CHEMISTRY CONCEPT PACKET • UNIT 1

Mass, Volume & Density

Everything you need to understand *before* tackling Worksheet 3 — explained with pictures, one idea at a time.

> **HOW TO USE THIS PACKET**
> Read each page in order. Every idea builds on the one before it. When you hit a green **"Try it"** box, actually try it with a pencil — that's where the understanding happens. Answers to the Try-it problems (not your worksheet!) are at the bottom of the last page.

Idea #1 — Everything is made of particles

Chemists picture all matter — solids, liquids, gases — as being made of **tiny particles** (atoms or molecules), way too small to see. In diagrams, we draw them as dots. This "particle view" is the secret weapon for this whole unit: almost every question can be answered just by **looking carefully at the dots**.

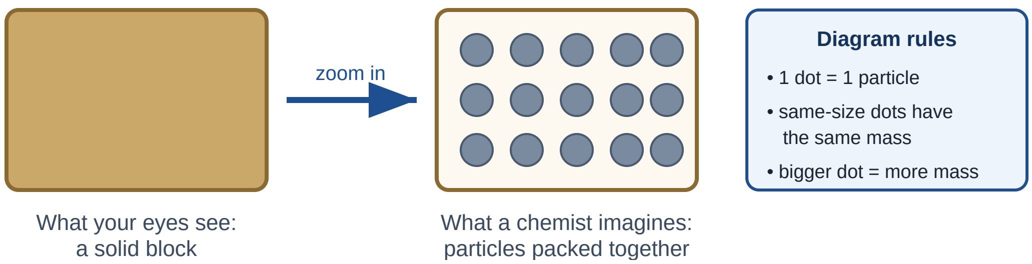

Fig. A — The same block, seen two ways. Worksheet diagrams show you the "zoomed-in" particle view.

Idea #2 — Mass: how much stuff

Mass = the amount of matter ("stuff") in an object. Measured in **grams (g)**.

In a particle diagram, mass is easy: **count the dots**. More dots (of the same size) = more mass. Ten identical particles always have twice the mass of five, no matter how spread out or squished together they are.

> **ANALOGY**
> Mass is like the number of people in a room. It doesn't matter if they're crowded near the door or spread along the walls — 20 people is 20 people.

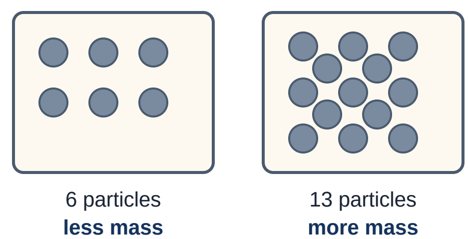

Fig. B — Count dots to compare mass.

Idea #3 — Volume: how much space

Volume = the amount of **space** an object takes up. Measured in **milliliters (mL)** or **cubic centimeters (cm^3)**.

In a particle diagram, volume is the **size of the box** — not the dots! A big box has a big volume even if it's nearly empty. A small box has a small volume even if it's crammed full.

> **COMMON MIX-UP**
> Volume has *nothing to do with how many dots there are*. Only the size of the container/object matters. Dots = mass. Box = volume.

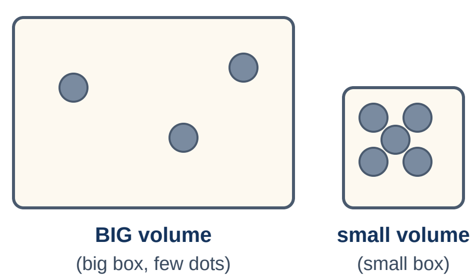

Fig. C — Volume is about the box, not the dots.

Idea #4 — Density: how crowded the stuff is

Density tells you how much mass is packed into each unit of space. It answers: *"How crowded are the particles?"*

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad D = m / V \qquad \text{units: } \mathbf{g/mL} \ \text{(grams } \textit{per} \text{ milliliter)}$$

ANALOGY — THE CROWDED PARTY

Imagine two rooms at a party. Room 1 is a small closet with 10 people inside. Room 2 is a gym with 10 people inside. Same number of people (same "mass"), but the closet is way more *crowded* — it has a higher "people density." Density = people ÷ room size. In chemistry: mass ÷ volume.

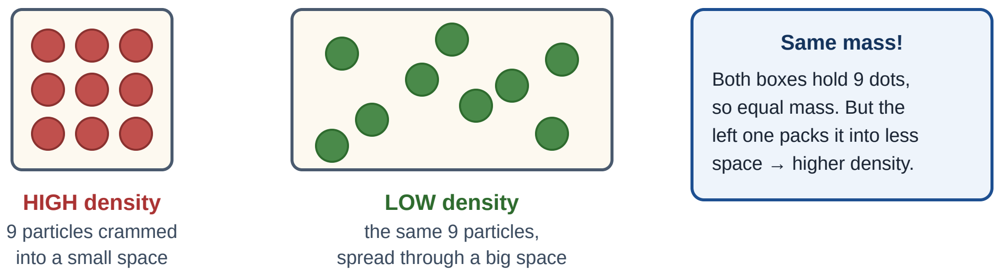

Fig. D — Density compares crowding, not just amount.

How to compare two particle diagrams — a 3-step routine

To compare…	Look at…	Ask yourself…
Mass	the number of dots (and their size)	"Which has more particle-stuff in total?"
Volume	the size of the box only	"Which takes up more space?"
Density	the *crowding* — dots per amount of space	"If I look at equal-sized chunks of each, which chunk holds more dots?"

Worked example (not from your worksheet)

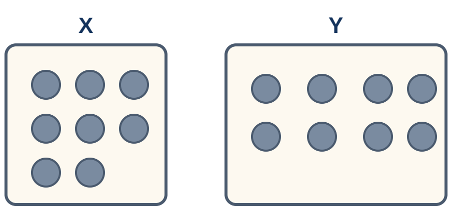

Fig. E — Boxes X and Y (all dots identical).

Mass: X has 8 dots, Y has 8 dots → masses are **equal**.
Volume: Y's box is clearly bigger → Y has **more volume**.
Density: same mass squeezed into less space → X is **denser**.

Notice how each answer used a *different feature* of the picture. That's the whole game.

THE MOST IMPORTANT IDEA IN THIS UNIT

Density is a property of the **substance**, not the amount. A drop of water and a swimming pool of water have wildly different masses and volumes — but the **same density** (1.00 g/mL), because water is equally "crowded" everywhere. So: two objects made of the same material always have the *same density*, no matter their size. In diagrams, same material = same crowding pattern.

TRY IT #1

Draw two boxes: box P is small with 6 dots almost touching; box Q is twice as wide with 12 of the same dots, spaced the same way (same crowding). Compare mass, volume, and density of P vs Q using <, >, or =.

Idea #5 — When the dots are different sizes

Some diagrams use **bigger dots** to mean **heavier particles**. Then you can't just count — you have to weigh the picture in your head: *total mass = (number of dots) × (mass of each dot)*.

Two boxes can hold the same *number* of particles, but if one box's particles are big and heavy, that box holds more mass in the same space → it's **denser**.

> **ANALOGY**
> A gym with 12 elephants is more "massive" than a gym with 12 cats — same headcount, very different total mass. Same-size rooms → the elephant room is denser.

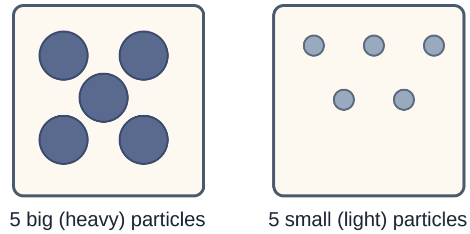

Fig. F — Same box size, same count — but the left box is denser because each particle weighs more.

Idea #6 — Thinking with a two-pan balance

A two-pan balance is a see-saw: **the heavier side drops**. Equal masses → it stays level. The trick in balance questions is to figure out the *mass on each pan* before deciding what happens.

Fig. G — A balance only "feels" mass. It knows nothing about volume.

> **THE BALANCE TRAP**
> **Equal masses** of two different substances → balance is level. Boring but true.
> **Equal volumes** of two different substances → the *denser* one packs more mass into that volume, so **the denser side drops**. Ask: "same scoop size — whose scoop weighs more?" The denser substance's scoop.

Idea #7 — Sink or float?

Drop an object in water and it's a density contest against water (**1.00 g/mL**):

- Density **greater than 1.00 g/mL → sinks** (more crowded than water)
- Density **less than 1.00 g/mL → floats**
- Exactly 1.00 → hovers, like a fish that gave up

Mass alone tells you *nothing*: a 50,000 kg ship floats; a 5 g pebble sinks. Only **density** decides.

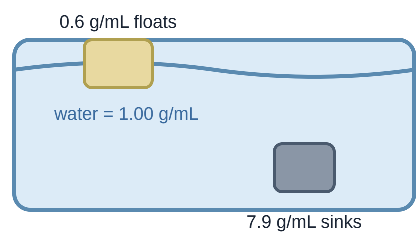

Fig. H — Beat 1.00 g/mL and you sink.

> **TRY IT #2**
> A candle (density 0.93 g/mL) and a marble (density 2.5 g/mL) are dropped into water. Predict what each does, then explain it in one sentence using the word "crowded."

Idea #8 — The mass-vs-volume graph (the star of the show)

Take a substance, measure the mass of different-sized samples, and plot **mass (y-axis)** against **volume (x-axis)**. You always get a **straight line through (0, 0)** — because zero stuff has zero mass, and doubling the sample doubles both mass and volume.

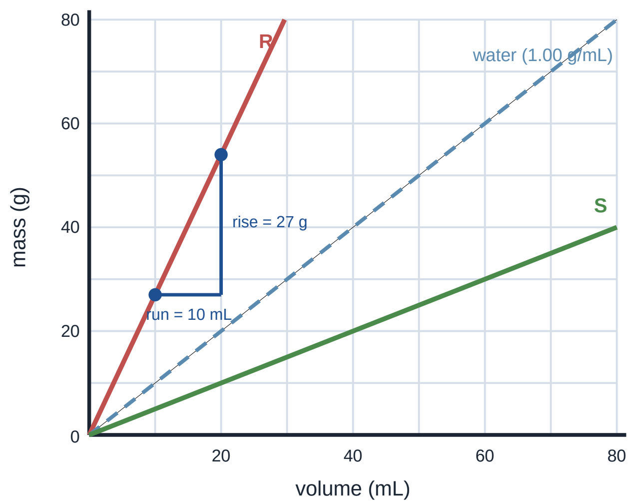

Fig. I — Two substances, R and S, plus the water line for reference.

What the slope means

Slope = rise ÷ run = **grams per mL** … wait, that's exactly the unit of **density**!

KEY FACT

The slope of a mass-vs-volume line IS the density of the substance.
Steeper line → denser substance.

Worked example (line R)

Pick two easy-to-read points on R: (10 mL, 27 g) and (20 mL, 54 g).

slope = (54 − 27) g ÷ (20 − 10) mL
= 27 g ÷ 10 mL = **2.7 g/mL**

Meaning in words: *"every 1 mL of substance R has a mass of 2.7 grams."* (That's the density of aluminum, by the way.)

Reading the graph like a pro

Question type	How to answer with the graph
Which substance is denser?	The **steeper** line. (R beats S above.)
Sink or float in water?	Compare to the water line: **steeper than water → sinks**; shallower → floats. R sinks, S floats.
"What's the mass of 30 mL of S?"	Find 30 on the volume axis, go up to line S, read across to the mass axis.
"What volume of R has mass 54 g?"	Find 54 on the mass axis, go across to line R, read down to the volume axis.
Equal volumes on a balance — who wins?	Pick one volume, read both masses straight up. The higher line (denser) is heavier → that pan drops.

SKETCHING A LINE WHEN YOU'RE GIVEN THE DENSITY

To draw a line for a substance of density, say, 1.00 g/mL: start at (0, 0), then move right and up in matching steps — (10, 10), (20, 20), (40, 40) — and connect with a ruler. For density 2 g/mL, the points would be (10, 20), (20, 40)… mass is always *density* × *volume*.

TRY IT #3

Using Fig. I: (a) find the slope of line S with two points and state its physical meaning; (b) what mass of S would balance 10 mL of R on a two-pan balance? Explain how you used the graph.

Idea #9 — The density triangle: one formula, three questions

Cover up the thing you want, and the triangle shows you the math:

- Want **density**? Cover D → *m over V* → **divide**: D = m ÷ V
- Want **mass**? Cover m → *D next to V* → **multiply**: m = D × V
- Want **volume**? Cover V → *m over D* → **divide**: V = m ÷ D

SANITY-CHECK TRICK

Density is a "price tag": gold "costs" 19.3 grams per mL. So 5 mL of gold "costs" 5 × 19.3 = 96.5 g. And if you have 38.6 g of gold, you can "afford" 38.6 ÷ 19.3 = 2 mL. If your answer feels absurd (a ring with the mass of a car), you probably divided when you should have multiplied.

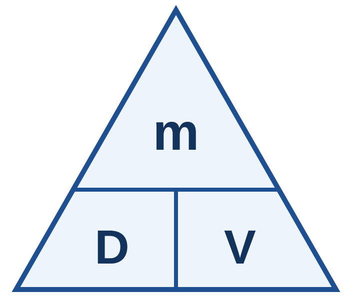

Fig. J — Cover what you want; what's left is the recipe.

Idea #10 — Cubes, cm³, and mL

Volume of a cube = **side** × **side** × **side**. A cube 3.00 cm on every side: 3 × 3 × 3 = **27.0 cm³**.

FREE CONVERSION

1 cm³ = 1 mL. Exactly. They're two names for the same amount of space (a sugar-cube's worth). So 27.0 cm³ = 27.0 mL — no math needed. That's why density tables can say g/mL and g/cm³ interchangeably.

Once you know a cube's volume, its mass comes from the price-tag move: **mass = density × volume**. Example: a 27.0 cm³ cube of aluminum (D = 2.70 g/cm³) → m = 2.70 × 27.0 = **72.9 g**.

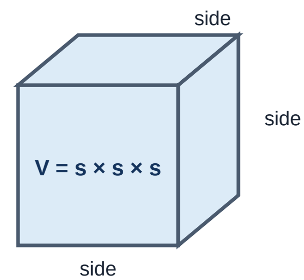

Fig. K — Three sides multiplied, and cm³ = mL for free.

Idea #11 — Using a density table to identify a mystery substance

Every substance has its own characteristic density — it works like a fingerprint. If you can measure an object's mass and volume, you can calculate its density and **look it up** to figure out what it's made of (or catch a fake!).

Substance	Density (g/mL)
Aluminum	2.70
Zinc	7.13
Iron	7.87
Copper	8.96
Silver	10.50
Lead	11.35
Gold	19.30

The 3-step fingerprint check

1. Measure the mass (grams) on a balance.
2. Measure the volume (mL) — next page shows the sneaky way to do this for weird shapes.
3. Divide: D = m ÷ V, then find the closest match in the table.

If someone claims a bracelet is pure silver but its density comes out near 7.87 g/mL… the table says it's actually **iron**. Density doesn't lie: you can't fake how crowded your atoms are.

WATCH OUT

Don't round too early! Keep all your digits until the final division, then compare. 8.96 vs 7.87 is an easy call, but sloppy rounding can blur two nearby metals.

TRY IT #4

A metal cube is 3.00 cm on each side and has a mass of 242 g. (a) Find its volume in cm³ and in mL. (b) Calculate its density. (c) Which metal in the table is it?

Idea #12 — Measuring volume of a weird shape: water displacement

You can't use $s \times s \times s$ on a ring, a rock, or a crown. Instead, dunk it! An object pushed underwater **shoves aside exactly its own volume** of water — so the water level rises by the object's volume.

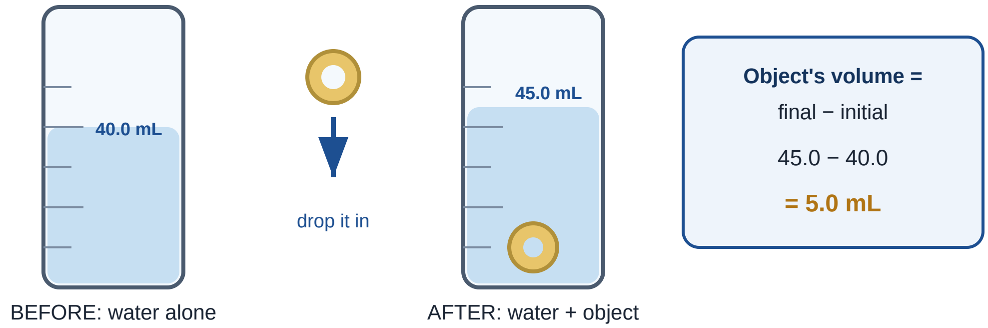

Fig. L — The rise in water level IS the object's volume. (Read the bottom of the curved water surface, called the meniscus, at eye level.)

Putting it ALL together — one full worked example

THE PENDANT PROBLEM (WORKED START TO FINISH)

A street vendor sells Maya a pendant, swearing it's **pure copper**. Maya measures: mass = **44.8 g**. She fills a graduated cylinder to **40.0 mL**, drops the pendant in, and the water rises to **45.0 mL**.

Step 1 — Volume (displacement): V = 45.0 − 40.0 = **5.0 mL**
Step 2 — Density (the fingerprint): D = m ÷ V = 44.8 g ÷ 5.0 mL = **8.96 g/mL**
Step 3 — Look it up: the table says copper = 8.96 g/mL. **Match!** The vendor told the truth.

Notice the shape of the argument: measure two things → divide → compare to the table → verdict, defended with numbers. That's exactly the reasoning your worksheet wants — with its own numbers, which will tell their own story…

Cheat sheet — tape this to your brain

Concept	The one-liner
Mass (g)	How much stuff. In diagrams: count the dots (big dots count for more).
Volume (mL or cm^3)	How much space. In diagrams: the size of the box. 1 cm^3 = 1 mL.
Density (g/mL)	Crowding = mass ÷ volume. Property of the substance, not the amount.
m–V graph	Straight line through (0,0). **Slope = density.** Steeper = denser.
Sink / float	Denser than water (1.00 g/mL) sinks; less dense floats. Steeper than the water line sinks.
Two-pan balance	Only feels mass. Equal volumes → denser side drops.
Cube volume	side × side × side.
Weird-shape volume	Water displacement: final − initial reading.
Identify a substance	Find D = m ÷ V, then match it in a density table.

Try-it answers (packet problems only — the worksheet is all yours!) **#1:** mass P < Q (6 vs 12 dots); volume P < Q; density P = Q — same crowding means same density, which is the point: amount changed, substance didn't. **#2:** candle floats (0.93 < 1.00), marble sinks (2.5 > 1.00) — the marble's particles are more crowded than water's, the candle's less. **#3:** (a) S: e.g. (40 mL, 20 g) and (80 mL, 40 g) → slope = 20 ÷ 40 = 0.5 g/mL; meaning: each mL of S has a mass of 0.5 g. (b) 10 mL of R has mass 27 g (read up to line R), so you need 27 g of S to balance — that's 54 mL of S (read across from 27 g to line S). **#4:** (a) V = 3×3×3 = 27.0 cm^3 = 27.0 mL; (b) D = 242 ÷ 27.0 ≈ 8.96 g/mL; (c) copper.