F1 Developing a model of the atom

This is the first lesson in an introductory course for post-16 chemistry learners covering key ideas in order of scale. Find out more about the course and approach here: rsc.li/4kGyaoN

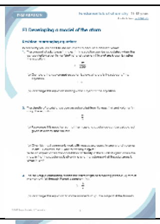
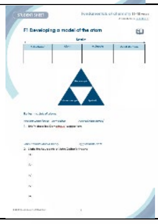
Before each lesson, ask learners to complete the preparation worksheet to revise knowledge from their 14–16 courses and introduce the topic for the lesson.

Then, get them to complete the student sheet during the lesson. It includes all key content and challenges misconceptions. Each student sheet has a scale and a Johnstone's triangle diagram at the top. Use these to help learners think about the relative scale of different aspects of chemistry and connect their understanding of sub-microscopic, macroscopic and symbolic representations.

This icon indicates that students will need access to learning materials, e.g. textbook or online resources to support their learning. See rsc.li/44UvIFi for links.

Begin each lesson by checking learners have completed the preparation work. Share the answers and ask learners to mark their own worksheets as part of their independent work.

Topics in this lesson

	**Preparation worksheet**	Revise: rearranging equations New content: sizes of subatomic particles
	**Lesson worksheet**	How the atomic model developed over time, from Ancient Greek ideas to Chadwick's discovery of the neutron
	Next lesson	F2 Counting protons, neutrons and electrons

Questions 4–6 and 13 are based on recreating the Rutherford, Geiger and Marsden gold foil experiment using a frame made from ping-pong balls and balls to throw at it (see image). If you don't have a frame handy (or a handy person prepared to build you one), see rsc.li/44UvIFi for suggestions for alternatives. Example data is given in the answers.

Answers

Revision: rearranging equations

1.

(a)

$$c = \frac{1000n}{v}$$

(b)

$$v = \frac{1000n}{c}$$

2.

(a)

$$m = d \times v$$

(b)

$$d = \frac{m \div 1000}{v \div 1{,}000{,}000}$$

$$d = \frac{1000m}{v}$$

3.

(a)

$$p = \frac{h}{\lambda}$$

(b)

$$mv = \frac{h}{\lambda}$$

$$\lambda = \frac{h}{mv}$$

$$\lambda mv = h$$

$$v = \frac{h}{m\lambda}$$

4.

$$x = 4.339 \times 10^{19}$$

New content: sub-atomic particles

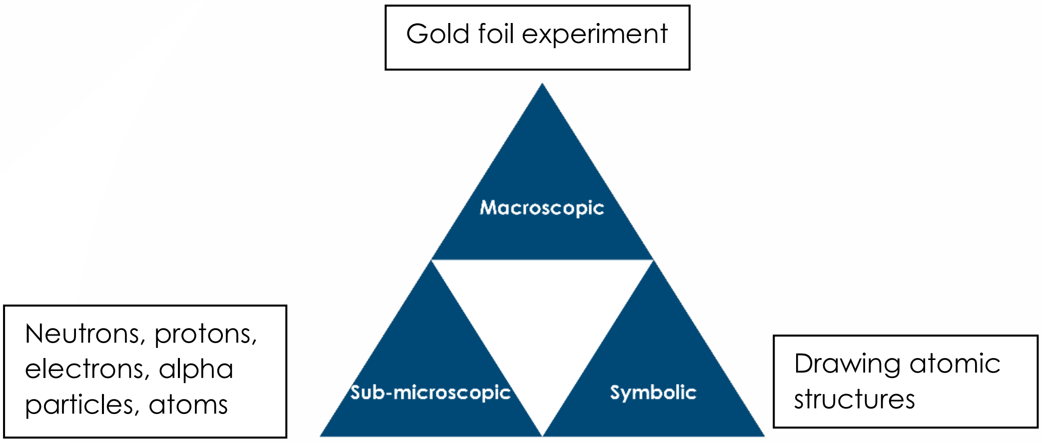
1.

Particle	Proton	Neutron	Electron
Mass (in kg)	1.673×10^{-27}	1.675×10^{-27}	9.109×10^{-31}
Charge (in coulombs, C)	$+1.602 \times 10^{-19}$	0	-1.602×10^{-19}

2. 1836.6 times
3. 1.001
4. 3677.86 electrons
5. It is opposite, but the same
6. -1

Worksheet

Sub-atomic	Atom	Molecule	Giant structure
Protons, nucleus, electrons, neutrons, alpha particles	Plum pudding nuclear atoms		Piece of gold foil



Ancient Greek ideas – Democritus **Approximate dates: 460–370 BC**

1. Democritus suggested that all matter in the universe was made up of tiny, indivisible, particles he called 'atomos'. 'Atom' means indivisible.

John Dalton's atomic theory — Approximate date: 1766–1844

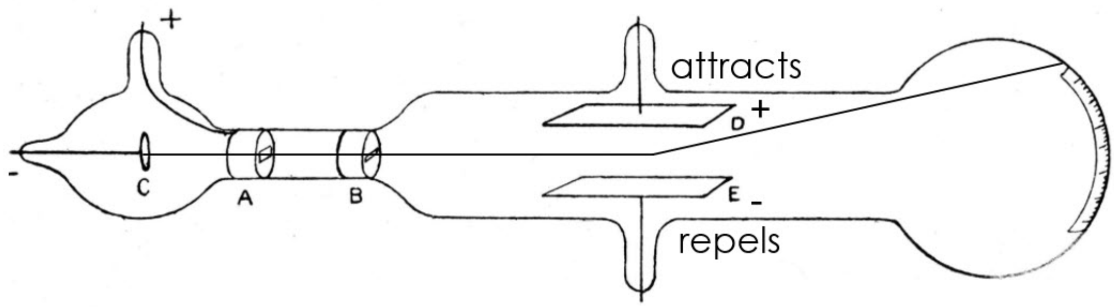
2.

(a) All matter is made of atoms, which are indivisible.
(b) Atoms cannot be created or destroyed.
(c) All atoms of one element are an identical mass/shape but different from other elements.
(d) Compounds are formed by completing different types of atom in whole number ratios.
(e) Chemical reactions are rearrangements of atoms.
(f) Atoms are the smaller units of matter that can take part in chemical reactions.

Joseph Thomson — Approximate date: 1897

3.

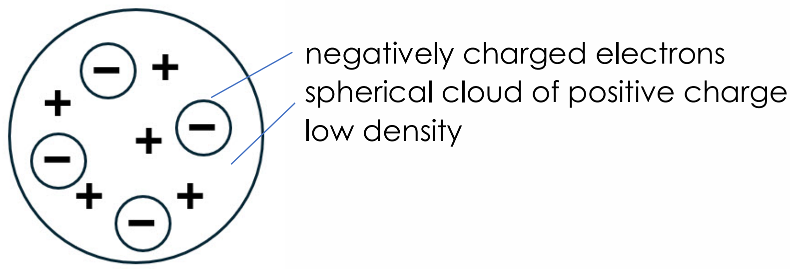
(a)



(b)
i. That the 'cathode rays' were negatively charged.
ii. How big the particles were.

(c) That they were very small and negatively charged.

(d)



Rutherford, Geiger, Marsden experiment — Approximate date: 1908–1913

4. Example answers

Total number of balls thrown	276
Total number passing through frame	225

Total number not passing through frame	51

5.

$$\frac{51}{276}$$

6.

$$\frac{\text{Area of 100 balls}}{\text{total area}} = \frac{\text{number of balls not passing through frame}}{\text{number of balls thrown}}$$

$$\frac{100\pi r^2}{1.35\ \times 1.40} = \frac{51}{276}$$

Note area will depend on the size of your frame

$$\sqrt{\frac{\left(\frac{51}{276}\right) \times 1.35\ \times 1.40}{100\pi}} = r$$

7.

(a) That all the alpha particles would travel straight through the gold foil.

(b)

$$\frac{835400}{(835400 + 503200 + 132000 + 7800 + 1435 + 477 + 211 + 70 + 52 + 43 + 33)} \times 100 = 56.4\%$$

(c) Mark should be made on the screen on the right of the image.
(d) The vast majority of particles went through the foil with only a small deflection (99.3% up to 15%).
A very small fraction was deflected through large angles.
(e) That most of the atom was empty space, so most of the particles went straight through the foil.
(f) As the nucleus is so small and dense, very few alpha particles would pass close enough to be repelled.
(g) Small dense positively charged nucleus, with mostly empty space and electrons orbiting the nucleus.

8. They would not have been deflected because they are not charged.

9. There would be much less deflection of the alpha particles because aluminium atoms only have 13 protons.

10. Radius = 160 pm
Diameter = 320 pm

$$4.0\ \mu\text{m} = 4{,}000{,}000\ \text{pm}$$

$$\frac{4{,}000{,}000}{320} = 12{,}500\ \text{gold atoms}$$

11.

$$\frac{5{,}000{,}000}{320} = 15{,}625$$

There would be more deflection of alpha particles as there are 3000 more gold atoms to go past.

12.

$$\frac{312 \times 10^{-12}\ \mathrm{m}}{11.7 \times 10^{-15}\ \mathrm{m}} = 26{,}666.6 \text{ times larger}$$

13. Suggested answers:

- Our experiment is only one 'atom' thick.
- 'Nuclei' are very large compared to 'atoms'.
- The 'alpha particles' are the same size as the 'gold nuclei'.
- There is physical contact between the ping-pong balls, not repulsion.

Moseley — Approximate date: 1912

14.

(a) The proton
(b) The proton was considered to be a physical property of the atom.
(c) There is a positive linear relationship between atomic number and the frequency of the x-rays.
(d) The frequency of the x-rays is related to the number of physical particles in the nucleus.

15. 43 – Tc – Technetium
61 – Pm – Promethium
72 – Hf – Hafnium
75 – Re – Rhenium

16.

(a) You could put charged plates above and below and see that they were not deflected.
(b) It was almost the same as a proton.
(c) Neutrons were added to the nucleus.
(d) Then the mass will be 8
(e)

$$\frac{143}{143+92} \times 100 = 60.85\% \text{ neutrons}$$

$$100\% - 60.85\% = 39.15\% \text{ protons}$$

The ratio of protons to neutrons is approx. 1:1.5 instead of 1:1