CHEMISTRY · UNIT 1 — PARENT COPY

Practice Workbook — Answer Key

How to use it. Finish a whole section before opening this. When something is wrong, read the **rule** line rather than the answer, then redo the problem. Sections 3, 4 and 5 are pure rule-following — more than two misses in any one of them means that rule needs another pass before the graph and density work will hold up.

1. Units

1a. The table

Quantity	Symbol	Units
Mass	**m**	**g, kg**
Volume (liquid)	**V**	**mL, L**
Volume (regular solid)	**V**	**cm^3**
Volume (irregular solid)	**V**	**mL (= cm^3)**
Length	**l**	**cm, mm, m**
Density	**D**	**g/mL or g/cm^3**
Temperature	**T**	**°C**

1b. a) **g** b) **g/mL** c) **cm^2** d) **cm^3** e) **g** f) **cm^3** g) **cm** h) **mL** i) **g/cm^3**
The pattern worth naming: adding and subtracting *keeps* the unit; multiplying and dividing *builds a new one*. That is why you can never add a mass to a volume, but you can divide one by the other.

1c. a) **1 mL** b) **45.0 mL** c) **2500 mL** (better: 2.50×10^3 mL) d) **1.25 kg** e) **750. g** f) **0.0035 L**

1d. Could be a density: **7.8 g/cm^3, 0.92 g/mL, 19.3 g/mL, 1.00 g/mL** — all are a mass unit *divided by* a volume unit.
Not densities: **12 cm^3** (volume), **25 g** (mass), **4.5 cm** (length).

1e. Thickness is a **length**, so it has to come out in cm — **g/cm is not a length, so the answer must be wrong**, no arithmetic check needed.
The step she skipped: **converting mass to volume with the density (V = m ÷ D)** before dividing by the area. She divided mass by area instead of volume by area.

THE RULE **Units are a free error-check.** Before you trust an answer, ask what unit it *should* have. If the units do not come out right, the method is wrong — and you know it without redoing a single calculation.

2. Certain and uncertain digits

2a. (i) **6.62 mL** — marks every 0.1, so 6.6 is certain and the **2** is estimated (3 sig figs).
(ii) **28.4 mL** — marks every 1 mL, so 28 is certain and the **4** is estimated (3 sig figs).
(iii) **23.6 °C** — marks every 1°, so 23 is certain and the **6** is estimated.
(iv) **4.35 cm** — marks every 0.1 cm, so 4.3 is certain and the **5** is estimated (3 sig figs).
(v) **12.40 g, 4 sig figs** — the display gives you the uncertain digit; the final **0** is a measured digit and must be written.

2b. Acceptable: **24.3 mL and 24.0 mL** (both estimate exactly one digit past the marks).
24 mL — no estimated digit; you threw away information the instrument gave you.
24.35 mL — two estimated digits; the cylinder cannot support that.
Note that 24.0 is a real reading: it means the meniscus sat right on the 24 mark.

2c. The trailing zero is a **measured digit, not decoration**. Writing 8.5 g claims you only knew the mass to the tenths place, when the balance actually resolved the hundredths. You would be throwing away a significant figure.

2d. **Yes, both can be right** — they used different rulers. “6.7 cm” came from a ruler marked every 1 cm (6 certain, 7 estimated). “6.70 cm” came from a finer ruler marked every 0.1 cm (6.7 certain, 0 estimated). The second is the more precise instrument.

THE RULE **Record every certain digit plus exactly one estimated digit.** How many decimals you are allowed is decided by the instrument, not by you.

3. Significant figures — adding and subtracting

THE RULE **Fewest decimal places wins.** Line the decimal points up; the answer cannot extend further right than the shortest column.

	Calculation	Calculator	Answer	Because
a)	12.11 + 18.0 + 1.013	31.123	**31.1 g**	18.0 has 1 dp
b)	45.6 − 3.21	42.39	**42.4 mL**	45.6 has 1 dp
c)	0.250 + 1.4	1.650	**1.7 m**	1.4 has 1 dp
d)	100.0 + 25	125.0	**125 g**	25 has 0 dp
e)	7.939 − 0.0031	7.9359	**7.936 s**	7.939 has 3 dp
f)	2.5 + 2.5	5.0	**5.0 cm**	both have 1 dp
g)	155.75 + 8.6	164.35	**164.4 g**	8.6 has 1 dp
h)	0.0045 + 0.00120	0.00570	**0.0057 L**	0.0045 has 4 dp
i)	34.6 − 34.1	0.5	**0.5 g**	both have 1 dp
j)	1.0 + 2.00 + 3.000	6.000	**6.0 mL**	1.0 has 1 dp

The follow-up on part (i). 34.6 − 34.1 = 0.5 g has only **1 significant figure**, even though both measurements had three. Subtracting two nearly-equal numbers destroys precision — the digits that agreed cancel out and only the uncertain tail survives. This is exactly why a displacement volume from two close readings is so fragile, and why chemists pick a cylinder where the object makes a *big* level change.

4. Significant figures — multiplying and dividing

THE RULE **Fewest significant figures wins.** Count sig figs in each measurement; the smallest count sets the answer.

	Calculation	Calculator	Answer	Because
a)	3.14 × 2.0	6.28	**6.3 cm^2**	2.0 has 2 sf
b)	45.0 ÷ 9.00	5.00	**5.00 g/mL**	both have 3 sf — keep the zeros
c)	0.0025 × 400.	1.0	**1.0 kg**	0.0025 has 2 sf
d)	12.5 × 3.0	37.5	**38 m^2**	3.0 has 2 sf
e)	144 ÷ 12	12	**12 g/mL**	12 has 2 sf
f)	6.022 × 2.0	12.044	**12 g**	2.0 has 2 sf
g)	98.6 ÷ 3.00	32.8666...	**32.9 g/mL**	both have 3 sf
h)	0.500 × 0.500	0.250	**0.250 cm^2**	3 sf — the trailing zero is required
i)	7.0 × 8.0 × 2.0	112	**1.1×10^2 cm^3**	2 sf — see section 5
j)	1.00 ÷ 3.00	0.33333...	**0.333 g/mL**	both have 3 sf

Watch part (i). 112 rounded to 2 sig figs is 110 — but written plainly, “110” looks like 2 sig figs to some readers and 3 to others. **1.1×10^2 cm^3** is unambiguous and is the answer to prefer. This is the bridge into the next section.

5. When the answer comes out to 10, 100 or 1000

THE RULE Plain **10** shows only **one** significant figure. To show more you must either add a decimal point (**10.**) or switch to scientific notation (**1.0×10^1**). At 100 the decimal point can only buy you *three* sig figs (100.), so a hundred that needs only **two** can be written just one way: 1.0×10^2.

	Calculation	Calculator says	Must show	Written correctly
a)	5.0 × 2.0	10	2	**10. or 1.0×10^1**
b)	25 × 4.0	100	2	**1.0×10^2**
c)	2.50 × 4.00	10	3	**10.0**
d)	round 9.96 to 2 sf	—	2	**10. or 1.0×10^1**
e)	round 99.7 to 2 sf	—	2	**1.0×10^2**
f)	9.8 g + 0.2 g	10	3 (set by the 1-dp rule)	**10.0 g**
g)	12.4 mL − 2.4 mL	10	3 (set by the 1-dp rule)	**10.0 mL**
h)	$(2.0\times10^3)(5.0\times10^{-2})$	100	2	**1.0×10^2**
i)	1000.0 ÷ 100.00	10	5	**10.000**
j)	round 0.00998 to 2 sf	—	2	**0.010 or 1.0×10^{-2}**
k)	8.00 cm + 2.00 cm	10	4 (set by the 2-dp rule)	**10.00 cm**

Notice the split. The *addition* ones (f, g, k) are easy — the decimal-place rule already forces you to write 10.0 or 10.00, so the zeros appear naturally. It is the *multiplication* and *rounding* ones that are dangerous, because the calculator hands you a bare “10” or “100” and it is on you to add the decimal point or the exponent.

If she is unsure, scientific notation is always right. 1.0×10^1 can only be read one way.

6. Mass vs. volume graphs

6a. i) **P > Q > R** — steeper line means denser.
ii) **Only R floats**. Its line lies *below* the dashed water line, so its density is under 1.00 g/mL. P and Q are both steeper than water, so they sink.
iii) Using (0, 0) and (40 mL, 100 g): slope = 100 g ÷ 40 mL = **2.5 g/mL**. In words: *every 1 mL of P has a mass of 2.5 g* — the slope is the density.
iv) Q's slope is 1.5 g/mL, so 20.0 mL × 1.5 g/mL = **30. g**.
v) R's slope is 0.60 g/mL, so V = 12 g ÷ 0.60 g/mL = **20 mL**.
vi) **The P side drops.** At any one volume, read straight up: P's line is higher, so equal volumes of P have more mass. A balance only feels mass.

6b. i) The slope is the density: **8.96 g/cm³ → copper**.
ii) M = 8.96(15.0) − 0.30 = 134.4 − 0.30 = 134.1 → **134 g** (3 sig figs).
iii) **Sinks** — 8.96 g/cm³ is far greater than water's 1.00 g/cm³.
iv) 5% of 180 g = 9 g. |−0.30 g| = 0.30 g, and 0.30 < 9, so the intercept is **negligible**. The line effectively passes through the origin.

6c. Densities: **7.85, 7.88, 7.87, 7.88 g/mL**.
(15.7÷2.00 = 7.85; 31.5÷4.00 = 7.875 → 7.88; 47.2÷6.00 = 7.8667 → 7.87; 63.0÷8.00 = 7.875 → 7.88)
Yes — all four cluster tightly around 7.87 g/mL, so this is one substance: **iron**.
Why they are not identical: each mass and volume carries measurement uncertainty, so each calculated density lands slightly differently. Real data never gives four identical numbers; the whole spread here is only 0.03 g/mL, and that level of agreement *is* the confirmation.

6d. Water: plot (10, 10) and (20, 20), draw a line from the origin. Aluminum: plot (10, 27) and (20, 54). The aluminum line should be noticeably **steeper**, and both must start at **(0, 0)**.
To sketch any density: step right by a convenient volume, up by (density × that volume), mark the point, repeat, connect to the origin with a ruler.

6e. 5% of 25 g = 1.25 g. The intercept is +1.4 g, and **1.4 > 1.25, so it is NOT negligible** — it has to be explained.
The most likely cause of a *positive* intercept: **they weighed each sample in a container and never subtracted the container's mass**. That adds the same constant to every reading, lifting the whole line off the origin. (Any constant added mass works as an answer — a piece of tape, a weigh boat, a balance not tared.)
Contrast this with 6b: same rule, opposite verdict. The point of the 5% rule is that it gives you a number to decide with, not a feeling.

THE RULE **Slope of mass vs. volume = density.** Steeper = denser. Compare to the water line to predict sink or float. A nonzero intercept is a statement about the *experiment*, never about the substance.

7. Conservation of mass — open vs. closed

Situation	Reading	Why
Ice melts in a sealed jar	**SAME**	Phase change only; sealed, so nothing enters or leaves.
Steel wool burned in open air	**UP**	Oxygen from the air bonds to the iron and is now on the balance.
Steel wool burned in a sealed flask	**SAME**	The oxygen was already inside the system — it just moved from air to solid.
Antacid fizzes in an open cup	**DOWN**	Carbon dioxide gas forms and escapes, carrying its mass away.
The same tablet in a sealed bottle	**SAME**	The gas is trapped, so it is still being weighed.
Sugar dissolves in an open beaker	**SAME**	Physical change, no gas produced; the particles just spread out.
Water evaporates from an open dish	**DOWN**	Water vapour leaves the dish.
An iron nail rusts in open air	**UP**	Oxygen from the air combines with the iron — slow burning, same idea.

7b. i) 20.7 − 15.0 = **5.7 g of oxygen**.
ii) Starting mass = 4.20 + 100.00 = 104.20 g. Escaped gas = 104.20 − 102.15 = **2.05 g of carbon dioxide**.
iii) **104.20 g** — sealed, so the carbon dioxide is still inside the bottle and still on the balance. Nothing was created or destroyed; it only changed form.

7c. The two boxes should contain the **same number of particles**. In BEFORE they are close together in the liquid at the bottom; in AFTER about half of them are spread far apart as gas filling the upper space, with the rest still liquid.
The explanation: evaporation is a phase change — particles moved and spread out, but none were created or destroyed, and the jar is sealed so none left. Same particle count means same mass.

THE RULE **Ask "can anything cross the boundary?"** Closed → the reading cannot change. Open → it can, and your job is to name what came in (mass up) or went out (mass down). Gas is almost always the answer.

8. Histograms

8a. i) **48.8 g** (4 groups). ii) **48.8 g** — the centre of the distribution; here the average works out to 48.8 g as well. iii) **48.6 g to 49.0 g, a spread of 0.4 g**. iv) Readings differ in the tenths place, so the balance is uncertain by about **±0.1 g**.

8b. i) **Class A**. Their bars are packed into a range of about 0.05 g, while Class B's spread over about 0.5 g — ten times wider. A **narrow** histogram means precise measurements.
ii) **Yes, both do.** Both distributions are centred at or very near zero change, which is what conservation of mass predicts. Class B's data are noisier, so their conclusion is weaker — but nothing in it contradicts conservation.
iii) Any two: use a **more precise balance**; **seal the container** so nothing evaporates or splashes; **standardise the technique** (same transfer method, tare every time); or **use a bigger sample** so the real change is large compared with the balance's noise.
Not a valid answer: "take more trials." More trials fill in the same distribution more densely — they pin down the *centre* better but do not make the histogram any *narrower*. Width comes from the quality of each measurement.

8c. i) A **narrow histogram centred on zero** — nothing can enter or leave, so any spread is just balance noise.
ii) A histogram **clearly shifted to the negative side**, centred on whatever mass of gas escaped, and not overlapping zero if the loss is large. That is what a *real* change looks like, as opposed to error.

THE RULE **Centre tells you the result; width tells you the precision.** Scatter that straddles zero is measurement error. A distribution sitting entirely to one side is something real.

9. What is this metal?

	Work	Density	Metal	Note
a)	52.5 g ÷ 5.00 mL	**10.5 g/mL**	**silver**	
b)	V = 30.0 − 20.0 = 10.0 mL; 89.6 ÷ 10.0	**8.96 g/mL**	**copper**	Volume is the *rise*, not the final reading.
c)	V = 2.00^3 = 8.00 cm^3; 21.6 ÷ 8.00	**2.70 g/cm^3**	**aluminum**	
d)	V = 4.00×2.00×1.50 = 12.0 cm^3; 85.6 ÷ 12.0	**7.13 g/cm^3**	**zinc**	
e)	227.0 g ÷ 20.00 mL	**11.35 g/mL**	**lead**	Both measurements carry 4 sig figs, so the answer does too.
f)	slope = density	**7.87 g/cm^3**	**iron**	No calculation needed — the slope *is* the density.
g)	38.6 g ÷ 2.00 mL	**19.3 g/mL**	**gold**	
h)	95.0 g ÷ 10.0 mL	**9.50 g/mL**	**not on the table**	Sits between copper (8.96) and silver (10.50), too far from either to be a pure sample. Most likely an alloy or a mixture.
i)	A: 15.74 ÷ 2.00 B: 39.35 ÷ 5.00	**both 7.87 g/mL**	**iron**	Different sizes, identical density — this is the demonstration that **density does not depend on how much you have**.
j)	54.0 g ÷ 20.0 mL	**2.70 g/mL**	**aluminum**	**She is wrong.** A large mass does not mean a dense material — it is a big piece of a light metal. Only density identifies a substance.

THE RULE **Density is a fingerprint.** Get a volume any way you can (formula, displacement, or a graph slope), divide, then match against the table. Finish with a sentence naming the substance — a bare number is not an identification.

10. Thickness — flat things (2-D)

a) Aluminum foil 12.0 × 8.00 cm, 0.518 g

$V = 0.518 \div 2.70 = 0.191852\ cm^3$ | $A = 96.0\ cm^2$ | $t = 0.191852 \div 96.0 = 0.00199846$

→ **2.00×10^{-3} cm** (3 sig figs)

b) Gold plating on 15.0 × 10.0 cm, 0.0290 g

$V = 0.0290 \div 19.3 = 0.00150259\ cm^3$ | $A = 150.\ cm^2$ | $t = 1.00173 \times 10^{-5}$

→ **1.00×10^{-5} cm** (3 sig figs)

c) Copper sheet 20.0 × 20.0 cm, 35.84 g

$V = 35.84 \div 8.96 = 4.00\ cm^3$ | $A = 400.\ cm^2$ | $t = 4.00 \div 400. = 0.0100$

→ **0.0100 cm** (3 sig figs — both zeros are required)

d) Silver leaf, run backwards — you are given thickness and asked for mass, so reverse the three moves:

$A = 5.00 \times 5.00 = 25.0\ cm^2$ | $V = A \times t = 25.0 \times 1.00{\times}10^{-5} = 2.50{\times}10^{-4}\ cm^3$

$m = D \times V = 10.50 \times 2.50{\times}10^{-4} = 2.625{\times}10^{-3}$

→ **2.63×10^{-3} g** (about 2.6 milligrams — silver leaf really is that light)

THE RULE **V = m ÷ D → A = L × W → t = V ÷ A.** A flat sheet is just a very thin box, so V = A × t. Carry full digits through the middle and round once at the end.

11. Cubes and blocks (3-D)

a) Aluminum cube, 21.6 g $V = 21.6 \div 2.70 =$ **$8.00\ cm^3$**; edge $= \sqrt[3]{8.00} =$ **2.00 cm**

b) Lead cube, 306.45 g $V = 306.45 \div 11.35 = 27.00\ cm^3$; edge $= \sqrt[3]{27.00} =$ **3.000 cm** (4 sig figs — both inputs support it)

c) Copper cube, 573.44 g $V = 573.44 \div 8.96 = 64.0\ cm^3$; edge $= \sqrt[3]{64.0} =$ **4.00 cm**

d) Iron cube, edge 1.50 cm $V = 1.50^3 = 3.375\ cm^3$; $m = 3.375 \times 7.87 = 26.56 \rightarrow$ **26.6 g** (3 sig figs)

e) Zinc block 5.00 × 3.00 × 2.00 cm $V = 30.0\ cm^3$; $m = 30.0 \times 7.13 = 213.9 \rightarrow$ **214 g**

f) Silver cube, edge 1.20 cm $V = 1.20^3 = 1.728\ cm^3$; $m = 1.728 \times 10.50 = 18.144 \rightarrow$ **18.1 g**

g) Gold coating on a 2.00 cm cube, 0.0464 g — the 3-D version of a thickness problem:

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V = 0.0464 ÷ 19.3 = 0.00240414 cm³
A = 6s² = 6 × (2.00)² = 24.0 cm²   ← six faces, not one
t = 0.00240414 ÷ 24.0 = 1.00173 × 10⁻⁴
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$\rightarrow$ **1.00×10^{-4} cm**

The trap: using $4.00\ cm^2$ (one face) instead of $24.0\ cm^2$ gives an answer six times too big.

THE RULE **Forward:** edge $\rightarrow V = s^3 \rightarrow m = D \times V$. **Backward:** $m \rightarrow V = m \div D \rightarrow s = \sqrt[3]{V}$. For a coating on a solid, the area is the **whole surface** — $6s^2$ for a cube.

12. Multi-step challenges

Challenge 1

a) $V = 32.0 - 22.0 =$ **10.0 mL**

b) $D = 89.6 \div 10.0 =$ **8.96 g/mL → copper**

c) $V = 3.00^3 = 27.0\ cm^3$; $m = 27.0 \times 8.96 = 241.92$ → **242 g**

d) **Sinks** — 8.96 g/mL is far above water's 1.00 g/mL. Note the density is the same for the cube as for the cylinder: the size changed, the substance did not.

Challenge 2

a) $V = 2.03 \div 2.70 =$ **0.752 cm^3** (carry 0.751852 forward)

b) $A = 30.0 \times 25.0 =$ **750. cm^2**

c) $t = 0.751852 \div 750. = 0.00100247$ → **1.00×10^{-3} cm**

d) 1.00 mm = **0.100 cm**. Number of sheets = $0.100 \div 0.00100247 = 99.75$ → **about 100 sheets**.

The unit trap is part (d) — mixing mm and cm here is the single most common way to be off by a factor of ten.

Challenge 3

a) **70.0 g** (50.0 + 20.0)

b) $V = 20.0 \div 7.13 = 2.805$ → **2.81 mL**

c) Total volume = 50.0 + 2.81 = 52.8 mL, and the flask holds 100.0 mL → **no overflow, with room to spare**

d) Still **70.0 g**. The flask is sealed, so nothing can enter or leave; conservation of mass guarantees the reading is unchanged.

Challenge 4

a) Slope = density = **2.70 g/cm^3 → aluminum**

b) $M = 2.70(12.0) - 0.20 = 32.4 - 0.20 =$ **32.2 g** (3 sig figs)

c) 5% of 40 g = 2.0 g; $|-0.20| = 0.20 < 2.0$ → **negligible**

d) **Sinks** — $2.70 > 1.00\ g/cm^3$.

Reading the results. Sections 3, 4 and 5 are rules — misses there are cheap to fix and worth fixing first, because every numeric answer on the exam depends on them. Sections 9, 10 and 11 are method — if the three moves can be stated out loud before the pencil moves, it is solid. Section 12 is the real test: those four are the difficulty of the last question on the Beta.