Gas Laws

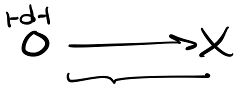
Idea of "Ideal Gas"

Model of a Gas → Appoximation or Simplification

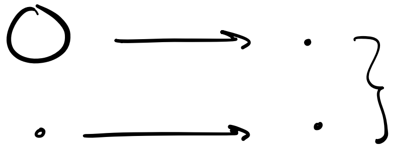
① Gas molecules can be treated as if they have mass but no size

⇒ as if a point mass

99.9% of a gas is empty space



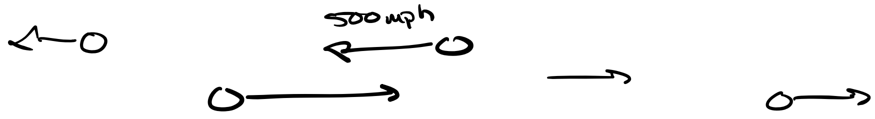
10x diameter
before hitting something



mass is important
not the volume
of the molecule

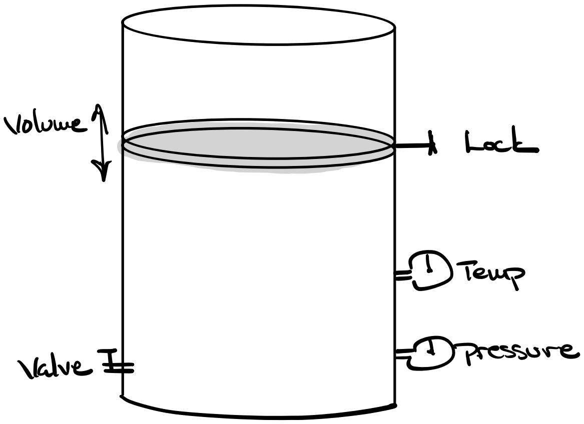
② Gases travel in straight lines and only change direction & speed through collisions.

③ Gases have no IMF's



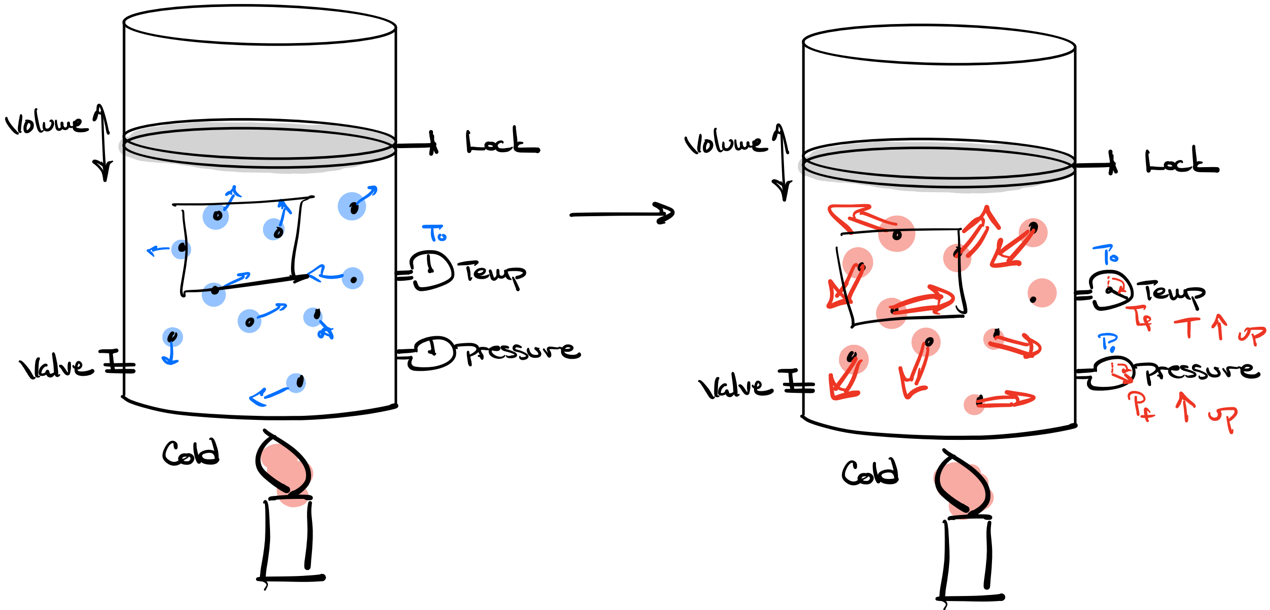
④ Gases have mass, ① volume, ② pressure, ③ temperature

mass → # ④ moles ⇒ 4 variables



Explore Relationship between

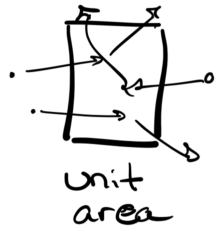
Pressure & Temperature (Hold Volume & moles Constant)



moving faster = more collisions

& stronger collisions = more force

Pressure = force applied to an area



more "collisions" = more force = more pressure

particles move faster = Colloide with more force = more pressure

Relationship between Pressure & Temperature

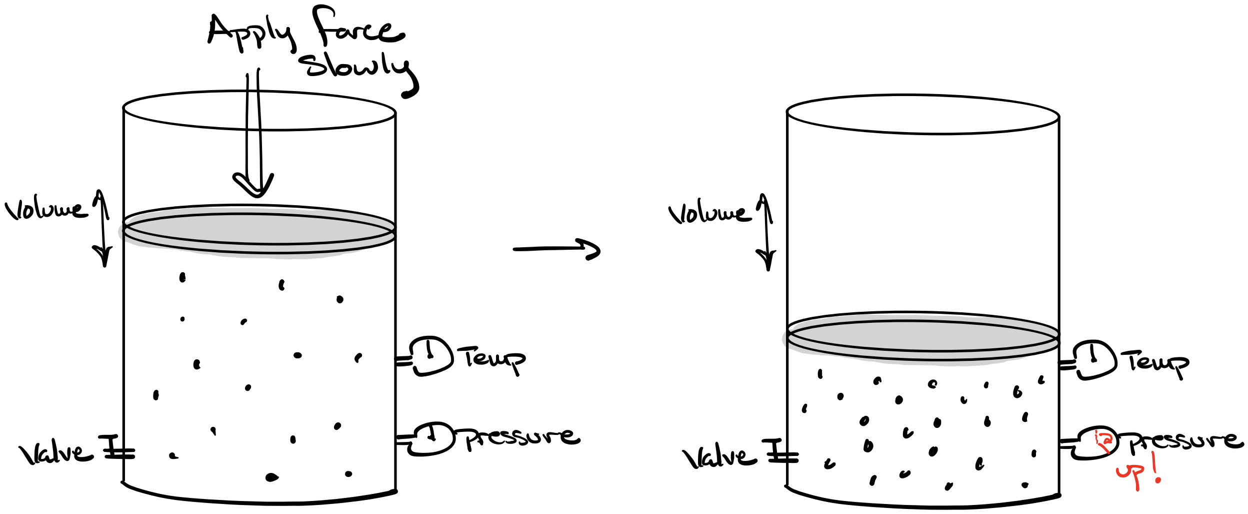
up $\uparrow P \quad \propto \quad T \uparrow$ up

$\propto$ = proportional

directly proportional means when one goes the other goes up

$P \propto T$ directly proportional

Pressure vs. Volume (hold moles & temp constant)



Volume went down

Pressure ?

- more particles per unit of volume
- more more collisions with the walls
- more collisions equals more force
- more force = more pressure

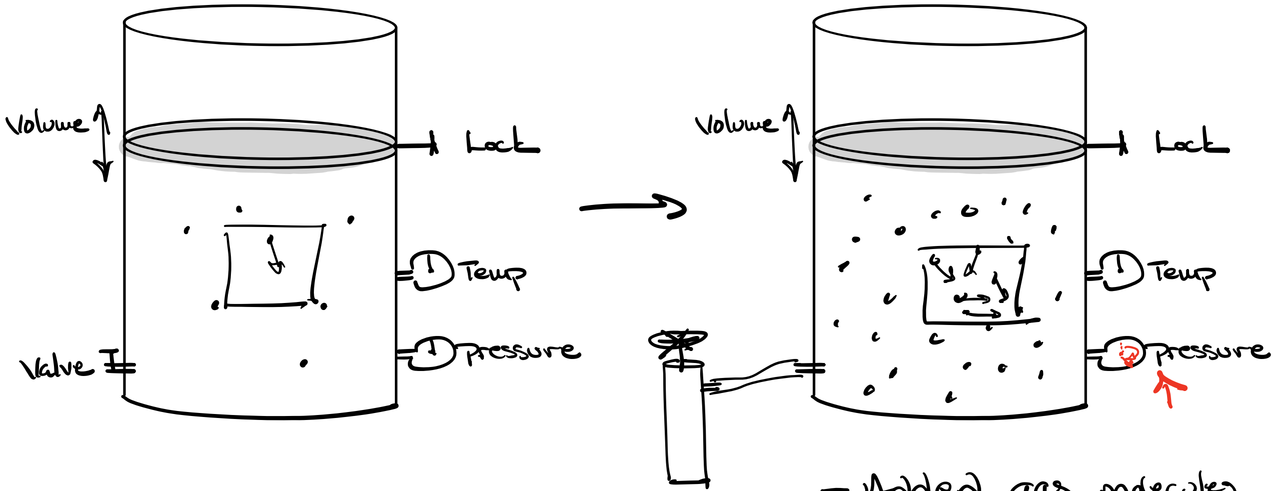
up ↑ $P \propto \frac{1}{V}$ ↓ down

Inversely proportional. They go in different directions

$\uparrow A \propto B \uparrow$ directly

$\uparrow A \propto \frac{1}{B} \downarrow$ Inversely

Pressure vs. Moles (Temp & Vol Constant



- Added gas molecules moles ↑
- More molecules per unit volume
- more Collisions
- more force on wall
- pressure goes $\underline{\underline{\text{UP}}}$ ↑

$\uparrow P \propto \text{moles} \uparrow$

Directly proportional

Summary

$P \propto$ moles

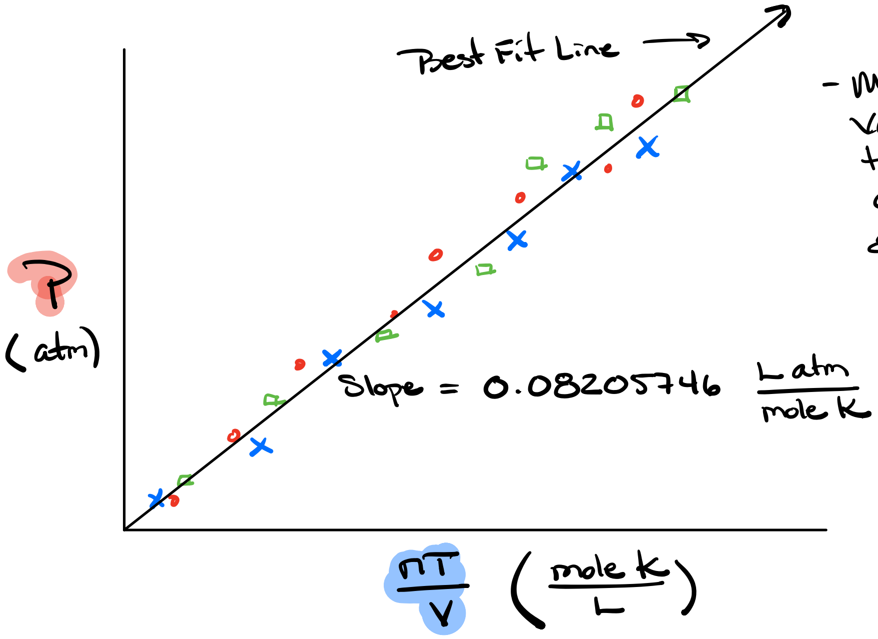
$P \propto$ Temp

$P \propto \frac{1}{\text{Volume}}$

moles = n
Temp = T
Volume = V
pressure = P

$$P \propto \frac{nT}{V}$$

proportional
It tells how they trend
- more useful to have an equality



- Measure all 4 varibles many times for many different gases & plot on graph

Formula for Straight

$$y = \underset{\substack{\uparrow \\ \text{Slope}}}{m}x + \underset{\substack{\uparrow \\ \text{y-Intercept}}}{b}$$

$$P = m\,\frac{nT}{V} + b$$

$$P \underset{\uparrow}{\propto} \frac{nT}{V}$$

Can make an equality with proportionality Constant ⟹ Slope of the best fit line

$$P = 0.0821\,\frac{L\,atm}{mole\,K} \times \frac{nT}{V}$$

<u>Equality</u>

$0.08205746\,\frac{L\,atm}{mole\,K}$ = Universal Gas Constant is a proportionality Constant from the best fit line.

We call it R

R to 3 sig figs = $0.0821\,\frac{L\,atm}{mole\,K}$

$$V \times P = R\,\frac{nT}{\cancel{V}} \times \cancel{V}$$

$PV = nRT$ Gas Law

Units

P = atm

V = L

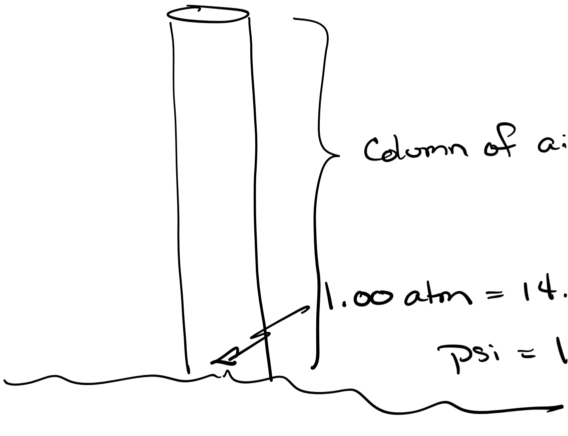
n = moles

T = K

$$R = \frac{L \cdot atm}{mole \cdot K}$$

Pressure

1 atm is the pressure on earth at sea level

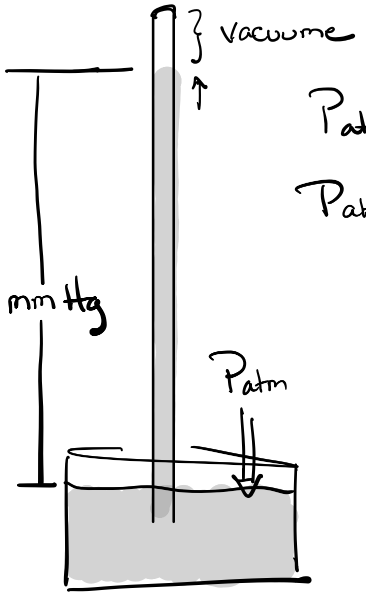


Column of air

1.00 atm = 14.7 psi

psi = lbs/in^2

Barrameter



Patm ↓ = mercury falls

Patm ↑ = mercury rises

1.00 atm = 760 mmHg

1.00 atm = 760 Torr

1 Torr = 1 mmHg

Temp Conversions

$K = °C + 273.15$ ⇐

$F° = °C \times \frac{180}{100} + 32°F$

$°C = (F° - 32) \times \frac{100}{180}$

Gas o⟹ motion = temp

°C	°F	K
↓	↓	↓
0	0	
↓	↓	
−°C	−°F	Absolute 0 no negative

Examples

Calculate the $\overset{?}{\text{Volume}}$ of a gas that has a pressure of 0.723 atm, a temperature of 29.7°C and 0.623 moles.

P = 0.723 atm ✓

V = ? L ✓

n = 0.623 moles ✓

memorize R = 0.0821 $\frac{\text{L atm}}{\text{mole K}}$ ✓

T = 29.7 °C ×

$\quad$ + 273.15 exact

$\quad$ 302.85 = 302.8 K ✓

$$\cancel{\frac{1}{P}} \times \cancel{P}\underline{V} = nRT \times \frac{1}{P}$$

$$\frac{\cancel{P}V}{\cancel{P}} = \frac{nRT}{P}$$

$$V = \frac{nRT}{P}$$

$$= \frac{\overset{3}{(0.623\ \cancel{\text{moles}})}\overset{3}{(0.0821\ \frac{\text{L}\ \cancel{\text{atm}}}{\cancel{\text{mol}}\ \cancel{\text{K}}})}\overset{4}{(302.8\ \cancel{\text{K}})}}{\underset{3}{0.723\ \cancel{\text{atm}}}}$$

$$= 21.4214456985\ \text{L}$$

$$\boxed{= 21.4\ \text{L}}$$

① make table of variables

② Parce problem

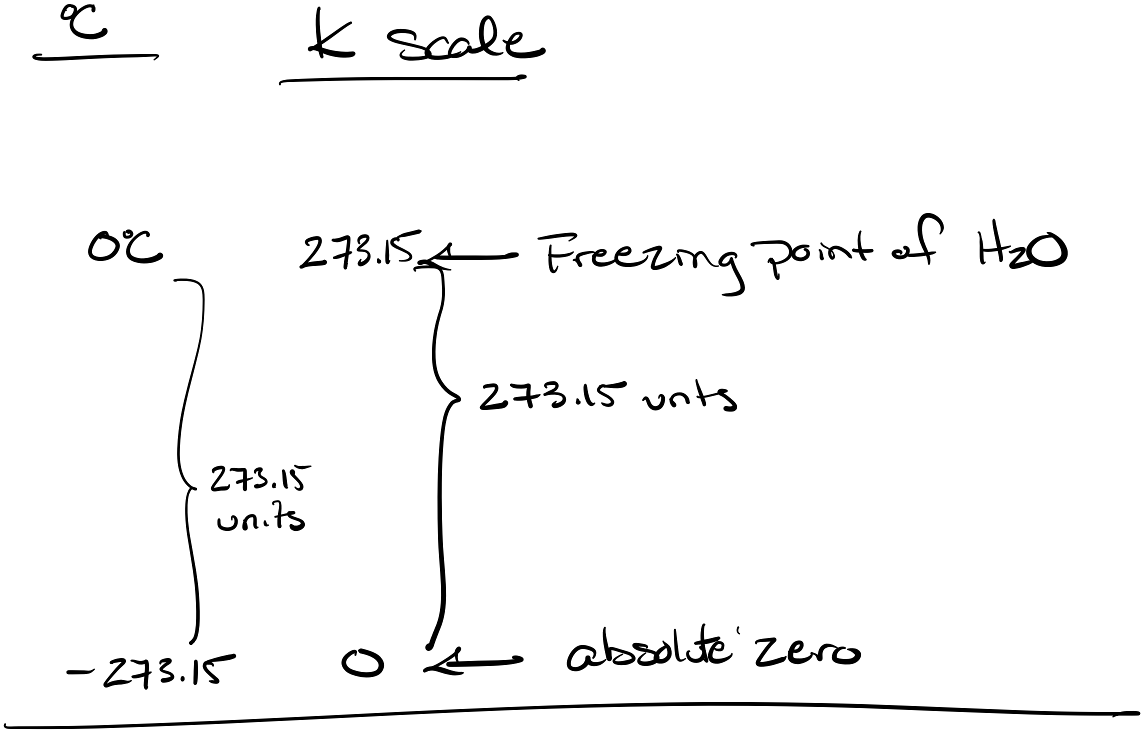
③ Check units

④ Convert units if needed

⑤ Solve equation

⑥ Calculation

⑦ Sig figs


°C
K scale
0°C
273.15
Freezing point of H_2O
273.15 units
273.15 units
−273.15
0
absolute zero

N_2

2.76 g of Nitrogen gas is in a vessel with a volume of 2.50 L. If the gas is at 40.1 °C, what is the pressure in the Container in atmospheres?

$P = ?$

$V = 2.50\,L$

$n = \overset{3}{2.76}\,g\,N_2 \times \frac{1\text{ mole }N_2}{\underset{4}{28.02}\,g\,N_2} = \overset{3}{0.0985}|010706638\text{ moles} = 0.0985\text{ moles }N_2$

$R = 0.0821\,\frac{L\,atm}{mol\,K}$

$T = 40.1\,°C + 273.15 = 313.25\,k = 313.2\,k$

$$\begin{array}{r} 40.1| \\ 273.1|5 \\ \hline 313.2|5 \end{array}$$

molar mass $N_2 = \frac{14.01\,g}{1\text{ mole }N} \times 2 = \frac{28.02\,g}{1\text{ mole }N_2}$

$$\frac{P\cancel{V}}{\cancel{V}} = \frac{nRT}{V}$$

$$P = \frac{nRT}{V} = \frac{(\overset{3}{0.0985}\,\cancel{\text{moles }N_2})(\overset{3}{0.0821}\,\frac{\cancel{L}\,atm}{\cancel{mol}\,\cancel{K}})(\overset{4}{313.2}\,\cancel{K})}{\underset{3}{2.50}\,\cancel{L}}$$

$= 1.01|3120568\text{ atm}$

$$\boxed{= 1.01\text{ atm}}$$

no Early Rounding

$= 1.01|329331906\text{ atm} = \boxed{1.01\text{ atm}}$

Idea

Solve $PV = n\underline{\underline{R}}T$ for R

$$\frac{PV}{nT} = \frac{\cancel{n}R\cancel{T}}{\cancel{n}\cancel{T}}$$

$$\frac{PV}{nT} = R$$

Now lets say I have 2 different Conditions

$$\frac{P_1V_1}{n_1T_1} = \text{1st Conditions}$$

$$\frac{P_2V_2}{n_2T_2} = \text{2nd Conditions}$$

$$\frac{P_1V_1}{n_1T_1} = \underbrace{R \qquad\qquad R}_{\text{no } R_1 \text{ or } R_2} = \frac{P_2V_2}{n_2T_2}$$

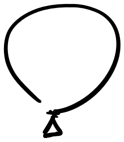
R is alway

$0.0821 \frac{L\,atm}{mol\,K}$

&

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

Combined Gas Law
used for Changing
Conditions



$P_2 = 0.802$ atm

$T_2 = 3.00$ °C

$V_2 = ?$

$n_2 = x$ mole

$P_1 = 1.00$ atm

$T_1 = 25.0$ °C

$V_1 = 1.00$ L

$n_1 = x$ Mole

close so stay the same

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

$$\cancel{x}^{a} \times \frac{P_1V_1}{\cancel{x}^{a}T_1} = \frac{P_2V_2}{\cancel{x}^{a}T_2} \times \cancel{x}^{a}$$

$$\frac{T_2}{P_2} \times \frac{P_1V_1}{T_1} = \frac{\cancel{P_2}V_2}{\cancel{T_2}} \times \frac{\cancel{T_2}}{\cancel{P_2}}$$

$$\frac{T_2P_1V_1}{P_2T_1} = V_2$$

$$\frac{T_2P_1V_1}{T_1P_2} = V_2$$