Question Types and Key Concepts

The nine question types that show up again and again on a first-unit chemistry assessment — what each one is really testing, how to answer it for full credit, and the concept underneath. Written to be usable no matter whose worksheet is in front of you.

> **How to use it.** Cover the answers and, for each type, say the **key concept** out loud before you work anything. On an exam, naming the concept is what tells you which move to make. If you can do that for all nine, you are ready.

1. Mass vs. volume (and mass vs. weight)

Learning target: define mass and volume, with units

What it looks like: "What is the difference between the mass of an object and its volume?" Sometimes with a follow-up about weight.

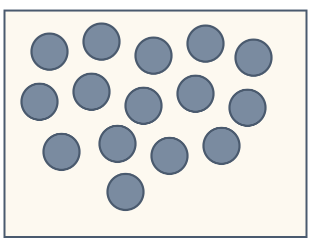
Mass is the amount of *matter* in an object — how much "stuff" it contains. Unit: **grams (g)**.
Volume is the amount of *space* the object takes up. Unit: **mL** or **cm³**.
Two objects can have the same volume and wildly different masses — a block of foam and a block of lead — which is exactly why both words are needed, and why dividing one by the other gives something useful.
★ **The trap:** writing "mass is the weight." Weight is the *force of gravity* on an object and changes on the Moon; mass is the amount of matter and does not. Different quantities, different units.

KEY CONCEPT **Mass and volume are independent properties.** Mass counts particles; volume measures the space they occupy. Density is the ratio that links them.

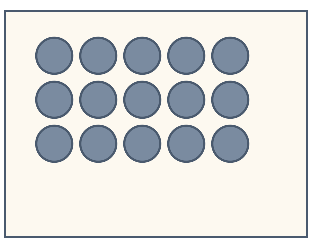
2. Particle diagram: liquid → solid

Learning target: particle diagrams for solids, liquids and gases

What it looks like: A box of atoms in the liquid phase is given; you draw the same atoms as a solid in an empty box beside it.



LIQUID
15 atoms, touching but jumbled



SOLID
the same 15 atoms, ordered rows

What has to be true:

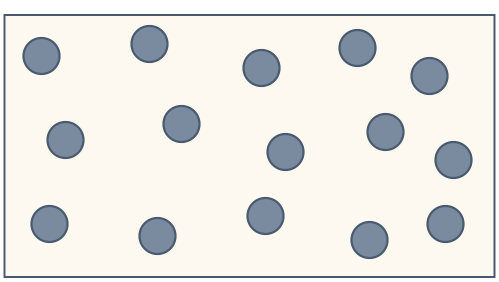
- **Same number of atoms** — nothing added, nothing removed.
- **Closer together** and in a **regular, repeating arrangement**.
- Same-size atoms — atoms never shrink; the *gaps* shrink.
- Slightly **smaller volume**, because for most substances the solid is denser than the liquid.

KEY CONCEPT **A phase change rearranges particles; it never creates or destroys them.** A denser phase is drawn as the same count packed into less space. (Water is the famous exception — ice is *less* dense than liquid water, which is why it floats.)

3. Particle diagram: the gas phase

Learning target: particle diagrams for solids, liquids and gases

What it looks like: "How would you represent the same atoms in the gaseous phase?"



GAS — the same 15 atoms, far apart, in a much larger box

Still the same atoms, but now:

- separated by **large empty spaces** — the box is mostly nothing
- arranged **randomly**, not touching
- filling a **much bigger volume**

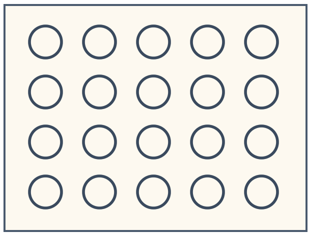
Same mass in a far larger volume means **much lower density** — that is the whole point of the drawing.

KEY CONCEPT **Gases are mostly empty space.** Solid > liquid > gas in density for almost every substance, and the drawing has to show it.

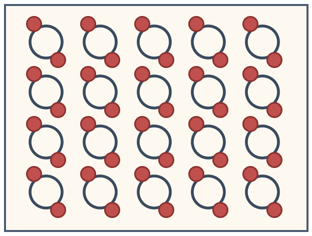
4. Burning metal in open air

Learning target: law of conservation of mass

What it looks like: A box of iron atoms in steel wool is given; you draw what it looks like after strong heating in air, and explain why the mass went up.



BEFORE
20 iron atoms



AFTER
same 20 iron atoms + oxygen bonded on

The move that earns the credit: add **new oxygen atoms from the air**, drawn in a different size or shade and **attached** to the iron — not floating loose.

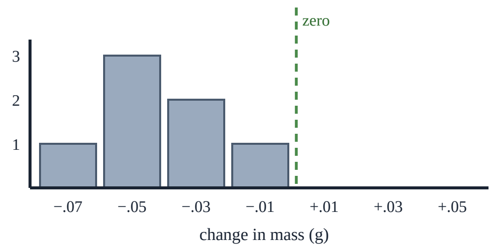
The sample **gains** mass because it now contains iron atoms *plus* oxygen atoms that were previously in the air. No iron was created and none was destroyed.

KEY CONCEPT **Conservation of mass in an open system.** If the measured mass changes, matter crossed the boundary. Burning in open air *adds* oxygen, so mass goes up. Sealed, the total would not change at all.

5. A histogram of a measured change

Learning target: represent and interpret class data

What it looks like: Class data for the change in mass during some process, with a conclusion offered that you have to accept, fix, or replace.



Ask two questions, in this order.
1. How big is the change compared with the instrument's uncertainty? A spread of a few hundredths of a gram, on balances uncertain by 0.01–0.1 g, is **experimental error**. A spread of a whole gram is not.
2. Do the readings scatter around a value, or all sit to one side? Scatter straddling zero is random error. A distribution sitting entirely on one side points to a **systematic** cause — material lost in transfer, or gas escaping.

For the case shown (small, mostly negative, reaching zero): the mass did not really change. Dissolving or mixing is a physical change; the particles are all still there. The slight negative lean is best explained by small losses during transfer — grains left on the weighing paper — on top of ordinary balance uncertainty.
Exam-language conclusion: “Within experimental error the mass did not change. The small negative readings are best explained by minor losses during transfer, not by matter disappearing. The result is consistent with the law of conservation of mass.”

Contrast: if the bars sat at about −1.0 g and none reached zero, that *is* a real change — and the answer would be that a gas formed and escaped an open container.

KEY CONCEPT **Telling experimental error from a real change.** Small and scattered means error. Large and one-sided means something physical happened. Say which, and why, in the same sentence.

6. Liquid volume vs. container volume

Learning target: $1\ cm^3 = 1\ mL$

What it looks like: A graph of how much liquid a container holds (mL) against its measured inside volume (cm^3), with a best-fit slope near 1.

The slope comes out at about **1 mL per cm^3**, which says that every 1 cm^3 of container space holds 1 mL of liquid — **cm^3 and mL measure the same amount of space**. The two units are interchangeable, which is why density can be written g/mL or g/cm^3 without converting anything.
You would expect the slope to be exactly **1.00**. Anything slightly off (0.995, 1.02) is ordinary measurement error in the ruler and the cylinder.

KEY CONCEPT **1 cm^3 = 1 mL, exactly.** On a proportional graph, the slope is the conversion factor between the two axes.

7. The mass vs. volume graph

Learning target: determine density from a graph

What it looks like: A mass-vs-volume graph with a fitted line, usually given as ***M = mV + b****, followed by four or five parts.*

a) Write the equation. Copy the fit with the real quantities in place: e.g. **M = 0.900V − 0.420**, mass in g, volume in cm^3. It is just y = mx + b.

b) What does the slope tell you? The slope **is the density**. Say it in words for full credit: *"every 1 cm^3 of this substance has a mass of 0.900 g."* "It's the density" alone often earns only half.

c) What about the y-intercept? It **should be zero** — no volume must mean no mass. A nonzero value is a statement about the **experiment**, not the substance: a balance not tared, samples weighed in a container, or dimensions measured on the outside. Negative and positive intercepts both have plausible causes.

d) Sink or float in water? Compare the slope with **1.00 g/cm^3**. Below it floats, above it sinks. *Quote both numbers* — a bare "it floats" is not a defended answer.

e) Predict the mass of a given volume. Substitute into the equation. If the volume is larger than anything they measured, you are **extrapolating** — trusting the model past the data — which is only legitimate because density does not change with sample size.

KEY CONCEPT **Slope of mass vs. volume = density.** Steeper means denser. Compare to the water line to predict sink or float. A nonzero intercept is always about the experiment, never about the substance.

8. Density as a conversion factor

Learning target: use density to convert mass ↔ volume

What it looks like: "X has a density of D. What volume does m grams occupy?" — or the same question run the other way.

Decide which one you want, then pick the form:

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want density → D = m ÷ V   |   want mass → m = D × V   |   want volume → V = m ÷ D
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Worked: mercury is 13.6 g/mL; find the volume of 112.0 g.

`V = 112.0 ÷ 13.6 = 8.2353... →` **8.24 mL** (3 sig figs, limited by 13.6)

Always sanity-check. Mercury is 13 times denser than water, so 112 g of it must take up far *less* than 112 mL. 8.24 mL is about a tablespoon and a half — believable. If you had multiplied instead, you would have got 1520 mL, which is a large bottle of a liquid metal. Absurdity is the fastest error check there is.

KEY CONCEPT **Density is a conversion factor between mass and volume.** Want mass, multiply. Want volume, divide. The physical sanity check catches the wrong operation instantly.

9. Is it pure? Identifying by density

Learning target: density is a characteristic property

What it looks like: A sample with a given mass and volume, plus the accepted density of some metal, and the question of whether it really is that metal.

Three steps, and the third is where the points are.

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1) Calculate: D = m ÷ V
2) Compare explicitly with the accepted value
3) State the verdict in a sentence
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Worked: a gold-coloured cube, V = 54 cm^3, m = 980 g. D = 980 ÷ 54 = **18 g/cm^3** (2 sig figs, limited by 54). Pure gold is 19.3 g/cm^3. At about 6% low, that is far outside measurement error, so **it is not pure gold** — most likely an alloy or a lighter metal with gold plating.

Students who compute 18 and stop lose the last points. Finish the sentence.

KEY CONCEPT **Density is a fingerprint.** It does not depend on sample size, so a measured density can be compared directly against a table to identify a substance or catch a fake. Colour cannot do this; density can.

10. The 5% rule for a y-intercept NOT ALWAYS TESTED

Learning target: judging whether an intercept is real

*What it looks like: "Show, using the 5% rule, whether this intercept is negligible." **Many teachers skip this entirely — check your own class notes first.***

The rule: compare the size of the intercept with 5% of the largest value on that axis. Under 5% it is buried in the experimental scatter and can be treated as zero.

`Example A: intercept −0.420 g, largest mass on the graph ≈ 22 g. 5% of 22 = 1.1 g. 0.42 < 1.1` → **negligible**

`Example B: intercept +1.4 g, largest mass 25 g. 5% of 25 = 1.25 g. 1.4 > 1.25` → **not negligible — must be explained**

A second argument strengthens the first: if the RMSE (the typical scatter of points about the line) is *larger* than the intercept itself, the intercept is smaller than the noise in the data.

KEY CONCEPT **A negligible intercept means the line passes through the origin**, so mass and volume are directly proportional and the constant of proportionality is the density.

Where to go when one of these is shaky

Question type	Key concept	Review deck slide	More practice
1	Mass vs. volume vs. weight	Slide 3	Practice Q1 · Baseline Q1
2, 3	Particle diagrams for phases	Slide 6	Practice Q7 · Baseline Q2, Q3
4	Conservation of mass, open system	Slide 5	Practice Q6 · Workbook §7
5	Error vs. a real change	Slide 9	Practice Q8 · Workbook §8
6	1 cm^3 = 1 mL	Slide 4	Workbook §1
7	Slope of mass vs. volume = density	Slides 15–16	Practice Q9 · Workbook §6
8	Density as a conversion factor	Slide 18	Practice Q11 · Workbook §10–11
9	Density as a fingerprint	Slide 17	Practice Q12 · Workbook §9
10	Intercepts and the 5% rule	Slide 16	Workbook §6e

The fastest useful drill. Cover this page and, for each of the nine types, say the key concept out loud before working anything. Naming the concept is what tells you which move to make — and it takes two minutes once the material is learned.