

Inside the atom: particles and isotopes

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Each answer shows the formula, the substitution and the result in bold. Check that your numbers of protons, neutrons and electrons add up, and that every relative atomic mass lies between the lightest and the heaviest isotope.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS1-1, GCSE C1

Problem 1 Particles in the atom

Proton: charge +1, mass 1, in the nucleus.

Neutron: charge 0, mass 1, in the nucleus.

Electron: charge -1, mass about 1/1840 (almost nothing), in shells around the nucleus.

Proton +1 and 1; neutron 0 and 1; electron -1 and about 1/1840.

Problem 2 Kitchen foil in Lagos

1. Protons = atomic number = 13.

2. Neutrons = $27 - 13 = 14$.

3. A neutral atom has electrons = protons = 13.

13 protons, 14 neutrons, 13 electrons.

Problem 3 Which element?

The number of protons is the atomic number, and it fixes the element.

1. **Chlorine.**

2. **Iron.**

3. **Oxygen.**

4. **Calcium.**

Problem 4 Reading an atom diagram

1. Counting: 4 red protons, 5 grey neutrons, 4 electrons.

2. Atomic number = 4; mass number = $4 + 5 = 9$.

3. The fourth element is beryllium.

Atom X is beryllium-9: 4 protons, 5 neutrons, 4 electrons, $Z = 4$, $A = 9$.

Problem 5 Why atoms are neutral

1. A neutral atom has the same number of electrons as protons, so 29.

2. The 29 positive charges of the protons are cancelled exactly by the 29 negative charges

of the electrons.

29 electrons; the charges balance, so the overall charge is zero.

Problem 6 Complete the table

Atom	Atomic number	Mass number	Protons	Neutrons	Electrons
Potassium	19	39	19	20	19
Sulfur	16	32	16	16	16
Calcium	20	40	20	20	20
Silver	47	107	47	60	47

Neutrons: K 20, S 16; mass numbers: Ca 40, Ag 107.

Problem 7 Neon isotopes

- Neon-20: $20 - 10 = 10$ neutrons. Neon-22: $22 - 10 = 12$ neutrons.
 - Same: 10 protons and 10 electrons. Different: the number of neutrons, so the mass.
 - They are atoms of one element (same atomic number) with different mass numbers.
- 10 and 12 neutrons.**

Problem 8 Counting in ions

- Mg^{2+} : 12 protons, $24 - 12 = 12$ neutrons, $12 - 2 = 10$ electrons.
- O^{2-} : 8 protons, $16 - 8 = 8$ neutrons, $8 + 2 = 10$ electrons.
- F^- : 9 protons, $19 - 9 = 10$ neutrons, $9 + 1 = 10$ electrons.

Mg^{2+} 12, 12, 10; O^{2-} 8, 8, 10; F^- 9, 10, 10.

Problem 9 Two lithium atoms

- Both have 3 protons.
- P: $3 + 3 = 6$. Q: $3 + 4 = 7$.
- Same number of protons, different neutrons: they are isotopes, lithium-6 and lithium-7.
- They react in the same way because both have 3 electrons arranged 2,1.

P is lithium-6 and Q is lithium-7.

Problem 10 Boron mixture

$$\text{Ar} = (10 \times 20 + 11 \times 80) \div 100 = (200 + 880) \div 100 = 1080 \div 100.$$

Ar = 10.8 (between 10 and 11, nearer 11 as expected).

Problem 11 Copper from wiring

$$1. \text{Ar} = (63 \times 69 + 65 \times 31) \div 100 = (4347 + 2015) \div 100 = 6362 \div 100 = 63.62.$$

2. Copper is a mixture of two isotopes, and Ar is their weighted average.

Ar = 63.6.

Problem 12 Build the symbol

1. Mass number = $26 + 30 = 56$, so iron-56 ($^{56}_{26}\text{Fe}$).

2. Neutrons = $197 - 79 = 118$.

3. Mass number = $15 + 16 = 31$, phosphorus-31.

Iron-56; 118 neutrons; phosphorus-31.

Problem 13 Spot the errors

1. 37 is the mass number. Chlorine has 17 protons and $37 - 17 = 20$ neutrons.

2. Isotopes of a neutral element have the same number of electrons; they differ in neutrons.

3. That defines the mass number. Relative atomic mass is a weighted average of the isotope masses.

Corrected: 17 protons; same electrons; Ar is an average.

Problem 14 Gallium abundances

1. Gallium-69 is 60.1 % and gallium-71 is 39.9 %.

2. $\text{Ar} = (69 \times 60.1 + 71 \times 39.9) \div 100 = (4146.9 + 2832.9) \div 100 = 6979.8 \div 100 = 69.798$.

Ar = 69.8.

Problem 15 Unknown abundance

1. $(79x + 81(100 - x)) \div 100 = 79.9$, so $79x + 8100 - 81x = 7990$.

2. $-2x = -110$, so $x = 55$. Check: $(79 \times 55 + 81 \times 45) \div 100 = (4345 + 3645) \div 100 = 79.9$.

3. Bromine-79: $79 - 35 = 44$ neutrons; bromine-81: $81 - 35 = 46$ neutrons.

55 % bromine-79 and 45 % bromine-81.

Problem 16 Neon from three isotopes

1. $\text{Ar} = (20 \times 90.5 + 21 \times 0.3 + 22 \times 9.2) \div 100 = (1810 + 6.3 + 202.4) \div 100 = 2018.7 \div 100 = 20.187$.

2. Its weighting is only 0.3 %, so it adds only 0.063 to the total.

Ar = 20.2.

Problem 17 Heavy water

1. H_2O : $2 \times 1 + 16 = 18$. D_2O : $2 \times 2 + 16 = 20$.

2. Increase = $(20 - 18) \div 18 \times 100 = 11.1$ %.

3. Both contain hydrogen atoms with one electron, so they react in similar ways.

18 and 20; 11.1 % heavier.

Problem 18 Carbon-14 and nitrogen-14

1. Carbon-14: 6 protons, 8 neutrons, 6 electrons. Nitrogen-14: 7 protons, 7 neutrons, 7 electrons.
 2. Isotopes need the same number of protons. Here the atomic numbers differ, so they are different elements.
 3. Carbon-14 is radioactive and decays at a steady rate, so the amount left shows the age.
- C-14 6, 8, 6; N-14 7, 7, 7; not isotopes.**

Problem 19 Identify the species

1. Atomic number 17 is chlorine; charge = $17 - 18 = -1$; mass number 35: **chlorine-35 ion, Cl^-** .
2. Atomic number 20 is calcium; charge = $20 - 18 = +2$; mass number 40: **Ca^{2+}** .
3. Atomic number 13 is aluminium; charge = $13 - 10 = +3$; mass number 27: **Al^{3+}** .

Problem 20 Gold foil evidence

1. $39\,996 \div 40\,000 \times 100 = 99.99\%$.
 2. Almost all particles went straight through, so most of the atom is empty space.
 3. A positive particle bounces back only if it meets a tiny, dense, positively charged centre that repels it: the nucleus.
- 99.99 % passed through; the atom is mostly empty with a small, dense, positive nucleus.**