Chapter 5
Gases

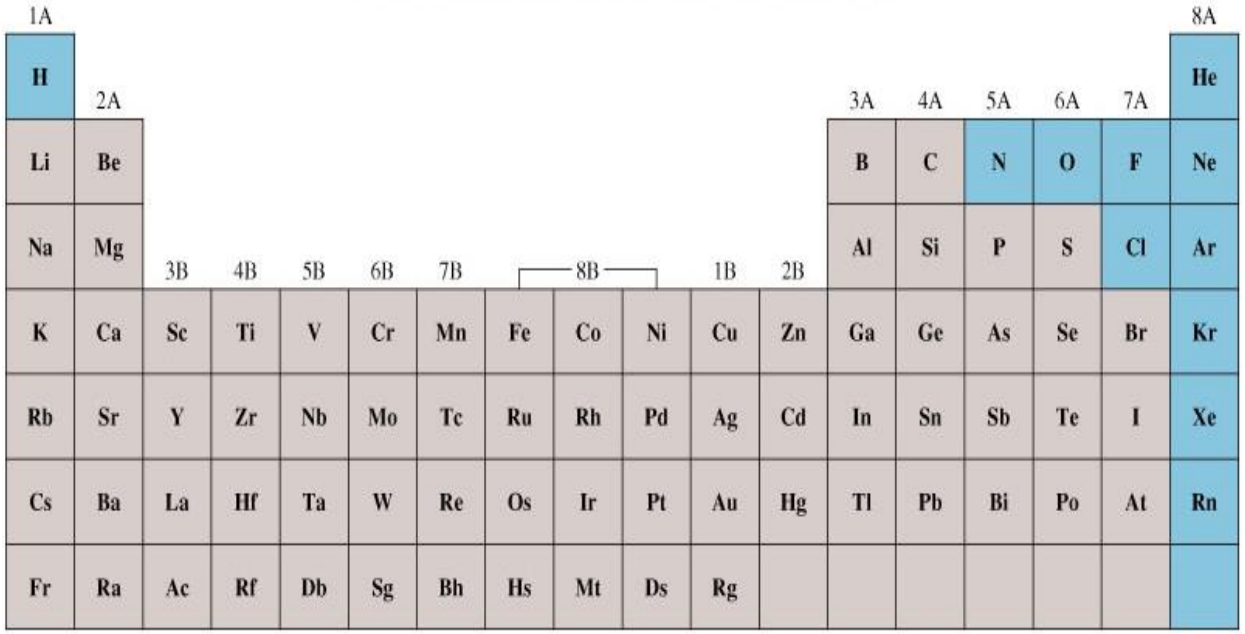
Dr. Dalal Alezi
dalezi@kau.edu.sa

28/10/2018

Chapter 5: Gases

- Gas Units
  - 1 atm= 760 mmHg (torr)= 101 kPa
    - 1 atm=760 mmHg
    - 1 atm=76 cmHg
    - 1 atm= 1.01325×10^2 kPa
    - 1torr= 1 mmHg
- Gas laws
  - Boyle's Law: $P_1V_1=P_2V_2$
    - Avogadro's Law: $V_1n_2=V_2n_1$
  - Charles's & Gay-Lussac's: $V_1T_2=V_2T_1$
    - Combined Gas Equation: $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$
- Ideal gas equation
  - PV=nRT
  - (STP condition)
- Density and MM of gases
  - Determine empirical and molecular formula
- Gas Stoichiometry
- Dalton's Law
  - $P_{total}= P_1 + P_2..$
  - $P_A = P_tX_A$
    - Collecting a Gas over Water

- Elements that exist as gases at 25 °C and 1 atm (blue boxes)



- Noble gases are monoatomic, e.g. He, Ne, Ar

- Other gases are diatomic, e.g. H_2, N_2, O_2

Pressure units

1 atm=760 mmHg

1 atm=76 cmHg

1 atm= 1.01325×10^5 Pa

1 atm= 1.01325×10^2 kPa

1torr= 1 mmHg

Convert 688 mmHg to atmosphere?

1 atm = 760 mmHg

1 atm $\rightarrow$ 760 mmHg

? atm $\rightarrow$ 688 mmHg

$(1 \times 688)/760 = 0.905$ atm

What is the pressure in kPa of 732 mmHg?

760 mmHg = 1.01325x102 kPa

760 mmHg $\rightarrow$ 1.01325x102 kPa

732 mmHg $\rightarrow$? kPa

= 97.6 kPa

(5.19 book)A gas sample occupying a volume of 725 ml at a pressure of 0.97 atm is allowed to expand at constant temperature until its pressure reaches 0.541 atm. What is its final volume?

V_1=725 ml P_1=0.97atm P_2=0.541 atm V_2= ?

$$P_1V_1=P_2V_2 \qquad V_2 = P_1V_1 / P_2$$

$$V_2 = 0.97x725/0.541 = 1299 \text{ ml}$$

(5.21 book) the volume of a gas is 5.8 L, measured at 1 atm. What is the pressure of the gas in mmHg if the volume is changed to 9.65 L? (the temperature remain constant)

V_1=5.8 L P_1=1atm V_2= 9.65 L P_2=? mmHg

$P_1V_1=P_2V_2$ ⟹ $P_2 = P_1V_1 / V_2$

P_2= 1x5.8/9.65=0.601 atm

P_2=0.601x760=456.76 mmHg

(5.23) A 36.4 L volume of methane gas is heated from 25 °C to 88°C at constant pressure . What is the final volume of the gas?

V_1=36.4 L T_1=25+273= 298 K T_2= 88+273=361 K V_2=?

$V_1T_2=V_2T_1 \Longrightarrow V_2 = V_1T_2 / T_1$

V_2 =36.4x361/298= 44.09 L

A student collects 125 ml sample of hydrogen gas. Later, the sample is found to have a volume of 128.6 ml at 26°C, at what temperature (in C) the sample was collected?

V_1=125ml　　T_1=?　　V_2=128.6 ml　　T_2= 26+273=299 K

$V_1T_2=V_2T_1 \Longrightarrow T_1 = V_1T_2 / V_2$

T_1 =125x299/128.6= 290.6 K

T_1=290.6-273= 17.6 °C

What pressure in atmosphere will 18.6 mol methane exert when its compressed in 12 L tank at temperature 45°C?

P=? n=18.6 mol V=12 L T=45+273=318 K **R=0.0821 atm.L/mol.K**

$$PV=nRT$$

$$P=nRT/V$$

$$P=18.6 \times 0.0821 \times 318/12= 40.5 \text{ atm}$$

What volume dose 0.056 mol of H_2 gas occupy at 25°C and 1.11 atm pressure ?

V=?   n=0.056 mol   T=25+273=298 K   P=1.11 atm

R=0.0821 atm.L/mol.K

$$PV=nRT$$

$$V = nRT/P$$

$$V = 0.056 \times 0.0821 \times 298/1.11 = 1.23\ L$$

What volume is occupied by 1 g H_2O vapor at temperature 134°C and pressure of 0.0552 atm?

V=? m=1 g T=134+273=407 K P=1.11 atm

$n=m/M \Longrightarrow n=1/18.016=0.056$ mol

$PV=nRT$

$V=nRT/P$

$V=0.056 \times 0.0821 \times 407/0.0552= 33.9$ L

How many moles are in 148 mL gas at 13°C and pressure 107 kPa?

$n=?$ $V=148ml/1000=0.148\ L$ $T=13+273=286\ K$

$P=107\ kPa\ /1.013x10^2 = 1.05\ atm$

$$PV=nRT$$

$$n = PV/RT$$

$$n= 1.05x0.148/0.0821x286=6.6x10^{-3}\ mol$$

A sample of nitrogen monoxide has a volume 72.6 ml at temperature 16°C and a pressure 104.1 kPa. What volume the sample will occupy at temperature 24 °C and pressure 99.3 kPa?

In this Question the sample has **n is constant**

V_1=72.6 mL P_1=104.1 kPa T_1= 16+273=289 K

V_2= ? P_2= 99.3 kPa T_2= 24+273=297 K

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

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

⇨ $V_2=P_1V_1T_2/P_2T_1$

V_2= 104.1x72.6x297/99.3x289

V_2=78.2 mL

A balloon was inflated with 2.42 L of helium gas at temperature 27°C. Later, the volume of balloon changed to 2.37L at temperature 19°C and pressure 99.7 kPa. What was the pressure when the balloon was inflated?

V_1= 2.42L T_1= 27+273=300 K P_1=?

V_2= 2.37 L T_2= 19+273=292 K P_2= 99.7 kPa

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

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$\Longrightarrow$ $P_1 = P_2V_2T_1 / V_1T_2$

P_1= 99.7x2.37x300/2.42x292= 100.3 kPa

What is the final volume of 5 L gas when the final pressure become double the original at constant temperature?

$V_1 = 5L$ $V_2 = ?$ P_1 $P_2 = 2 P_1$

$$P_1V_1 = P_2V_2$$

$$P_1 x 5 = 2P_1 x V_2$$

$$V_2 = 5P_1 / 2P_1$$

$$V_2 = 5/2 = 2.5 L$$

Ans: 2.5 L

Calculate the density of sulfur dioxide (SO_2) in grams per liter (g/L) at 2.3 atm and 60 C°

d=?? g/L

P= 2.3 atm

T=60+273.15=333.15 K

M= $32.06 + (2 \times 16) = 64.06 g/mol$

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

$$d = \frac{2.3 \times 64.06}{0.082 \times 333.15}$$

d= 5.39 g/L

Ans: 5.39 g/L

Calculate the density of gas in grams per liter (g/L) at 1.5 atm and 30 °C. Assuming that we have 4.5 mole of this gas. If you know that the mass of this gas is 126 g.

d=?? g/L

P= 1.5atm

T=30+273.15=303.15 K

$$M=\frac{m}{n}=\frac{126}{4.5}=28\ g/mol$$

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

$$d=\frac{1.5\times 28}{0.082\ \times 303.15}$$

d= 1.69 g/L

Ans: 1.69 g/L

Which of these gases will have the greatest density at the same specified temperature and pressure?

A) O_2 B) Kr C) CO D) C_2H_6

The density of a gas is directly proportional to its molar mass

كثافة الغاز تتناسب طرديا مع كتلته المولارية

$d \propto M$

Gases	Molar mass
O_2	2×16=32 g/mol
Kr	83.8 g/mol
CO	12+16=28 g/mol
C_2H_6	2×12+6×1.008= 30.05 g/mol

What is the molar mass of Freon-12 gas if its density is 11.19 g/L at 2.3 atm and 30 ^oC?

M=??

d=11.19 g/L

P= 2.3 atm

T=30+273.15=303.15 K

$$M = \frac{dRT}{P}$$

$$M = \frac{11.19 \times 0.082 \times 303.15}{2.3}$$

M= 120.94 g/mol

Ans: 120.94 g/mol

Calculate the volume of CO(in L) produced from 4.2L of (O_2) at the same T & P

$$2CH_4(g) + 3O_2(g) \rightarrow 4H_2O(g) + 2CO(g)$$

	Volume of CO	Volume of O_2
من المعادلة الكيميائية	2L	3L
من المسألة	??L	4.2L

$$V_{CO} = (4.2 \times 2)/3 = 2.8\ L$$

Ans: 2.8 L

What volume of CO_2 gas at 800 torr and 565 K could be produced by the reaction of 62 g of $CaCO_3$ according to the equation?

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

	moles of CO_2	moles of $CaCO_3$
من المعادلة الكيميائية →	1	1
من المسألة →	??	$\frac{62}{40.08 + 12 + (3 \times 16)} = 0.62$

$n_{CO_2} = 0.62$ mol

P= 800 torr/760= 1.05 atm

T= 565 K

$V_{CO_2} = ?$

PV=nRT

$1.05 \times V = 0.62 \times 0.082 \times 565$

V=27.35 L

Ans: 27.35 L

A mixture of two gases has a total pressure of 1852 mmHg at 21°C. The mixture is analyzed and is found to contain 6.5 mol CO, and 3.6 mol He. What is the partial pressure of He?

$$P_{He} = P_T X_{He}$$

$$X_{He} = \frac{n_{He}}{n_T}$$

P_T= 1852 mmHg, n_{CO}= 6.5 mol, n_{He}=3.6 mol n_T=n_{CO}+n_{He}= 6.5+3.6=10.1 mol

$$P_{He} = 1852 \times \frac{3.6}{10.1}$$

$$P_{He} = 660.1\ mmHg$$

Ans: 660.1 mmHg

A mixture of two gases has a total pressure of 5 atm at 25°C. The mixture is analyzed and is found to contain 500 g Kr, and 50 g He. What is the partial pressure of Kr?

$$P_{Kr} = P_T X_{Kr}$$

$$X_{Kr} = \frac{n_{Kr}}{n_T}$$

P_T= 5 atm, $n_{kr} = \frac{500}{83.8}$ =5.97 mol, $n_{He} = \frac{50}{4}$ =12.5 mol,

$n_T = n_{Kr} + n_{He}$ = 5.97+12.5=18.47 mol

$$P_{Kr} = 5 \times \frac{5.97}{18.47}$$

$$P_{Kr} = 1.6\ atm$$

Ans: 1.6 atm

A sample of oxygen gas was collected over water at 30°C and 701 mmHg. The volume of the container was 5.66 L. Calculate the mole of O_2 collected. (Vapor pressure of water = 31.82 mmHg at 30°C.)

T=30+273.15=303.15K

P_T= 701 mmHg P_{H2O}=31.82 mmHg P_{O2}= P_T -P_{H2O} = 701 – 31.82=669mmHg/760

=0.88 atm

V=5.66L n_{O2}=??

PV=nRT

0.88×5.66=n ×0.082×303.15

n=0.2 mol

Ans: 0.2 mol

A sample of hydrogen gas was collected over water at 30°C and 2 atm. The volume of the container was 100 ml . Calculate the mass of $H_2(g)$ collected. (Vapor pressure of water = 0.04 atm at 30°C.)

$T=30+273.15=303.15K$

$P_T= 2$ atm $P_{H2O}=0.04$ atm $P_{H2}= P_T - P_{H2O} = 2 - 0.04=1.96$ atm

$V=100/1000=0.1L$

$m=??$

$$PV=nRT$$

$$1.96\times0.1=n\times0.082\times303.15$$

$$n=7.88\times10^{-3} \text{ mol}$$

$$n=\frac{m}{M}$$

$$7.88\times10^{-3}=\frac{m}{(2\times1.008)}$$

$$m=0.016 \text{ g}$$

Ans: 0.016 g

A sample of hydrogen gas was collected over water occupied 1.2 L at 288.15K and pressure 500 torr. What volume would H_2 occupy if were dry at STP? The pressure of water at 288.15K is 12.79 torr

V_1=1.2L

T_1=288.15K

P_T= 500 torr , P_{H2O}=12.79 torr , P_1= P_T -P_{H2O} = 500 – 12.79=487.21 torr/760=0.64atm

V_2=??

STP → P_2=1 atm T_2=273.15K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{0.64 \times 1.2}{288.15} = \frac{1 \times V_2}{273.15}$$

V_2=0.73 L

Ans: 0.73 L

A sample of hydrogen gas was collected over water occupied 4.0 L at 288.15K and pressure 0.87 atm. What volume would H_2 occupy if were dry at 400 K and 1.01 atm? The pressure of water at 288.15K is 0.017 atm.

V_1=4.0 L

T_1=288.15K

P_T= 0.87 atm , P_{H2O}=0.017 atm , P_1= P_T -P_{H2O} = 0.87 – 0.017 =0.853 atm

V_2=??

P_2=1.01 atm T_2=400 K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{0.853 \times 4}{288.15} = \frac{1.01 \times V_2}{400}$$

V_2=4.69 L

Ans: 4.69 L