

1.2 Atomic structure and the periodic table

Name: _____ Class: _____ Date: _____

Total: 15 marks

KEY WORDS isotope • relative atomic mass
• successive ionisation energies • mass spectrometer

Objective

Practise Topic 2: isotopes and relative atomic mass, electronic configurations, ionisation-energy trends and their anomalies, and reading mass spectra including diatomic patterns.

1 Key knowledge and worked examples

■ Relative atomic mass

$$A_r = \frac{\sum(\text{isotope mass} \times \text{abundance})}{100}$$

■ Worked example: finding a missing abundance

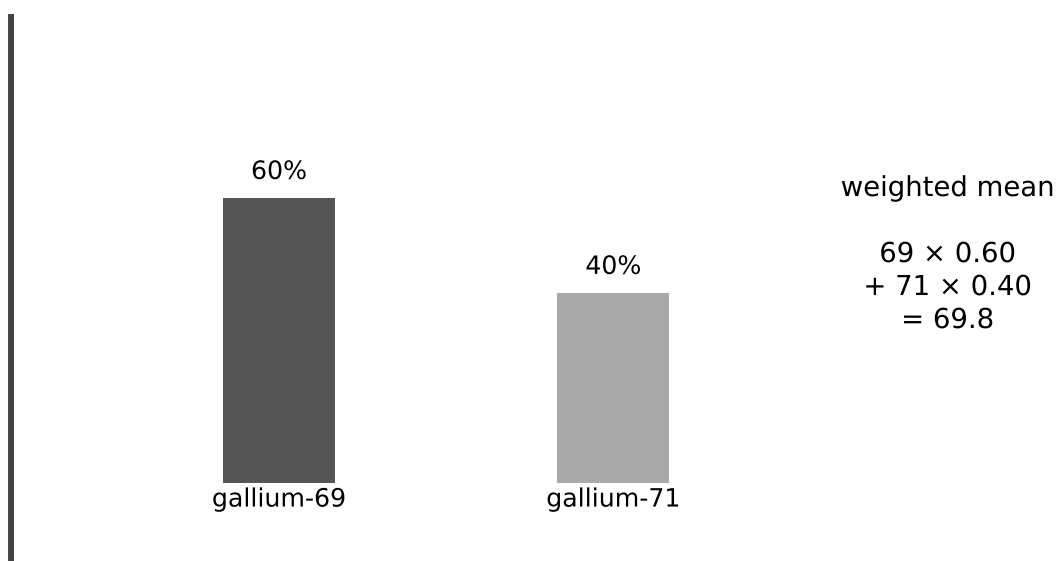
Gallium: masses 69 and 71, mean 69.8. Let x = % of 71: $(69(100 - x) + 71x)/100 = 69.8$. Simplifying gives $69.0 + 0.02x = 69.8$, so $x = (69.8 - 69.0)/0.02 = 40$. So 60% is 69 and 40% is 71.

■ Successive ionisation energies

Small rises within a shell; a big jump marks a NEW shell being opened. An element with jumps after the 2nd and 10th ionisation energies is in Group 2 of Period 3 (Mg).

■ Chlorine in the mass spectrometer

Peaks at 35 and 37 (3:1) for atoms; for Cl_2 molecules the combinations are 70, 72, 74 with heights 9:6:1 – because $P(70) = 3/4 \times 3/4$ etc..



2 Practice

2.1 State what is meant by an isotope.

[2]

2.2 Boron has A_r 10.8 from isotopes ^{10}B and ^{11}B . Calculate the percentage abundance of each.

[2]

2.3 Give the electronic configuration of a Cr^{3+} ion. (Cr: $[\text{Ar}] 3d^5 4s^1$)

[1]

3 Exam-style questions

3.1 The first seven ionisation energies of an element are 578, 1817, 2745, 11577, 14842, 18379, 23326 kJ mol⁻¹. Deduce its group from the jump. State whether the jump alone establishes its period, and explain why. [3]

3.2 Explain why the first ionisation energy of sulfur is lower than that of phosphorus, even though sulfur has the greater nuclear charge. [3]

3.3 Bromine has isotopes ⁷⁹Br and ⁸¹Br in approximately equal abundance. Predict the m/z values and relative heights of the peaks in the mass spectrum of Br₂ molecules, showing how you obtain the ratio. [4]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Atoms of the same element with the same number of protons but different numbers of neutrons.

2.2 Let $x = \%$ of ^{11}B : $(10(100-x) + 11x)/100 = 10.8 \rightarrow x = 80$. So 20% ^{10}B , 80% ^{11}B .

2.3 $[\text{Ar}] 3\text{d}^3$ – the 4s electron is lost first, then two of the 3d.

3.1 The large jump is between the 3rd and 4th ionisation energies ($11577 \gg 2745$): three electrons in the outer shell, so Group 3; these seven values show the number of outer electrons but do not by themselves count all occupied shells, so the jump alone does not establish the period. These are aluminium values, but identifying a familiar dataset is additional knowledge.

3.2 Sulfur's fourth 3p electron is the first to pair in an orbital; the inter-electron repulsion of the pair makes that electron easier to remove; the removed electrons are in the same 3p subshell with similar shielding by inner electrons. The extra repulsion explains the dip despite sulfur's larger nuclear charge.

3.3 Combinations: $79+79 = 158$, $79+81 = 160$, $81+81 = 162$. With a 1:1 abundance, $P(158) = 1/4$, $P(160) = 1/2$, $P(162) = 1/4$; peaks at m/z 158, 160, 162 in the ratio 1 : 2 : 1.