Unit 6 · Atomic Structure

ANSWER KEY · FOR TEACHERS

Full marks 42

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. cathode rays → **f.** fast electrons streaming from the negative plate of a discharge tube
2. canal rays → **g.** positive rays from a gas, passing back through holes in the cathode
3. nucleons → **d.** protons and neutrons together
4. isotopes → **e.** same atomic number, different mass numbers
5. isobars → **c.** same mass number, different atomic numbers
6. isotones → **b.** same number of neutrons, different numbers of protons

K · 3

Each carries 0.5 mark.

2 Fill in the diagram

1. radii 1 : 4 : 9 : 16
2. −0.85 eV
3. −1.51 eV
4. −3.40 eV
5. 10.2 eV ultraviolet, 122 nm
6. −13.60 eV

A · 3

Each carries 0.5 mark.

3 Multiple choice

i. **c.** neutron — K · 1

Chadwick showed that the radiation from beryllium hit by alpha particles was a stream of neutral particles with about a proton's mass: neutrons.

ii. **c.** an atom is the smallest particle that takes part in a chemical reaction — U · 1

In a chemical reaction only the outer electrons are involved and atoms are never split, so the atom is still the smallest unit of chemistry. The other three were modified by the discovery of subatomic particles, isotopes and isobars.

iii. **b.** the positive charge and mass of an atom are concentrated in a tiny nucleus — U · 1

Only a tiny, heavy, strongly charged center could turn a fast alpha particle right round, and only a few hit it because it is so small. "Most of the atom is empty space" is shown by the alpha particles that went straight through.

iv. **b.** $\frac{nh}{2\pi}$ — K · 1

Bohr's rule is $mvr = \frac{nh}{2\pi}$, with $n = 1, 2, 3\ldots$: angular momentum comes in whole-number steps of $\frac{h}{2\pi}$.

v. **c.** $^{23}_{11}\mathrm{Na}$ and $^{24}_{12}\mathrm{Mg}$ — A · 1

Sodium-23 has $23 - 11 = 12$ neutrons and magnesium-24 has $24 - 12 = 12$: the same number of neutrons, different elements. Argon-40 and calcium-40 are isobars; the carbons and the hydrogens are isotopes.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ One-twelfth of the mass of a carbon-12 atom.

b. MARKING SCHEME — K · 1

✓ Millikan, with charged oil drops (both needed).

c. MARKING SCHEME — U · 1

✓ 18.

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d. MARKING SCHEME U · 1

✓ Without it the electron would radiate and fall into the nucleus (the atom would not be stable).

5 Short answers

a. MARKING SCHEME U · 2

✓ The charges of a proton and an electron are exactly equal and opposite; neutrons have no charge.

✓ A neutral atom has as many electrons as protons, so the charges cancel.

b. MARKING SCHEME U · 2

✓ Chemical properties depend on the number and arrangement of electrons.

✓ Isotopes have the same atomic number, so the same electrons arranged in the same way.

c. MARKING SCHEME U · 2

✓ Isotopes, with an example such as chlorine-35 and chlorine-37.

✓ Isobars, with an example such as argon-40 and calcium-40.

d. MARKING SCHEME A · 2

✓ Chlorine is a mixture of isotopes (chlorine-35 and chlorine-37).

✓ Its atomic mass is their average, weighted by how common each is, so it isn't a whole number.

6 Long answers

a. ANSWER U · 4

Experiment: A beam of alpha particles from a radioactive source in a lead box with a narrow slit was directed at a very thin gold foil. A circular screen coated with zinc sulphide round the foil flashed where each alpha particle struck, and the flashes were counted through a microscope at different angles. (Diagram: the lead box and source, the beam, the gold foil, the circular zinc sulphide screen, the microscope, and paths: most straight through, a few bent, one or two bouncing back, as in Practical 12.)

Observations and conclusions:

- Most alpha particles passed straight through: most of the atom is empty space.
- Some were deflected through small or large angles: the positive charge is concentrated in a small region that repels them.
- A very few bounced back: the positive charge and nearly all the mass are in a tiny, dense nucleus at the center.

MARKING SCHEME

✓ A labeled diagram: source in a lead box, beam, gold foil, zinc sulphide screen.

✓ Most passed straight through: most of the atom is empty space.

✓ Some were deflected: the positive charge is concentrated in a small region that repels them.

✓ A very few bounced back: the positive charge and nearly all the mass are in a tiny, dense nucleus.

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b. ANSWER K · 4

Postulates (any three):

- Electrons revolve round the nucleus only in certain fixed circular orbits (stationary orbits or energy levels).
- An electron in a stationary orbit doesn't radiate energy.
- Each orbit has a fixed energy, lowest in the K shell and increasing outward.
- Only orbits in which the angular momentum $mvr = \frac{nh}{2\pi}$ are allowed.
- Energy is given out or taken in only when an electron jumps from one orbit to another: $\Delta E = E_2 - E_1 = h\nu$.

Merit (any one): it explains the stability of atoms; it explains and calculates the line spectrum of hydrogen.

Limitation (any one): it works only for atoms with one electron; it treats the electron as a particle on a fixed path, whereas an electron has no definite path.

MARKING SCHEME

✓ Any two postulates.
✓ A third postulate.
✓ One merit.
✓ One limitation.

7 Numerical problems

a. ANSWER A · 4

i. Al: 13 protons, $27 - 13 = 14$ neutrons, 13 electrons.
ii. Fe: 26 protons, $56 - 26 = 30$ neutrons, 26 electrons.
iii. Mg^{2+}: 12 protons, 12 neutrons, $12 - 2 = 10$ electrons.
iv. O^{2-}: 8 protons, 8 neutrons, $8 + 2 = 10$ electrons.

MARKING SCHEME

✓ Al: 13 protons, 14 neutrons, 13 electrons.
✓ Fe: 26 protons, 30 neutrons, 26 electrons.
✓ Mg^{2+}: 12 protons, 12 neutrons, 10 electrons.
✓ O^{2-}: 8 protons, 8 neutrons, 10 electrons.

b. ANSWER A · 2

$$\frac{10.013 \times 19.9 + 11.009 \times 80.1}{100} = \frac{199.26 + 881.82}{100} = 10.81$$

10.81. It is nearer 11 than 10 because boron-11 is about four times as common.

MARKING SCHEME

✓ $(10.013 \times 19.9 + 11.009 \times 80.1) \div 100$.
✓ Average atomic mass = 10.81.

c. ANSWER A · 3

$$\frac{62.93x + 64.93(100 - x)}{100} = 63.55$$

$$62.93x + 6493 - 64.93x = 6355 \quad \Rightarrow \quad 2x = 138 \quad \Rightarrow \quad x = 69$$

Copper-63 69%, copper-65 31%.

MARKING SCHEME

✓ The equation: $(62.93x + 64.93(100 - x)) \div 100 = 63.55$.
✓ $x = 69$.
✓ Copper-63 69%, copper-65 31%.

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8 Think

ANSWER HA · 2

Potassium-40 and calcium-40 are isobars: the same number of nucleons, but 19 and 20 protons, so they are different elements. Chemical behavior depends on the electrons, and a neutral potassium atom has 19 (2, 8, 8, 1) while calcium has 20 (2, 8, 8, 2). Potassium gives up one electron and forms K^+; calcium gives up two and forms Ca^{2+}. Equal mass says nothing about chemistry; it is isotopes, with the same number of protons, that behave the same way.

MARKING SCHEME

- ✓ They are isobars: different elements with 19 and 20 protons, so different numbers of electrons.
- ✓ Chemical behavior depends on the electrons, not the mass (potassium forms K^+, calcium Ca^{2+}).

9 Activity: Find a hidden shape with marbles

(not marked)

WHAT STUDENTS SHOULD FIND

Marbles that miss come out straight; those that hit come out at an angle, and the angles show where the edges are and whether they are flat or round. It takes many marbles to find a small object. Rutherford's problem was the same, with an object he could never lift the cardboard to see.

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- **The Giant Periodic Table** (exhibit): The elements stand in order of atomic number: step along a row and each element has one proton more than the one before it.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	11	14	15	2	**42**

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