Gas Laws:
Pressure, Volume, and Temperature

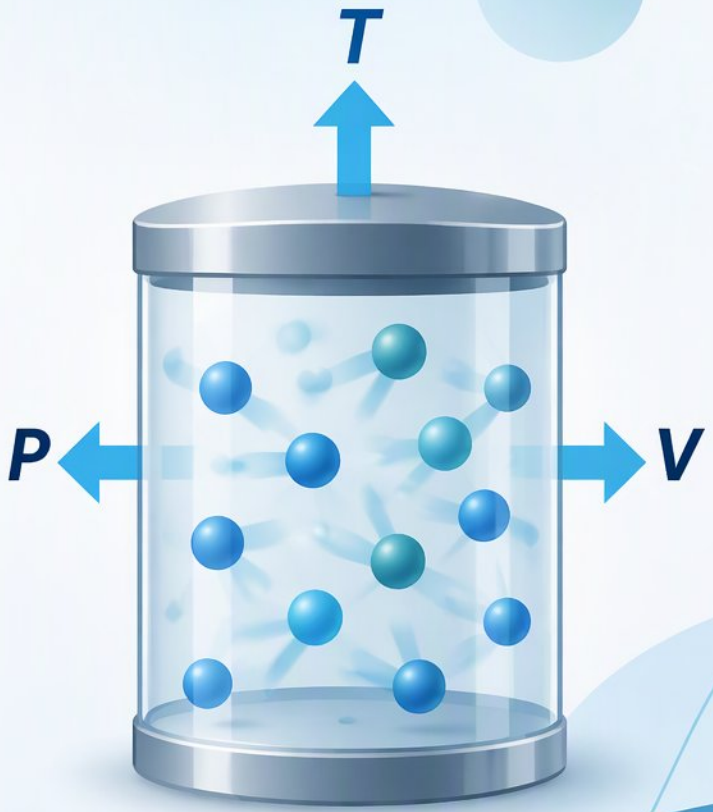
Course purpose: see how pressure, volume, and temperature connect in gases — at work, in science, in daily life

Learning goals: define P, V, T with correct units; apply Boyle's, Charles's, Gay-Lussac's, combined, and ideal gas laws

Read gas-law graphs and solve contextual problems with confidence (Kelvin and unit checks built in)

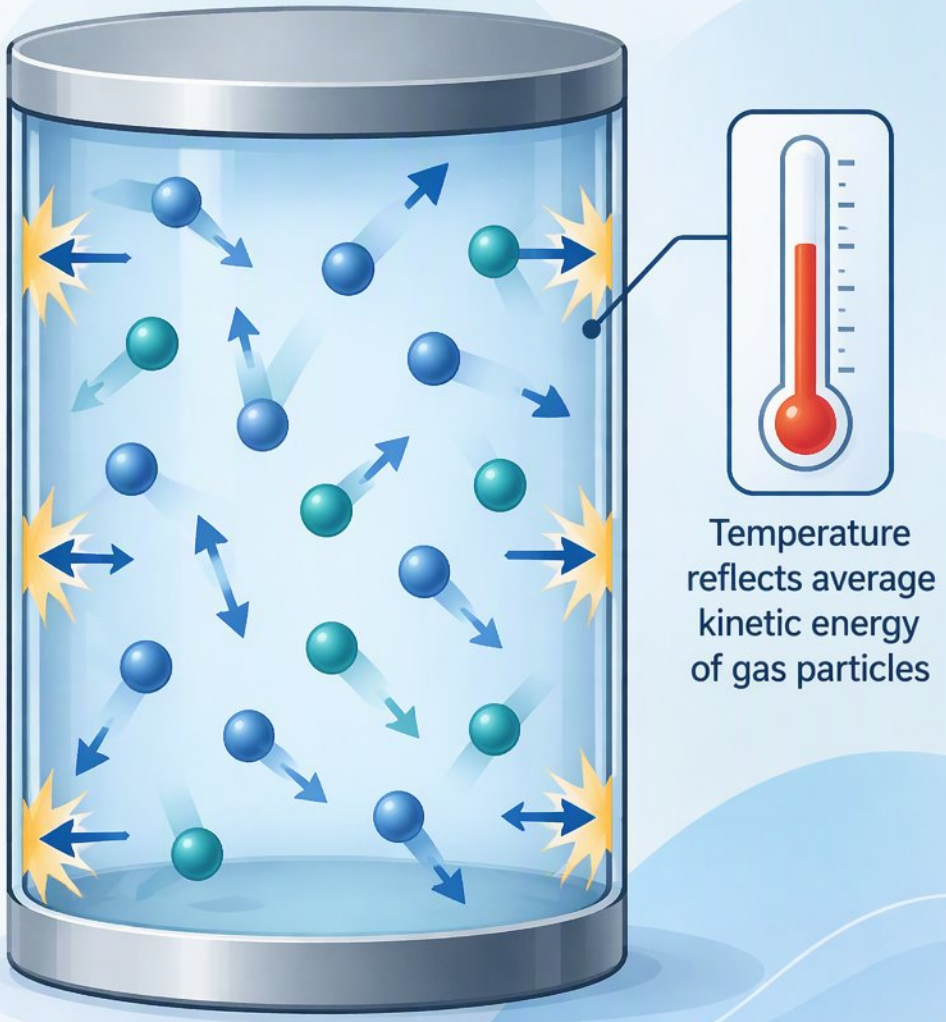
Roadmap: core concepts and units → individual gas laws → combined and ideal relationships → graphs, applications, practice

For students, adult learners, and educators: worked examples, facilitation notes, and teaching tips included



Core Concepts: Why Gases Behave the Way They Do

- Kinetic molecular theory: particles move randomly; wall collisions create pressure
- Temperature reflects average kinetic energy of gas particles
- State variables and units: pressure (Pa, atm, mmHg), volume (L, m^3), temperature (K vs °C)
- Gas-law ratios require Kelvin: absolute zero is the zero of Kelvin
- Ideal gas assumptions; real gases deviate at high pressure and low temperature



Units, Conversions, and Standard Conditions

Same Units Bigger Understanding

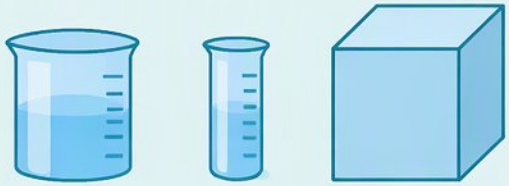
Pressure



1 atm = 101.325 kPa
= 1.01325 bar
= 760 mmHg

atm kPa bar mmHg

Volume



convert among L, mL, and m³ before solving

L mL m³

Temperature



K = °C + 273.15

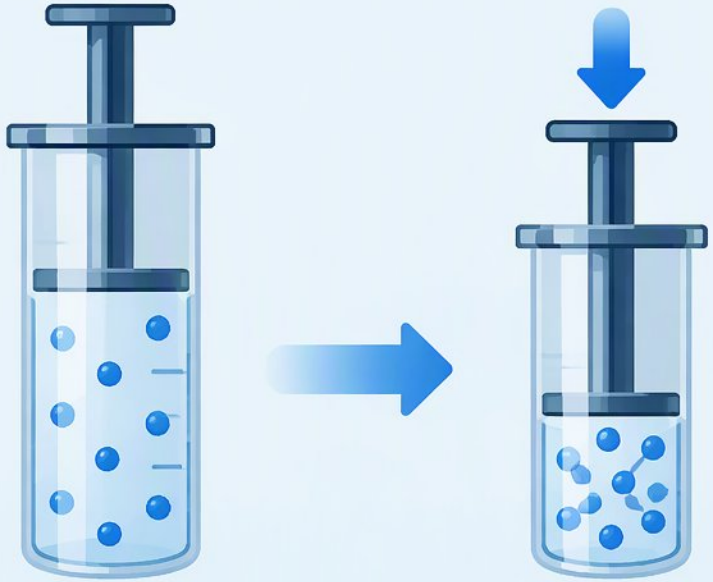
never use Celsius in gas-law ratios

K °C

1. **Pressure:** 1 atm = 101.325 kPa = 1.01325 bar = 760 mmHg
2. **Volume:** convert among L, mL, and m³ before solving
3. **Temperature:** K = °C + 273.15; never use Celsius in gas-law ratios
4. **IUPAC STP since 1982:** 273.15 K and exactly 100 kPa (1 bar)
5. **Always state reference conditions:** older 1 atm standard is still common
6. **Avoid traps:** mixing atm and kPa, skipping Kelvin, dropping units

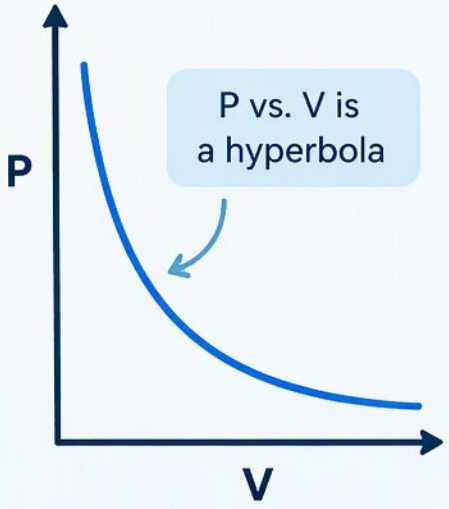
Units Connect Ideas

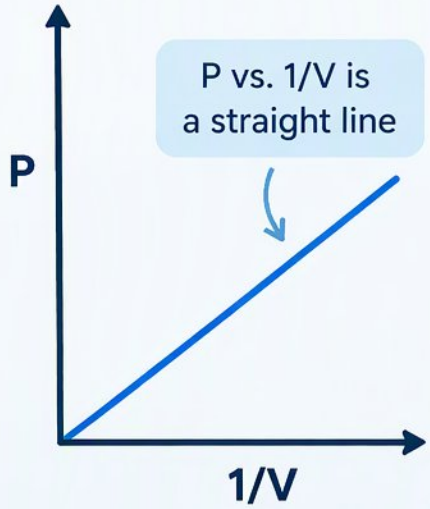
Pressure and Volume: Boyle's Law



Lower Pressure
Larger Volume

Higher Pressure
Smaller Volume



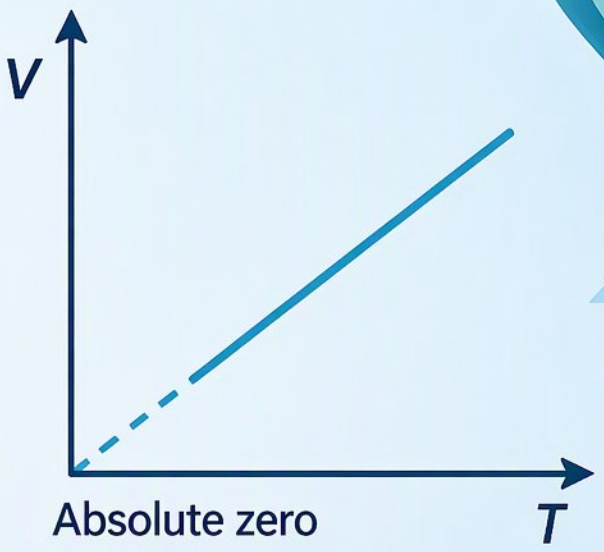


- At constant T and n: pressure and volume are inversely related
- Formula: $P_1V_1 = P_2V_2$
- Graph: P vs. V is a hyperbola; P vs. 1/V is a straight line

- **Example:** compressing gas in a syringe or cylinder predicts new volume
- **Applications:** breathing, hydraulics, compressed gas safety
- At 2 atm, gas volume halves; at 3 atm, it is one-third

Volume and Temperature: Charles's Law

- At constant pressure, volume is directly proportional to absolute temperature
- Formula: $V_1/T_1 = V_2/T_2$ — kelvin required
- Graph: V vs. T is a straight line through absolute zero
- Example: heated gas expands in a flexible container
- Trap: Celsius in the ratio crashes your answer — convert first







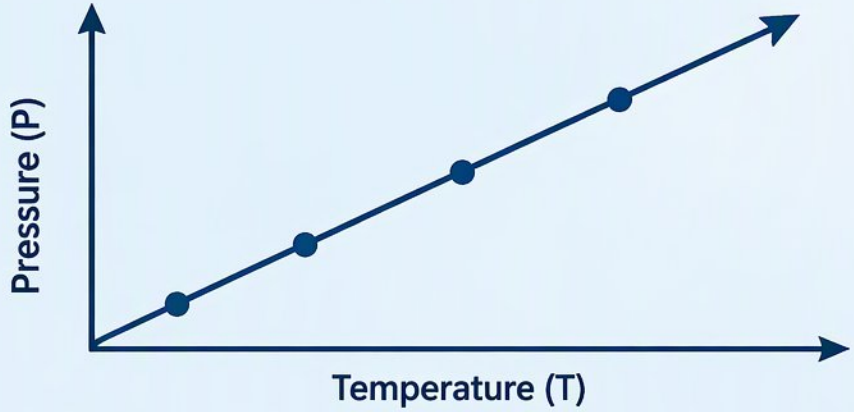
°C + 273.15 → K

Pressure and Temperature: Gay-Lussac's Law (Amontons's Law)

- At constant volume, pressure is directly proportional to absolute temperature:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

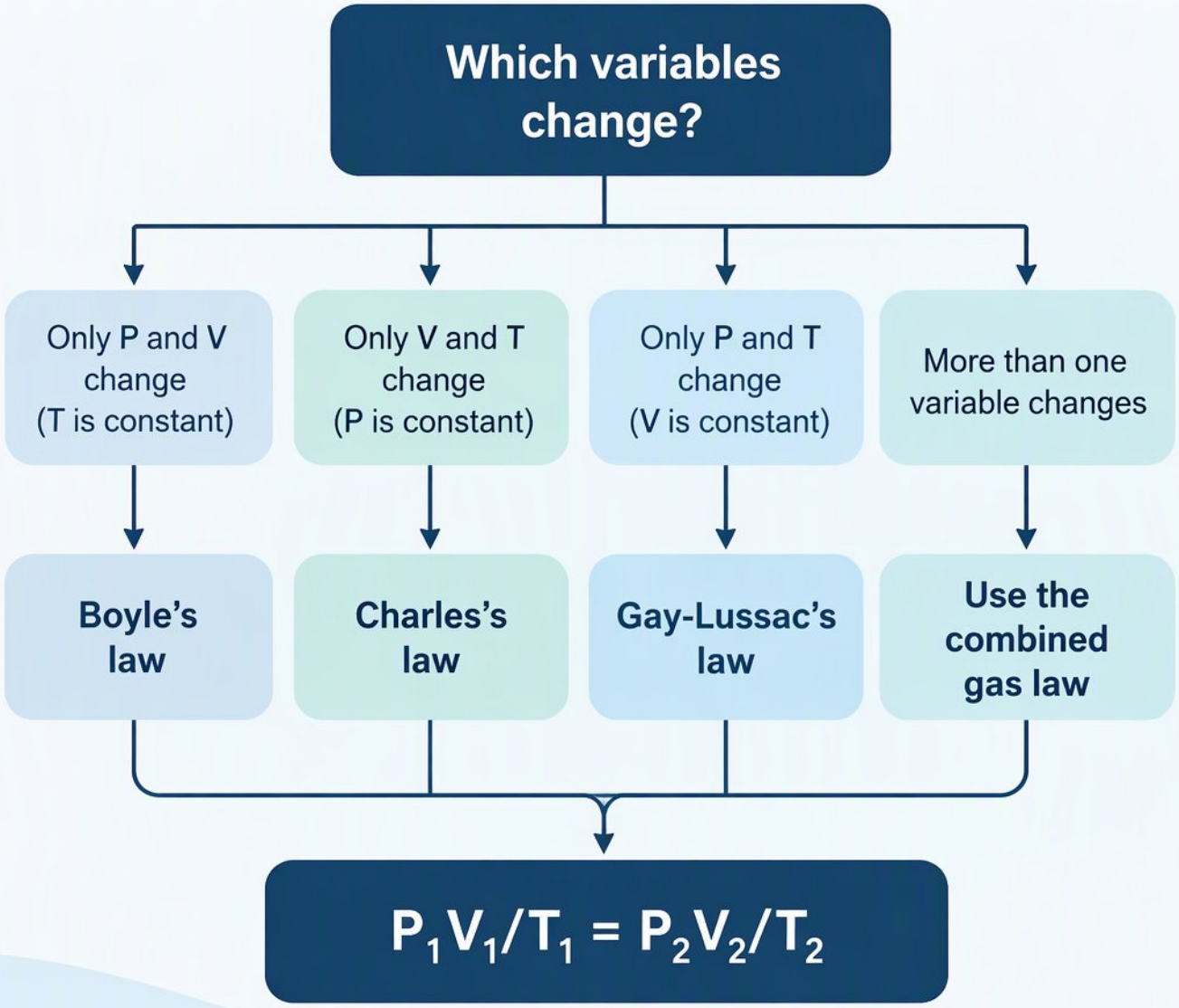
- T must be in Kelvin; use absolute pressure in the ratio
- Naming: Amontons's law (~1700) or Gay-Lussac's law — check your curriculum
- Everyday example: sealed aerosol can or tire pressure rises with heating





Safety: never heat sealed containers; pressure can build to rupture

Bringing It Together: The Combined Gas Law



- Combined law: $P_1V_1/T_1 = P_2V_2/T_2$ replaces separate laws for one gas sample.
- Setting one variable constant recovers Boyle's, Charles's, or Gay-Lussac's law.
- Decision strategy: list changing variables and the constant, then pick the simplest law.
- Protocol: knowns → Kelvin → solve symbolically → substitute → check reasonableness.
- Worked example (scuba tank: 13.2 L, 153 atm, 27 °C → 3.13 atm, 37 °C) gives ≈667 L.



SAME GAS. MANY CONDITIONS. ONE RELATIONSHIP.

The Ideal Gas Law and Its Uses

Simple Ideas
Real Understanding

- PV = nRT: pressure × volume equals moles × constant × Kelvin temperature
- Match R to your units: 8.314 J K^{-1} mol^{-1}, 8.314 kPa L mol^{-1} K^{-1}, or 0.08206 L atm mol^{-1} K^{-1}
- IUPAC STP since 1982: 273.15 K and 100 kPa; molar volume ≈ 22.7 L (≈ 22.4 L at 1 atm)
- Ideal model works well at ordinary conditions; real gases deviate at high pressure and low temperature
- Worked example: find moles (n = PV/RT), then convert to mass or density

$$PV = nRT$$

- P — Pressure (P)
- V — Volume (V)
- n — Moles (n)
- R — Gas constant (R)
- T — Kelvin temperature (T)

Common Values for R (Match to Your Units)

- 8.314 J K^{-1} mol^{-1}
- 8.314 kPa L mol^{-1} K^{-1}
- 0.08206 L atm mol^{-1} K^{-1}

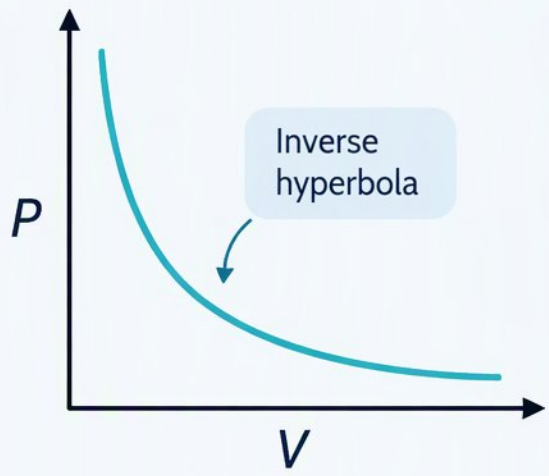


GASES CONNECT
IDEAS TO THE WORLD

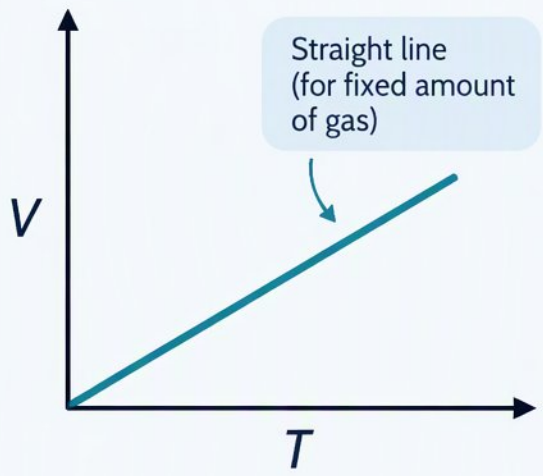
Reading and Creating Gas Law Graphs

GRAPHS REVEAL RELATIONSHIPS

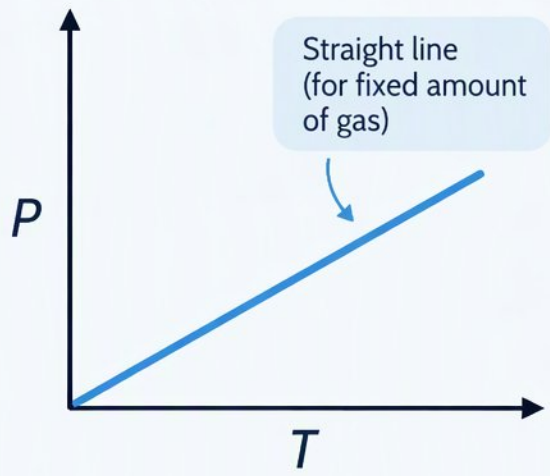
P–V



V–T



P–T



- P–V: inverse hyperbola; P vs. 1/V gives a straight line through the origin
- V–T and P–T: straight lines for a fixed amount of gas
- Read direct vs. inverse relationships from shape and slope, not memorized formulas
- Extrapolation hits absolute zero; real gases liquefy before reaching it
- Watch for unlabeled axes, Celsius on temperature axes, and curved lines misread as linear

Check your axes and units!

SAME IDEAS. BIGGER UNDERSTANDING.

Real-World Applications: Diving, Balloons, Tires, and HVAC

- Scuba: ~1 atm per 10 m of seawater; gas shrinks on descent, expands on ascent
- Buoyancy control, ear equalization, and air consumption all follow Boyle's law
- Balloons: gas expands as ambient pressure falls; this sets lift and burst altitude
- Sealed tanks: steel changes about 5 psi per °F, aluminum about 6 psi
- HVAC, manufacturing, and breathing: gas-law reasoning drives design and control



Applying the Gas Laws: A Structured Problem-Solving Protocol

SAME PRINCIPLES
DEEPER UNDERSTANDING

1. **Identify variables**
   Five steps: identify variables, choose the law, convert units, solve, and check
2. **Choose the law**
   Mixed practice: choose among Boyle's, Charles's, Gay-Lussac's, combined, and ideal laws
3. **Convert units**
   Convert temperature to Kelvin before substituting any values
4. **Solve**
5. **Check**
   That high-pressure result is only a ballpark estimate—ideal behavior is imperfect here



Scuba Example



13.2 L tank at **153 atm** and **27 °C**

L atm K

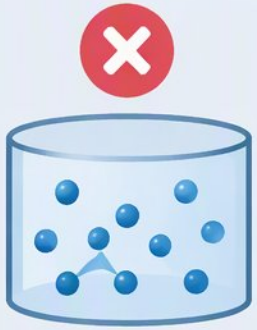
gives about **667 L** at **3.13 atm** and **37 °C**

L atm K

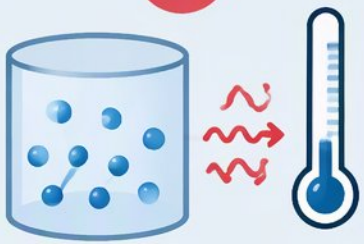
That high-pressure result is only a ballpark estimate—ideal behavior is imperfect here

IDEAS FLOW
FURTHER

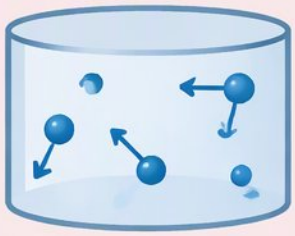
Correcting Common Misconceptions



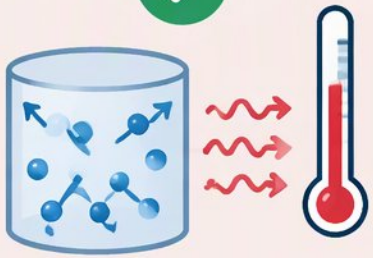














- Gas particles do not expand or shrink; spacing and motion change instead
- Gases have mass and weight; the ideal gas law lets you calculate it
- Heat is energy transfer; temperature tracks average kinetic energy
- Learners often assign absolute relationships among variables

- Predict–observe–explain demos and labs contradict these ideas



Teaching Strategies and Formative Checks

Engage • Check • Reinforce
Deeper Understanding

- Use demos and analogies to make particle motion and pressure intuitive
- Formative checks: conceptual questions, calculations, graph reading, and quick misconception probes
- Retrieval practice, faded worked examples, and peer explanation build **durable understanding**
- Multiple representations and clear unit conventions support diverse prior knowledge
- Probes target known misconceptions: gas weight, heat vs. temperature, absolute relationships

Make Ideas Visible

Demos make abstract ideas concrete.



What happens to the pressure if you push the plunger?

How does particle motion explain this?

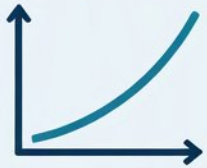
What misconceptions might this reveal?

Multiple Representations

Verbal



Graphical



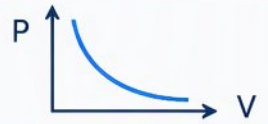
Symbolic

$$PV = nRT$$

Different Backgrounds. Brighter Thinking.

Wrap-Up: Key Takeaways and Next Steps

Same Laws Brighter Understanding

Law	Formula	Constant Variable	Graph Shape
Boyle's Law	$PV = \text{constant}$	Temperature (T)	
Charles's Law	$\frac{V}{T} = \text{constant}$	Pressure (P)	
Gay-Lussac's Law	$\frac{P}{T} = \text{constant}$	Volume (V)	
Combined Gas Law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	Amount of gas (n)	Linear relationship (depends on variables)
Ideal Gas Law	$PV = nRT$	None (all variables can change)	Linear relationship (in multiple forms)

Top Takeaways

- Convert to Kelvin
- Track units
- Identify the constant

Next Steps

- Check whether the ideal-gas assumption is reasonable for your conditions

Assessment Options

- Conceptual questions
- Calculations
- Graph interpretation
- Applied cases

References

- IUPAC Green Book and Gold Book
- OpenStax Chemistry

IUPAC STP since 1982: 273.15 K and exactly 100 kPa

Connect Concepts
Build Confidence
Keep Exploring

PersonWise.

PersonWise • AI digital-human course platform



Scan the code or click anywhere to watch this course live, with voice Q&A

personwise.ai/t/6e2c6206/public