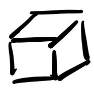
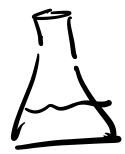
Finished Chapter 7 yesterday

Today is Chapter 8 - Gas Laws

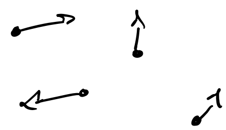
Gases have variable shape & variable volume



Solid
20% empty space



liquid
25-30 empty space



Gas
99.9% empty space

(Solid and liquid: Condensed matter)

Properties of Gas

- Volume (L)
- Mass (moles)
- Temperature (k)

⇒ Pressure (atm)

1st Problem: How do the 4 variables relate to one another?

2nd Problem: Units

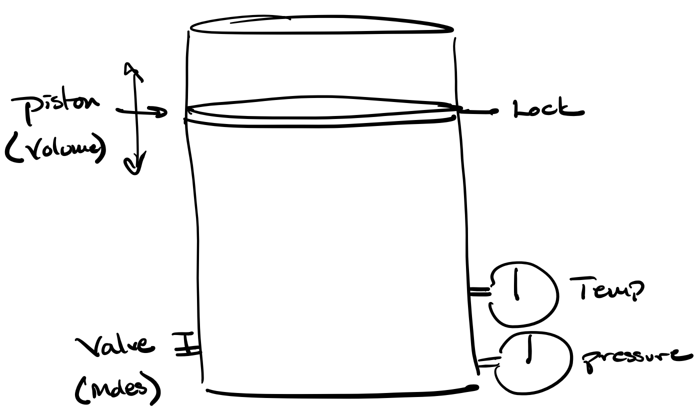
Real Gasses are Complex.

Simplify the model to make a workable Model

⟹ Ideal Gas

- No attractive forces between molecules
- Travel in straight lines, unaffected by gravity and intermolecular attractive forces. They travel until they hit something. The change speed & direction only through Collisions.
- 99.9% Volume is empty space, the size of the gas molecule is irrelevent.
  - ⟹ Treat gas as a point mass, A mass with no volume.

Apparatus



Test the 4 variables
Hold 2 constant &
Look at the relationship of remaining 2

Two types of relationships

directly proportional

$\uparrow A \propto B \uparrow$

inversely proportional

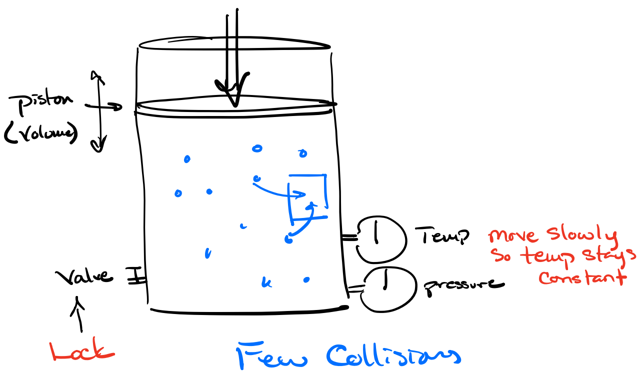
$\uparrow A \propto \frac{1}{B} \downarrow$

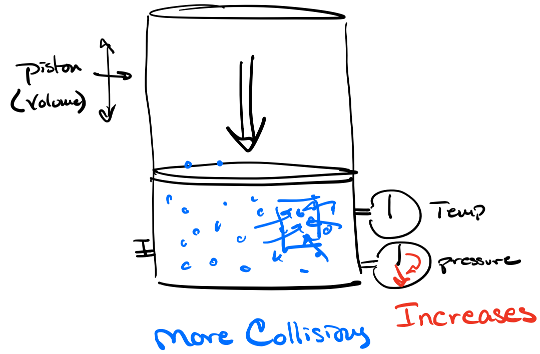
$\propto$ proportional (How do they trend)

= equality

① Pressure vs. Volume (Hold Temp & moles Constant)

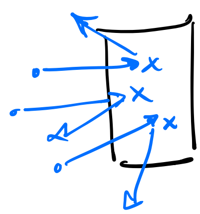
$$\uparrow P \propto \frac{1}{V} \downarrow$$





$$\text{Pressure} = \text{Force} \times \text{Area}$$

Force ↑ Collisions, Area ↑ wall

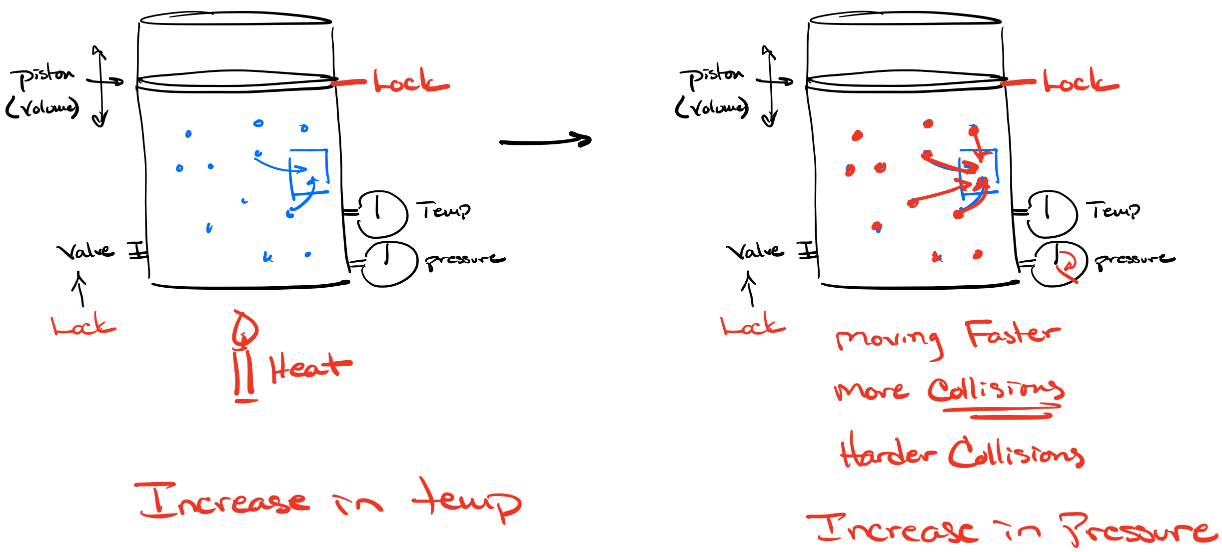


Pressure inversely proportional to volume

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

(2) Pressure vs Temp (hold Volume & moles Constant)

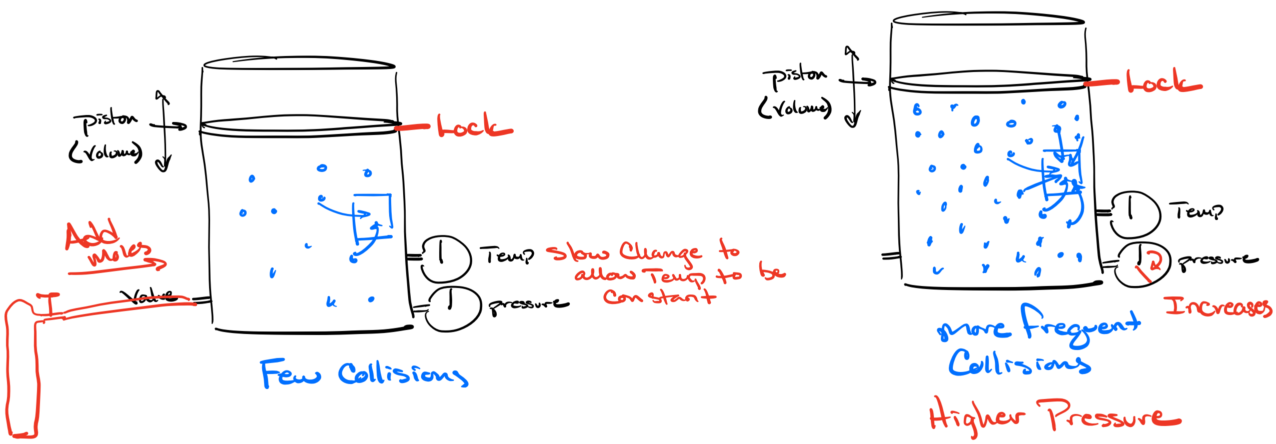
$\uparrow P \propto T \uparrow$



Pressure is directly proportional to temp $P \propto T$

③ Pressure vs. Moles (Temp & Volume Const)

$\uparrow P \propto n \uparrow$



Pressure and moles are directly proportional

$P \propto n$

Conclusion of 3 experiments

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

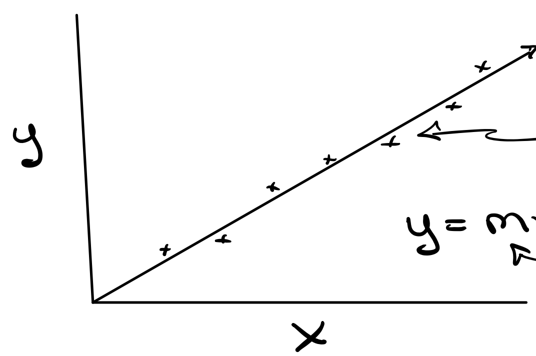
$P \propto T$

$P \propto n$

$P \propto \frac{nT}{V}$ How the variables relate or trend

↑ need an equality

Proportionality Constant looks at the relationship between variables and relates the two with an equality



← Slope $= \frac{y}{x} = m$

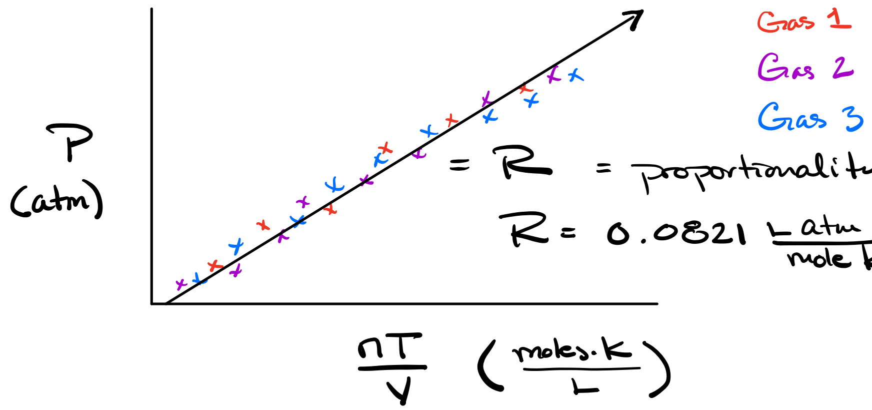
$y = mx + b$ straight line

↑ proportionality Constant

$\uparrow y \propto x \uparrow$

$y = mx + c$ ← Intercept

Find the proportionality Constant



$= R$ = proportionality Constant

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

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

$$\boxed{P = R \cdot \frac{nT}{V}}$$

$$y = m\,x + c \quad \leftarrow = \emptyset$$

Ideal Gas Law

$$PV = nRT$$

Universal Gas Constant

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

units

P = atmosphere atm

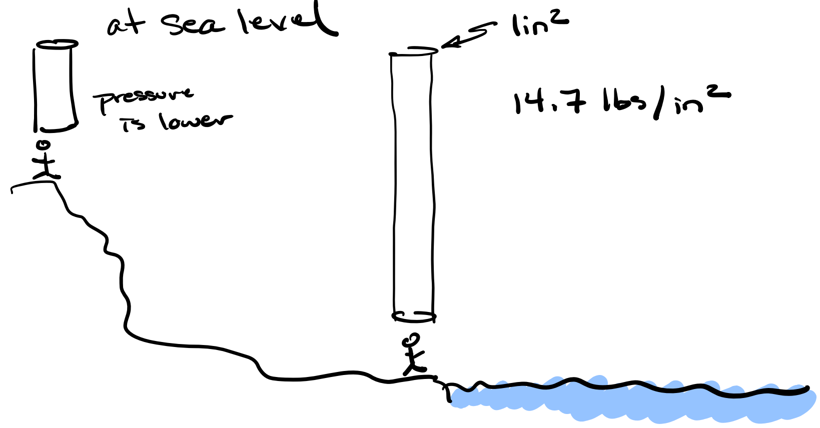
V = Liters L

n = moles moles

T = Temperature K

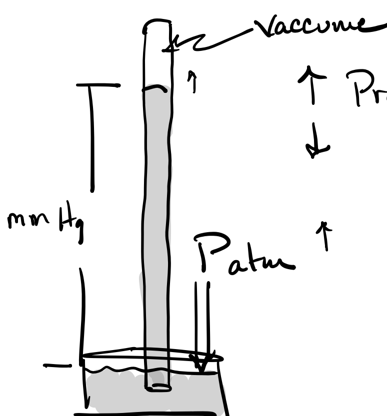
Pressure Force per unit area

atmosphere = the pressure the atmosphere of earth at sea level



$14.7\ lbs/in^2 = 14.7\ psi = 1\ atm$

mmHg = millimeters of mercury (Barometric pressure)



↑ Pressure = Hg ↑
↓ ↓

Exact definition

1 atm = 760 mmHg

1 Torr = 1 mmHg

1 atm = 760 Torr = 760 mmHg

3 most Common units of pressure used.

$$30.0\ in\ Hg \times \frac{2.54\ cm}{1\ in} \times \frac{10\ mm}{1\ cm} = 762\ mmHg$$

3 main types of Gas Law Problems

- Ideal Gas Law (1 set variables)
- Combined Gas Law (Changing Conditions, 2 set Variables)
- Dalton's Law of Partial Pressure (mult. gases)

Ex Ideal Gas Law

A container holds 0.0362 moles of nitrogen gas. The container has a volume of 100. mL and a temperature of 25°C. What is the pressure in the container?

$$PV = nRT$$

4 variables & a constant $\left(R = 0.0821 \frac{L\,atm}{mol\,K}\right)$

Given 3 find the 4th

P = ?

V = 100. mL $\times \frac{1\ L}{1000\ mL} = 0.100\ L$ ✓

n = 0.0362 moles ✓

R = $0.0821 \frac{L\,atm}{mol\,K}$ ✓

T = 25°C + 273.15 = 298.15 K ✓

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

Solve for P

$$P = \frac{nRT}{V} = \frac{(0.0362\ moles)(0.0821\ \frac{L\,atm}{mol\,K})(298.15\ K)}{0.100\ L}$$

$$= 8.861077663\ atm$$

$$= 8.86\ atm$$

Steps to Solve

- make a table
- Parce Problem
- ID unknown variable
- Convert any variable not in same units as R

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

- Solve $PV = nRT$ for unknown
- Plug in values
- Calc
- Sig figs & units

Ex Ideal Gas Law

A can with a volume of 22.4 L has 6.753 g of nitrogen gas at 24.6 °C. What is the pressure in the can?

HOFBrINCl H_2 O_2 F_2 Br_2 I_2 N_2 Cl_2

N_2 2(14.01 g/mol) = 28.02 g/mole N_2

$P = ?$

$V = 22.4\ L$ ✓

$n = 6.753\ g$ Nitrogen gas? $6.753\ g\ N_2 \times \frac{1\ \text{mole}\ N_2}{28.02\ g\ N_2} = 0.241006423$ mole N_2

$= 0.2410$ moles N_2

$T = 24.6\ °C + 273.15 = 297.75\ K$ ✓

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

$$PV = nRT$$

$$P = \frac{nRT}{V} = \frac{(0.241006423\ mole)(0.0821\ \frac{L\ atm}{mol\ K})(297.75\ K)}{22.4\ L}$$

$= 0.263011978$ atm

$= 0.263$ atm

Combined Gas Law Problems (Changing Conditions)

Combined → Two gas law formulas Combined

All come from Combined Gas Law:

- Boyles Law $P_1V_1 = P_2V_2$
- Charles Law $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- Avagadros Law

$$\frac{PV}{nT} = \frac{nRT}{nT}$$ Solve for R

$$\frac{PV}{nT} = R$$ $$\frac{atm\ L}{mole\ K} = \frac{L\ atm}{mole\ K} = R$$

1st Conditions

$$\frac{P_1V_1}{n_1T_1} = R$$

2nd Conditions

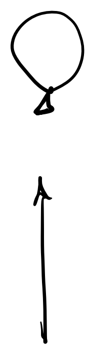
$$\frac{P_2V_2}{n_2T_2} = R$$

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$ Combined Gas Law

Ex

A weather balloon is filled to a volume of 250. L at 1.00 atm and 25°C. The balloon is released and reaches an altitude of 1.5 miles where the pressure is 0.852 atm and temp is -16.0 °C. What is the new volume of the balloon?

distraction → (of 1.5 miles)



$P_2 = 0.852\ atm$ ✓

$T_2 = -16.0\ °C + 273.15 = 257.15\ K$ ✓

$n_2 = n_1$

$V_2 = ?$

$P_1 = 1.00\ atm$ ✓

$T_1 = 25\ °C + 273.15 = 298.15\ K$ ✓

$n_1 = x$

$V_1 = 250.\ L$ ✓

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

Solve for V_2

$$\frac{1}{P_2} \times \frac{P_1V_1n_2T_2}{n_1T_1} = P_2V_2 \times \frac{1}{P_2}$$

$n_1 = n_2$

$$\frac{P_1V_1n_2T_2}{P_2\ n_1T_1} = V_2$$ ✓

$$V_2 = \frac{P_1V_1T_2}{P_2\ T_1}$$

$$V_2 = \frac{(1.00\ \text{atm})(250.\ \text{L})(257.15\ \text{K})}{(0.852\ \text{atm})(298.15\ \text{K})}$$

$$V_2 = 253.076680\ \text{L}$$

$$V_2 = 253\ \text{L}$$

Ex

Scuba diver runs out of air at 150. ft under water. He panics & tries to hold his breath as he makes his way to the surface. Lungs hold ~ 4L air. How much would the air in his lungs expand as he rises. 33 ft = 1 atm

$P_2 = 1\ \text{atm}$
$V_2 = ?$
$n_2 = x$
$T_2 = x$

$P_1 = 150\ \text{ft} \times \frac{1\ \text{atm}}{33\ \text{ft}} = 4.54\overline{54}\ \text{atm}$
$V_1 = 4.0\ \text{L}$
$n_1 = x$
$T_1 = x$

$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

$$\frac{P_1 V_1}{P_2} = \frac{P_2 V_2}{P_2}$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{(4.545\overline{4}\ \text{atm})(4.0\ \text{L})}{(1.0\ \text{atm})}$$

$$= 18.181\overline{8}\ \text{L}$$

$$= 18\ \text{L}$$