HIGH SCHOOL CHEMISTRY

CHAPTER 1

Set 3: Problem Solving

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- The **four-step method** for every conversion.
- **Density** made simple, with displacement worked out.
- Real **exam traps** and practice with **full solutions**.
- ★ HONORS A taste of Honors, clearly marked.

For high school chemistry, Chapter 1: Matter, Measurement, and Problem Solving. Regular and Honors.

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THE FULL SET

Seven files, one complete topic

File	What it gives you	Pages
Complete Study Notes	The full lesson: the four-step method, conversion factors, one-step and multi-step conversions, rounding, density, with 30+ worked examples.	51
Quick Revision Sheets	Every topic on a page of tables and flowcharts, a one-page cheat sheet, memory hooks and a 20-question self-test.	18
Exam Traps and Mistakes	The mistakes that cost the most points, each shown wrong, then right, with why it happens and how to dodge it.	27
Practice Question Bank	133 questions from warm-up to challenge, every one with a full worked solution.	33
Mock Test	A timed 75-point unit test with an answer key, scoring guide and self-score table.	21
Glossary and Flashcards	Every key term explained with an example, plus printable cut-out flashcards.	26
Lab Skills for Tests	Lab safety, recording data, worked data tables, sources of error and test-style lab questions.	18

Regular and Honors in one set. Honors material sits in blue boxes, so Regular students can skip it.

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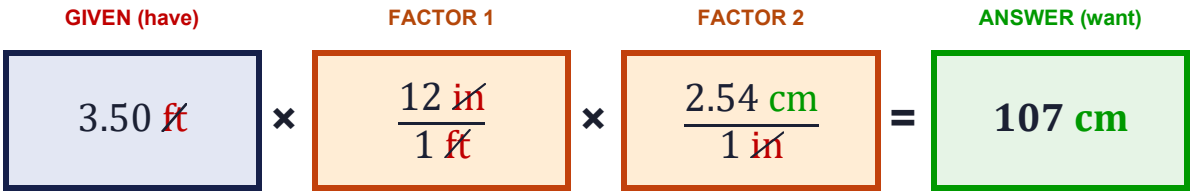
SNEAK PEEK

See the method, then watch it work



Every unit you do not want gets cancelled: ft with ft, in with in. Only cm is left.

The "unit train": each factor cancels the unit before it.

WORKED EXAMPLE | Feet to centimeters in one line

Read	**Given:** a shelf 3.50 ft long. **Find:** its length in cm.
Plan	Road map: ft → in → cm. Factors: $\frac{12\ \text{in}}{1\ \text{ft}}$ (exact) and $\frac{2.54\ \text{cm}}{1\ \text{in}}$ (exact).
Solve	$3.50\ \text{ft} \times \frac{12\ \text{in}}{1\ \text{ft}} \times \frac{2.54\ \text{cm}}{1\ \text{in}} = 106.68\ \text{cm}$ $= \mathbf{107\ cm}$
Check	Unit is cm. A centimeter is much smaller than a foot, so the number should grow a lot: 3.50 → 107 makes sense. Both factors are exact, so 3.50 (3 sig figs) sets the answer: 107 cm.

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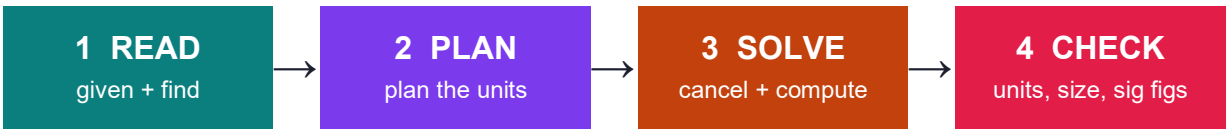
SECTION 2 A Strategy for Any Problem

LEARNING GOALS | By the end of this section you can

- Solve any problem with the four steps: Read, Plan, Solve, Check.
- Estimate an answer before you use a calculator.
- Check the unit, the size and the sig figs of a final answer.

KEY IDEA

Good problem solvers do not start by pressing calculator buttons. They follow the same four steps every time: **Read, Plan, Solve, Check.**



↺ **Answer looks wrong? Go back to Read and plan again.**

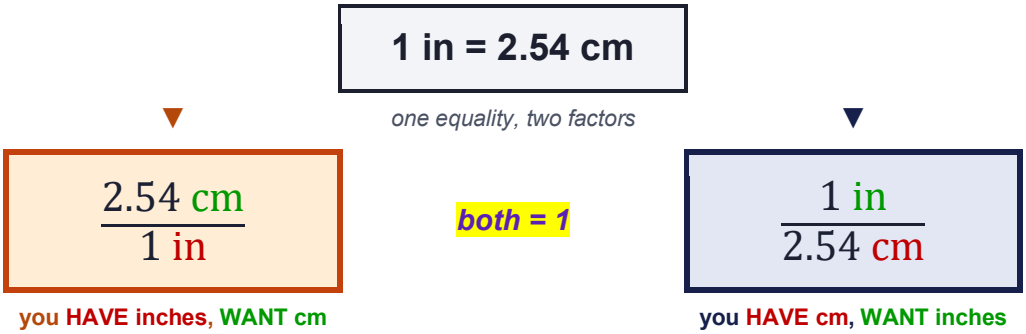
Read: write what you are GIVEN and what you must FIND, with units.

Plan: map the units from given to find, and list the factors you need.

Solve: multiply the factors, cancel units, round only at the end.

Check: right unit? sensible size? right number of sig figs?

The four-step method used in every example in this set.



One equality, two factors. Choose the one that cancels the unit you have. One equality gives two conversion factors. Both equal 1, so multiplying by either never changes the amount, only the unit. Pick the one with the unit you HAVE on the bottom.

3.1 Which way up?

Put the unit you **have** on the **bottom** of the factor, so it cancels. The unit you **want** goes on the **top**, so it is left over.

$$given\ unit \times \frac{wanted\ unit}{given\ unit} = wanted\ unit$$

MEMORY HOOK | Want over have

Say it as you write each factor: "**want over have**". The unit you want sits on top; the unit you have sits underneath and cancels.

3.2 Equalities you should know

Your teacher will tell you which ones to memorize and which will be given on tests. Metric and time equalities are always worth knowing by heart.

SECTION 5 Multi-Step Conversions

LEARNING GOALS | By the end of this section you can

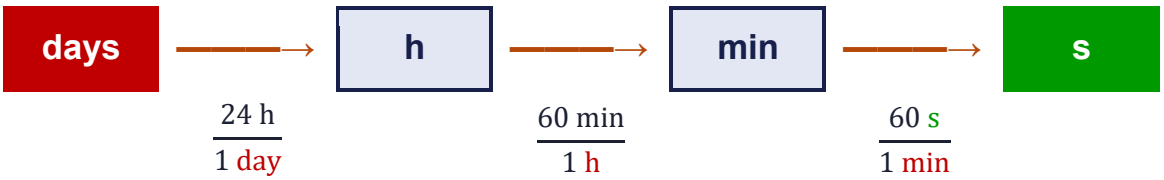
- Plan a road map of units from the given to the find.
- Chain several factors in one line of work.
- Convert just one unit of a rate, like miles in mi/h.

KEY IDEA

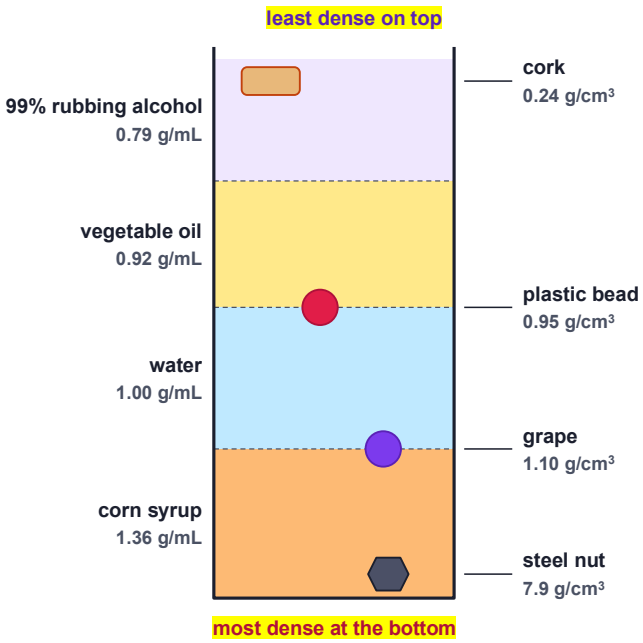
When no single equality links your units, chain several factors together in **one line**. Plan the chain first with a **road map** of units.

DEFINITION | Road map (conceptual plan)

A sketch of the units in order, from given to find, with the equality for each step written under its arrow. It is your plan before any calculation.



Road map for converting days to seconds. A road map (conceptual plan) lists the units in order from what you have to what you want. Under each arrow, write the factor that makes that step. Then the math is just one line.

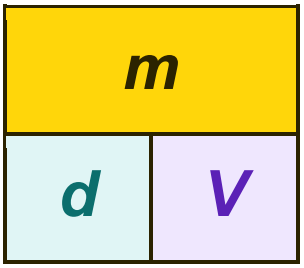


A density column: the order of layers and objects follows density. Liquids that do not mix stack in order of density. A solid sinks until it reaches a liquid denser than itself, then floats on that layer. Densities shown are typical room-temperature values.

EXAM TRAP | Heavy does not mean dense

A ship made of steel floats, and a tiny pebble sinks. What matters is mass **per volume**, not mass alone. "Which is heavier, a kilogram of feathers or a kilogram of lead?" They have the **same mass**; lead has a much higher **density**, so the lead takes up far less space.

7.3 Rearranging the density formula



cover what you want

want density?	$d = \frac{m}{V}$
want mass?	$m = d \times V$
want volume?	$V = \frac{m}{d}$

Cover the quantity you want to see the formula for it. Cover the letter you want. What is left shows the operation: side by side means multiply, one over the other means divide. m is always on top.

To find density	To find mass	To find volume
$d = \frac{m}{V}$	$m = d \times V$	$V = \frac{m}{d}$

WORKED EXAMPLE | Finding density, then identifying the metal

Read	**Given:** a metal sample with mass 54.0 g and volume 20.0 cm^3. **Find:** density, and a likely identity.
Plan	$d = \frac{m}{V}$, then compare with the density table.
Solve	$d = \frac{54.0\ \text{g}}{20.0\ \text{cm}^3} = \mathbf{2.70\ g/cm^3}$
Check	Units g/cm^3, 3 sig figs. 2.70 g/cm^3 matches **aluminum**.

7.4 Density as a conversion factor

A density is an equality between mass and volume. Ethanol's density of 0.789 g/mL means **0.789 g = 1 mL** for ethanol, so you can use it as a factor in either direction: $\frac{0.789\ \text{g}}{1\ \text{mL}}$ or $\frac{1\ \text{mL}}{0.789\ \text{g}}$.

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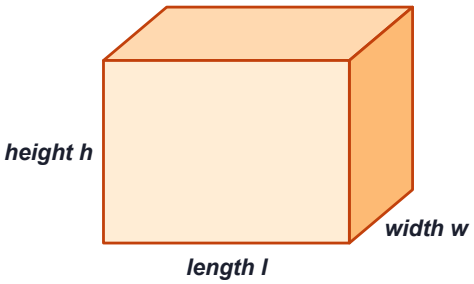
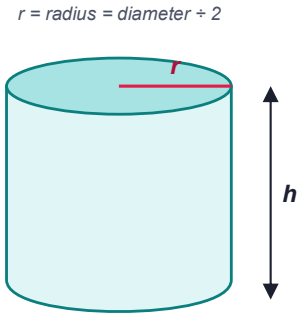
7.5 Finding volume: regular solids

For an object with a regular shape, measure its dimensions and use a geometry formula.



V = l × w × h

Box (rectangular solid): multiply the three edge lengths. cm × cm × cm = cm^3.



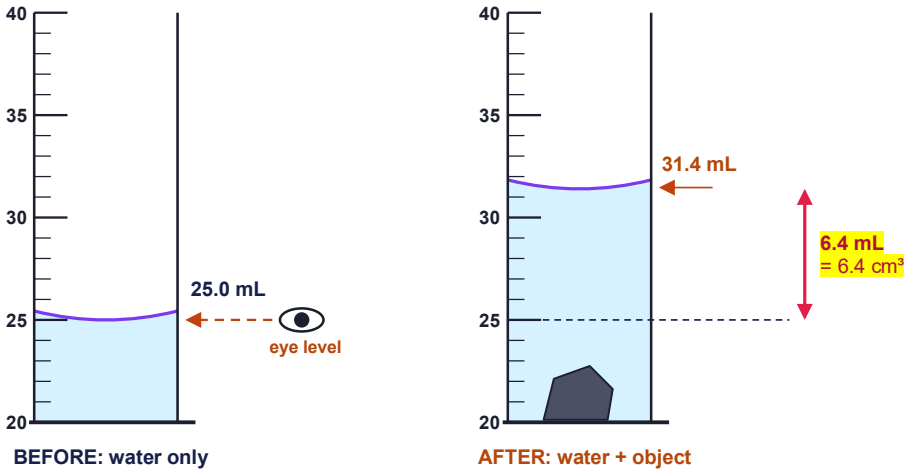
V = πr²h

Cylinder: r is the radius, half the diameter. Square r, multiply by π and by the height.

Volume formulas for a box and a cylinder.

WORKED EXAMPLE | Density of a rectangular block

Read	**Given:** a block 4.00 cm × 2.50 cm × 1.50 cm with mass 134.4 g. **Find:** density and identity.
Plan	$V = l \times w \times h$, then $d = \frac{m}{V}$.
Solve	$V = 4.00\ \text{cm} \times 2.50\ \text{cm} \times 1.50\ \text{cm} = 15.0\ \text{cm}^3$ $d = \frac{134.4\ \text{g}}{15.0\ \text{cm}^3} = \mathbf{8.96\ g/cm^3}$
Check	cm × cm × cm = cm^3. Every length has 3 sig figs, so 3 in the answer. 8.96 g/cm^3 matches **copper**.



Read both levels at eye level, at the bottom of the meniscus.

Volume by water displacement. The object pushes aside (displaces) its own volume of water. Volume of object = final reading − initial reading = 31.4 mL − 25.0 mL = 6.4 mL, and 1 mL = 1 cm^3. Read both levels at the bottom of the meniscus.

WORKED EXAMPLE | Density of an irregular rock

Read	**Given:** rock mass 17.3 g; water level 25.0 mL before, 31.4 mL after the rock is added. **Find:** density of the rock.
Plan	Volume by displacement: $V = V_{\text{final}} - V_{\text{initial}}$. Then $d = \frac{m}{V}$.
Solve	$V = 31.4\ \text{mL} - 25.0\ \text{mL} = 6.4\ \text{mL} = 6.4\ \text{cm}^3$ $d = \frac{m}{V} = \frac{17.3\ \text{g}}{6.4\ \text{cm}^3} = 2.703\ldots\ \text{g/cm}^3$ $= \mathbf{2.7\ g/cm^3}$
Check	Subtraction keeps one decimal place, so 6.4 mL has only 2 sig figs, and the density gets 2 sig figs. Most rocks are 2.5 to 3 g/cm^3, so 2.7 is sensible.

TIP | Displacement only works if it sinks

The object must sink completely and must not dissolve in or soak up the water. For a floating object, push it under with a thin wire, or use a different liquid.

★ HONORS 8 Squared and Cubed Units

★ HONORS EXTENSION · Regular students may skip | **This whole section is Honors**

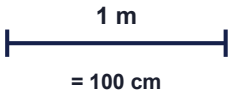
Regular students can skip to the chapter summary. Honors students: make sure Sections 3 to 5 feel easy first.

LEARNING GOALS | **By the end of this section you can**

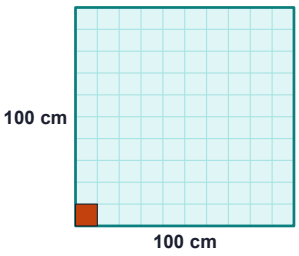
- Convert squared and cubed units by squaring or cubing the factor.
- Convert between cubic units and liters, like m^3 to L.

KEY IDEA

When a unit is squared or cubed, the **conversion factor must be squared or cubed too**. Raise the number **and** the unit to the same power.



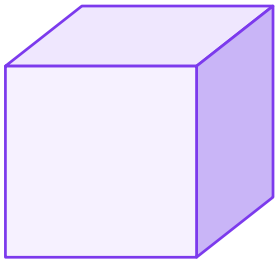
× 100



$1\ m^2 = (100\ cm)^2$
$= 10\ 000\ cm^2$

not to scale: each grid square is 10 cm × 10 cm = 100 cm^2

× 100^2



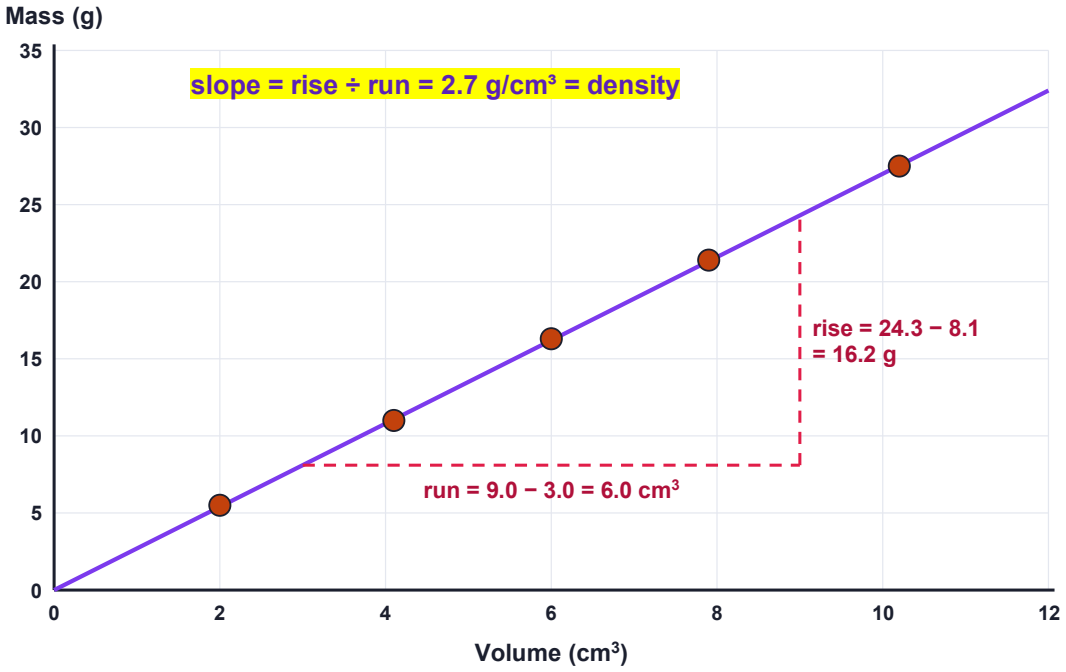
$1\ m^3 = (100\ cm)^3$
$= 1\ 000\ 000\ cm^3$

× 100^3

Why 1 m^3 is a million cm^3, not a hundred. Length: 1 m = 100 cm. Area: 100 cm on each side, so 100 × 100 = 10^4 squares of 1 cm^2. The grid is not to scale: each of its squares is 10 cm × 10 cm = 100 cm^2. Volume: 100 × 100 × 100 = 10^6 cubes of 1 cm^3. Raise the NUMBER and the UNIT to the same power.

KEY IDEA

The **slope** of a mass vs. volume graph is $\frac{rise}{run} = \frac{\Delta m}{\Delta V}$, which is mass per volume: the **density**. A steeper line means a denser material.



Mass vs. volume for pieces of one material. The slope of the best-fit line is the density.

WORKED EXAMPLE | Density from the slope

Read	**Given:** the best-fit line in the graph above. **Find:** the density and the material.
Plan	Pick two points **on the line** (not data points), far apart, like the corners of the dashed triangle. Slope = rise ÷ run, with units.
Solve	$slope = \frac{24.3\ \text{g} - 8.1\ \text{g}}{9.0\ \text{cm}^3 - 3.0\ \text{cm}^3} = \frac{16.2\ \text{g}}{6.0\ \text{cm}^3} = \mathbf{2.7\ g/cm^3}$
Check	Unit is g/cm³, a density. 2.7 g/cm³ matches **aluminum** (2.70) in the table.

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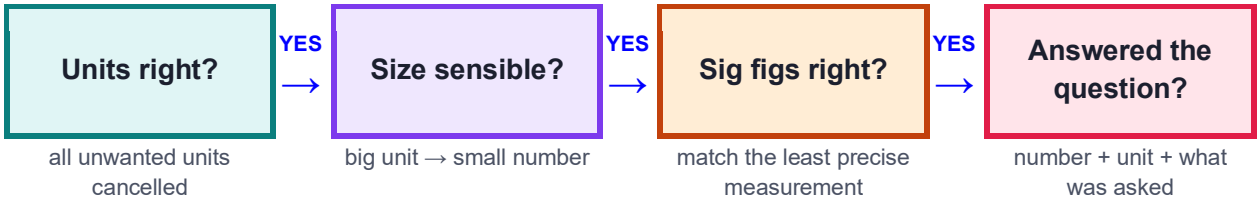
Calculation	Rounded	Estimate
$\frac{142}{2.205}$	$\frac{140}{2}$	about 70 (exact: 64.4)
3.25×3.785	3×4	about 12 (exact: 12.3)
26.2×1.609	25×1.6	about 40 (exact: 42.2)

2.3 The final check



Four questions to ask before you box an answer. Run the four checks in order before you box an answer. A "no" at any step means go back to Plan, not to the calculator.

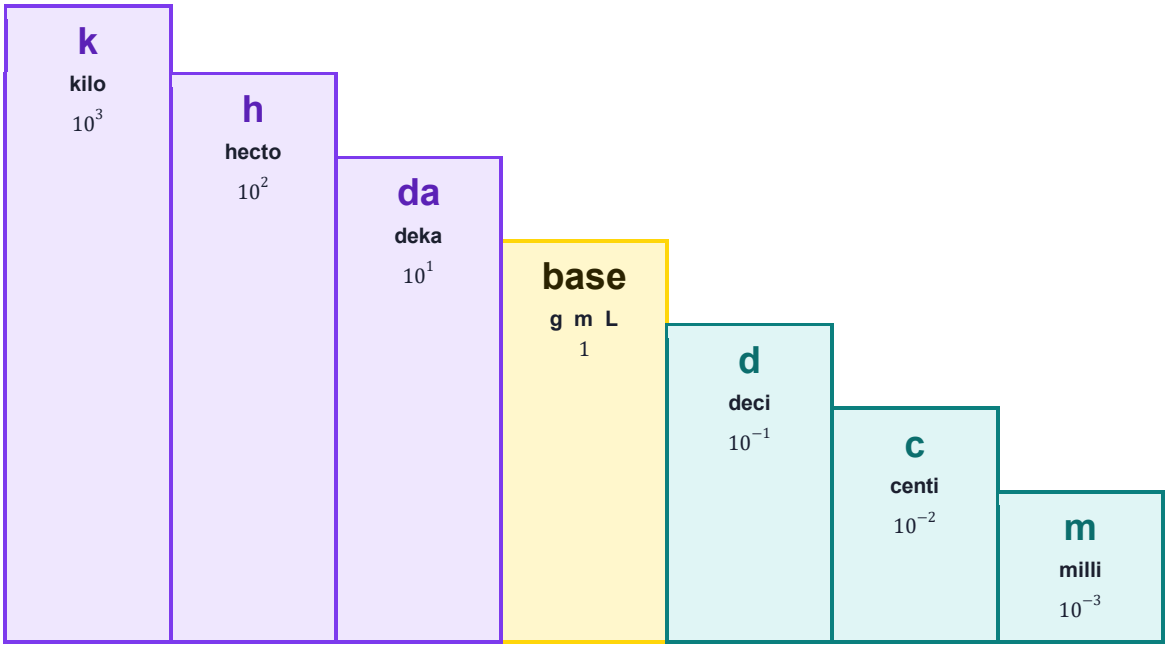
MEMORY HOOK | Big unit, small number

The **bigger** the unit, the **smaller** the number. 1 km = 1000 m: kilometers are big, so you need only 1 of them. If you convert to a smaller unit and your number gets smaller, your factor is upside down.

QUICK CHECK | Try it before you move on

1. Name the four steps of the problem-solving method, in order.
2. Without a calculator, estimate $\frac{4.92 \times 61}{2.1}$.
3. A student converts 5.0 m to centimeters and gets 0.050 cm. Which check tells you this is wrong, and why?

Answers: 1) Read, Plan, Solve, Check. 2) About $\frac{5 \times 60}{2} = 150$ (exact value 142.9). 3) The size check: centimeters are smaller than meters, so the number must get bigger (500 cm), not smaller. The factor was upside down.



Step DOWN to the right: move the decimal point RIGHT, × 10 for each step →

King Henry Died By Drinking Chocolate Milk

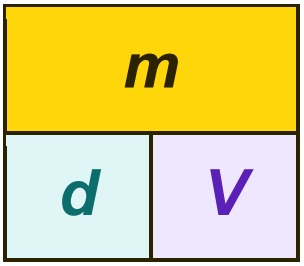
The metric staircase from kilo to milli. Each step is a factor of 10. Going down the stairs (to a smaller unit) the number gets BIGGER: 2.5 km = 2500 m. Going up the stairs (to a bigger unit) the number gets SMALLER: 450 mg = 0.450 g. Beyond milli: micro (μ, 10^{-6}) and nano (n, 10^{-9}).

Prefix	Symbol	Meaning	Equality to write
kilo	k	1000 times the base	1 km = 1000 m
centi	c	1/100 of the base	1 m = 100 cm
milli	m	1/1000 of the base	1 L = 1000 mL
micro	μ	1/1 000 000 of the base	1 g = 10^6 μg
nano	n	1/1 000 000 000 of the base	1 m = 10^9 nm

FREE PREVIEW · from 02 Quick Revision Sheets, page 3 of 18

SNEAK PEEK

Density on one page



cover what you want

want density?	$d = \frac{m}{V}$
want mass?	$m = d \times V$
want volume?	$V = \frac{m}{d}$

Cover the letter you want.

Regular shape	Irregular solid (sinks)	Liquid
Measure and use a formula: $l \times w \times h$ or $\pi r^2 h$	Water displacement: $V_{\text{final}} - V_{\text{initial}}$	Read a graduated cylinder at the bottom of the meniscus

SHEET 1 The Four-Step Method

1 READ given + find → **2 PLAN** plan the units → **3 SOLVE** cancel + compute → **4 CHECK** units, size, sig figs

↺ **Answer looks wrong? Go back to Read and plan again.**

Use it on every problem, even easy ones.

Step	Ask yourself	Write down
Read	What am I given? What must I find? Which units?	Given: ... Find: ...
Plan	What path of units gets me there? Which equalities?	Road map: unit → unit → unit
Solve	Is every unwanted unit on top once and on the bottom once?	One line of factors, then the number
Check	Right unit? Sensible size? Right sig figs?	Answer with unit, boxed

Units right? YES → **Size sensible?** YES → **Sig figs right?** YES → **Answered the question?**

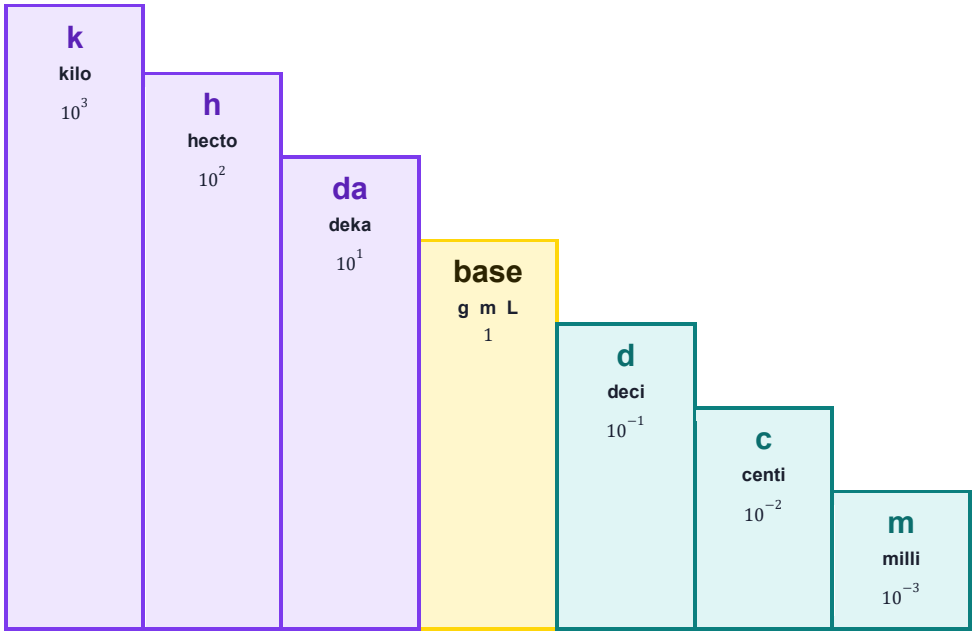
all unwanted units cancelled | big unit → small number | match the least precise measurement | number + unit + what was asked

The final check before you box an answer.

MEMORY HOOK | Big unit, small number

Converting to a **smaller** unit → the number gets **bigger**. Converting to a **bigger** unit → the number gets **smaller**.

SHEET 3 Metric Prefixes for Conversions



Step DOWN to the right: move the decimal point RIGHT, × 10 for each step →

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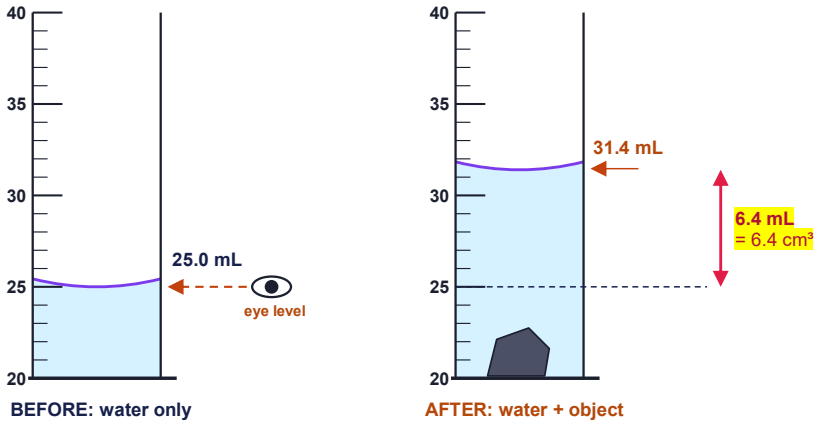
Each step is × 10 or ÷ 10.

Prefix	Symbol	Size	Write the equality as
kilo	k	10^3	1 km = 1000 m; 1 kg = 1000 g
centi	c	10^{-2}	1 m = 100 cm
milli	m	10^{-3}	1 L = 1000 mL; 1 g = 1000 mg
micro	μ	10^{-6}	1 m = 10^6 μm
nano	n	10^{-9}	1 m = 10^9 nm

MEMORY HOOK | King Henry Died By Drinking Chocolate Milk

kilo, **h**ecto, **d**eka, **B**ase, **d**eci, **c**enti, **m**illi. Moving down the stairs (left to right), move the decimal point **right** one place per step.



Read both levels at eye level, at the bottom of the meniscus.

Displacement: the rise in water level is the object's volume.

SHEET 7 Density Problems in Three Moves

You are asked for	Do this	Watch for
Density	Find V first (formula or displacement), then $d = \frac{m}{V}$	Radius = diameter ÷ 2. Subtraction sig figs.
Mass	Volume × density, with $\frac{\text{g}}{\text{mL}}$ so mL cancels	Volume units must match the density units.
Volume	Mass × flipped density, $\frac{\text{mL}}{\text{g}}$, so g cancels	A denser substance → smaller volume.
Identity	Calculate d, compare with a table	Pick the closest value, then say so.
Float or sink?	Calculate d, compare with the liquid	Heavy is not the same as dense.

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SNEAK PEEK

Spot the problem before you read the fix

TRAP 1 The factor is upside down

The question	Convert 45.0 cm to inches.
WRONG	$$45.0\ \text{cm} \times \frac{2.54\ \text{cm}}{1\ \text{in}} = 114.3\ \frac{\text{cm}^2}{\text{in}}$$ The student writes "114 in". The units did not cancel, and the answer got bigger even though inches are bigger than centimeters.
RIGHT	$$45.0\ \cancel{\text{cm}} \times \frac{1\ \text{in}}{2.54\ \cancel{\text{cm}}} = 17.716\ldots\ \text{in} = \mathbf{17.7\ in}$$
Why it happens	The equality 1 in = 2.54 cm is remembered as one fraction, and that fraction gets used no matter which way the conversion goes.
Dodge it	**Want over have: the unit you HAVE goes on the bottom, every time.**

TRAP 20 Using the diameter as the radius

The question	A metal rod has diameter 2.00 cm, length 6.00 cm and mass 50.9 g. Find its density.
WRONG	$$V = \pi\,(2.00\ \text{cm})^2(6.00\ \text{cm}) = 75.4\ \text{cm}^3$$ $$d = \frac{50.9\ \text{g}}{75.4\ \text{cm}^3} = 0.675\ \text{g/cm}^3$$ This would mean a metal rod floats in water.
RIGHT	$$r = \frac{2.00\ \text{cm}}{2} = 1.00\ \text{cm}$$ $$V = \pi\,(1.00\ \text{cm})^2(6.00\ \text{cm}) = 18.85\ \text{cm}^3$$ $$d = \frac{50.9\ \text{g}}{18.85\ \text{cm}^3} = \mathbf{2.70\ g/cm^3}\ \text{(aluminum)}$$
Why it happens	Problems give the diameter because that is what you measure with calipers. The formula needs the radius.
Dodge it	**Write r = d ÷ 2 as its own line before using the cylinder formula.**

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SECTION 1 Setting Up Conversions

KEY IDEA

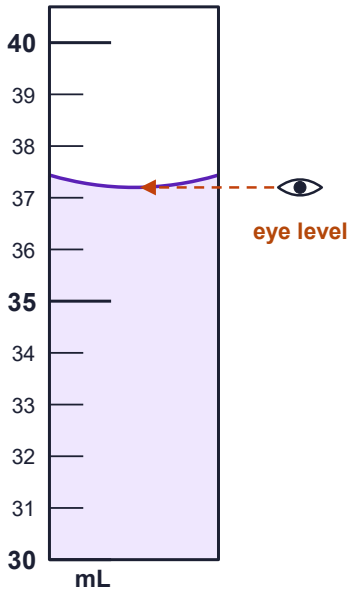
Almost every wrong conversion has the same root cause: the units were not written, so a backwards factor went unnoticed.

TRAP 1 The factor is upside down

The question	Convert 45.0 cm to inches.
WRONG	$$45.0\ \text{cm} \times \frac{2.54\ \text{cm}}{1\ \text{in}} = 114.3\ \frac{\text{cm}^2}{\text{in}}$$ The student writes "114 in". The units did not cancel, and the answer got bigger even though inches are bigger than centimeters.
RIGHT	$$45.0\ \cancel{\text{cm}} \times \frac{1\ \text{in}}{2.54\ \cancel{\text{cm}}} = 17.716\ldots\ \text{in} = \mathbf{17.7\ in}$$
Why it happens	The equality 1 in = 2.54 cm is remembered as one fraction, and that fraction gets used no matter which way the conversion goes.
Dodge it	**Want over have: the unit you HAVE goes on the bottom, every time.**

TRAP 2 A backwards metric equality

The question	Convert 3.20 m to centimeters.
WRONG	$$3.20\ \text{m} \times \frac{1\ \text{cm}}{100\ \text{m}} = 0.0320\ \text{cm}$$ Built from the false equality "1 cm = 100 m". A 3-meter board cannot be a third of a millimeter long.
RIGHT	$$3.20\ \cancel{\text{m}} \times \frac{100\ \text{cm}}{1\ \cancel{\text{m}}} = 320.\text{cm} = \mathbf{3.20 \times 10^2\ cm}$$
Why it happens	Prefixes are learned as "centi means 100", and the 100 gets attached to the wrong unit.
Dodge it	**Put the 1 beside the BIGGER unit: 1 m = 100 cm, 1 L = 1000 mL, 1 kg = 1000 g.**



The cylinder for Trap 24. Each line is 1 mL. Read the volume yourself before you look at the WRONG and RIGHT rows below.

TRAP 24	Reading the top of the meniscus
The question	Water in a graduated cylinder curves down in the middle. What is the volume?
WRONG	The student reads where the water touches the glass at the edges: 37.4 mL.
RIGHT	Read the **bottom** of the curve, with your eye level with it: **37.2 mL**.
Why it happens	The edges are easier to see, and looking from above or below shifts the reading.
Dodge it	**Eye level, bottom of the curve, estimate one digit past the smallest marking.**

FREE PREVIEW · from 03 Exam Traps and Mistakes, page 27 of 27

SECTION 8 Top 10 Traps Checklist

Tear out this page and keep it with your calculator. Before you hand in any test, run down the list.

#	Check	Dodge-it rule
1	**Units on every number?**	Write a unit beside every number in every line.
2	**Factors the right way up?**	Want over have: the unit you have goes on the bottom.
3	**Equalities correct?**	The 1 goes with the bigger unit: 1 m = 100 cm, 1 L = 1000 mL.
4	**Did every unwanted unit cancel?**	Only the unit you want should be left.
5	**Is the size sensible?**	Smaller unit, bigger number. Bigger unit, smaller number.
6	**Typed correctly?**	Top numbers ×, bottom numbers ÷. EE means "× 10^{n}" already.
7	**Rounded only once?**	One calculator run, round at the end.
8	**Sig figs from measurements only?**	Exact numbers never limit. After subtracting, recount.
9	**Density set up right?**	d = m/V with matching units; use density as a factor for m or V.
10	**Volume found correctly?**	Radius, not diameter; final minus initial for displacement.

★ **HONORS EXTENSION** · Regular students may skip | **Honors add-ons**

11. Squared or cubed unit? Raise the whole factor to the power, number and unit.

12. Derived unit? Convert the top unit AND the bottom unit, each with its own factors.

SNEAK PEEK

Three questions and a full solution

26. ●●○ CORE Convert 48.0 cm to inches.

65. ●●○ CORE What is the mass of 40.0 mL of gasoline (0.74 g/mL)?

87. ●●● CHALLENGE **Find the mistake.** A 20.1 g rock raises water from 25.0 mL to 31.6 mL. A student reports $d = \frac{20.1\ \text{g}}{31.6\ \text{mL}} = 0.636\ \text{g/mL}$ and says the rock floats. Fix the error.

WORKED EXAMPLE | Worked solution to question 87

87. **Answer: The volume is the change in level, 6.6 mL, not 31.6 mL. Density = 3.0 g/cm³; the rock sinks.**

$$V = 31.6\ \text{mL} - 25.0\ \text{mL} = 6.6\ \text{mL}$$

$$d = \frac{20.1\ \text{g}}{6.6\ \text{cm}^3} = 3.045\ldots\ \text{g/cm}^3 = 3.0\ \text{g/cm}^3$$

Every question in the bank has a solution laid out like this, with units cancelled at every step.

11 Mixed review and data reading

99. ●●○ CORE A student records these data for liquid X. Use them to find its density.

Volume (mL)	10.0	20.0	30.0
Mass (g)	8.9	17.8	26.7

100. ●●○ CORE Using your answer to the previous question, predict the mass of 45.0 mL of liquid X.

101. ●●● CHALLENGE What volume, in cm^3, does 1.00 lb of aluminum occupy? (1 lb = 453.6 g)

102. ●●● CHALLENGE Scrap copper sells for $4.25 per pound. What is a copper block with a volume of 250. cm^3 worth?

103. ●●● CHALLENGE How many liters of ethanol (0.789 g/mL) have a mass of 2.00 kg?

104. ●●● CHALLENGE An empty flask has a mass of 48.37 g. Filled with 25.00 mL of a liquid, its mass is 73.62 g. Find the density of the liquid.

★ HONORS PART 2 Honors Questions

★ HONORS EXTENSION · Regular students may skip | **This whole part is Honors**

Regular students can skip to Part 3. Honors students: these questions build on the core, so be confident with Part 1 first.

★ HONORS A Squared and cubed units

H1. ●○○ WARM-UP Convert 4.2 m^2 to cm^2.

H2. ●○○ WARM-UP Convert 750. cm^2 to m^2.

H3. ●○○ WARM-UP 1 cm^3 is equal to how many mm^3?

(A) 10
(B) 100
(C) 1000
(D) 10^6

WORKED EXAMPLE | Sample question, scored the way your teacher will score it

21. A rectangular metal block measures 2.50 cm × 3.00 cm × 4.00 cm and has a mass of 236 g. Find its density and identify the metal. **(7 pts)**

Key. **Answer: 7.87 g/cm³; iron (7 pts)**

$$V = 2.50\ \text{cm} \times 3.00\ \text{cm} \times 4.00\ \text{cm} = 30.0\ \text{cm}^3$$

$$d = \frac{236\ \text{g}}{30.0\ \text{cm}^3} = 7.866\ldots\ \text{g/cm}^3 = 7.87\ \text{g/cm}^3$$

Scoring guide

- Volume formula for a box ..... **1 pt**
- Volume = 30.0 cm³ ..... **2 pts**
- Density set-up ..... **1 pt**
- Density = 7.87 g/cm³ ..... **1 pt**
- 3 sig figs ..... **1 pt**
- Identifies iron ..... **1 pt**

FREE PREVIEW · from 05 Mock Test, page 8 of 21

SECTION A Multiple Choice (30 points)

Choose the best answer and write its letter in the grid. Each question is worth 2 points.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

1. Which conversion factor changes meters to centimeters?

(A) $\frac{1\ \text{m}}{100\ \text{cm}}$

(B) $\frac{100\ \text{cm}}{1\ \text{m}}$

(C) $\frac{1\ \text{cm}}{100\ \text{m}}$

(D) $\frac{100\ \text{m}}{1\ \text{cm}}$

2. Which equality is exact (defined)?

(A) 1 kg = 2.205 lb

(B) 1 in = 2.54 cm

(C) 1 L = 1.057 qt

(D) 1 mi = 1.609 km

3. 0.528 L is equal to:

(A) 5.28 mL

(B) 52.8 mL

(C) 528 mL

(D) 5280 mL

4. Which of these is a unit of density?

(A) cm^3

(B) g

(C) g/cm^3

(D) $\text{g} \cdot \text{cm}^3$

5. Which list gives the four problem-solving steps in order?

(A) Read, Plan, Solve, Check

(B) Solve, Check, Read, Plan

(C) Plan, Solve, Read, Check

(D) Check, Read, Solve, Plan

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FREE PREVIEW · from 06 Glossary and Flashcards, page 3 of 26

SNEAK PEEK

Front and back, exactly as they print

Left: the front of the card. Right: its back. On the real sheets, fronts and backs are on separate pages so they line up when printed double-sided.

CONVERSION #25 1 in = ? cm	CONVERSION #25 *1 in = ? cm* 1 in = 2.54 cm (exact, by definition)
QUICK PROBLEM #56 Mass of 20.0 mL of mercury (13.6 g/mL)?	QUICK PROBLEM #56 *Mass of 20.0 mL of mercury (13.6 g/mL)?* 272 g

FREE PREVIEW · from 06 Glossary and Flashcards, page 15 of 26

FRONTS Sheet 3 of 8 · cards 17 to 24 · print the next page on the back

CONVERSION #17 1 km = ? m	**CONVERSION** #18 1 m = ? cm
CONVERSION #19 1 m = ? mm	**CONVERSION** #20 1 L = ? mL
CONVERSION #21 1 mL = ? cm^3	**CONVERSION** #22 1 kg = ? g
CONVERSION #23 1 g = ? mg	**CONVERSION** #24 1 g = ? µg

SECTION 3 Density of Regular Solids

Tests often give you a finished data table and ask you to analyze it. Here a student measured the mass and the sides of three objects.

Object	Mass (g)	Measurements (cm)	Volume (cm^3)	Density (g/cm^3)
A block	50.9	l = 5.02, w = 2.48, h = 1.51	18.8	2.71
B cylinder	88.6	diameter = 1.90, h = 3.50	9.92	8.93
C cube	16.5	edge = 3.00	27.0	0.611

WORKED EXAMPLE | Worked analysis: regular solids

Block A

$$V = l \times w \times h = 5.02\ \text{cm} \times 2.48\ \text{cm} \times 1.51\ \text{cm} = 18.799\ \text{cm}^3$$

$$d = \frac{m}{V} = \frac{50.9\ \text{g}}{18.799\ \text{cm}^3} = 2.7076\ \text{g/cm}^3 = \mathbf{2.71\ g/cm^3}$$

Cylinder B

$$r = \frac{1.90\ \text{cm}}{2} = 0.950\ \text{cm}$$

$$V = \pi r^2 h = \pi \times (0.950\ \text{cm})^2 \times 3.50\ \text{cm} = 9.9235\ \text{cm}^3$$

$$d = \frac{88.6\ \text{g}}{9.9235\ \text{cm}^3} = 8.928\ \text{g/cm}^3 = \mathbf{8.93\ g/cm^3}$$

Cube C

$$V = (3.00\ \text{cm})^3 = 27.0\ \text{cm}^3$$

$$d = \frac{16.5\ \text{g}}{27.0\ \text{cm}^3} = 0.6111\ \text{g/cm}^3 = \mathbf{0.611\ g/cm^3}$$

Identify

Block A at 2.71 g/cm^3 matches **aluminum** (2.70). Cylinder B at 8.93 g/cm^3 matches **copper** (8.96). Cube C is less dense than water, so it floats: it is a **light wood**, which is not on the table.

Check

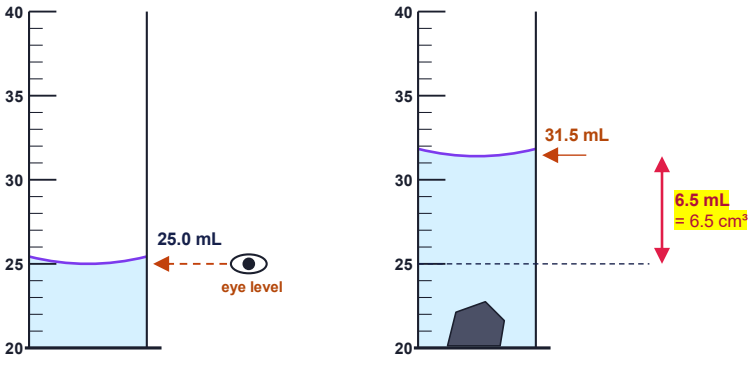
Every measurement has 3 sig figs, so every density gets 3. The table shows volumes rounded to 3 sig figs, but the calculations keep all digits until the final answer.

WORKED EXAMPLE | Worked analysis: water displacement

Rock	$V = 31.5\ \text{mL} - 25.0\ \text{mL} = 6.5\ \text{mL} = 6.5\ \text{cm}^3$ $d = \dfrac{17.6\ \text{g}}{6.5\ \text{cm}^3} = 2.708\ \text{g/cm}^3 = \mathbf{2.7\ g/cm^3}$
Bolt	$V = 35.0\ \text{mL} - 30.0\ \text{mL} = 5.0\ \text{mL} = 5.0\ \text{cm}^3$ $d = \dfrac{39.4\ \text{g}}{5.0\ \text{cm}^3} = 7.88\ \text{g/cm}^3 = \mathbf{7.9\ g/cm^3}$
Identify	The rock at 2.7 g/cm^3 is typical of common rock such as granite. The bolt at 7.9 g/cm^3 matches **iron** (steel is mostly iron, 7.87).
Check	Each volume comes from a subtraction with one decimal place, so it has only 2 sig figs. That limits each density to 2 sig figs, even though the masses have 3.

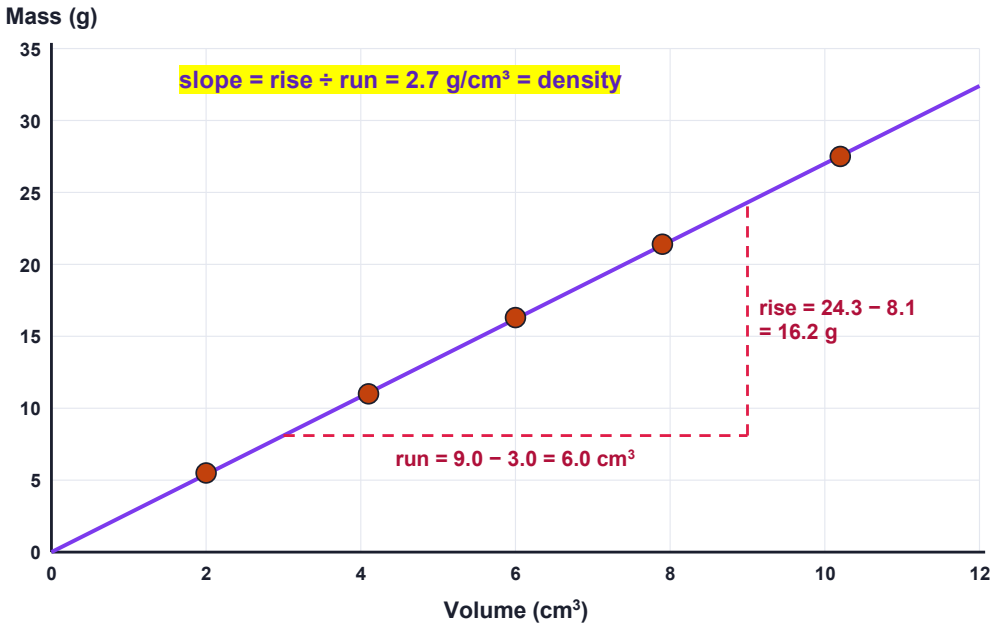
Questions on this data

1. The masses have 3 sig figs. Why do the densities have only 2?
2. An air bubble stays stuck to the rock. Will the measured density be too high or too low? Explain.
3. Why must you find the mass **before** the object goes into the water?



Read both levels at eye level, at the bottom of the meniscus.

Reading at eye level: the water rises by exactly the volume of the object.



Mass vs. volume for the data above, with the best-fit line and the slope triangle. Orange points are measured data. The best-fit line passes through the origin (zero volume has zero mass). Read rise and run from two points ON THE LINE, far apart, not from data points.

WORKED EXAMPLE | Worked analysis: slope of the best-fit line

Pick two points

Choose two points **on the line**, far apart, not data points: (3.0 cm^3, 8.1 g) and (9.0 cm^3, 24.3 g).

Slope

$$slope = \frac{rise}{run} = \frac{24.3\ \text{g} - 8.1\ \text{g}}{9.0\ \text{cm}^3 - 3.0\ \text{cm}^3} = \frac{16.2\ \text{g}}{6.0\ \text{cm}^3}$$
$$= \mathbf{2.7\ g/cm^3}$$

Identify

The slope is the density: 2.7 g/cm^3 matches **aluminum** (2.70 g/cm^3).

Check

The run, 6.0 cm^3, has 2 sig figs, so the slope gets 2. The units come out as g/cm^3 because mass is on the y-axis and volume on the x-axis.

Questions on this data

1. Why should the best-fit line pass through the origin?
2. Use the slope to predict the mass of an aluminum piece with a volume of 12.0 cm^3.
3. Use the slope to predict the volume of a 50.0 g piece of aluminum.

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