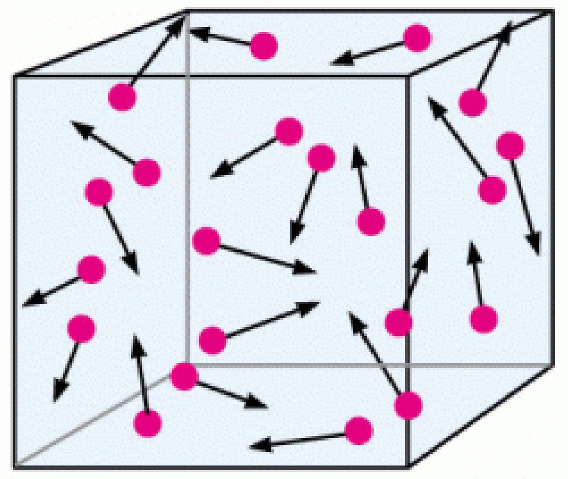
Gas Laws

IB PHYSICS | THERMAL PHYSICS

Ideal Gas

Assumptions:

- Large # of identical molecules
- Volume of molecules is negligible
- Motion is random
- No forces between molecules
- All collisions are elastic



No longer ideal when…

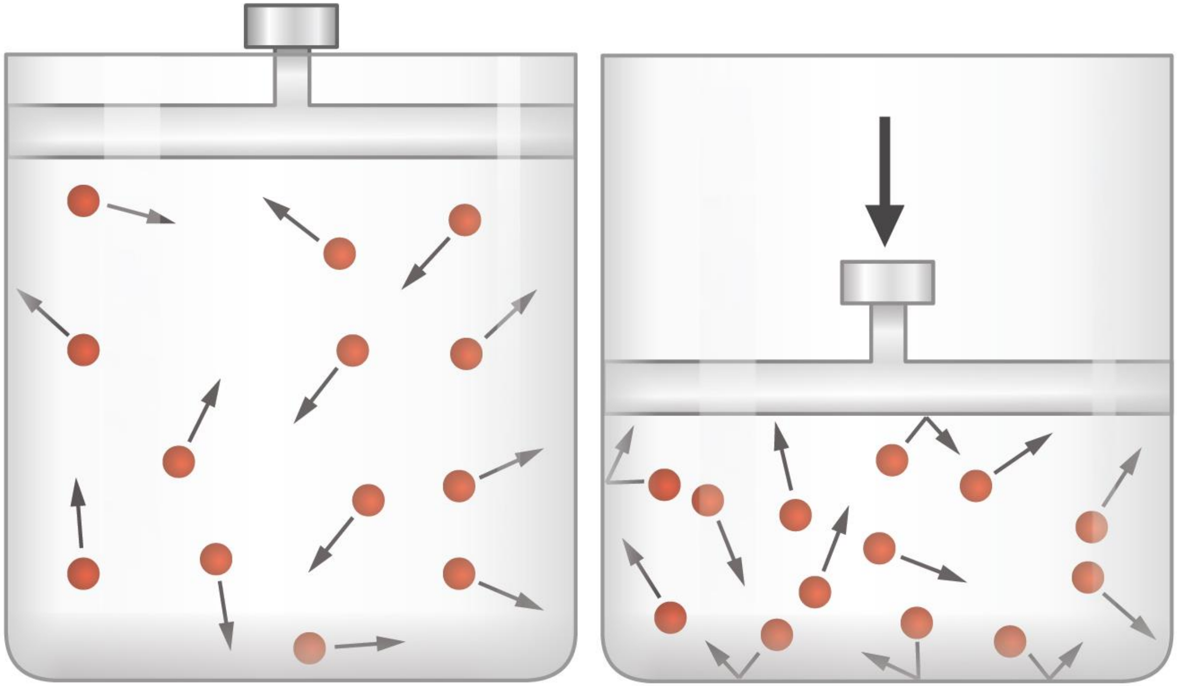
- Compressed
  - Molecules close together
- Close to Phase Change
  - All internal energy is from E_k

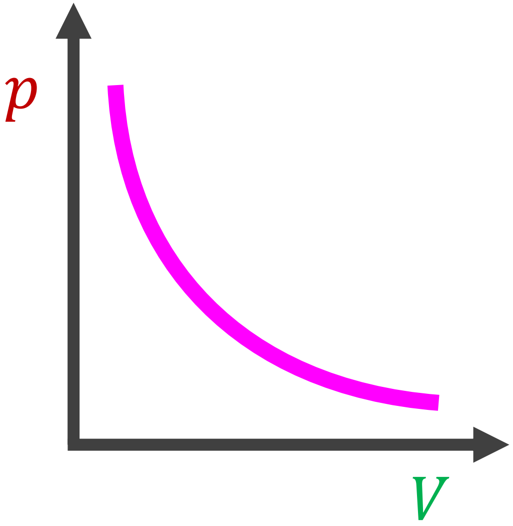
Boyle’s Law | Volume and Pressure

↓ Volume

↑ Pressure

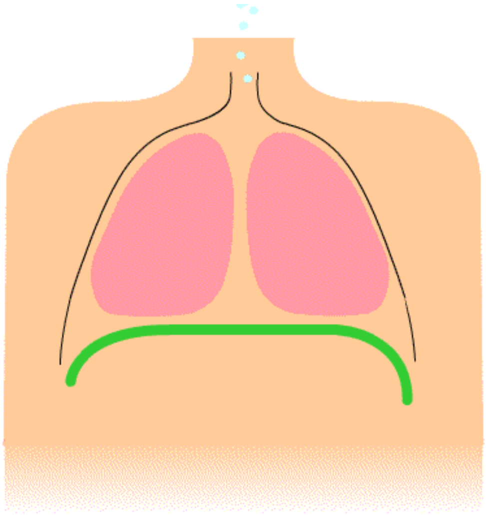
$$p \propto \frac{1}{V}$$

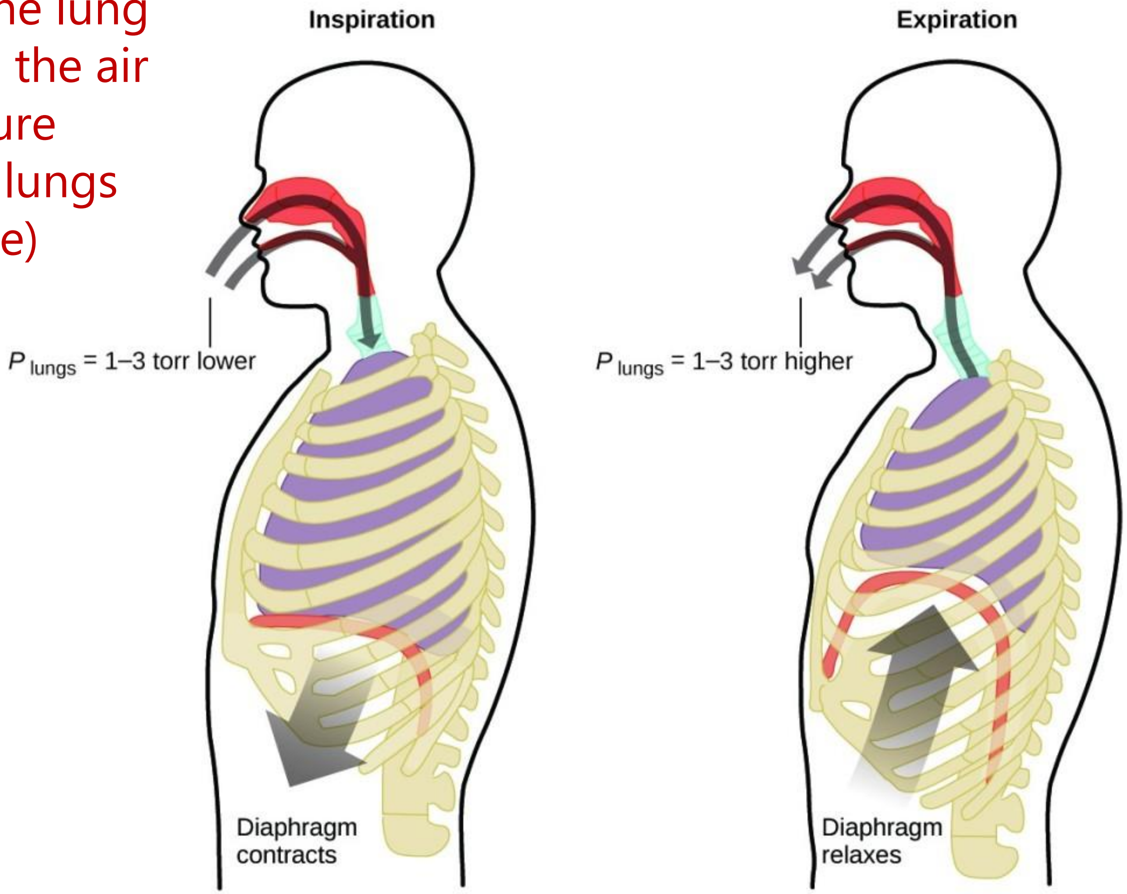




Boyle’s Law | Volume and Pressure

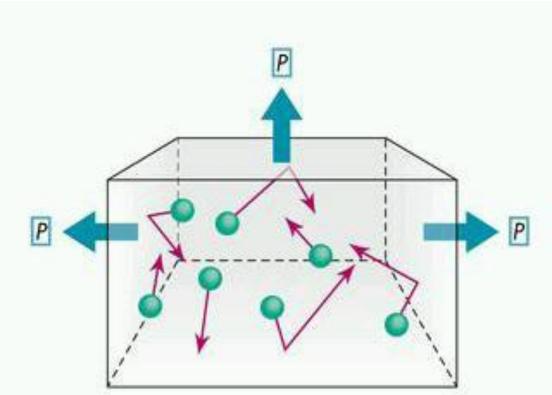
When diaphragm contracts the lung volume increases, decreasing the air pressure inside. With a pressure differential, air flows into the lungs (high pressure to low pressure)

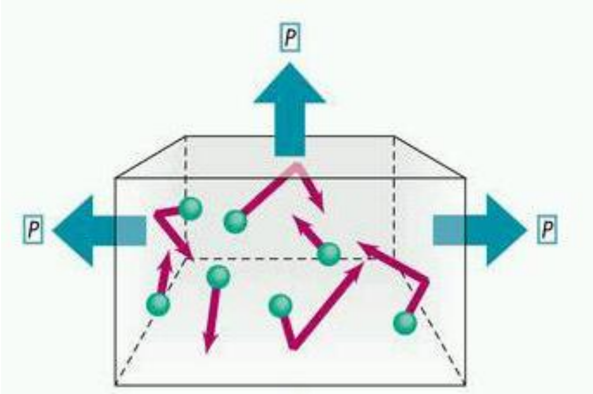


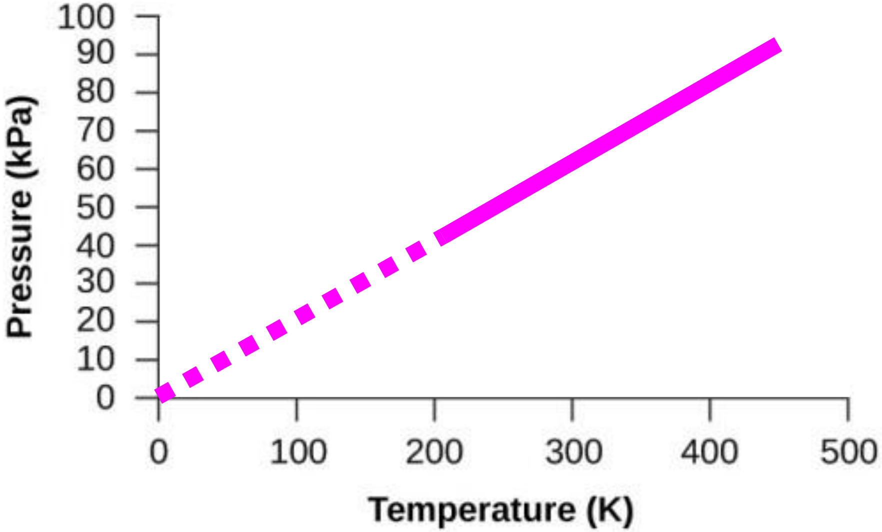


Pressure Law | Temp and Pressure

↑ Temperature ↑ Pressure $p \propto T$







Pressure Law | Temp and Pressure

When you spray, the pressure decreases dramatically and the temperature drops

CAUTION

EXTREMELY FLAMMABLE

Pressurised container: protect from
and do not expose to temperatures
exceeding 50°C. Do not pierce or burn,
after use. Do not spray on a naked
any incandescent material. Keep away
of ignition - No smoking. Use only in well
areas. Do not spray towards eyes or face.
OUT OF REACH OF BABIES, CHILDREN AND

WARNING

Solvent abuse can

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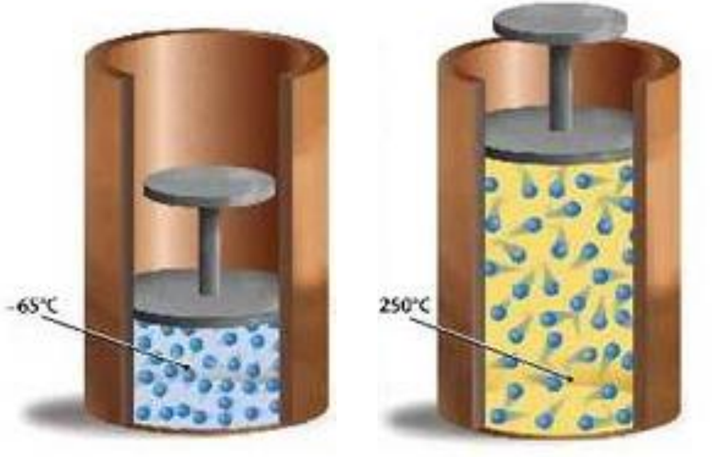
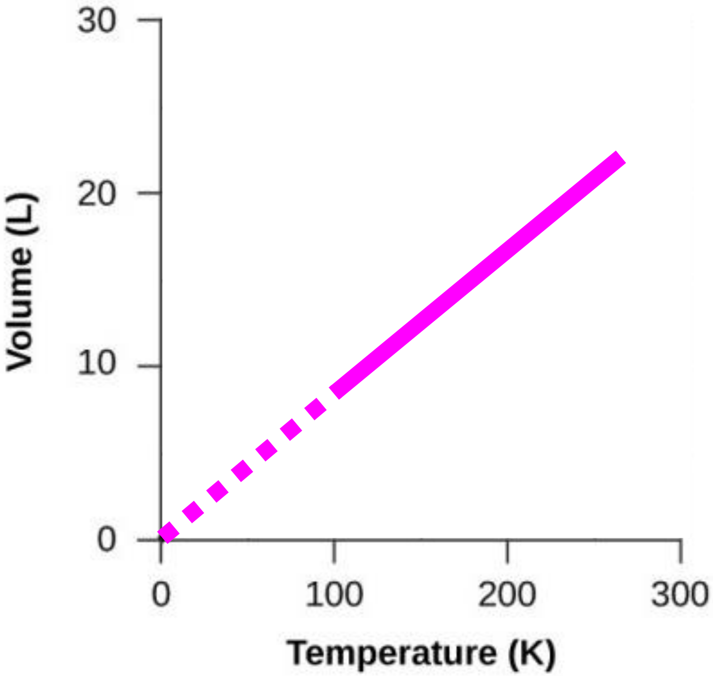
If temperature exceeds a certain amount, the increasing pressure could make a pressurized container explode!

Charles’s Law | Temp and Volume

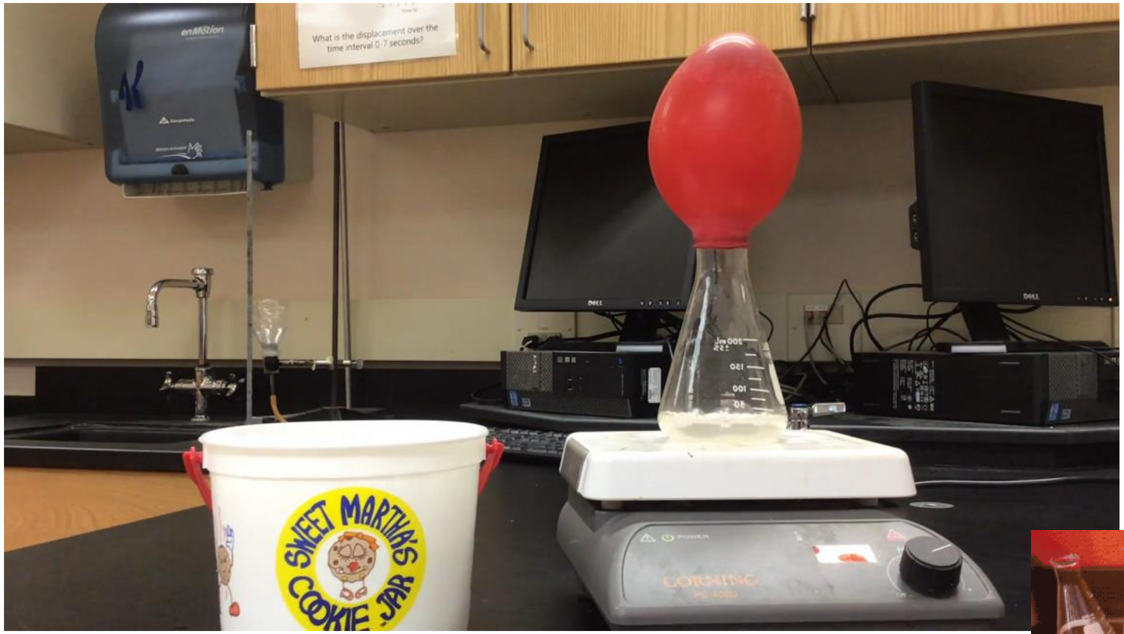
⬆ Temperature ⬆ Volume

$V \propto T$

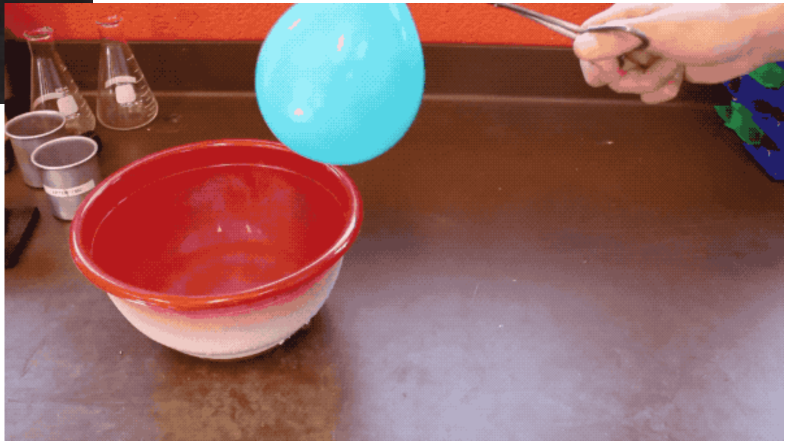




Charles's Law | Temp and Volume



When the temperature of the air inside a balloon decreases, so does the volume. (this effect is even more dramatic when the gas condenses into a liquid)



Ideal Gas Law

$p \propto \frac{1}{V}$ $p \propto T$ $V \propto T$

$$pV = nRT$$

Ideal Gas Law

Quantity	Symbol	Unit
Pressure	p	$[\mathrm{Pa}]$
Volume	V	$[\mathrm{m}^3]$
Amount	n	$[\mathrm{mol}]$
Temperature	T	$[\mathrm{K}]$

$$pV = nRT$$

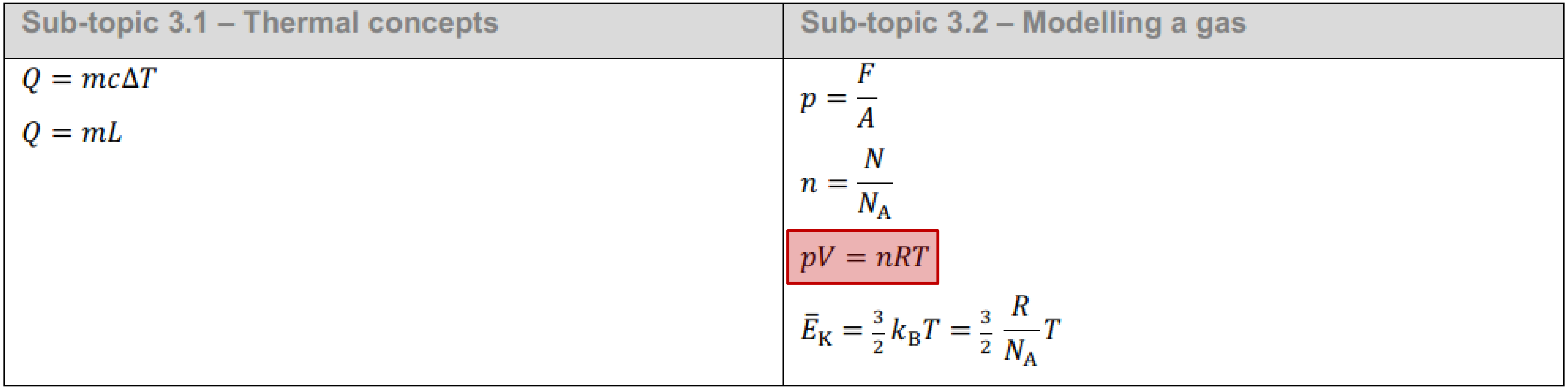
$[\mathrm{atm}]$

$[\mathrm{L}]$

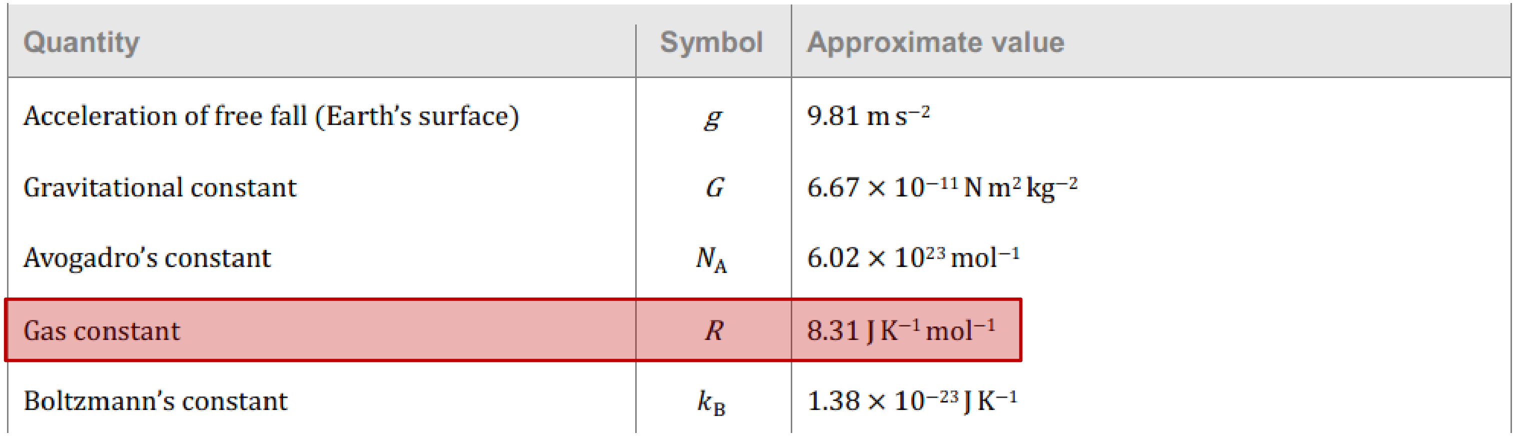
Gas Constant

$R = 8.31\ J\ K^{-1}\ mol^{-1}$

IB Physics Data Booklet



Sub-topic 3.1 – Thermal concepts	Sub-topic 3.2 – Modelling a gas
$Q = mc\Delta T$ $Q = mL$	$p = \frac{F}{A}$ $n = \frac{N}{N_A}$ $pV = nRT$ $\bar{E}_K = \frac{3}{2} k_B T = \frac{3}{2} \frac{R}{N_A} T$



Quantity	Symbol	Approximate value
Acceleration of free fall (Earth's surface)	g	$9.81\ \mathrm{m\,s^{-2}}$
Gravitational constant	G	$6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$
Avogadro's constant	N_A	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Gas constant	R	$8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$

Try This

What is the pressure of 23 mol of a gas behaving ideally in a 0.25 m^3 container at 310 K?

$p = ?$

$V = 0.25\ \mathrm{m}^3$

$n = 23\ \mathrm{mol}$

$R = 8.31\ J\ K^{-1}\ mol^{-1}$

$T = 310\ \mathrm{K}$

$$pV = nRT$$

$$p(0.25) = (23)(8.31)(310)$$

$$\boxed{p = 237{,}000\ \mathrm{Pa}}$$

Change in Volume

A fixed mass of an ideal gas has a volume of 0.14 m^3 at 301 K. If its temperature is increased to 365 K at the same pressure, what is its new volume, V_2?

$$pV = nRT$$

Rearrange so constants are on one side

$$\boxed{\frac{V}{T}} = \frac{nR}{p}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow \frac{0.14\ \mathrm{m}^3}{301\ \mathrm{K}} = \frac{V_2}{365\ \mathrm{K}}$$

$$\boxed{V_2 = 0.17\ \mathrm{m}^3}$$

Try This

A sample of ammonia is found to occupy 0.250 L under laboratory conditions of 27 °C and 0.850 atm. Find the volume of this sample at 0 °C and 1.00 atm.

$$pV = nRT$$

Rearrange so constants are on one side

$$\frac{pV}{T} = nR$$

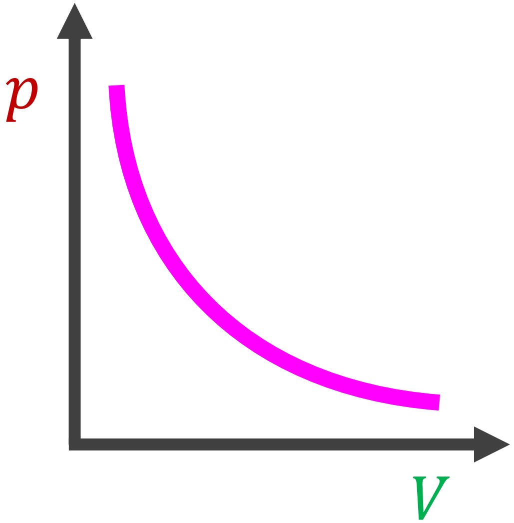
$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

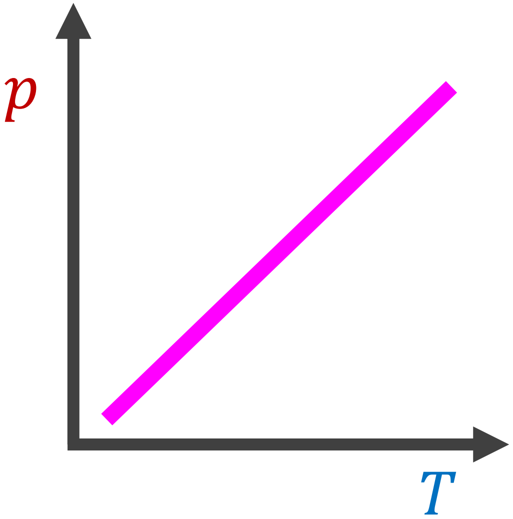
$$\frac{(0.850)(0.250)}{(27+273)} = \frac{(1.00)(V_2)}{(0+273)}$$

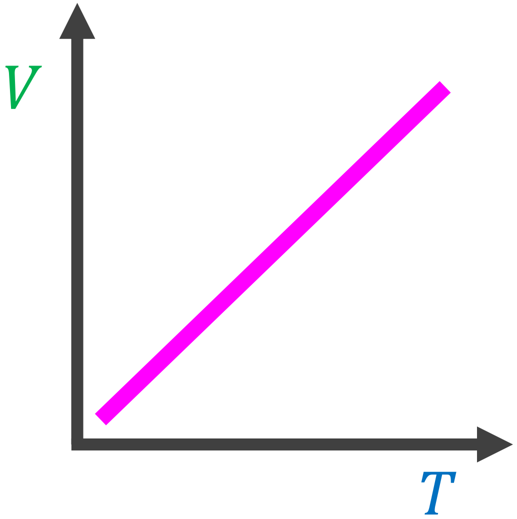
$$\boxed{V_2 = 0.19\ L}$$

Draw these graphs

$$pV = nRT$$







Related Constants

Gas Constant

$R = 8.31\ J\ K^{-1}\ mol^{-1}$

$$\frac{R}{k_B} = \frac{8.31\ J\ K^{-1}\ mol^{-1}}{1.38 \times 10^{-23}\ J\ K^{-1}} = \overset{N_A}{\underset{}{\Downarrow}}\; 6.02 \times 10^{23}\ mol^{-1}$$

Boltzmann's constant

$k_B = 1.38 \times 10^{-23}\ J\ K^{-1}$

Average Kinetic Energy

$$\bar{E}_K = \frac{3}{2}\boxed{k_B}T = \frac{3}{2}\boxed{\frac{R}{N_A}}T$$

Same Constant Value

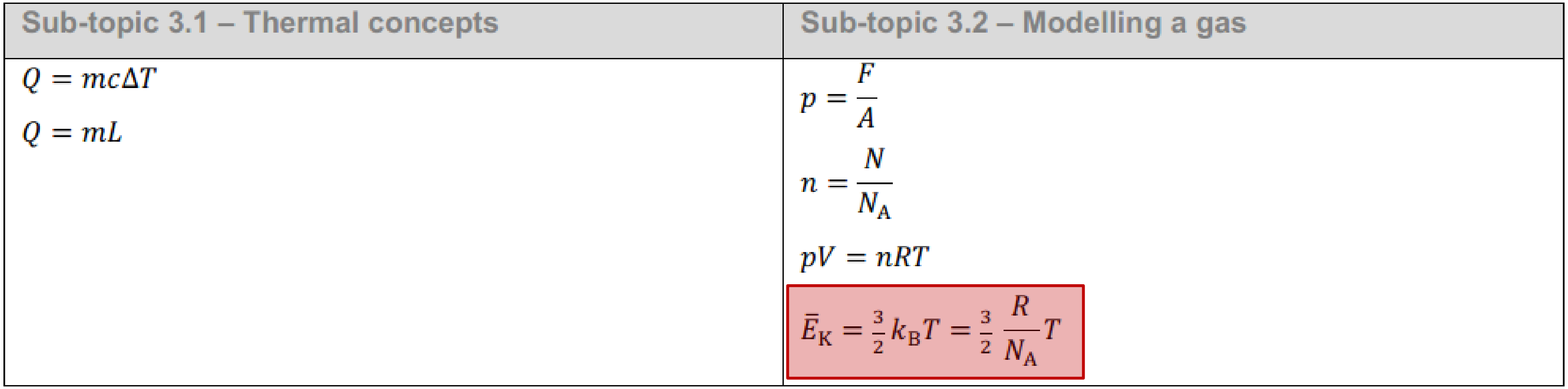
Boltzmann' s constant

$k_B = 1.38 \times 10^{-23}\ J\ K^{-1}$

Gas Constant

$R = 8.31\ J\ K^{-1}\ mol^{-1}$

IB Physics Data Booklet



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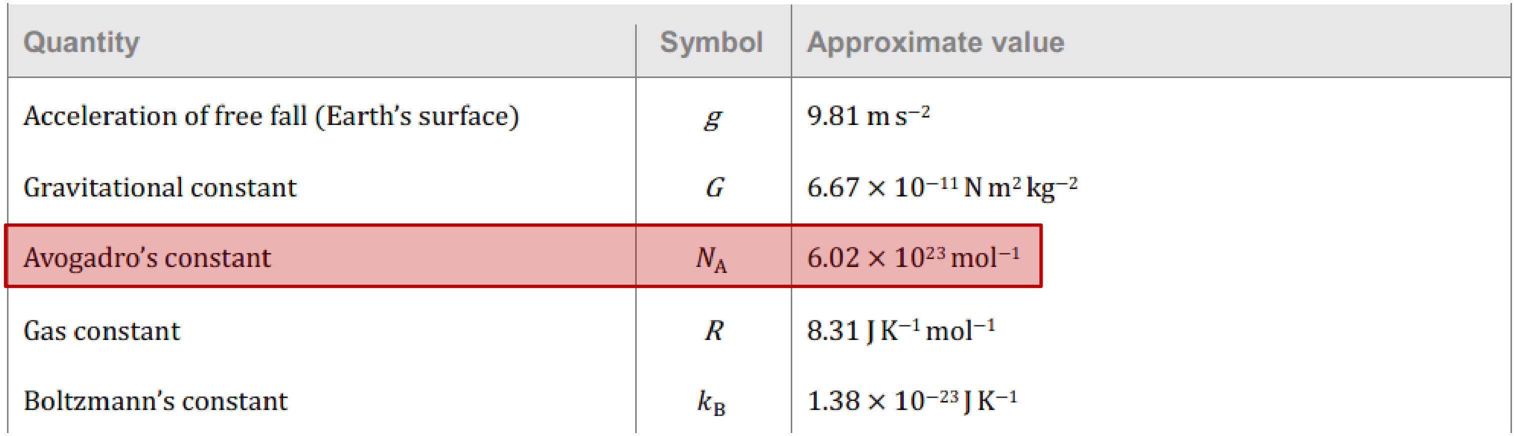

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Lesson Takeaways

- ☐ I can identify conditions when a substance is no longer considered an ideal gas
- ☐ I can describe the relationships between volume, temperature, and pressure in an ideal gas
- ☐ I can use the Ideal Gas Law to solve for pressure, volume, amount, or temperature
- ☐ I can use the Ideal Gas Law to describe how changing one or more variable(s) would affect another