremely small.	
	Total: 6 marks

(Total for Question 5 is 12 marks)