The development of the model of the atom

6.4.1.3 · Physics · revision notes

How the model of the atom changed as new evidence was found: from tiny indivisible spheres, to the plum pudding model, to the nuclear model, then Bohr's energy levels, protons and neutrons. Expect 'describe', 'compare' and 'explain' questions, especially on why the alpha particle scattering experiment led to the nuclear model, and sometimes a 6-mark answer.

Key facts

- Order: tiny spheres → plum pudding → nuclear model → Bohr's energy levels → protons → neutrons (Chadwick)
- Nuclear model: tiny positive nucleus with most of the mass, electrons around it
- A few deflected through large angles → positive charge concentrated at the centre
- Bohr: electrons orbit at specific distances
- Plum pudding: ball of positive charge with electrons embedded in it
- Most alpha particles went straight through → atom is mostly empty space
- Very few bounced back → mass concentrated in a tiny nucleus
- Chadwick: evidence for neutrons

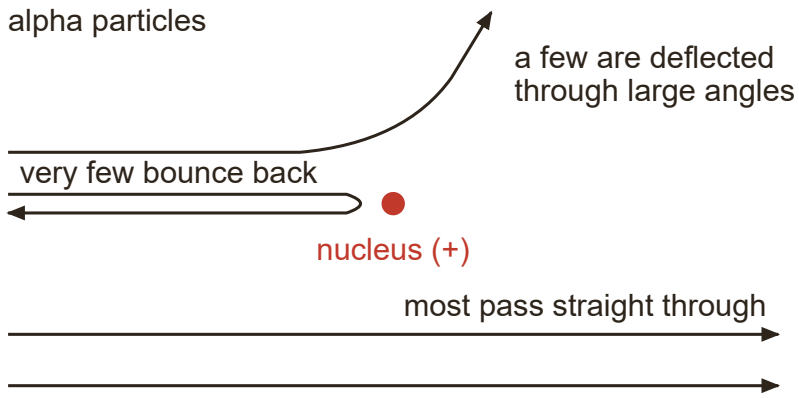
Notes

Early models

- Scientific models change when new experimental evidence cannot be explained by the old model.
- Before the electron was discovered, atoms were thought to be tiny spheres that could not be divided.
- The discovery of the **electron** showed that atoms contain smaller particles. This led to the **plum pudding model**: the atom is a ball of positive charge with negative electrons embedded in it.

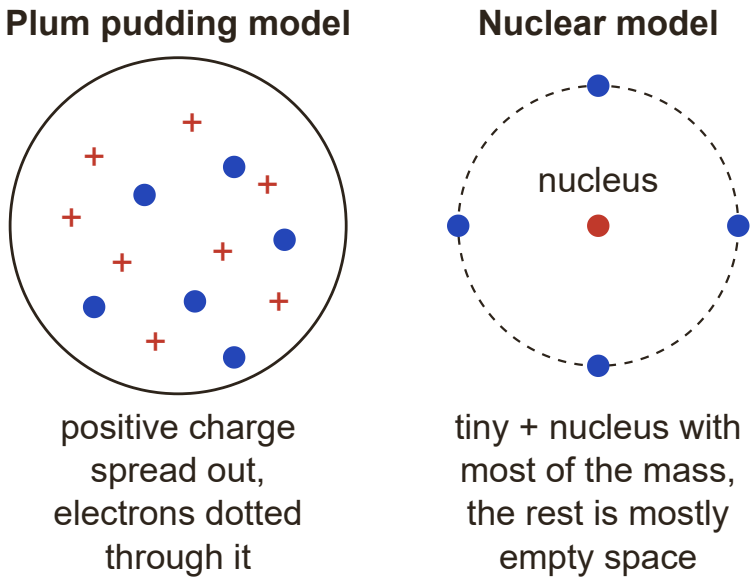
The alpha particle scattering experiment

- Positively charged alpha particles were fired at a very thin sheet of gold foil, and detectors recorded where they went.
- The plum pudding model predicted that they would all pass through with very small deflections, because the positive charge and mass were spread out.
- **Most** alpha particles passed straight through → most of the atom is **empty space**.
- A **few** were deflected through large angles → the positive charge is concentrated in a tiny region at the centre, which repels the alpha particles.
- A **very small number bounced back** → most of the mass is concentrated in that tiny region, the **nucleus**.



Paths of alpha particles near a gold nucleus (the nucleus is drawn far bigger than it really is).

- So the **nuclear model** replaced the plum pudding model: a tiny, positively charged nucleus containing most of the mass, with electrons around it.



Before and after the alpha scattering experiment (red + = positive charge, blue = electrons).

Later developments

- **Niels Bohr** adapted the nuclear model: electrons orbit the nucleus at specific distances (energy levels). His theoretical calculations agreed with experimental observations.
- Later experiments showed that the positive charge of any nucleus could be divided into smaller particles, each with the same amount of positive charge. These are **protons**.
- **James Chadwick**'s experiments provided evidence for **neutrons** in the nucleus, about 20 years after the nucleus became an accepted idea.

How to answer each type of question

Compare the plum pudding and nuclear models 2 marks **Grade 5**

1. Pick a feature: where the positive charge is, where the mass is, or empty space.
2. Say what each model says about it in the same sentence.
3. Use 'whereas' to make the comparison clear.

Example. Describe two differences between the plum pudding model and the nuclear model of the atom.

Model answer. In the plum pudding model the positive charge is spread through the whole atom, whereas in the nuclear model it is concentrated in a tiny nucleus (1). In the plum pudding model the mass is spread evenly, whereas in the nuclear model most of the mass is in the nucleus (1). Also accept: the nuclear model is mostly empty space; the plum pudding model has no nucleus.

Explain the alpha scattering observations 3 marks **Grade 5**

1. Match each observation to one conclusion.
2. Straight through → empty space.
3. Deflected → positive charge concentrated in the nucleus. Bounced back → mass concentrated in the nucleus.

Example. In the alpha particle scattering experiment, alpha particles were fired at thin gold foil. Explain what each observation shows about the structure of the atom.
(a) Most alpha particles passed straight through the foil.
(b) A few alpha particles were deflected through large angles.
(c) A very small number of alpha particles bounced back.

Model answer.

(a) Most of the atom is empty space (1)

(b) The centre of the atom (the nucleus) is positively charged, so it repels the positive alpha particles (1)

(c) Most of the mass of the atom is concentrated in a very small nucleus (1)

Explain why the model was replaced 2 marks **Grade 5**

1. Say what the old model predicted would happen.
2. Say what the experiment actually showed, and that the old model could not explain it.

Example. Explain why the alpha particle scattering experiment led to the plum pudding model being replaced.

Model answer. The plum pudding model predicted that alpha particles would pass through the foil with little or no deflection (1). Some alpha particles were deflected through large angles or bounced back, which the plum pudding model could not explain (1).

6-mark: describe how the model of the atom developed 6 marks (level of response) **Grade 5**

1. Go in time order, starting from the plum pudding model.
2. For each change, give the evidence and the new model.
3. Include the alpha scattering results and what they showed, then Bohr, protons and Chadwick.

Example. Describe how the model of the atom has changed from the plum pudding model to the model used today. Include the evidence for each change.

Model answer.

Model answer: In the plum pudding model, the atom was a ball of positive charge with negative electrons embedded in it. In the alpha particle scattering experiment, positive alpha particles were fired at thin gold foil. The plum pudding model predicted they would pass through with very little deflection. Most did pass straight through, showing that the atom is mostly empty space. But a few were deflected through large angles and a very small number bounced back, showing that the positive charge and most of the mass are concentrated in a tiny nucleus. So the nuclear model replaced the plum pudding model. Niels Bohr then suggested that electrons orbit the nucleus at specific distances, and his calculations agreed with experimental observations. Later experiments showed that the positive charge of the nucleus is made of smaller particles with the same charge, called protons. About 20 years after the nucleus was accepted, James Chadwick provided evidence that the nucleus also contains neutrons.

Level 3 (5 to 6 marks): the models described in the correct order, each change clearly linked to its evidence, including what the alpha scattering results showed.

Level 2 (3 to 4 marks): most models described in order, with some evidence given.

Level 1 (1 to 2 marks): some models named or described, with little order or evidence.

Don’t lose marks

- Describing the plum pudding model without saying the 'pudding' is positive charge.
- Saying alpha particles bounced back because they hit electrons. Electrons are far too light to turn an alpha particle back.

- Saying most alpha particles were deflected. Most went straight through; only a few were deflected through large angles.
- Mixing up the scientists: Bohr = electrons at specific distances; Chadwick = neutrons.
- Saying the old model was 'wrong' without saying what new evidence it could not explain.

More tips

Memory tricks

- Order of models: '**S**ome **P**upils **N**eed **B**etter **P**hysics **N**otes' = Spheres, Plum pudding, Nuclear, Bohr, Protons, Neutrons.
- Alpha results in three words: **through** (empty space), **deflected** (positive nucleus), **back** (mass in the nucleus).
- **Ch**adwick found the **ch**argeless particle: the neutron.

Exam technique

- For each alpha scattering observation, give the observation AND what it shows about the atom.
- In 6-mark answers, keep a clear time order and link every change to the evidence that caused it.
- 'Compare' means each point must mention both models, e.g. using 'whereas'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Put the models of the atom in order**
Tiny spheres, plum pudding, nuclear model, Bohr's energy levels, then protons and neutrons.

Grade 4 — **Describe the plum pudding model**
The atom is a ball of positive charge with negative electrons embedded in it.

Grade 5 — **Describe the nuclear model**
A tiny, positively charged nucleus containing most of the mass, with electrons around it.

Grade 5 — **Compare plum pudding and nuclear models**
Charge and mass spread out, compared with concentrated in a nucleus with empty space around it.

Grade 5 — **Explain each alpha scattering observation**
Link 'straight through', 'deflected' and 'bounced back' to what each shows about the atom.

Grade 5 — **Explain why the plum pudding model was replaced**
It predicted only tiny deflections, so large deflections needed a new model with a concentrated, charged nucleus.

Grade 7 — **Explain how new evidence changes models**
When experiments give results a model cannot explain, scientists change or replace the model.

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