CHEMISTRY · UNIT 1 — ANSWER KEY & WORKED SOLUTIONS

Practice Exam — Answer Key

Every answer with the reasoning behind it. Sig-fig decisions are called out in **bold** so you can point at the exact rule that set the final digit.

How to use this: attempt a whole question type (all three levels) before opening this. When something is wrong, read the *reasoning* line rather than the answer, then redo the problem. The most common Unit 1 point-losses are sig figs on the last line and forgetting that displacement volume is a *subtraction*.

Q1. Mass vs. Volume — definitions and units

L1 **Mass** measures the **amount of matter ("stuff")** in an object — measured in **grams (g)**.
Volume measures the **amount of space** an object takes up — measured in **milliliters (mL)** or **cubic centimeters (cm^3)**.

L2 **What's wrong:** weight is the *force of gravity* pulling on an object, so it changes with location (you weigh less on the Moon). Mass does not change with location. They are also different quantities with different units (mass in grams; weight is a force, in newtons).
Correct definition: mass is the amount of matter in an object.
★ **Very common:** "mass is the weight of something" is the single most frequent wrong answer here, and it is a teacher favourite for exactly that reason. Worth 60 seconds out loud.

L3 **1. Block A is denser.** Same volume, more mass → more mass packed into the same space (D = m/V, same V and bigger m gives bigger D).
2. On the Moon each block's **mass is unchanged** (same atoms, same amount of matter) but its **weight drops to about one-sixth** (weaker gravity). Densities are also unchanged.

Q2. Reading instruments & uncertainty

L1 **26.4 mL** — **3 sig figs.** The 2 and 6 are certain (read off the marks); the 4 is estimated. Rule: record all certain digits plus *one* estimated digit.

L2 **1. 52.8 mL** **2.** The uncertain digit is the **8** (the tenths place) — it was estimated by eye.
3. Because the cylinder is only marked every 1 mL, you may estimate *one* digit past the marks. Writing 52.83 claims two estimated digits, which the instrument cannot support.

L3 **1. Balance A** has greater uncertainty: it reads to the tenths place (±0.1 g) while B reads to the hundredths (±0.01 g).
2. Balance B is more precise — more decimal places it can resolve.
3. Use Balance B, because A cannot resolve 0.01 g at all; its last digit is already an estimate at the 0.1 g level.

Q3. Counting significant figures

L1 a) 45.2 → **3** (all nonzero) b) 0.0067 → **2** (leading zeros never count) c) 3200 → **2** (trailing zeros, no decimal point) d) 5.010 → **4** (captive zero counts; trailing zero counts because there is a decimal point)

L2 a) 0.003040 → **4** (3, 0, 4, 0 — leading zeros out, captive and trailing zeros in) b) 100.0 → **4** (decimal point present) c) 2.50×10^4 → **3** (only the front number counts — that is the whole point of scientific notation) d) 8000. → **4** (that trailing decimal point is deliberate and makes every zero count)

L3 a) 0.0100500 → **6** (1, 0, 0, 5, 0, 0) b) 1.0×10^{-3} → **2** c) **Infinite (unlimited)** — a counted or defined number is exact, so it never limits the sig figs of an answer.

Q4. Rounding to a given number of sig figs

L1 a) 5.6789 → 3 sf: keep 5.67, next digit is 8 → round up → **5.68**
b) 0.0034567 → 2 sf: sig digits are 3 and 4; next digit 5 → round up → **0.0035**

L2 a) 2.4995 → 3 sf: keep 2.49, next digit 9 → round up → 2.50 → **2.50** (**keep the trailing zero** — without it you have only 2 sf)

b) 1,349 → 2 sf: keep 1, 3; next digit 4 → round down → **1,300** (or **1.3×10^3**, which is clearer)

L3 a) 9.9987 → 3 sf: keep 9.99, next digit 8 → round up → 9.99 becomes **10.0** (the carry moves a digit in front of the decimal — still exactly 3 sf)
b) 0.049996 → 3 sf: sig digits 4, 9, 9; next digit 9 → round up → **0.0500** (both trailing zeros are required to show 3 sf)

Q5. Calculating with significant figures

L1 a) 14.2 + 3.56 = 17.76 → **addition** → **fewest decimal places** (14.2 has 1) → **17.8 g**
b) 3.0 × 4.25 = 12.75 → **multiplication** → **fewest sig figs** (3.0 has 2) → **13 cm²**

L2 a) 100.00 − 27.3 = 72.70 → **fewest decimal places** (27.3 has 1) → **72.7 mL**
b) 45.62 ÷ 7.0 = 6.5171... → **fewest sig figs** (7.0 has 2) → **6.5 g/mL**

L3 a) 0.0045 + 1.2 = 1.2045 → **fewest decimal places** (1.2 has 1) → **1.2 m**. Note how the tiny number contributes nothing — that is the rule working correctly, not a mistake.
b) $(2.50 \times 10^3)(4.0 \times 10^{-2}) = 2.50 \times 4.0 = 10.0$, and $10^3 \times 10^{-2} = 10^1$ → 100 → **fewest sig figs** (4.0 has 2) → **1.0×10^2**
c) **Two different rules, in order:**

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Step 1 (subtract): 18.72 − 2.5 = 16.22 → 1 decimal place → 16.2 g
Step 2 (divide): 16.2 ÷ 5.00 = 3.24 → 3 sig figs → 3.24 g/mL
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What the subtraction really does is fix the numerator at *3 significant figures* (16.2, not 16.22). You may keep typing 16.22 into the calculator — 16.22 ÷ 5.00 = 3.244, which still rounds to 3.24 — but you must know the subtraction capped you at 3 sig figs, because that is what sets the final answer.

Q6. Conservation of mass

L1 **5.0 g.** Melting is a phase change: the same water molecules are still there, just arranged differently. In a sealed container nothing enters or leaves, so mass before = mass after.

L2 **1. No, mass was not created.** Iron atoms combined with oxygen atoms from the air to form iron oxide, and those oxygen atoms are now part of the solid being weighed.
2. The extra **2.5 g is the mass of oxygen** from the air that bonded to the iron (14.5 − 12.0 = 2.5 g).
3. In a sealed container the total mass would be **unchanged** — the oxygen was already inside the system, so it just moved from the air to the solid.

L3 **1. 110.0 g** (10.0 + 100.0). Dissolving is a physical change; the sugar particles spread out between the water particles but none are destroyed.
2. Best explanation: **a small amount of material never made it into the flask** — sugar grains left on the weighing paper or stuck to the transfer container, plus the ordinary uncertainty of the balance. The flask was sealed, so nothing could escape after sealing; the shortfall happened during the transfer, before it was closed.
“Mass disappeared” is **not** it, because matter cannot be created or destroyed. If you weighed the leftover grains on the paper and added them back, you would recover the missing 0.2 g.
Teaching note: be careful not to call this “balance error.” A 0.2 g gap on a 110 g reading is far bigger than any classroom balance's uncertainty (0.1 g or 0.01 g). It is *lost material*, which is still perfectly consistent with conservation of mass.

Q7. Particle diagrams for solids, liquids, and gases

L1 **SOLID:** particles touching, in a neat ordered pattern, filling a small box. **LIQUID:** particles still touching but disordered/jumbled, box slightly larger. **GAS:** same particles spread far apart with lots of empty space, filling a much bigger box.
• Largest volume: **gas** • Greatest density: **solid** • Does mass change? **No** — same number of particles in every box, so identical mass. Only the spacing changes.

L2 Draw the **same number of atoms**, but **closer together and in an orderly arrangement**, occupying slightly less space than the liquid.
Sentence: "I kept the same atoms but packed them closer in a regular pattern, because solid aluminum is denser than liquid aluminum — same mass in a smaller volume."
Grading note: the two things that earn the points are (a) the atom *count* is unchanged and (b) the spacing is tighter/ordered. Drawing *fewer* atoms is the classic error.

L3 Draw the **same iron atoms** plus **additional oxygen atoms now bonded to them** (use a different shade/size for oxygen and show them attached to the iron, not floating free).
Explanation: the mass increased because *extra matter — oxygen from the air — was added to the sample*. No iron atoms were created; the box simply contains more atoms than before, which is exactly consistent with conservation of mass once you count the air as part of the system.

Q8. Histograms and what scatter means

L1 Tallest bar: **24.7 g** (it appears 4 times). Best single estimate of the true mass: **24.7 g** — the centre of the distribution, where repeated measurements cluster. Here the most common value and the average agree (the mean is 24.69 → 24.7 g), which is what you expect when the scatter is symmetric. When a distribution is lopsided, trust the average over the tallest bar.

L2 **1. The flaw:** a change of a few hundredths of a gram is the size of the **experimental error in the whole procedure** — not evidence that matter was destroyed. Conservation of mass says the sugar particles are all still there, just spread through the water. Notice too that the bars sit mostly *below* zero rather than spreading evenly on both sides. That one-sided pattern is the signature of a **small systematic loss** — grains left on the weighing paper, a splash during transfer — rather than pure random scatter.
2. Better conclusion: "The mass did not change when the sugar dissolved. Our readings cluster about 0.04 g below zero, which we attribute to small losses during transfer rather than to matter disappearing. The result is consistent with the law of conservation of mass."
Credit note: the essential move is rejecting "mass decreased" and naming experimental error. Spotting that the bias is one-sided is a bonus observation that will impress a grader.

L3 Any two, with reasons:
• **Use a more precise balance** (0.001 g instead of 0.01 g) — smaller uncertainty means a narrower spread.
• **Seal the container** — prevents splashing/evaporation losses that bias readings low.
• **Take more trials** — more data makes the center of the distribution clearer and averages out random error.
• **Standardize technique** (same person, same transfer method, zero the balance each time) — removes operator-to-operator variation.

Q9. Mass vs. volume graphs

L1 **1.** slope = rise ÷ run = 25.0 g ÷ 10.0 mL = **2.50 g/mL**
2. That slope **is the density** of the substance. (Grams per milliliter *is* the unit of density — that is the whole reason the graph is worth drawing.)

L2 **1. A is denser.** A steeper slope means more grams per milliliter, and slope = density.
2. B floats. Its line is *less steep than the water line*, so its density is below 1.00 g/mL. (A is steeper than water, so A sinks.)
3. The pan holding A drops. At one chosen volume, read straight up: A's line is higher, so equal volumes of A have more mass. A balance only feels mass.

L3 **1.** Slope = **2.65 g/cm³** = the density of the substance; every 1 cm³ of it has a mass of 2.65 g.
2. The intercept **should be 0** — zero volume must mean zero mass. A value of −0.310 g points to a **small systematic error** in the experiment: most likely the balance was not zeroed (tared) properly, or every sample's mass was read slightly low. It is not a property of the substance.
3. M = 2.65(45.0) − 0.310
`= 119.25 − 0.310 = 118.94` → **119 g** (3 sig figs, set by 45.0 and 2.65)
Also acceptable if she ignores the tiny intercept and uses density alone: 2.65 × 45.0 = 119 g — same answer to 3 sf.
4. Sinks. Its density, 2.65 g/cm³, is greater than water's 1.00 g/cm³.

Q10. Calculating density from measurements

L1 D = m/V = 24.0 g ÷ 3.0 mL = 8.0 → **8.0 g/mL** (2 sig figs, limited by 3.0)

L2 **Step 1 — volume by displacement (a subtraction):**
`V = 45.2 − 31.2 = 14.0 mL`
Step 2 — density:
`D = 33.4 g ÷ 14.0 mL = 2.3857...` → **2.39 g/mL** (3 sig figs)
The classic error: using 45.2 mL as the volume. The object's volume is only the *rise* in the water level.

L3 **1.** V = 2.50 × 2.50 × 2.50 = 15.625 → **15.6 cm³ = 15.6 mL** (1 cm³ = 1 mL exactly)
2. D = 164 g ÷ 15.625 cm³ = 10.496 → **10.5 g/cm³** (3 sig figs)
3. Matches **silver** (10.50 g/mL) on the table.
Tip: divide by the unrounded 15.625, not by 15.6, then round once at the end.

Q11. Density as a conversion factor (mass ↔ volume)

L1 Want mass → **m = D × V**
`m = 2.70 g/mL × 5.00 mL = 13.5 g` → **13.5 g** (3 sig figs)

L2 Want volume → **V = m ÷ D**
`V = 250.0 g ÷ 13.6 g/mL = 18.382...` → **18.4 mL** (3 sig figs, limited by 13.6)
Sanity check: mercury is very dense, so a big mass should occupy a small volume — 18.4 mL is about a tablespoon. Reasonable.

L3 **Three moves — mass → volume → thickness:**
`1) V = m ÷ D = 0.0385 g ÷ 19.32 g/cm³ = 0.00199275 cm³`
`2) A = 20.15 cm × 12.40 cm = 249.86 cm²`
`3) t = V ÷ A = 0.00199275 ÷ 249.86 = 7.9755 × 10⁻⁶`
→ **7.98×10^{-6} cm** (3 sig figs, limited by 0.0385)
Why it works: the plating is a very flat rectangular box, and volume of a box = area × thickness. So thickness = volume ÷ area. Carry full digits through and round only at the end.

Q12. Density as a fingerprint

L1 **Copper** (8.96 g/mL on the table). Density is a characteristic property — it identifies a substance regardless of how big the sample is.

L2 `D = 445 g ÷ 25.0 cm³ = 17.8 g/cm³` (3 sig figs)
No, it is not pure gold. Pure gold is 19.3 g/cm³, and 17.8 is well below that — far outside any reasonable measurement error. Most likely it is an alloy of gold with a less dense metal, or a lighter metal with gold plating — the density alone tells you it is not pure gold, not exactly what else is in it.
Full-credit answer form: state the calculated density, compare it to the accepted value, then give the verdict in a sentence.

L3 **1.** V = 17.00 − 12.00 = **5.00 mL**
2. D = 56.8 g ÷ 5.00 mL = 11.36 → **11.4 g/mL** (3 sig figs)
3. Closest match is **lead** (11.35 g/mL) — and the agreement is very good (11.4 vs 11.35, well within the precision of these measurements). The next nearest table entries, silver at 10.50 and mercury at 13.6, are far away, so the identification is confident.

Q13. Multi-step challenge — aluminum foil thickness

L3 **Same three moves as the gold plating:**

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1) V = m ÷ D = 0.746 g ÷ 2.70 g/cm³ = 0.276296 cm³
2) A = 15.0 cm × 10.0 cm = 150. cm²
3) t = V ÷ A = 0.276296 ÷ 150. = 0.00184197 cm
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→ **1.84×10^{-3} cm** (3 sig figs) = 0.00184 cm = about 18 µm
Reality check worth making out loud: real household foil is roughly 0.0016–0.0024 cm thick, so this answer is right in range. If she gets something like 0.18 cm, she divided in the wrong place — foil that thick would be a sheet of metal.

Scoring guide for you. If she misses two or more inside one question type, that topic needs a second pass before the exam. In rough order of how often these cost points on a Unit 1 exam: (1) sig figs on the final line, (2) displacement volume as a subtraction, (3) drawing the wrong number of particles in a phase-change diagram, (4) calling the y-intercept a property of the substance instead of an experimental error, (5) mass vs. weight.

Answer key — Unit 1 Practice Exam. Built from the official AMTA Unit 1 Review, the class sig-fig worksheet, and the Unit 1 learning targets.