Gases and the gas laws slide deck

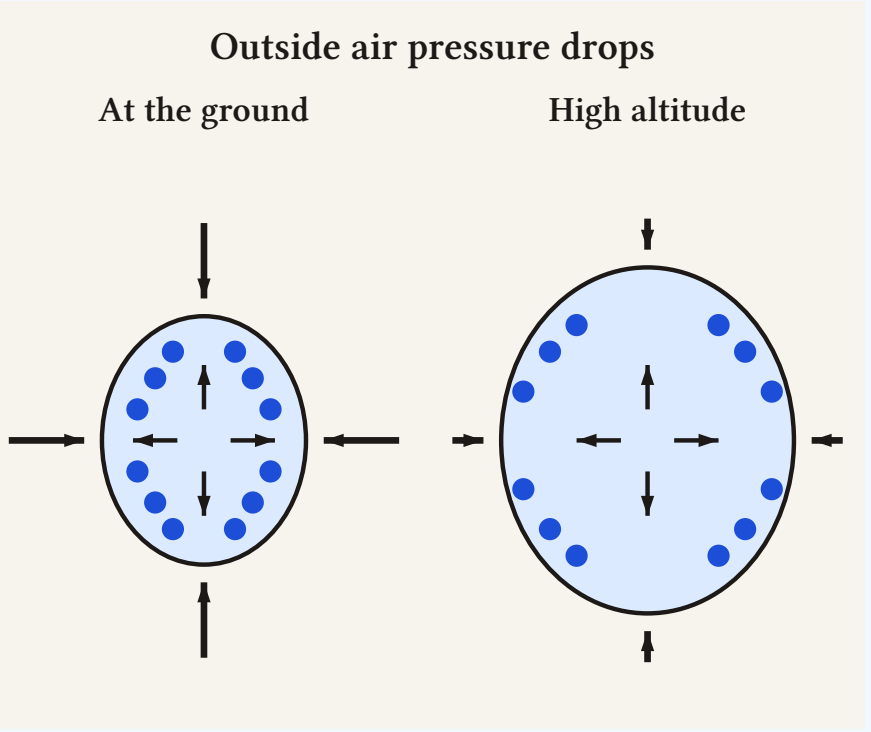
Chemistry 20

Unit B: Gases and the gas laws

Real gases and the ideal gas model

One balloon, two altitudes

- The balloon grows because the outside air pressure drops, while the gas inside keeps pushing out.
- Outside arrows point in, long at the ground and short at altitude. Inside arrows point out and stay the same length.



Three rules build the ideal picture

- An ideal gas uses negligible particle volume, elastic collisions, and no attractive forces.
- A real gas keeps the same moving particles, and its volume and attractions show up at high pressure and low temperature.

Key terms

kinetic molecular theory

A model that explains gas pressure and temperature through the motion and collisions of tiny particles. (KMT)

ideal gas

A gas model in which particle volume is negligible, collisions are elastic, and particles have no attractive forces.

real gas

A gas whose particle volume and attractive forces change the measurements at high pressure or low temperature.

Altitude keeps helium near the ideal picture

- Helium in the weather balloon is far above its condensation temperature, and the pressure on its skin is low.
- The larger volume in thin air follows from a lower outside pressure acting on the same moving particles.



Balloon and cold cylinder

- Helium at ordinary weather-balloon pressures matches the ideal gas rules.
- Carbon dioxide that is cold and highly compressed needs the real-gas corrections.

Nitrogen in two conditions

- Nitrogen in open room air is warm relative to its boiling point and is only lightly compressed.
- Nitrogen squeezed and cooled toward the liquid needs the real-gas picture.

Which picture fits

- Explain the weather balloon at low altitude and in thin air with one ideal-gas story.
- Name the conditions that make particle volume and attractions matter for a real gas.

Image credits

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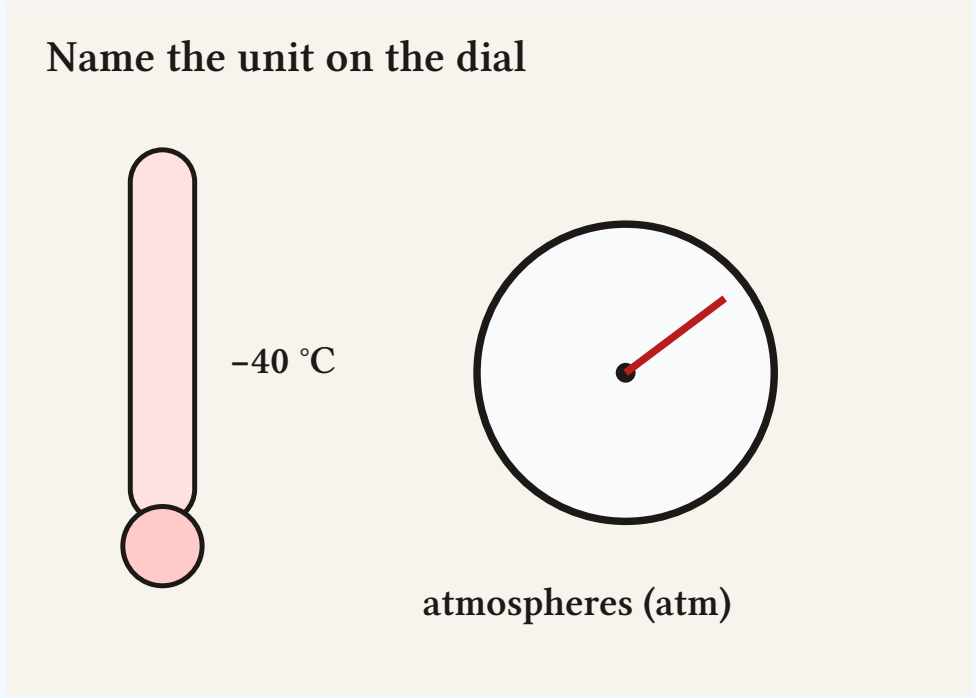
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Unit B: Gases and the gas laws

Kelvin temperature and pressure units

A cold morning and two dials

- A bench thermometer can read −40 °C while a nearby gauge is marked in atmospheres.
- Gas calculations need one temperature scale and a stated pressure unit before any proportion is written.



Kelvin and pressure units

- Kelvin temperature equals the Celsius reading plus 273.15, and absolute zero is 0 K.
- Sea-level air pressure can be written 101.325 kPa, 1 atm, or 760 mmHg, and precise instruments made those readings trustworthy.

Key terms

kelvin

The temperature scale that places its zero at absolute zero and is reached from Celsius by adding 273.15. (K)

absolute zero

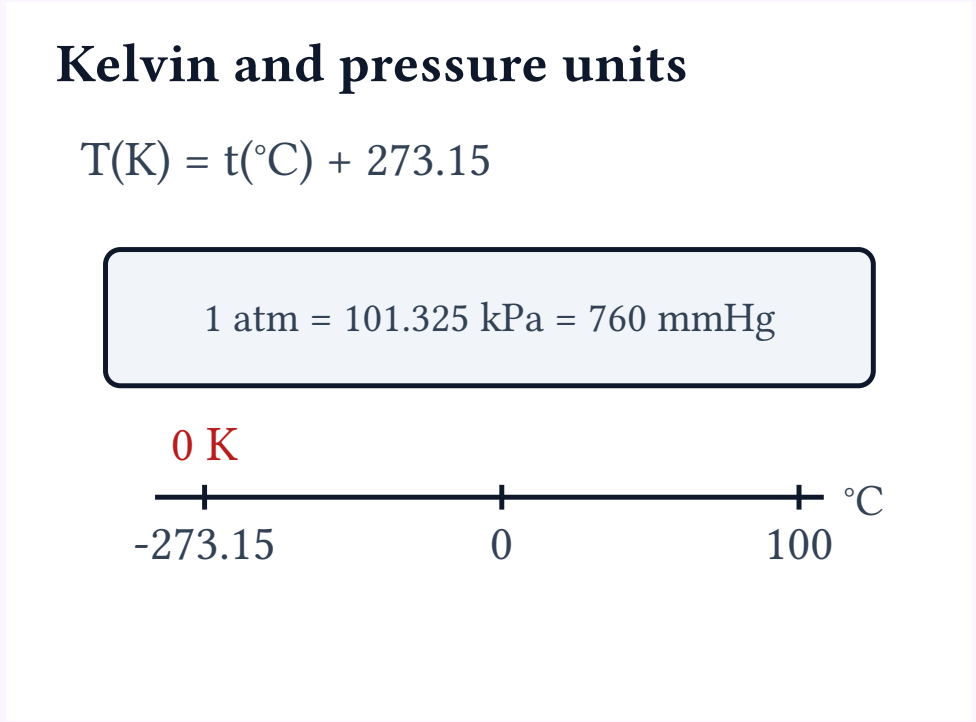
The zero point on the kelvin scale, written 0 K, equal to −273.15 degrees Celsius. (0 K)

kilopascal

A pressure unit in which average sea-level air pressure is 101.325, the same pressure as 1 atmosphere or 760 millimetres of mercury. (kPa)

Absolute zero and pressure units

- T(K) = t(C) + 273.15, so 0 K equals −273.15 °C.
- That same pressure is 101.325 kPa, 1 atm, and 760 mmHg.



Three temperature conversions

- Each Celsius reading increases by 273.15 on the way to kelvin.
- For a negative Celsius reading, you still add 273.15.

Converting 2.00 atm both ways

- Use 101.325 kPa for each atmosphere when the target unit is kilopascals.
- Use 760 mmHg for each atmosphere when the target unit is millimetres of mercury.

Temperature and pressure

- Convert 100 °C to kelvin and state the Celsius mark of absolute zero.
- Say what a thermocouple, a thermistor, and a Bourdon gauge measure.

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The gas laws

Syringe compression and heating

- Pushing a sealed syringe in at one temperature makes the trapped air push back harder.
- Warming that same air while the plunger is free to move makes the volume grow instead.

Three equations, each with a fixed quantity

- Boyle’s law is P1V1 = P2V2 when temperature and amount stay constant.
- Charles’s law is $V_1/T_1 = V_2/T_2$ in kelvin, and the combined law is $P1V1/T_1 = P2V2/T_2$.

Key terms

Boyle's law

At constant temperature and amount of gas, the product of pressure and volume stays the same. (P1V1 = P2V2)

Charles's law

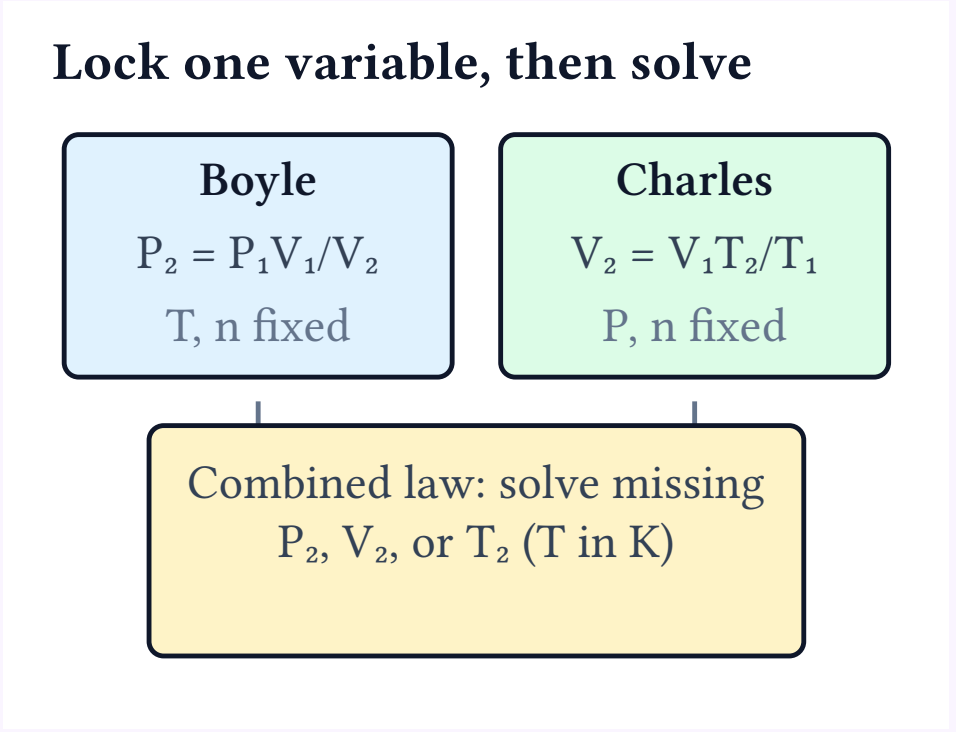
At constant pressure and amount of gas, volume divided by kelvin temperature stays the same. ($V_1/T_1 = V_2/T_2$)

combined gas law

For a fixed amount of gas, $P1V1/T_1$ equals $P2V2/T_2$ when pressure and temperature both change. ($P1V1/T_1 = P2V2/T_2$)

Lock one variable, then solve

- Boyle's law solves $P_2 = P1V1/V_2$, and Charles's law solves $V_2 = V1T2/T_1$.
- The combined law solves whichever of P_2, V_2, or T_2 is missing, with T in kelvin.



Compress 2.40 L at 100 kPa to 0.800 L

- Temperature and amount stay constant, so Boyle’s law applies.
- The new pressure is the original pressure scaled by 2.40/0.800.

Heat 1.50 L from 300 K to 450 K

- Pressure and amount stay constant, so Charles’s law applies.
- Both temperatures are already kelvin, so no 273.15 shift is still waiting.

Pressure and temperature both change

- A fixed amount of gas starts at 100 kPa, 3.00 L, and 300 K.
- Find the volume at 200 kPa and 400 K with the combined law.

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Calculations with the ideal gas law

Four measurements, one equation

- A sealed sample has a pressure, a volume, a temperature, and an amount of gas, and any three determine the fourth.
- The link among those four is the ideal gas law, once the temperature is in kelvin and the units match R.

PV = nRT and molar volumes

- Rearrange PV = nRT to isolate the measurement the problem asks for.
- At STP one mole occupies 22.4 L, and at SATP one mole occupies 24.8 L.

Key terms

ideal gas law

The equation PV = nRT connecting pressure, volume, amount of gas, and kelvin temperature. (PV = nRT)

molar volume

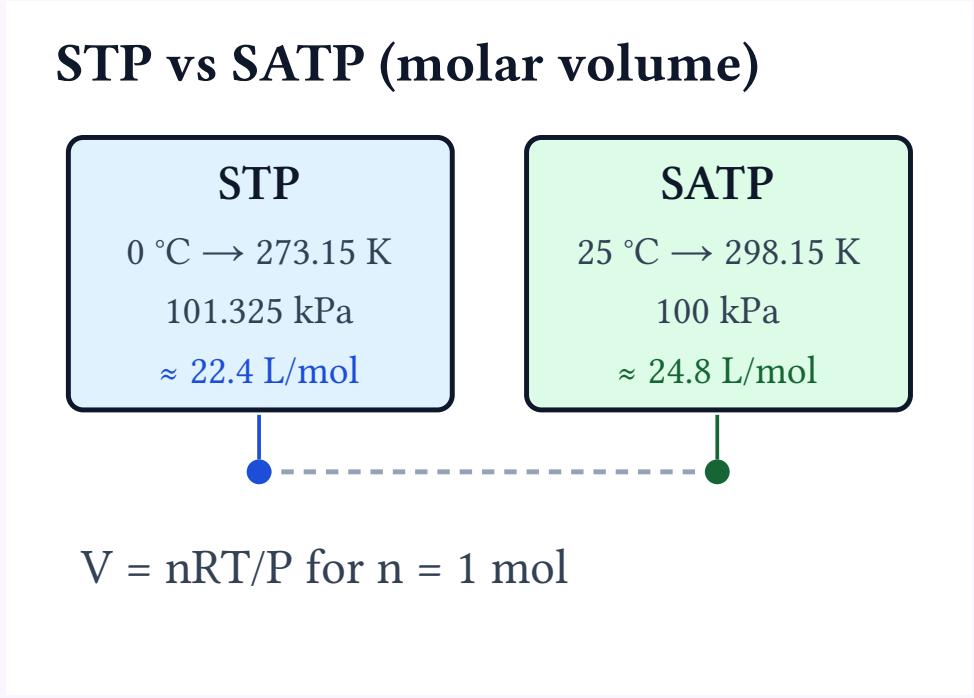
The volume of one mole of gas at a stated temperature and pressure, 22.4 $L \cdot mol^{-1}$ at STP and 24.8 $L \cdot mol^{-1}$ at SATP. ($L \cdot mol^{-1}$)

gas constant

The constant R in PV = nRT, equal to 8.314 when pressure is in kilopascals, volume in litres, amount in moles, and temperature in kelvin. (R)

Where 22.4 and 24.8 come from

- STP is 0 °C, which is 273.15 K, and 101.325 kPa.
- SATP is 25 °C, which is 298.15 K, and 100 kPa.



Pressure of 0.250 mol in 5.00 L

- The sample is 0.250 mol in 5.00 L at 298.15 K.
- Pressure is nRT/V, and the result rounds to 124 kPa.

Amount in 11.2 L at STP

- STP supplies the molar volume 22.4 $L \cdot mol^{-1}$.
- The same amount should appear from PV/RT within ordinary rounding.

SATP volume and the right conditions

- Find the volume of 0.200 mol at SATP using 24.8 $\mathrm{L \cdot mol^{-1}}$.
- Say what volume you would wrongly get if you used 22.4 $\mathrm{L \cdot mol^{-1}}$ instead.

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Combining volumes and gas technologies

Hydrogen and oxygen volume ratio

- When hydrogen gas and oxygen gas form water vapour at one temperature and one pressure, their volumes follow the coefficients.
- The reaction $2\,H_2 + O_2 \longrightarrow 2\,H_2O(g)$ therefore uses volumes in the ratio 2:1:2.

Volume ratios in devices

- Multiply a known gas volume by a coefficient ratio to find the other gas volumes at the same temperature and pressure.
- Breathing, diffusion, weather, balloons, tanks, air bags, turbines, and engines each show a gas property in use.

Key terms

law of combining volumes

At the same temperature and pressure, the volumes of gases in a reaction are in the same ratio as their coefficients. (2:1:2)

density

Mass divided by volume. Heated air in an open balloon has a lower density than the cooler air outside. (g/L)

diffusion

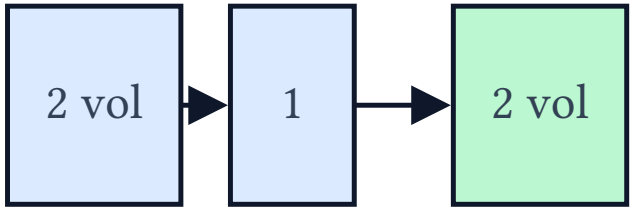
The net spread of gas particles from a region of higher concentration toward a region of lower concentration.

Coefficients are the volume recipe for gases

- The law of combining volumes applies only to substances that are gases at the shared temperature and pressure.
- A coefficient of 2 means twice the volume of a coefficient of 1.

Coefficients = gas volumes

$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$



Same T and P; gases only
Coeff 2 = twice volume of 1

Volumes for 6.00 L of hydrogen

- Hydrogen's coefficient is 2, oxygen's coefficient is 1, and water vapour's coefficient is 2.
- The gases react completely at one temperature and one pressure.

Scaling ammonia from 9.00 L of hydrogen

- The equation $N_2 + 3\ H_2 \longrightarrow 2\ NH_3$ uses gas volumes in the ratio 1:3:2.
- Hydrogen is the known volume, 9.00 L, at the same temperature and pressure as the other gases.

Gases in devices

- Explain a hot-air balloon, an air bag, and a scuba tank with three different gas properties.
- Keep the balloon answer on density and the air-bag answer on a reaction that produces gas.

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Investigations of gas behaviour

A falling gauge and a capped syringe

- People connected with the land, including Indigenous communities and agricultural workers, have read plant and animal responses as signs of changing atmospheric pressure.
- A capped syringe on the same bench asks a different question: which quantities you will hold still while you change one other.

Safety first, then a fair table

- Read the WHMIS label and the safety data sheet before a gas cylinder is opened or a reaction that makes a gas is started.
- The investigation names controlled variables, graphs the data, identifies a gas or finds R, and keeps every trial.

Key terms

controlled variable

A quantity kept unchanged so the test shows the effect of the one quantity that is deliberately varied.

molar mass

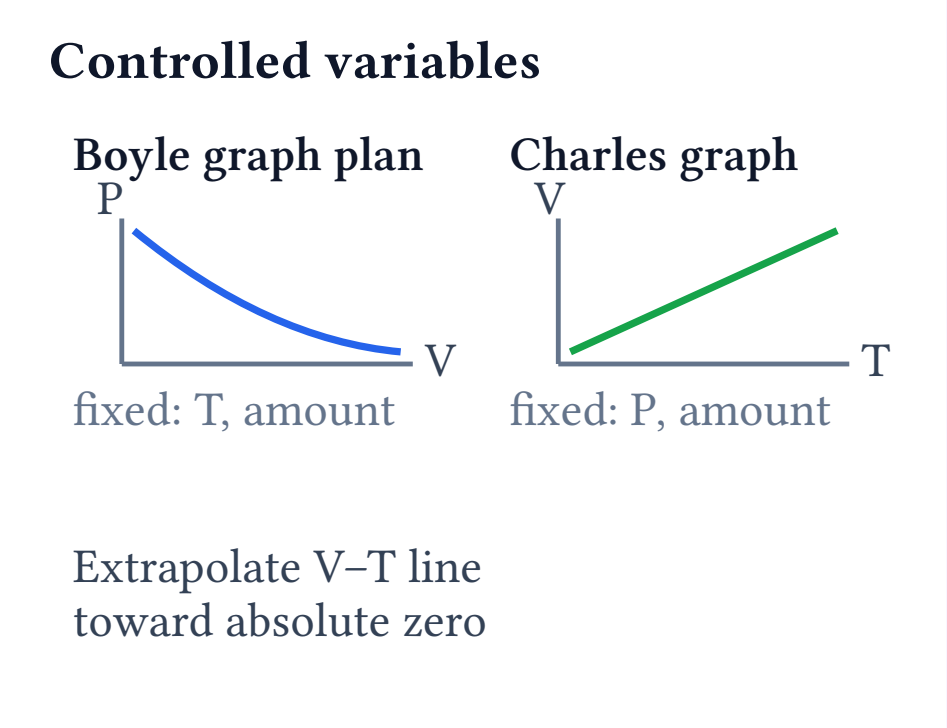
The mass of one mole of a substance. For an unknown gas it is calculated from $M = mRT/PV$. ($g \cdot mol^{-1}$)

WHMIS

The Workplace Hazardous Materials Information System of labels and safety data sheets used before hazardous products are handled.

Controlled variables and graphs

- A Boyle plan keeps temperature and amount fixed while pressure and volume change.
- A Charles plan, or an absolute-zero graph, keeps pressure and amount fixed while volume and temperature change.



Gas identity from M = mRT/PV

- A 2.200 g sample occupies 1.120 L at 101.325 kPa and 273.15 K.
- The molar mass is compared with carbon dioxide, 44.01 g·mol⁻¹.

A constant product and a temperature window

- Three Boyle pairs can be tested by multiplying pressure by volume.
- The thermometer limit belongs in the same report as the graph.

R from the whole table

- A group presentation shows how pressure, volume, temperature, and amount determine R.
- Every trial remains in the shared table while groups compare values.