Chapter – 5 (States of Matter)

Exercise Questions:

Question :1 What will be the minimum pressure required to compress 500 dm3 of air at 1 bar to 200 dm3 at 30 degree C?

Answer:

Initial pressure, p1 = 1bar

Initial volume, V1 = 500 dm^3

Final volume, V2 = 200 dm^3

As the temperature remains the same, the final pressure can be calculated with the help of Boyle's law.

Acc., Boyle's law,

P1 V1 = P2 V2

P2 = P1 V1 / V2

= 1 x 500 / 200

= 2.5 bar

: The minimum pressure required to compress is 2.5 bar.

Question :2 A vessel of 120 mL capacity contains a certain amount vessel of volume 180 mL at 35 degree C. What would be it's pressure?

Answer:

Initial pressure, P1 = 1.2 bar

Initial volume, V1 = 120 mL

Final volume, V2 = 180 mL

As the temperature remains the same, final pressure can be calculated with the help of Boyle's law.

According to the Boyle's law,

P1 V1 = P2 V2

P2 = P1 V1 / V2

= 1.2 x 120 / 180

= 0.8 bar

Therefore, the min pressure required is 0.8 bar.

Question :3 Using the equation of state pV = nRT; show that at a given temperature density of a gas is proportional to gas pressure p.

Answer:
The equation of state is given by,
$pV = nRT$ ……..(1)
Where, p = pressure
V = volume
N = number of moles
R = gas constant
T = temp.
$n/V = p / nRT$
Replace with m / M, therefore,
$m / MV = p / RT$ ….(2)
Where, m = mass
M = molar mass
But, $m / V = d$
Where, d = density
Therefore, from equation (2), we get
$d / M = p / RT$
$d = (M / RT)p$
Therefore, at a given temperature, the density of the gas is proportional to its pressure.

Question :4 At 0 degree C, density of a certain oxide of a gas at 2 bar is same as that of dinitrogen at 5 bar. What is the molecular mass of the oxide?

Answer:
We know, density (d) = PM/RT
When T and d are constant {e.g. same}
Then, PM = constant
$P_1 M_1 = P_2 M_2$
Here, P1 = pressure of certain oxide of = 2 bar
P2 = pressure of N_2 gas = 5 bar
M1 = molar mass of that oxide
M2 = molar mass of N_2 gas = 28 g/mol
Now, $2 \times M_1 = 5 \times 28$
$M_1 = 70$ g/mol
Hence, molar mass of unknown oxide = 70g/mol

Question :5 Pressure 1 g of an ideal gas A at 27 degree C is found to be 2 bar . When 2 g of another ideal gas B is introduced in the same flask at same temperature the pressure becomes 3 bar. Find a relationship between their molecular masses.

Answer:

Mass of gas A, WA = 1g

Mass of gas B, WB = 2g

Pressure exerted by the gas A = 2 bar

Total pressure due to both the gases = 3 bar

In this case temperature & volume remain constant

Now if MA & MB are molar masses of the gases A & B respectively, therefore

pA V= WA RT/MA & P_{total} V = (WA/MA + WB/ MB) RT

= 2 X V = 1 X RT/MA & 3 X V = (1/MA + 2/MB) RT

From these two equations, we get

3/2 = (1/MA + 2/MB) / (1 /MA) = (MB + 2MA) / MB

This result in 2MA/ MB = (3/2) -1 = ½

OR

MB = 4MA

Thus, a relationship between the molecular masses of A and B is given by

4MA = MB

Question :6 The drain cleaner, Drainex contains small bits of aluminium which react with caustic soda to produce dihydrogen. What volume of dihydrogen at 20 degree C and one bar will be released when 0.15 g of aluminium reacts?

Answer:

The reaction of aluminium with caustic soda is as given below:

2Al + 2NaOH + 2H2O → 2NaAlO2 + 3H2

At standard temperature pressure, 54g of Al gives 3 x 22400 mL of H2

Therefore, 0.15 g Al gives:

= 3 x 22400 x 0.15 / 54 mL of H2

= 186.67 mL H2

At standard temperature pressure,

p_1 = 1 atm

V1 = 186.67 mL

T1 = 273.15 K

Let the volume of dihydrogen be V2 at p2 = 0.987 atm and T2 = 20^0C = (273.15 + 20) K = 293.15 K.

Now,

P1V1 / T1 = p2V2/T2

V2 = p1 V1 T2 / p2 T1

= 1 x 186.67 x 293.15 / 0.987 x 273.15

= 202.98 mL

= 203 mL

Hence, 203 mL of dihydrogen will be released.

Question :7 What will be the pressure exerted by a mixture of 3.2 g of methane and 4.4 g of carbohydrates dioxide contained in a 9 dm3 flask at 27 degree C?

Answer:

It is known that,

p = m/M . RT/V

For methane (CH4),

P_{CH4},

= 3.2/16 x 8.314 x 300 / 9 x 10^{-3}m [Since 9 dm^3 = 9 x 10^{-3} m^3 27^0C = 300K]

= 5.543 x 10^4 Pa

For carbon dioxide (CO_2)

P_{CO2}

= 4.4/44 x 8.314 x 300 / 9 x 10^{-3}

= 2.771 x 10^4 Pa

Total pressure exerted by the mixture can be calculated as:

$p = p_{CH4} + p_{CO2}$

= (5.543 x 10^4 + 2.771 x 10^4) Pa

= 8.314 x 10^4 Pa.

Question :8 What will be the pressure of the gaseous mixture when 0.5 L of H2 at 0.8 bar and 2.0 L of dioxygen at 0.7 bar are introduced in a 1L vessel at 27 degree C?

Answer:

From the equation Pv = n RT for the two gases. We can write

0.8 x 0.5 = nH2 x RT or nH2 = 0.8 x 0.5 / RT

Also, 0.7 x 2.0 = n_{02} . RT or n02 = 0.7 x 2 / RT

When introduced in 1 L vessel, then

P x 1L = (n_{02} + nH_2) RT

Putting the values, we get

P = 0.4 + 1.4 = 1.8 bar

Hence, the total pressure of the gaseous mixture in the vessel is 1.8 bar

Question :9 Density of a gas is found to be 5.46 g/dm3 at 27 degree C at 2 bar pressure. What will be it’s density at STP?

Answer:

Given:

d_1 = 5.46 g/dm^3

p_1 = 2 bar

T1 = 27^0C = (27 + 273k) = 300K
p_2 = 1bar
T2 = 273 K
d_2 = ?
the density of the gas at STP can be calculated using the equation,
d = Mp/RT d1/d2 = p1 T2 / p2 T1
d2 = p2 T1 d1 / p1 T2
= 1 x 300 x 5.46 / 2 x 273
= 3 g dm^{-3}
Hence, the density of the gas at STP will be 3 g dm^{-3}.

Question :10 34.05 mL of phosphorus vapour weighs 0.0625 g at 546 degree C and 0.1 bar pressure. What is the molar mass of phosphorous?

Answer
Given,
p = 0.1 bar
V = 34.05 mL = 34.05 × 10–3 L = 34.05 × 10–3 dm3
R = 0.083 bar dm3 K–1 mol^{-1}
T = 546°C = (546 + 273) K = 819 K
From the gas equation PV = w. RT / M, we get
M = w. RT/ Pv ……….(1)
Substituting the given values in the equation (1), we get
M = (0.0625 / 0.1 x 34.04) X 82.1 X 819 = 124.75 g/mol
Hence, the molar mass of phosphorus is 124.75 g mol^{-1}

Question :11 A student forgot to add the reaction mixture to the round bottomed flask at 27 degree C but Instead he/she placed the flask on the flame. After a lapse of time, he realised his mistake, and using a pyrometer he found the temperature of flask was 477 degree C. What fraction of air would have been expelled out?

Answer:
Let the volume of the constant be V.
The volume of the air inside the constant at 27 ^{0}C is V.
Now,
V1 = V
T1 = 27 ^{0} C = 300 K V2 = ?
T2 = 477^0 C = 750K
Acc. to Charles' law.

V1 / T1 = V2/T2

V1 = V1 T2 / T1

= 750V /300

= 2.5V

Therefore, volume of air expelled out = 2.5 V – V = 1.5V

Hence, fraction of air expelled out

= 1.5 V / 2.5 V

= 3 / 5.

Question :12 Calculate the temperature of 4.0 MIL of a gas occupying 5 dm3 at 3.32 bar.

Answer:

Given:

N = 4.0 mol

V = 5 dm^3

p = 3.32 bar

R = 0.083 bar dm^3 at $K^{-1}mol^{-1}$

The temp. can be calculated using the ideal gas equation as :

T = Pv / n R

= 3.32 x 5 / 4 x 0.083

= 50 K

Therefore, the required temp, is 50K.

Question :13 Calculate the total no. of electrons present in 1.4 g of dinitrogen gas.

Answer:

Molar mass of dinitrogen (N2) = 28 g/mol

Thus, 1.4 g of N2

= 1.4 / 28

= 0.05 mol

= 0.05 x 6.02 x 10^{23} no. of molecules

= 3.01 x 10^{23} no. of molecules

Now, 1 molecule of N2 has 14 electrons

Therefore, 3.01 x 10^{23} molecules N2 contains,

= 14 x 3.01 x 10^{23}

= 4.214 x 10^{23} electrons.

Question :14 How much time would it take to distribute one Avogadro number of wheat grains. If 10^{10} grains are distributed each second?

Answer:

Avogadro no. = 6.02×10^{23}

Therefore, time taken

= 6.02×10^{23}s / 10^{10}

= 6.02×10^{13}s

= 6.02×10^{23} years / 60 x 60 x 24 x 365

= 1.909×10^{6} years

Therefore, the time taken would be 1.909×10^{6} years.

Question :15 Calculate the total pressure in mixture of 8 g of dioxygen and 4 g of dihydrogen confined in a vessel of 1 dm3 at 27 degree C.

Answer:

Given,

Mass of oxygen = 8 g, molar mass of oxygen = 32 g/mol

Mass of hydrogen = 4 g, molar mass of hydrogen = 2 g/mol

Therefore amount of oxygen = 8/ 32 = 0.25 mol

And amount of hydrogen = 4/2 = 2 mol

From the gas equation PV = n RT, we get,

P X 1 = (0.25 + 2) X 0.083 X 300 = 56.02 bar

Hence, the total pressure of the mixture is 56.02 bar.

Question :16 Pay load is defined as the difference between the mass of displaced air and the mass of the balloon. Calculate the pay load when a balloon of radius 10 m, mass 100 kg is filled with helium at 1.66 bar at 27degree C.

Answer:

Payload of the balloon = mass of the displaced air – mass of the balloon

Radius of the balloon, r = 10 m

Mass of the balloon, m = 100kg

Therefore volume of the balloon = 4/3πr3 = 4/3 x 22/7 x (10)3 = 4190.5 m3

Now volume of the displaced air = 4190.5 m3

Given,

Density of air = 1.2 kg m^{-3}

Therefore, the mass of the displaced air

= 4190.5 x 1.2 = 5028.6 kg

Let w be the mass of helium gas filled into the balloon, then

PV = (w/m) RT
OR w = PVM/RT
= (1.66 X 4190.5 X 103 X 4) / (0.083 X 300)
= 1117 kg (approx)
Total mass of the balloon filled with He = 1117 + 100 = 1217 kg
Therefore payload of the balloon = 5028.6 – 1217 = 3811.6 kg
Hence, the pay load of the balloon is 3811.6 kg.

Question :17 Calculate the volume occupied by 8.8 g of CO2 at 31.1 degree C and 1 bar pressure.

Answer:
V = mRT / Mp
Given:
m = 8.8 g
R = 0.083 bar dm^3 at K^{-1} mol^{-1}
T = 31.1 ^0C = 304.1 K
M = 44g
P = 1 bar
Thus, Volume (V),
= 8.8 x 0.083 x 304.1 / 44 x 1
5.04806 L
5.05 L
Therefore, the volume occupied is 5.05 L

Question :18 2.9 g of gas at 95 degree C occupied the same volume as 0.184 g of dihydrogen at 17 degree C, at the same pressure. What is the molar mass of the gas?

Answer:
Volume,
V = mRT / Mp
= 0.184 x R x 290 / 2 x p
Let M be the molar mass of the unknown gas.
Volume occupied by the unknown gas is,
= mRT /Mp
= 2.09 x R x 368/M x p
According to the que,
0.184 x R x 290 / 2 x p = 2.09 x R x 368/M x p
= 0.184 x 290 / 2 = 2.9 x 368 / M
M = 2.9 x 368 x 2 / 0.184 x 290

$= 40\ g\ mol^{-1}$
Therefore, the molar mass of the gas is 40 g/mol

Question :19 A mixture of dihydrogen and dioxygen at one bar pressure contains 20% by weight of dihydrogen. Calculate the partial pressure of dihydrogen.

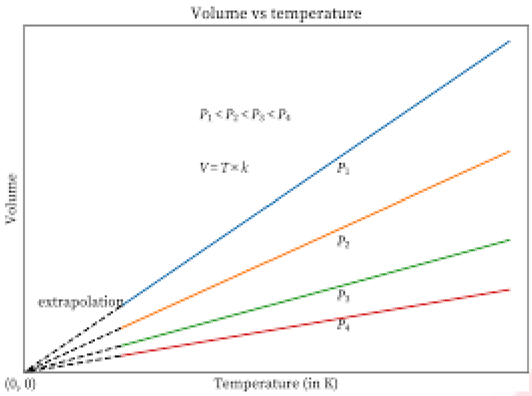
Answer:
Pressure of the gas mixture = 1 bar
Let us consider 100g of the mixture
So, mass of hydrogen in the mixture = 20 g
And mass of oxygen in the mixture = 80 g
Using the respective molar masses, we get
nH = 20/ 2 = 10 mol
nO = 80 / 32 = 2.5 mol
Then, pH = XH x Ptotal
= (nH / nH + nO) x P total
= (10 / 10 + 2.5) x 1
= 0.8 bar
Hence, the partial pressure of dihydrogen is 0.8 bar

Question :20 What would be the SI unit for the quantity pVT2/n?

Answer:
SI unit of pressure, $p = Nm^{-2}$
SI unit of volume, $V = m^3$
SI unit of temperature, T = K
Hence, SI unit of pV^2T^2/n is,
$= (Nm^{-2})(m^2)^2(K)^2/mol$
$= Nm^4K^2mol^{-1.}$

Question :21 In terms of Charles's law explain why -273 degree C is the lowest possible temperature?

Answer:
According to Charles' law
At constant pressure, the volume of a fixed mass of gas is directly proportional to its absolute temperature.



It was found that for all gases, the plot of volume vs. temperature is straight line.
If we extend the line to zero volume, then it intersect the temperature axis at -273^{0}C. that is the volume of reaching -273^{0}C .
Therefore, it can be said that -273^{0}C is the lowest possible temperature.

Question "22 Critical temperature for carbon dioxide and methane are 31.1 degree C and -81.9 degree C respectively. Which of these has stronger intermolecular forces and why?

Answer:

If the critical temperature of a gas is higher than it is easier to liquefy. That is the intermolecular forces of attraction. Among the molecules of gas are directly proportional to its critical temperature.
Therefore, in CO2 intermolecular forces of attraction are stronger.

Question :23 Explain the physical significance of van see Walls parameters.

Answer:

The physical significance of 'a'
The magnitude of intermolecular attractive forces within gas is represented by 'a'.
The physical significance of 'b':
The volume of a gas molecule is represented by 'b'.