سنتر فيوتشر

" الشافعي "

Subject: الكيمياء " اعدادي هندسة "

Chapter: " Gases " الغازات

العنوان:

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Gases

* The pressure-Volume Relationship العلاقة بين الضغط والحجم

Boyle's Law

$P \propto \frac{1}{V}$ قانون بويل ← الضغط يتناسب عكسياً مع الحجم

* شروط تطبيق قانون بويل

at Const temperature ① عند ثبوت درجة الحرارة

for fixed amount of gas ② عدد المولات ثابتة

Boyle's Law states that the pressure of fixed amount of gas at Const temp is inversely proportional to the volume of gas

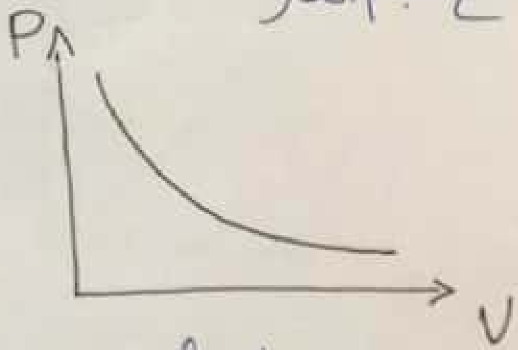
عند كمية ثابتة من الغاز وعند ثبوت درجة الحرارة فإن ضغط الغاز يتناسب عكسياً مع حجم الغاز

$P \propto \frac{1}{V}$ when $T = Const$, $n = Const$

$P = k_1 * \frac{1}{V}$

$\boxed{PV = k_1}$

k_1 → ثابت التناسب



temp = Const
n = Const

gas in initial state	gas in final state
P_1, V_1	P_2, V_2
$P_1 V_1 = k_1$	$P_2 V_2 = k_1$

$$\therefore \boxed{P_1 V_1 = P_2 V_2} = k_1$$

* The temperature - Volume Relationship العلاقة بين درجة الحرارة والحجم

Charle's - Gay lussac's Law

قانون شارل في صورة الحجوم

قانون شارل ← الحجم يتناسب طردي مع درجة الحرارة

at Constant pressure * شروط تطبيق قانون شارل ① عند ثبوت الضغط

for fixed amount of gas ② عدد المولات ثابتة

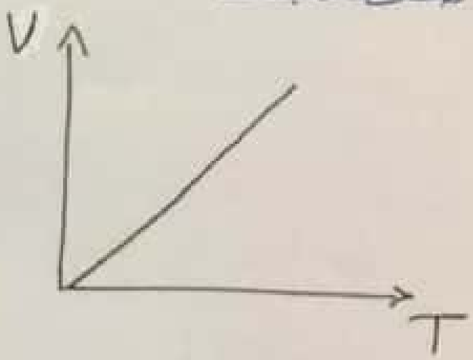
Charle's Law states that for fixed amount of gas the Volume of gas is directly proportional with it's temperature at Constant pressure

عندما تكون كمية الغاز ثابتة فإن حجم الغاز يتناسب طردي مع درجة الحرارة عند ضغط ثابت

$V \propto T$ when $P = Const$, $n = Const$

$V = k_2 T$

$$\boxed{\frac{V}{T} = k_2}$$



gas in initial state gas in final state

$P = Const$

$n = Const$

$\boxed{V_1 \; T_1}$ $\boxed{V_2 \; T_2}$

$$\frac{V_1}{T_1} = k_2 \qquad \frac{V_2}{T_2} = k_2$$

$$\therefore \boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}} = k_2$$

(*) another form of charle's Law قانون شارل في صورة الضغوط

قانون شارل ← الضغط يتناسب طردي مع درجة الحرارة

at Constant Volume ① عند ثبوت الحجم

for fixed amount of gas ② عدد المولات ثابتة

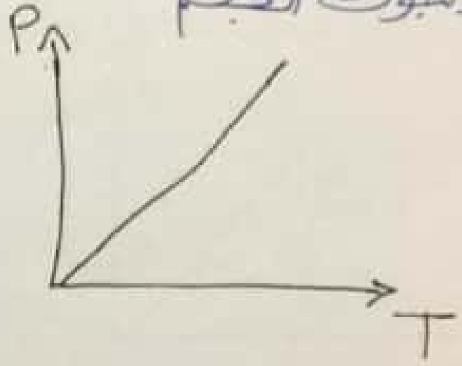
charle's Law states that for fixed amount of the gas the pressure of the gas is directly proportional with it's temperatu at Constant Volume

عندما تكون كمية الغاز ثابتة فإن ضغط الغاز يتناسب طردي مع درجة الحرارة عند ثبوت الحجم

$P \propto T$ when $V = Const$, $n = Const$

$P = k_3 T$

$$\boxed{\frac{P}{T} = k_3}$$



gas in initial state gas in final state

$V = Const$

$n = Const$

$\boxed{P_1, T_1}$ $\boxed{P_2, T_2}$

$\frac{P_1}{T_1} = k_3$ $\frac{P_2}{T_2} = k_3$

$$\therefore \boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}} = k_3$$

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Ex 2| Calculate the volume in liters occupied by 7.80 g of NH_3 at S.T.P

Solution

at S.T.P $\Rightarrow$ $T = 0°C + 273 = 273\ k$

$P = 1\ atm$

$V = ??$

$m_{NH_3} = 7.80\ gm \Rightarrow$ no. of moles $= \frac{mass}{\text{molar mass of } NH_3}$

no. of moles $= \frac{7.80}{14 + (3 \times 1)} = 0.46$ mole

$\therefore V = \frac{nRT}{P} = \frac{0.46 * 0.082 * 273}{1} = 10.27\ L$

Ex 3| Argon is an inert gas used in lightbulbs to retard the vaporization of the tungsten filament.
A certain lightbulb containing argon at 1.20 atm and 18°c is heated to 85°c at constant volume. Calculate it's final pressure?

Solution

$P_1 = 1.2\ atm$

$T_1 = 18°c + 273 = 291\ k$

heated

$P_2 = ??$

$T_2 = 85°c + 273 = 358\ k$

according to charle's law $\Rightarrow$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{1.2}{291} = \frac{P_2}{358}$ $\therefore P_2 = 1.48\ atm$

⊛ The Volume - amount Relationship العلاقة بين الحجم وعدد المولات

(4)

Avogadro's Law

قانون أفوجادرو ← حجم الغاز يتناسب طردي مع عدد مولاته

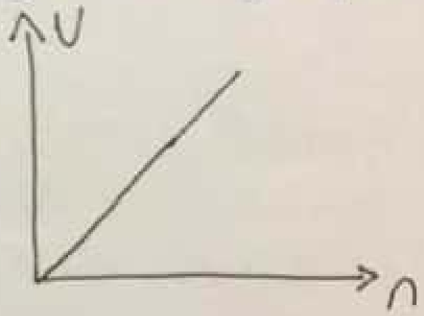
at Const pressure ① عند ثبوت الضغط

at Const temp ② عند ثبوت درجة الحرارة

Avogadro's Law states that the volume of the gas is directly proportional with it's number of moles at Constant pressure and temperature

حجم الغاز يتناسب طردي مع عدد مولاته عند ضغط ثابت ودرجة حرارة ثابتة

$V \propto n$ when $P = \text{Const}$, $T = \text{Const}$



$V = k_4 n$

$$\boxed{\frac{V}{n} = k_4}$$

Example 8: In synthesis of Ammonia

$$3H_{2(g)} + N_{2(g)} \longrightarrow 2NH_{3(g)}$$

3 mole + 1 mole ⟶ 2 mole

3 Volume + 1 Volume ⟶ 2 Volume

طبقا للعلاقة $V \propto n$

لأن عند ثبوت الضغط ودرجة الحرارة عدد مولات الغاز يتناسب طرديا مع حجمه

Ex| A chemist has synthesized a greenish-yellow gaseous Compound of chlorine and oxygen and find it's density is 7.71 gm/L at 36°c and 2.88 atm

Calculate the molar mass of the Compound and determine it's molecular formula ??

Solution

$d_{gas} = 7.71$ gm/L

$T = 36°C + 273 = 309$ k

$P = 2.88$ atm

$\mathcal{M}_{Compound}$??

Compound

Cl   O

if $\mathcal{M}_{Cl} = 35.45$ gm

$\mathcal{M}_{O} = 16.0$ gm

① $d = \frac{P\mathcal{M}}{RT}$

molar mass $\mathcal{M} = \frac{dRT}{P} = \frac{7.71 \times 0.082 \times 309}{2.88}$

$\mathcal{M}_{Compound} = 67.9$ gm/mol

② from ideal gas eqn $\longrightarrow$ $n = \frac{PV}{RT} = \frac{2.88 * 1L}{0.082 * 309} = 0.1135$ mol

but no.of moles $= \frac{\text{mass of Compound}}{\text{molar mass of Compound}}$ $\frac{m}{\mathcal{M}}$

$\mathcal{M} = \frac{m}{n} = \frac{7.71 \text{ gm}}{0.1135 \text{ mol}} = 67.9$ gm/mol

it's molecular formula is ClO_2

Density Calculation for gas

from ideal gas equation $PV = nRT$

where $n = \frac{m}{M} \longrightarrow PV = \frac{m}{M} RT$

$$\therefore PM = \frac{m}{V} RT$$

$$PM = d\, RT$$

$$\therefore \boxed{d = \frac{PM}{RT}}$$

density الكثافة ← d

$$gm/liter = \frac{atm * \left(\frac{gm}{mole}\right)}{\frac{L.atm}{mol\,k} * k}$$

Ex) Calculate the denisty of Carbon dioxide CO_2 in gm/L at 0.99 atm & 55°c ??

Solution

for CO_2 $M = 12 + (2 \times 16) = 44$ gm/mole

$P = 0.99$ atm

$T = 55°c + 273 = 328$ k

$$d = \frac{PM}{RT} = \frac{0.99\, \cancel{atm} * 44\, gm/\cancel{mole}}{0.082 \frac{L.\cancel{atm}}{\cancel{mol}\,\cancel{k}} * 328\, \cancel{k}}$$

$$\therefore d = 1.62 \text{ gm/L}$$

⊛ The ideal gas equation :- المعادلة العامة للغازات

From

1. Boyle's law $V \propto \frac{1}{P}$ [at Const T & n]
2. Charles's law $V \propto T$ [at Const P & n]
3. Avogadro's law $V \propto n$ [at Const P & T]

بجمع جميع العلاقات السابقة

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

$$V = \underline{R}\,\frac{nT}{P}$$

R ← الثابت العام للغازات
gas Constant

$$PV = nRT$$

as $P \rightarrow$ ضغط الغاز
$V \rightarrow$ حجم الغاز
$n \rightarrow$ عدد المولات
$R \rightarrow$ gas Const الثابت العام للغازات
$T \rightarrow$ درجة الحرارة

gas in initial state: P_1, V_1, n_1, T_1

gas in final state: P_2, V_2, n_2, T_2

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

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

at fixed amount of gas $n = \text{Const}$ $\Longrightarrow$ $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ at $n_1 = n_2$

at fixed temp $\Longrightarrow$ $\frac{P_1 V_1}{n_1} = \frac{P_2 V_2}{n_2}$ at $T_1 = T_2$

at fixed Volume $\Longrightarrow$ $\frac{P_1}{n_1 T_1} = \frac{P_2}{n_2 T_2}$ at $V_1 = V_2$

★ At S.T.P 1 mole of any gas occupies 22.4 L

S.T.P ⟹ 1 atm & 0°C

عند الظروف القياسية من الضغط ودرجة الحرارة

١ مول من أي غاز يشغل حجم ٢٢,٤ لتر

⟹ To Calculate the value of general gas Constant ??

$PV = nRT$ من المعادلة العامة للغازات

$$R = \frac{P \cdot V}{n \cdot T} = \frac{1 \text{ atm} * 22.4 \text{ litre}}{1 \text{ mole} * 273 \text{ k}}$$

$$\therefore R = 0.082 \frac{L \cdot atm}{mol \cdot k}$$

Ex 1 sulfur hexafluoride (SF_6) is Colorless (عديم اللون), odorless (عديم الرائحة), very unreactive gas (غير نشط كيميائيا). Calculate the pressure in atm exerted by 1.82 moles of the gas in a steel vessel of volume 5.43 L at 69.5°C

Solution

$P = ??$

$n = 1.82$ mole

$V = 5.43$ L

$T = 69.5 + 273 = 342.5$ k

$$PV = nRT$$

$$P = \frac{nRT}{V} = \frac{1.82 * 0.082 * 342.5}{5.43 \text{ L}}$$

$\therefore P = 9.4$ atm

Ex 4 An inflated helium balloon with the Volume of 0.55 L at sea level (1 atm) is allowed to rise to height of 6.5 km where the pressure is about 0.4 atm
assume that the temperature is Constant what is the final Volume of the ballon ??

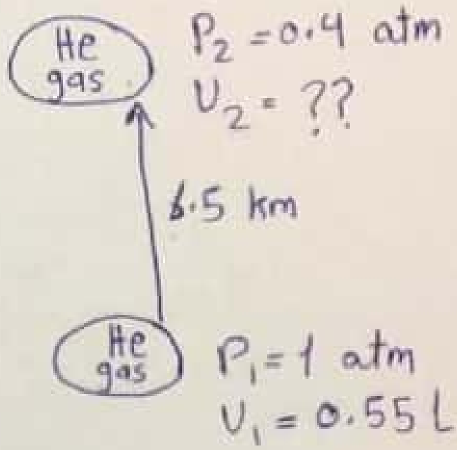
Solution

according to Boyel's Law

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{1\ atm * 0.55 L}{0.4\ atm}$$

$$\therefore V_2 = 1.4\ L$$



Ex 5 A small bubble rises from the bottom قاع of a lake بحيرة where the temp and pressure are 8°c and 6.4 atm to water's surface where the temperature is 25°c and pressure is 1.0 atm
Calculate final Volume of the bubble if its initial Volume was 2.1 ml

Solution

$P_1 = 6.4$ atm
$T_1 = 8°c + 273 = 281$ k
$V_1 = 2.1$ ml

$P_2 = 1$ atm
$T_2 = 25°c + 273 = 298$ k
$V_2 = ??$

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

$$\therefore V_2 = \frac{P_1 V_1}{T_1} * \frac{T_2}{P_2}$$

$$V_2 = \frac{6.4 \times 2.1}{281} * \frac{298}{1} = 14.25\ ml$$

For $\underline{\underline{O_2 \text{ gas}}}$

$$P_{O_2} V_{O_2} = n_{O_2} R T$$

$$P_{O_2} V_{O_2} = \frac{m_{O_2}}{\mu_{O_2}} R T$$

$$\frac{739.6}{760} \text{ atm} * 0.128 \text{ L} = \frac{m_{O_2}}{32 \text{ gm/mole}} * 0.082 * 297$$

$$m_{O_2} = 0.164 \text{ gm}$$

Ex Sodium azide (NaN_3) is used in some automobile air bags, the impact of collision يستخدم في أكياس الهواء إذا حدث تصادم
the decomposition of NaN_3 as follow يسبب في تحلل NaN_3

$$2NaN_3 \longrightarrow 2Na + 3N_{2(g)}$$

the nitrogen gas produced quickly inflates ليملأ the bag between the driver and windshield

Calculate the volume of N_2 generated at 80°C and 823 mmHg by the decomposition of 60.0 g of NaN_3??

Solution

$T = 80°C + 273 = 353\ k$

$P = 823\ mmHg = \frac{823}{760}\ atm$

$m_{NaN_3} = 60.0\ gm$

$V_{N_2} = ??$ حساب حجم غاز N_2 الناتج من تحلل 60gm of NaN_3

$n_{NaN_3} = \frac{m_{NaN_3}}{M_{NaN_3}}$

$n_{NaN_3} = \frac{60.0\ gm}{23 + 3(14)} = \frac{60}{65}\ mole$

$$2NaN_3 \longrightarrow 2Na + 3N_{2(g)}$$

2 mole → 3 mole

$\frac{60}{65}$ mole → ??

$$n_{N_2} = \frac{3}{2} \times \left(\frac{60}{65}\right) = 1.38\ mole$$

for N_2 gas $\rightarrow$ $P_{N_2} V_{N_2} = n_{N_2} RT$

$$\frac{823}{760} V_{N_2} = 1.38 \times 0.082 \times 353$$

$$\therefore V_{N_2} = 37\ liter$$

(*) Dalton's Law useful for Calculating Volumes of gases Collected over water

Ex| Potassium chlorate ($KClO_3$) heated and decomposed to KCl & O_2 $\quad 2KClO_{3(s)} \xrightarrow{\Delta} 2KCl + 3O_2$

Oxygen gas Collected over water

$$\therefore P_T = P_{O_2} + P_{H_2O}$$

Example| Oxygen gas generated by the decomposition of potassium chlorate

The volume of oxygen Collected at 24°C & atmospheric pressure of 762 mmHg is 128 ml. **Calculate the mass (in grams) of oxygen gas obtains?** as the pressure of the water Vapour at 24°C is 22.4 mmHg

Solution

$V_{O_2} = 128\ ml = 0.128\ L$

$T_{O_2} = 24°C + 273 = 297\ K$

$P_T = 762\ mmHg = \frac{762}{760}\ atm \simeq 1\ atm$

m_{O_2} ??

$P_{H_2O} = 22.4\ mmHg = \frac{22.4}{760}\ atm$

$T_{H_2O} = 24°C + 273 = 297\ K$

$$P_T = P_{O_2} + P_{H_2O}$$

$$762\ mmHg = P_{O_2} + 22.4\ mmHg$$

$$P_{O_2} = 739.6\ mmHg$$

* Deviation from ideal behavior الحيود عن السلوك المثالى

gas

الغاز المثالى Ideal gas

* neglect volume of gas molecules
  يهمل حجم جزيئات الغاز مقارنة بحجم الوعاء الحاوى له

* neglect attraction forces & Repulsion forces in gas molecules
  إهمال قوى التجاذب والتنافر بين جزيئات الغاز

* neglect collision between gas molecules and wall of container
  إهمال التصادمات بين جزيئات الغاز والتصادم مع جدران الإناء الحاوى لها

* obey ideal gas eqn
  $PV = nRT$

الغاز الحقيقى Real gas

* doesn't neglect volume of gas molecules
  لا نستطيع إهمال حجم جزيئات الغاز
  $nb \rightarrow$ volume of gas molecules

* doesn't neglect attraction forces between gas molecules
  الضغط يزيد بمقدار قوى التجاذب والتنافر والتصادم بين جزيئات الغاز وجدران الإناء يزيد بمقدار $\frac{an^2}{V^2}$

* doesn't neglect collision between gas molecules and wall of container

* doesn't obey ideal gas eqn
  $\times \; PV = nRT$

  obey van der waal equation

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT \rightarrow \text{درجة الحرارة}$$

P → P_{ideal}

$\frac{an^2}{V^2}$ → الضغط نتيجة قوى التجاذب والتنافر

V → حجم الوعاء

nb → حجم جزيئات الغاز

n → عدد المولات

Ex 1 3.5 moles of NH_3 occupy 5.20 L at 47 °c
Calculate the pressure of the gas (in atm)
using - ideal gas equation
- Van der waal equation

Solution

$n = 3.5$ moles
$V = 5.20$ L
$T = 47°c + 273 = 320$ k

$P = ??$
for NH_3 $a = 4.17$
$b = 0.0371$

a) using ideal gas equation

$$P = \frac{nRT}{V} = \frac{3.5 * 0.082 * 320}{5.20}$$

$$P = 17.7 \text{ atm}$$

b) using Van der waal equation

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

$$(P + 1.89)(5.2 - 0.13) = 3.5 * 0.082 * 320$$

$$P = 16.2 \text{ atm}$$

$$\frac{P_A}{P_T} = \frac{n_A \frac{R\cancel{T}}{\cancel{V}}}{n_T \frac{R\cancel{T}}{\cancel{V}}}$$

$$\frac{P_A}{P_T} = \frac{n_A}{n_T}$$

$$\frac{P_i}{P_T} = \frac{n_i}{n_T}$$

$$\therefore \boxed{P_i = \frac{n_i}{n_T} P_T}$$

$$\therefore \boxed{P_i = X_i P_T}$$

as X_i : mole fraction الكسر المولى

$$X_i = \frac{n_i}{n_T}$$

mole fraction of gas A $X_A = \frac{n_A}{n_T} = \frac{n_A}{n_A + n_B}$ $\frac{\text{عدد مولات الغاز A}}{\text{مجموع عدد مولات الخليط}}$

mole fraction of gas B $X_B = \frac{n_B}{n_T} = \frac{n_B}{n_A + n_B}$ $\frac{\text{عدد مولات الغاز B}}{\text{مجموع عدد مولات الخليط}}$

ملحوظة مجموع الكسور الجزيئية للغازات المكونة للخليط تساوى 1

$$X_A + X_B = 1$$

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Ex) A mixture of gases contain 4.46 moles of (Ne) & 0.74 mole of (Ar) and 2.15 moles of (Xe). Calculate the partial pressure of the gases if the total pressure is 2.0 atm at certain temperature

Solution

total no. of moles $= n_{Ne} + n_{Ar} + n_{Xe}$

$= 4.46 + 0.74 + 2.15 = 7.35$ moles

∴ partial pressure

$$P_{Ne} = \frac{n_{Ne}}{n_T} P_T$$

$$P_{Ne} = \frac{4.46}{7.35} \times 2.0 = 1.21 \text{ atm}$$

&

$$P_{Ar} = \frac{n_{Ar}}{n_T} P_T$$

$$P_{Ar} = \frac{0.74}{7.35} \times 2.0 = 0.2 \text{ atm}$$

&

$$P_{Xe} = \frac{n_{Xe}}{n_T} P_T$$

$$P_{Xe} = \frac{2.15}{7.35} \times 2.0 = 0.585 \text{ atm}$$

$$P_{Ne} + P_{Ar} + P_{Xe} = 2 = P_T$$

لاحظ

Ex) A flammable gas made up only of Carbon and hydrogen is found to effuse through a porous barrier in 1.50 min under the same Conditions of temp & pressure it takes an equal volume of bromine vapour 4.73 min to effuse through the same barrier

Calculate the molar mass of the unknown gas and suggest what this gas might be ??

Solution

unknown gas $\rightarrow$ C, H

$t_{C\&H} = 1.50$ min

STP $\rightarrow$ T = 273

P = 1 atm

V = Constant

$t_{Br_2} = 4.73$ min

$M_{Br_2} = 159.8$ gm/mol

$M_{C\&H} = ??$

$Br_2 \rightarrow$ gas 1

unknown gas $\rightarrow$ gas 2

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\frac{\left(\frac{V}{t_1}\right)}{\left(\frac{V}{t_2}\right)} = \sqrt{\frac{M_2}{M_1}} \rightarrow \frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$$

$$\frac{1.50\text{ min}}{4.73\text{ min}} = \sqrt{\frac{M_2}{159.8}}$$

$$\therefore M_2 = \left(\frac{1.5}{4.73}\right)^2 \times 159.8$$

$$M_2 = 16.07 \text{ gm/mol}$$

unknown gas $\rightarrow$ C = 12, 4H = 4

CH_4

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⊛ Dalton's Law of partial Pressure

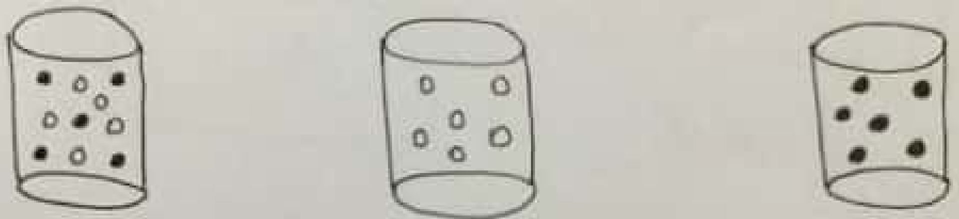
قانون دالتون للضغوط الجزيئية ينص على الضغط الكلي لخليط من الغازات يساوي مجموع الضغوط الجزيئية لمكونات الخليط

The total pressure of mixture of gases equal to the sum of the pressures that each gas would exert if it was present alone

⟹ Partial pressure :- الضغط الجزئي

is the pressure of individual gas Component in Mixture

هو الضغط الذي يحدثه الغاز بمفرده في الوعاء عند نفس الظروف



gas A & B | gas A | gas B

$P_T =$ | $P_A = \frac{n_A RT}{V}$ | $P_B = \frac{n_B RT}{V}$

$$P_T = P_A + P_B$$

$$P_T = \frac{n_A RT}{V} + \frac{n_B RT}{V}$$

$$P_T = (n_A + n_B)\frac{RT}{V}$$

$$P_T = n_T \frac{RT}{V} \quad \& \quad n_T = n_A + n_B$$

(*) Gas Diffusion انتشار الغازات

is the gradual mixing of molecules of one gas with molecules of another by virtue of their kinetic energy

انتشار الغاز هو المزج او الخلط المنتظم لجزيئات غاز واحد مع جزيئات غاز آخر تحت تأثير خواصه الحركية

(*) Gas effusion تدفق الغازات

is the process in which gas under pressure escapes from one compartment of container to another by passing through small opening

تدفق الغاز هو هروب الغاز تحت تأثير الضغط من خلال فتحة ضيقة

(*) Graham's Law of Diffusion قانون جرهام للانتشار

under the same conditions of temperature and pressure rates of diffusion for gases are inversely proportional to the square root of their molar mass or denisty

تحت نفس الظروف من الضغط ودرجة الحرارة معدل انتشار الغاز يتناسب عكسياً مع الجذر التربيعي للوزن الجزيئي او الكثافة

at T & P = Const $\quad r \propto \frac{1}{\sqrt{M}}$ → molar mass

r: rate of diffusion of gas

$$d = \frac{PM}{RT}$$

$$\boxed{\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}}$$ for molar mass

$$d \propto M$$

$$\boxed{\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}}$$ for denisty

as rate of diffusion of gas $r = \frac{V_{gas}}{t}$ $\quad \frac{\text{حجم الغاز عند الانتشار}}{\text{زمن الانتشار}}$