

SI Units and Unit Conversions

How do you convert units using dimensional analysis?

●○○ Beginner

Foundations

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Before you start: it helps to understand Significant Figures and Measurement.

What is it?

A measurement is a **number with a unit**: “5” means nothing, but “5 g” or “5 L” does. Scientists use the **SI** (Système International), built on seven **base units**:

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

Every other unit is **derived** from these: area (m^2), volume (m^3), speed (m/s), density (kg/m^3), energy (joule, $\text{J} = \text{kg} \cdot \text{m}^2/\text{s}^2$) and pressure (pascal, $\text{Pa} = \text{N/m}^2$).

KEY IDEA

To convert a unit, multiply by a **conversion factor**: a fraction equal to 1, such as $\frac{1000 \text{ m}}{1 \text{ km}}$. Arrange it so the unit you don't want **cancels** and the unit you want is left. This method is called **dimensional analysis**.

Why does it matter?

- **Data comes in many units.** Labs use mL, g and °C; equations often need L, kg and K.
- **Units catch mistakes.** If the units don't cancel to the answer's unit, the setup is wrong, before you even press a calculator key.

- **Real consequences.** Unit errors have wrecked spacecraft and caused medication overdoses. Writing units on every number prevents them.

How does it work?

1. Metric prefixes

A prefix multiplies a unit by a power of ten. The most useful in chemistry:

Prefix	Symbol	Factor
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

So 1 km = 1000 m, 1 mL = 0.001 L and 1 nm = 10^{-9} m.

2. Conversion factors

Any equality gives **two** conversion factors. From 1 L = 1000 mL:

$$\frac{1000 \text{ mL}}{1 \text{ L}} \quad \text{or} \quad \frac{1 \text{ L}}{1000 \text{ mL}}$$

Choose the one with the unit you want to remove **in the denominator**.

3. Squared and cubed units

Square or cube the **whole** conversion factor, number and unit:

- 1 m = 100 cm, so $1 \text{ m}^2 = (100 \text{ cm})^2 = 10^4 \text{ cm}^2$ and $1 \text{ m}^3 = (100 \text{ cm})^3 = 10^6 \text{ cm}^3$
- **1 mL = 1 cm³** and **1 L = 1000 cm³ = 1 dm³**

4. Density as a conversion factor

Density links mass and volume: $\rho = \frac{m}{V}$. A density of 13.6 g/mL means $\frac{13.6 \text{ g}}{1 \text{ mL}}$, which converts volume into mass (or, flipped, mass into volume).

∞ THINK OF IT LIKE THIS

Converting units is like changing money. 50 dollars is still the same amount of money when you express it in cents (5000 cents); only the number and the unit change, together. A conversion factor is the exchange rate.

🔍 MORE PRECISELY

The litre is not an SI unit, but it is accepted for use with the SI: $1 \text{ L} = 1 \text{ dm}^3$ exactly. The kilogram is the only base unit whose name already contains a prefix, so prefixes are attached to “gram” instead (mg, not μkg). Since 2019, all seven base units are defined by fixing the values of physical constants.

Visualise it

Metric prefixes

Each prefix multiplies the unit by a power of ten.

G	giga	10^9	Gm, GHz
M	mega	10^6	MHz, MJ
k	kilo	10^3	km, kg
—	(base unit)	10^0	m, g, L, s
d	deci	10^{-1}	dm
c	centi	10^{-2}	cm
m	milli	10^{-3}	mL, mg
μ	micro	10^{-6}	μm , μg
n	nano	10^{-9}	nm
p	pico	10^{-12}	pm

$$1 \text{ km} = 10^3 \text{ m} = 1000 \text{ m} \cdot 1 \text{ mg} = 10^{-3} \text{ g} = 0.001 \text{ g}$$

Each step on the ladder is a power of ten.

Worked example

WORKED EXAMPLE: A one-step conversion

Question: Convert 350 mL to litres.

Step 1 Use 1 L = 1000 mL, with mL in the denominator so it cancels:

$$\begin{aligned} 350 \cancel{\text{mL}} &\times \frac{1 \text{ L}}{1000 \cancel{\text{mL}}} \\ &= 0.350 \text{ L} \end{aligned}$$

Step 2 The answer is **0.350 L**.

WORKED EXAMPLE: Converting two units at once

Question: A car travels at 72 km/h. What is this speed in m/s?

Step 1 Convert km to m (top) and h to s (bottom):

$$\begin{aligned} \frac{72 \cancel{\text{km}}}{1 \cancel{\text{h}}} &\times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \\ &\times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} \\ &= 20 \text{ m/s} \end{aligned}$$

Step 2 km and h cancel, leaving m/s: **20 m/s**.

WORKED EXAMPLE: A cubed unit

Question: The density of a liquid is 1.20 g/cm³. What is it in kg/m³?

Step 1 Convert g to kg, and cm³ to m³ using 1 m³ = 10⁶ cm³:

$$\begin{aligned} \frac{1.20 \cancel{\text{g}}}{1 \cancel{\text{cm}^3}} &\times \frac{1 \text{ kg}}{1000 \cancel{\text{g}}} \\ &\times \frac{10^6 \cancel{\text{cm}^3}}{1 \text{ m}^3} \\ &= 1.20 \times 10^3 \text{ kg/m}^3 \end{aligned}$$

Step 2 The density is **1.20 × 10³ kg/m³**.

 WORKED EXAMPLE: Using density

Question: Mercury has a density of 13.6 g/mL. What is the mass of 15.0 mL of mercury?

$$15.0 \text{ mL} \times \frac{13.6 \text{ g}}{1 \text{ mL}} = 204 \text{ g}$$

Common mistake

 COMMON MISTAKE: Using the conversion factor upside down

$350 \text{ mL} \times \frac{1000 \text{ mL}}{1 \text{ L}}$ gives 350 000 mL²/L, which is clearly wrong: the units don't cancel. If the units don't work out, flip the factor.

 COMMON MISTAKE: Forgetting to square or cube the factor

1 m² is **not** 100 cm². It is (100 cm)² = 10 000 cm², because both the length and the width are converted.

 COMMON MISTAKE: Mixing up m (milli) and M (mega)

Symbols are case-sensitive: 1 mg is a thousandth of a gram, but 1 Mg is a million grams. Likewise, “m” alone means metre, and “M” in chemistry also means mol/L.

 NOTATION NOTE

- Units can be written with a slash or with negative powers: g/cm³ = g cm⁻³; J/(mol·K) = J mol⁻¹ K⁻¹.
- A space separates the number and the unit: 5.0 g, not 5.0g. Percent and degree signs follow the same rule in SI style (25 °C).

Remember this

 REMEMBER THIS

- Seven SI base units: m, kg, s, K, mol, A, cd. Everything else is derived.
- k = 10³, c = 10⁻², m = 10⁻³, μ = 10⁻⁶, n = 10⁻⁹.
- Multiply by conversion factors (fractions equal to 1) so unwanted units cancel.
- Square or cube the whole factor for areas and volumes; 1 mL = 1 cm³; 1 L = 1 dm³.

References

1. Bureau International des Poids et Mesures (BIPM). The International System of Units (SI), 9th ed.; BIPM, 2019.
[Link](#)
2. Brown, T. L.; LeMay, H. E., Jr.; Bursten, B. E.; Murphy, C. J.; Woodward, P. M.; Stoltzfus, M. W. Chemistry: The Central Science, 15th ed.; Pearson, 2022.

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