Development of the model of the atom

4.1.1.3 · Atomic structure and the periodic table · 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 electron shells, protons and neutrons. Expect 'describe the differences' and 'explain how the evidence changed the model' questions, often worth 3 to 6 marks.

Key facts

- Order: indivisible spheres → plum pudding → nuclear model → Bohr (shells) → protons → neutrons
- Most alpha particles pass straight through: atom is mostly empty space
- Very few bounce back: mass concentrated in a tiny nucleus
- Chadwick: evidence for neutrons, about 20 years after the nucleus was accepted
- Plum pudding: ball of positive charge with electrons embedded in it
- Some alpha particles deflected: the nucleus is (positively) charged
- Bohr: electrons orbit the nucleus at specific distances

Notes

Why models change

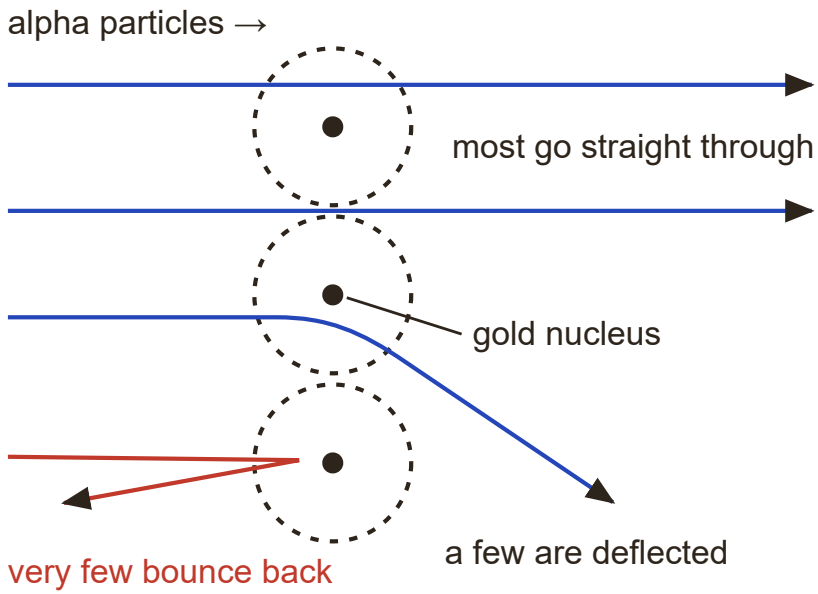
- A scientific model is changed or replaced when new experimental evidence cannot be explained by it.
- Before the electron was discovered, atoms were thought to be tiny spheres that could not be divided.

The plum pudding model

- The discovery of the **electron** showed that atoms contain even smaller, negatively charged particles, so atoms can be divided.
- This led to the **plum pudding model**: the atom is a ball of positive charge with negative electrons embedded in it. The charges balance, so the atom is neutral.

Alpha particle scattering and the nuclear model

- In the alpha particle scattering experiment, positively charged alpha particles were fired at a very thin sheet of gold.
- Most alpha particles went straight through → most of the atom is **empty space**.
- A few were deflected (changed direction) → the centre of the atom is **charged**: it is positive, because it repels the positive alpha particles.
- Very few bounced back → the mass is **concentrated in a tiny nucleus** at the centre.



Alpha scattering: the paths show that the positive charge and mass are in a tiny nucleus.

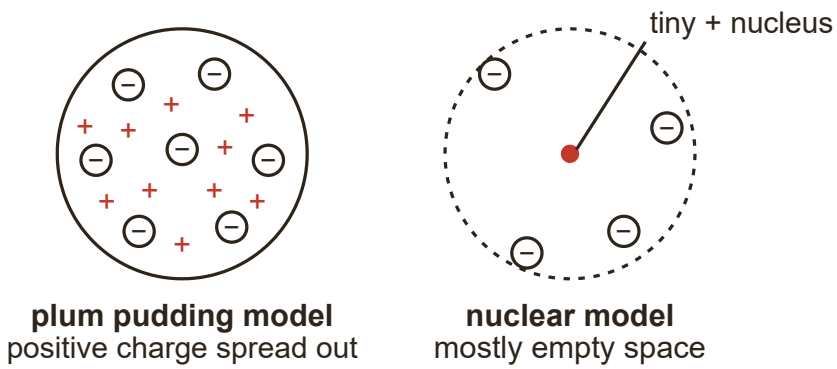
- The plum pudding model could not explain this, because its positive charge and mass are spread out. So the **nuclear model** (a tiny, positive nucleus with electrons around it) replaced it.

Bohr, protons and neutrons

- **Niels Bohr** adapted the nuclear model: electrons orbit the nucleus at **specific distances** (in shells, or energy levels). His theoretical calculations agreed with experimental observations.
- Later experiments showed that the positive charge of a nucleus can be divided into a whole number of smaller particles, each with the same positive charge. These were named **protons**.
- The experimental work of **James Chadwick** provided evidence for **neutrons** in the nucleus, about 20 years after the nucleus became an accepted idea.

Plum pudding compared with nuclear

- Plum pudding: positive charge spread through the whole atom; mass spread evenly; electrons embedded in the positive charge; no nucleus.
- Nuclear: positive charge and almost all the mass concentrated in a tiny nucleus; electrons outside the nucleus; most of the atom is empty space.



Plum pudding (left) and nuclear model (right).

How to answer each type of question

Describe the differences between the plum pudding and nuclear models

2 to 4 marks | **Grade 5**

1. Compare where the positive charge is in each model.
2. Compare where the mass is.
3. Compare where the electrons are, and whether there is empty space.
4. Write each point as a matched pair using 'but' or 'whereas'.

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

Model answer. In the nuclear model the positive charge is concentrated in the nucleus, but in the plum pudding model it is spread through the whole atom (1). In the nuclear model almost all the mass is in the nucleus, but in the plum pudding model the mass is spread evenly (1). In the nuclear model the electrons are outside the nucleus and most of the atom is empty space, but in the plum pudding model the electrons are embedded in the positive charge (1).

Explain how the alpha scattering results changed the model

3 to 4 marks | Grade 7

1. Give an observation, then its conclusion, joined with 'so'.
2. Most went straight through → mostly empty space.
3. Very few bounced back → mass and positive charge concentrated in a tiny nucleus.
4. Say why the plum pudding model could not explain the results.

Example. Scientists fired alpha particles at a thin sheet of gold.
Explain how the results showed that the plum pudding model was wrong.

Model answer. Most alpha particles passed straight through the gold (1), so most of the atom must be empty space (1). A very small number bounced back (1). This could not happen if the charge and mass were spread out, so the mass and positive charge must be concentrated in a tiny nucleus (1).

Recall scientists and what they found

1 mark each | Grade 4

1. Bohr: electrons orbit at specific distances.
2. Chadwick: evidence for neutrons.
3. You don't need details of their experiments, only what they found.

Example. (a) Name the scientist whose experimental work provided evidence for neutrons.
(b) Describe how Niels Bohr changed the nuclear model of the atom.

Model answer.

(a) (James) Chadwick (1)
(b) He suggested that electrons orbit the nucleus at specific distances / in fixed energy levels (1).

Explain why a model was accepted or replaced

1 to 2 marks | Grade 6

1. A model is accepted when predictions or calculations from it agree with experimental results.
2. A model is replaced when new evidence cannot be explained by it.

Example. (a) Suggest why other scientists accepted Bohr's model.
(b) Explain why the plum pudding model was replaced.

Model answer.

(a) His theoretical calculations agreed with experimental observations (1).
(b) New evidence from the alpha scattering experiment could not be explained by the plum pudding model (1).

Don’t lose marks

- ✗ Saying the alpha particles bounced off electrons. They were repelled by the positive nucleus.

- Writing that most alpha particles were deflected. Most went straight through.
- Describing the plum pudding model as having a nucleus.
- Getting the order wrong: Bohr's shells came after the nuclear model, and protons were identified before neutrons.
- Describing only one model when the question asks for differences.

More tips

Memory tricks

- Order of models: 'Some People Never Bake Proper Nougat' = Spheres, Plum pudding, Nuclear, Bohr, Protons, Neutrons.
- Alpha results in six words: 'most through, some bent, few back'. Then: empty space, charged nucleus, tiny massive nucleus.
- The neutral neutron was the last particle found, about 20 years after the nucleus.

Exam technique

- For 'describe the differences', write matched pairs: 'In the plum pudding model…, but in the nuclear model…'.
- For scattering questions, give each observation and then its conclusion, linked with 'so'.
- Only Bohr and Chadwick are named in the specification; you don't need details of their experiments.

What each grade needs

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

Grade 3 — **State that models change with new evidence**
A scientific model may be changed or replaced when new experimental evidence doesn't fit it.

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

Grade 4 — **Put the atomic models in order**
Indivisible spheres → plum pudding → nuclear model → Bohr's shells → protons → neutrons (Chadwick).

Grade 5 — **Describe the nuclear model**
A tiny, positively charged nucleus that contains almost all the mass, with electrons outside it.

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

Grade 7 — **Explain what alpha scattering showed**
Link each observation (most straight through, some deflected, very few bounced back) to its conclusion about the atom.

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