

Inside the atom: particles and isotopes

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

These model answers use the sample results. The weighted mean links the bolt model directly to the formula for relative atomic mass, and the graph shows how the average changes with the mix.

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

Question 1 Predict handful 1

Expected mass = $28 \times 4.02 + 12 \times 5.98 = 112.56 + 71.76 = 184.32$ g. Mean = $184.32 \div 40 = 4.608$ g.

Expected mean = 4.61 g, the same as measured.

Question 2 Compare with measurements

Handful 2: $25 \times 4.02 + 15 \times 5.98 = 100.50 + 89.70 = 190.20$ g (measured 190.1).

Handful 3: $31 \times 4.02 + 9 \times 5.98 = 124.62 + 53.82 = 178.44$ g (measured 178.5).

Handful 4: $22 \times 4.02 + 18 \times 5.98 = 88.44 + 107.64 = 196.08$ g (measured 196.0).

Differences: 0.1, 0.06 and 0.08 g.

Largest difference = 0.1 g, within balance resolution.

Question 3 Plot the graph

Fractions: $12 \div 40 = 0.300$; $15 \div 40 = 0.375$; $9 \div 40 = 0.225$; $18 \div 40 = 0.450$.

Points: (0.300, 4.61), (0.375, 4.75), (0.225, 4.46), (0.450, 4.90).

The points lie on a straight line rising from about 4.0 g at $x = 0$ to about 6.0 g at $x = 1$.

Question 4 Meaning of intercept and gradient

Gradient = $(4.90 - 4.46) \div (0.450 - 0.225) = 0.44 \div 0.225 = 1.96$ g. This equals $5.98 - 4.02$, the difference between the two bolt masses.

Intercept ≈ 4.02 g, the mass of one small bolt (no large bolts).

Gradient 1.96 g; intercept 4.02 g.

Question 5 Link to isotopes

- (a) Each size of bolt is like an isotope with its own mass.
- (b) The fraction of each size of bolt in the handful matches the percentage abundance.
- (c) The mean mass per bolt matches the relative atomic mass.

Bolt size = isotope; fraction = abundance; mean mass = Ar.

Question 6 Not a bolt mass

The mean is a weighted average of two masses, 4.02 g and 5.98 g, so it falls between them. No bolt weighs 4.61 g.

Chlorine is similar: its Ar of 35.5 is an average, and no chlorine atom has a mass number of 35.5.

The average falls between the two masses and matches nothing single.

Question 7 Balance uncertainty

Percentage uncertainty in total = $0.1 \div 184.4 \times 100 = 0.054 \%$.

Dividing by exactly 40 does not change the percentage, so the mean mass also has 0.054 % uncertainty, about ± 0.002 g.

0.054 %, so the mean is 4.61 ± 0.003 g (rounded).

Question 8 Estimate an unknown mixture

Mean = $192.0 \div 40 = 4.80$ g. Fraction = $(4.80 - 4.02) \div 1.96 = 0.78 \div 1.96 = 0.398$, so about 40 % large bolts.

Improvement: use more handfuls of different sizes and a balance reading to 0.01 g.

About 40 % large bolts.