TEMPERATURE AND THERMAL EXPANSIONS
3. EXPANSION OF GASES

POINTS TO REMBER

1. Since the expansion of gases is much more than that of liquid, all the expansions of gases are real.
2. Volume expansion co-efficient of a gas at constant pressure

$$\alpha = \frac{V_t - V_0}{V_0 t}/°C \quad \text{Or } \alpha = \frac{V_2 - V_1}{V_1 t_2 - V_2 t_1}/° \quad \text{Or} \quad V_t = V_0(1+\alpha t)$$

3. Pressure co-efficient of a gas at constant volume

$$\beta = \frac{P_t - P_0}{P_0 t}/°C \quad \text{Or } \beta = \frac{P_2 - P_1}{P_1 t_2 - P_2 t_1}/° \quad \text{Or} \quad P_t = P_0(1+\beta t)$$

4. Volume co-efficient = Pressure co-efficient $\alpha = \beta = \frac{1}{273.16}/°C = 0.0036/°C$
5. Volume co-efficient is determined by Regnault's method and
6. Pressure co-efficient is determined by Jolly's bulb method.
7. The lowest possible temperature attainable by a gas is called absolute temperature
8. **Boyle's Law:** The volume of a given mass of gas is inversely proportional to its pressure at constant temperature.

   PV = constant (or) $P_1v_1 = P_2V_2$ (Temperature = constant)
9. **Charles' Law (I):** The volume of a given mass of a gas is proportional to its absolute temperature at constant pressure. V α T (or) $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ (P = const)
10. **Charles' Law (II):** The pressure of a given mass of a gas is proportional to its absolute temperature at constant volume. (Gay-lusacs' law)

    P α T (or) $\frac{P_1}{P_2} = \frac{T_1}{T_2}$ (V = const)
11. The constant volume gas thermometer works on the principle of Gay-lusacs' law.
12. **Gas Equation**:

    a) For 1 gm of a gas $\frac{PV}{T} = r$

    b) For m grams of the gas $\frac{PV}{T} = mr$

    'r' is the specific gas constant which depends on nature of the gas and amount of the gas and different for different gases.

    c) For one mole of a gas $\frac{PV}{T} = R$

    d) For n moles of a gas $\frac{PV}{T} = nR$

    R is the universal gas constant. which is constant for all gases

    1) PV = nRT = $\frac{m}{M}RT \Rightarrow$ PV = mrT (or)
13. **Significance of universal gas constant:** Universal gas constant is the gas constant for one mole of a gas. It is same for all gases since according to Avogadro's hypotheses at the same temperature and pressure one mole of any gas occupies the same volume

$$R = 8.317\,J/mole-K = 8317\,J/kmole-K$$

14. If two vessels of volumes V_1 and V_2 containing same gas at the same temperature and at the pressureP_1 and P_2 are connected by a fine capillary tube, the final common pressure is $P^1 = \frac{P_1V_1 + P_2V_2}{V_1 + V_2}$
15. A gas which obeys gas laws at all temperatures and pressures is called an ideal gas.
16. **Perfect gas:** It can be defined as the gas whose molecules are force from inner molecular free of attraction and of point size

LONG ANSWER QUESTIONS

1. **Define volume coefficient of a gas and describe an experiment to determine it. Why do we not distinguish between apparent and real expansion in the case of gases as we do in the case of liquids?**
   (March 2010, March 2007)

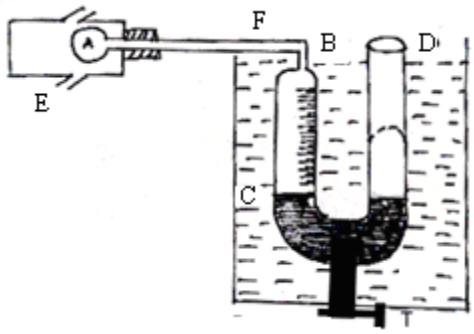
Ans: **Definition:** "The ratio of the increase in volume of a gas per 1ºC rise in Temperature to its volume at 0ºC at constant pressure is called volume co-efficient of gas".

If V_0 and V_t are volumes of gas at 0ºC and tºC respectively, then Volume coefficient of gas is given by

$$\alpha = \frac{v_t - v_0}{v_o t} / {}^0C$$

Regnault's Method:

Description: The apparatus consist of a spherical glass bulb (A) of volume about 700 cc which is connected to a mercury manometer BCD through a horizontal capillary tube F. The manometer is placed in a constant temperature water bath. The limb BC is calibrated to measure the volume of the gas. The mercury levels in the limbs of the manometer can be made equal using the tap T at the bottom of the manometer.

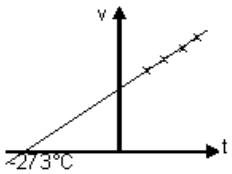


Procedure: The bulb and capillary tube are filled with a gas whose volume coefficient is to be determined through side tube E and it is sealed. . The bulb is now placed in an ice bath at 0ºC.When the gas inside the bulb attains 0ºC, the mercury levels in the two limbs of manometer are made equal by draining mercury through tap T. Since the levels are equal the pressure of gas in both the limbs become equal to atmospheric pressure. Then the volume of gas (V_0) is noted.

Now the bulb is maintained at t^oC and by equalizing the mercury levels in limbs using the tap T volume of the gas V_t is noted.

The volume coefficient of the gas at constant pressure is given by $\alpha = \frac{v_t - v_0}{v_o t} / {}^0C$

Group: A graph is drawn between temperature on X-axis and volume on Y-axis. It is a straight line making negative intercept on X-axis which represents absolute zero.



The volume co-efficient is found to be same for all gases and it is $\frac{1}{273}/°C$

Precautions:

1) The gas present in the bulb should be pure and dry.
2) The bulb must be completely immersed in the water bath.

- The expansion of gases is much more than that of solids and hence the expansion in the vessel is neglected.

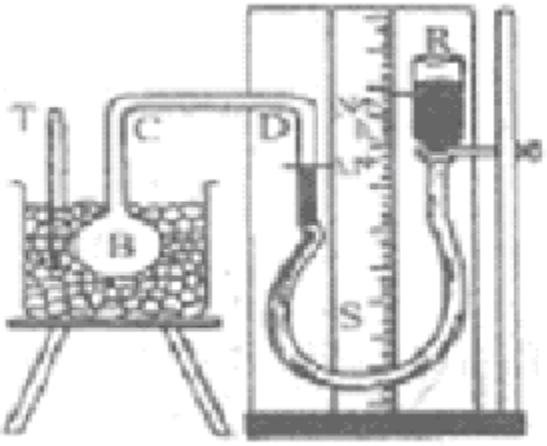
2. Define pressure coefficient of a gas and describe an experiment to determine it. (June2010,Jun 2004, Mar 2008)

A foot ball is inflated in a warm room. What happens to it when it is taken outside in the cold? Explain?

Ans. **Definition:** The ratio of the increase in pressure of a gas per 1^0 C rise of temperature, to its pressure at 0ºC at constant volume is called pressure coefficient of a gas.

If P_0 and P_1 are pressures of a gas at 0ºC and tºC, then pressure coefficient of a gas is $\beta = \frac{p_t - p_0}{p_o t} / {}^0C$

Jolly's Bulb Apparatus:



Description: The apparatus consist of a gas bulb B which contains gas. The bulb is attached to a glass tube bent twice at right angles at C and D. The other end of the glass tube is connected to a reservoir R by means of a rubber tube. The whole apparatus is fixed to a vertical wooden board which contains a metre scale S. A part of the glass tube, the entire rubber tube and part of the reservoir R are filled with mercury. The reservoir can be raised or lowered and can be fixed art any position with the help of the screw arranged to the stand

Procedure:

The glass bulb is immersed in an ice bath containing ice cubes (0°C). Then the reservoir R is adjusted such that the mercury level in the closed limb is at the mark M and the difference of levels NM is noted .Let it be h_0.

Pressure of the gas at 0°C is given by $P_0 = H \pm h_o$, where 'H' is atmospheric pressure

Positive sign indicates mercury level N is above the constant mark M.

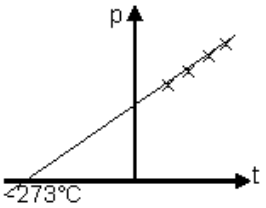
Negative sign indicates mercury level N is below the constant mark M.

Now the glass bulb is heated to a temperature t°C. The gas expands and pushes the mercury. The reservoir is adjusted such that the mercury is at the constant mark M. The difference of levels NM is noted. Let it be h_t.

Pressure at t° C is given by $P_t = H \pm h_t$

$$\therefore \beta = \frac{p_t - p_0}{p_0 t} / °C$$

Graph: A graph is plotted with temperature on X-axis and pressure on Y-axis. It is a straight line making negative intercept on X-axis - 273.16^0C. This t represents absolute zero.



The pressure co-efficient is found to be same for all gases and it is $\frac{1}{273} / °C$

Precautions: 1) The gas enclosed in the glass bulb should be perfectly dry.

2) Care should be taken so that mercury does not fall into the bulb while cooling.

- As temperature decreases the air in side the foot ball contracts.

3. State Boyle's law and Charles' law. Hence derive ideal gas equation. Which of the two laws is better for the purpose of thermometry and why? (May2009, March – 2009, May 2005, March 2006)

Ans. **Boyle's Law:** "At constant temperature, the pressure of a given mass of a gas is inversely proportional to its volume".

If P is pressure and V is volume of given mass of gas at constant temperature,

Then, $P \alpha \frac{1}{V}$ Or PV = constant

Charles' Law at constant pressure: "At constant Pressure, the volume of given mass of gas is directly proportional to its absolute scale of temperature"

Let V and T be the volume and absolute temperature of a gas at constant pressure .Then, $V \alpha T$ (or) V / T = constant

Charles' Law at constant volume:

"At constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature".

Let P and T be the pressure and absolute temperature of a given mass of a gas at constant volume .then, $P \alpha T$ (or) $\frac{P}{T}$ =Constant

Ideal gas equation : The gases which obey Boyle's law and Charles law at all temperatures and pressures are known as ideal gases. Consider a gas of mass 1 gm whose volume, pressure and temperature are V_1, P_1 and T_1 respectively. Let these are changed to V_2, P_2 and T_2 in two different stages.

A) Keeping the temperature T_1 constant, when the pressure of the gas is changed from P_1 to P_2, let its volume changes from V_1 to V.

According to Boyles law, $P_1V_1 = P_2V$

$$\therefore V = \frac{P_1V_1}{P_2} \quad \text{..... (1)}$$

B) Now Keeping pressure P_2 constant, when the temperature of the gas is changed from T_1 to T_2, let its volume changes from V_1 to V_2.

According to Charles' law, $V \propto T$

Or $\frac{V}{T_1} = \frac{V_2}{T_2}$

$\therefore V = \frac{V_2 T_1}{T_2}$ ..... (2)

From equation (1) and (2)

Or $\frac{P_1 V_1}{P_2} = \frac{V_2 T_1}{T_2}$ $\Rightarrow \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow \frac{P V}{T} =$ r

The constant r for one gram of a gas is called specific gas constant. Its value is different for different gases. For one mole of gas, the gas constant is R. Its is called universal gas constant. Its value is constant for all gases.

PV = RT where R = 8.314 J $mole^{-1}$ k^{-1}

This is called ideal gas equation.

For 'n' moles of gas , PV = nRT

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

SHORT ANSWER QUESTIONS:

1. Derive the relation between volume coefficient and pressure coefficient of a gas. (Jun 2003, Jun 2004, May 2007)

Ans. Let P_0 and V_0 be the pressure and volume of a given mass of gas at 0ºC. Keeping the pressure P_0 constant the gas is heated from 0ºC to tºC. Let volume of the gas changes from V_0 to V_t . If α is volume coefficient of the gas

$V_t = V_0 (1+\alpha t)$ …… (1)

Multiplying the equation (1) with $P_t = P_0$ on both sides

$P_t V_t = P_0 V_0 (1+\alpha t)$ …….(2)

Again by keeping the volume V_0 constant, the gas is heated from 0ºC to tºC Let pressure of the gas changes from P_0 to P_t. If β is pressure coefficient of the gas.

$P_t = P_0 (1+\beta t)$ ……. (3)

Multiplying the equation (3) with $V_t = V_0$ on the both sides

$P_1 V_t = P_0 V_0 (1+\beta t)$ …….(4)

From equations (2) and (4)

$P_0 V_0 (1+ \alpha t) = P_0 V_0 (1+\beta t)$

$1+ \alpha t = 1+ \beta t$

$\alpha t = \beta t$ or $\alpha = \beta$

Hence Volume coefficient of gas = Pressure coefficient of gas

For all gases,

$$a = \beta = \frac{1}{273.16} / {}^0C = 0.00366 / {}^0C$$

2 Write a short note on Kelvin scale of temperature.

Ans. $V_t = V_0(1+\alpha t)$

Where V_0 to V_t are the volumes of a gas at 0ºC and tºC respectively .But

$\alpha = \frac{1}{273.15} / {}^0C$

$\therefore V_t = V_0\left[1+\frac{t}{273.15}\right]$

Similarly $P_t = P_0\left[1+\frac{1}{273.15}t\right]$

If the temperature of the gas is decreased below 0ºC , at $t = -273.15^0C$, the pressure and volume of a gas becomes zero. Hence the lowest possible temperature attainable by the gas is called the absolute temperature

Absolute zero: The temperature at (or) volume of a gas becomes zero is called absolute zero temperature.

Absolute scale of temperature: The scale of temperature which starts from absolute zero (-273.15ºC) and the size of degree is same as that of the of the Celsius scale is called the absolute scale of temperature.

The relation between Kelvin scale and Celsius scale of temperature is T(K)=tºC+ 237.15

3. State and explain gas laws.

Ans. **Boyle's Law:** "At constant temperature, the pressure of a given mass of a gas is inversely proportional to its volume".

If P is pressure and V is volume of given mass of gas at constant temperature,

Then, $P \alpha \frac{1}{V}$ Or PV = constant

Charles' Law at constant pressure: "At constant Pressure, the volume of given mass of gas is directly proportional to its absolute scale of temperature"

let V and T be the volume and absolute temperature of a gas at constant pressure .Then, $V \alpha T$ (or) V / T = constant

Charles' Law at constant volume:

"At constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature".

Let P and T be the pressure and absolute temperature of a given mass of a gas at constant volume .then, $P \alpha T$ (or) $\frac{P}{T}$=Constant

4. What is the significance of universal gas constant? Find its value.

Ans. Universal gas constant is the gas constant for one mole of a gas. It is same for all gases **Value of R:**

For one gram – mole of a gas at N.T.P

V = 22.4 liter = 22.4×10^{-3} m^3; T= 273 K: P = 76 cm of Hg = $0.76\times13600\times9.8$ N / m^2.

Using the ideal gas equation, for one mole of gas, $R=\frac{PV}{T}$

$R=\frac{0.76\times136\times9.8\times22.4\times10^{-3}}{273}$ = 8.317J/ mole - k

VERY SHORT QUESTIONS

1. Why is it necessary to define pressure and volume coefficients for a gas?

Ans. When gas is heated both its volume and pressure changes

2. What is the nature of graph in the following?

i) Pressure and volume, keeping temperature constant.

ii) Pressure and reciprocal volume, keeping temperature constant

Ans.

1) Pressure - volume graph



2)Pressure-reciprocal of volume

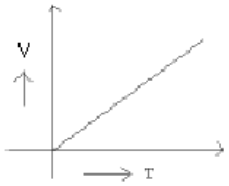


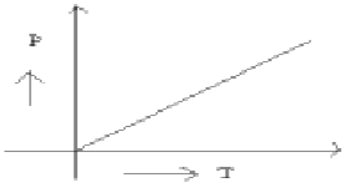
3. What is the nature of graph in the following?

i) Volume and temperature on Kelvin scale, keeping pressure constant.

ii) Pressure and temperature on Kelvin scale, keeping volume constant

Ans. 1) A straight line passing through the origin.





2) A straight line passing through the origin.

4. What is an ideal gas?

Ans. A gas which obeys gas laws at all temperatures and pressures are called an ideal gas.

5. Distinguish between a real gas and an ideal gas?

Ans. **Real gas.:** Real gases obey gas laws at low pressure and high temperatures.

Ideal gas: A gas which obeys gas laws at all temperatures and pressures is called an ideal gas.

6. What are the units and dimensions of universal gas constant?

Ans. Units: Joule/mole – k Dimensions: $ML^2T^{-2}K^{-1}$ $mole^{-1}$

7. What is specific gas constant? Is it same for all gases?

Ans. For 1 gm of a gas $\frac{PV}{T} = r$

For m grams of the gas $\frac{PV}{T} = mr$

'r' is the specific gas constant which depends on nature of the gas and amount of the gas and different for different gases

8. What are the units and dimensions of specific gas constant?

Ans. Units: $J\ Kg^{-1}\ K^{-1}$ Dimensions $M^oL^2\ T^{-2}K^{-1}$

9. What are the units and dimensions of the coefficient of thermal expansion of a solid or liquid or gas?

Ans. Units: $^oC^{-1}$ or K^{-1} Dimensions $M^oL^0\ T^oK^{-1}$

10. What is the relation between universal gas constant and Boltzmann constant? (May 2008)

Ans . $K = \frac{R}{N}$ where K is the Boltzmann constant and N is the Avogadro number .

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Exercise 1

1. The coefficient of linear expansion of nickel is $13\times10^{-6}/^{o}C$ **. Find its coefficients of a real and cubical expansion.**

Sol: $\alpha = 13\times10^{-6}/^{o}C$

Co-efficient of a areal expansion, $\beta = 2\alpha = 2\times13\times10^{-6} = 26\times10^{-6}/^{o}C$

Co-efficient of cubical expansion, $\gamma = 3\alpha = 3\times13\times10^{-6} = 39\times10^{-6}/^{o}C$

2. At constant pressure, 100c.c. of hydrogen at $0^{o}C$ **expands to 136.6c.c at** $100^{o}C$. **Find the volume coefficient of hydrogen.**

Sol: $V_o = 100c.c; t = 100^{o}C; V_t = 136.6c.c$

$$\alpha = \frac{V_t - V_0}{V_0 t} = \frac{136.6-100}{100(100)} = 0.00366/^{o}C$$

3. The pressure of a gas of volume 1 litre is 76cm of Hg. If the pressure is increased to 114cm of Hg at constant temperature, find its volume. (May2009)

Sol: $V_1 = 1litre = 1000c.c;\ P_1 = 76cm\ \ of\ \ Hg : P_2 = 114cm\ \ of\ \ Hg$.

From Boyle's law, $P_1V_1 = P_2V_2$ **6. The coefficient of linear expansion of gold is**$14\times10^{-6}/^{o}C$ **.**

4. Find the coefficient of linear expansion on Farenheit scale.

Sol: A difference of $1^{o}C$ = A difference of$1.8^{o}F$.

Co $\Rightarrow\ V_2 = \frac{P_1V_1}{P_2} = \frac{76\times1000}{114} = 666.7c.c$

5. The volume of a gas is 210c.c. at a temperature of$27^{o}C$ **. Find its volume if its temperature is increased to** $127^{o}C$ **at constant pressure. (Assume that absolute zero corresponds to**$-273^{o}C$ **).**

Sol: $V_1 = 210c.c.;\ T_1 = 273+27 = 300K;\ T_2 = 273+127 = 400K$

From Charle's law of volumes, $\frac{V_1}{T_1} = \frac{V_2}{T_2}\ \Rightarrow V_2 = \frac{210}{300}\times400 = 280c.c$

6. A glass of vessel capacity 1 litre is heated at sea-level from $0^{o}C$ **to** $100^{o}C$ **with its mouth open. Find the mass of air expelled. (Neglect the expansion of the glass globe. (Density of air at NTP=0.001293** g/cm^3)

Sol: $m_1T_1 = m_2T_2$

$T_1 = 273K$; $m_1 = 1000 \times 0.001293 = 1.293g$; $T_2 = 373K$

$$1.293 \times 273 = m_2 \times 373 \qquad \Rightarrow m_2 = \frac{273 \times 1.293}{373} = 0.9464g$$

The mass of air expelled $= 1.293 - 0.9464 = 0.3466g$

7. A barometer tube 90cm long contains some air above mercury. The reading 74.5cm long contains some air above mercury. The reading is 74.5 cm when the true pressure is 76cm and the temperature is 15^oC. If the reading is observed to be 75.38cm on a day when the temperature is 5^oC, what is the true pressure?

Sol: $V_1 =$ length of the barometer tube –reading = 90-74.5cm=15.5cm.

$P_1 =$ True pressure -reading=76.0-74.5=1.5cm

$T_1 = 273+15=288$K ; $T_2 = 273+5=278$K.

$V_2 = 90.0-75.8=14.2$. $T_2 = 273+5 = 278$K.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \Rightarrow \frac{1.5 \times 15.5}{288} = \frac{P_2 \times 14.2}{278} \Rightarrow P_2 = \frac{1.5 \times 15.5 \times 278}{288 \times 14.2} = 1.58cm$$

8. The mass of a litre of a gas is 1.562g at 0^oC under a pressure of 76cm of mercury. The temperature is increased to 250^oC and the pressure to 78cm of mercury. What is the mass of one litre of the gas under new conditions?

Sol: $P_1 = 76cm$ of mercury; $T_1 = 273K$; $\rho_1 = 1.562g/litre; P_2 = 78cm\,of\ mercury$

$T_2 = 273 + 250 = 523K$

$$\frac{P_1}{\rho_1 T_1} = \frac{P_2}{\rho_2 T_2} \Rightarrow \rho_2 = \frac{P_2 T_1 \rho_1}{P_1 T_2} = \frac{78 \times 273 \times 1.562}{76 \times 523} = 0.8366g/litre$$

9. Two bulbs of 100c.c and 200c.c. capacity are connected by a capillary tube of negligible volume. Initially both were at 0^oC. The temperature of the bigger bulb is finally raised to 100^oC, the smaller being kept at 0^oC. If the initial pressure was 76cm of mercury, what is the final pressure?

Sol: $$\frac{P_1V_1}{T} + \frac{P_2V_2}{T} = \frac{P'V_1}{T_1} + \frac{P'V_2}{T_2}$$

$$\frac{P}{T}(V_1 + V_2) = P'\left(\frac{V_1}{T_1} + \frac{V_2}{T_2}\right)$$

P =76cm; T=273K; V_1=100c.c; V_2=200c.c

$$\frac{76}{273}(100 + 200) = P'\left(\frac{100}{273} + \frac{200}{373}\right) \Rightarrow P' = 92.53cm$$

10. A glass bulb of volume 200c.c is sealed at 27^oC. If the pressure of the gas inside the bulb 1.25×10^{-4} cm of Hg, calculate the number of molecules inside the bulb. (Avogadro number = 6.0225×10^{23}, $R = 8.314 \times 10^7 erg/mole - K$).

Sol: V=200cm^3; P=1.25×10^{-4} cm of Hg $= 1.25 \times 10^{-4} \times 13.6 \times 980 \frac{dyne}{cm^2}$

T=273+27 = 300K,

Avogadro number, N=6.0225×10^{23}; $R = 8.314 \times 10^7 erg/mole - K$.

By ideal gas equation, PV=nRT

$$n = \frac{PV}{RT} = \frac{1.25\times10^{-4}\times13.6\times980\times200}{8.314\times10^{7}\times300}\,moles$$

Number of molecules inside the bulb =number of moles X Avogadro number

$$= \frac{1.25\times10^{-4}\times13.6\times980\times200}{8.314\times10^{7}\times300}\times6.0225\times10^{23} = 8.018\times10^{15}$$

Exercise 2

1. A litre of air is heated from 27ºC to 177ºC at constant pressure. Find its volume

Sol: $T_1 = 27^0 C = 300K \;\; ; \;\; T_2 = 177^0 C = 450K$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{1000}{300} = \frac{V_2}{450} = V_2 = 1500 = V_2 = 1.5lit$$

2. The pressure of a given mass of gas at 27°C is 75 cm of mercury. Find the temperature in 0°C at which the pressure is doubled, the gas being heated at constant volume.

Sol: $\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow T_2 = \frac{P_2T_1}{P_1} = \frac{150\times300}{75} \Rightarrow T_2 = 600\,K = 327^0 C$

3. The volume of a mass of gas at 37°C and a pressure of 75cm of mercury is 620 c.c. Find the volume at N.T.P.

Sol: At NTP, $P_1 = 76cm, T_1 = 273K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{75\times620}{310} = \frac{76\times V}{273} \Rightarrow \text{V} = 538.8\ cc$$

4. A balloon of volume V contains a gas of mass m at a pressure P and temperature 15ºC. Gas is pumped into the balloon so that its volume is doubled and the pressure is trebled. If the temperature increases 6ºC in the process, find the ratio of the increase in a mass to the original mass.

Sol: $V_2 = 2V_1,\ P_2 = 3P_1$

$$\frac{P_1V_1}{m_1T_1} = \frac{P_2V_2}{m_2T_2} \Rightarrow$$

$$\frac{P_1V_1}{m_1(288)} = \frac{3P_1\times2V_1}{m_2(294)} \Rightarrow \frac{m_1}{m_2} = \frac{294}{288\times6} \Rightarrow \frac{m_2 - m_1}{m_1} = \frac{1728-294}{294}$$

$$\frac{m}{m_1} = \frac{1434}{296} \Rightarrow m : m_1 = 239 : 49$$

5. Calculate the value of the gas constant for one gram of hydrogen, given that the density of hydrogen at N.T.P is 0.00009 g / cm^3.

Sol: $PV = nRT$ Or $R = \dfrac{P}{\left(\frac{m}{v}\right).T}$

$$R = \frac{(0.76)(13600)(9.8)}{(0.09)(273)} \Rightarrow R = 4.1226\,Jg^{-1}K^{-1}$$

6. The mass of a litre of dry air at N.T.P. is 1.293g. Find the mass of 3 litres of air at 117ºC and a pressure of 4 atmospheres?

Sol: $\frac{P_1V_1}{m_1T_1}=\frac{P_2V_2}{m_2T_2}$

$\Rightarrow m_2=\frac{P_2V_2}{T_2}\times\frac{m_1T_1}{P_1V_1}=\frac{4\times3}{390}\times\frac{273}{1\times1}(1.293)$

$\therefore m_2=10.8612g$

7. A glass vessel contains air at 60ºC. To what temperature must it be heated to expel one third of the air, the pressure remaining constant. (Neglect the expansion of the vessel).

Sol: $m_1T_1=m_2T_2$

$Or\ \ m_1(333)=\frac{2m_1}{3}T_2\ \Rightarrow\ \ T_2=226.5^0C$

8. The density of oxygen at N.T.P. is 1.429 g / litre. A certain mass of the gas is enclosed in a cylinder, whose volume is 2.5 litres, under a pressure of 780mm at a temperature of 27ºC. What is the mass of the gas in the cylinder?

Sol: $\frac{P_1V_1}{m_1T_1}=\frac{P_2V_2}{m_2T_2}\ \ \Rightarrow\ \frac{P_1V_1}{P_1T_1}=\frac{P_2V_2}{T_2M_2}$

$m_2=\frac{P_2V_2}{T_2}\times\frac{P_1T_1}{P_1V_1}=\frac{780\times2.5}{300}\times\frac{1.429\times273}{600}=3.336\,g$

9. If the volume of nitrogen of mass 14kg is 0.4 m^3 at 30ºC. Calculate the pressure.

Sol: $m=14kg$

$M=28kg;\ V=0.4\,m^3$

$T=303^0k$ P= ?

$PV=nRT$

$PV=\frac{m}{M}RT\ \Rightarrow P=\frac{mRT}{MV}=\frac{14\times8.314\times10\times303}{28\times0.4}$

$\therefore P=31.49\times10^5\ N/m^2$

10. An air bubble comes from the bottom to the surface of a lake of depth 2.5 m. The surface temperature of the lake is 40ºC. The diameter of the bubble at the bottom and at the surface is 3.6 mm and 4 mm respectively. Find the temperature of the lake at the bottom.

Sol: At the bottom of the lake, $P_1=1atm+\frac{250\times1\times980}{76\times13.6\times980}\times atm=\ P_1=1.2418\,atm$

$V_1=\frac{4}{3}\pi r^3\Rightarrow V_1\ \alpha\ r^3=(1.8)^3\ ;\ \ T_1=?$

At the surface of the lake, $P_2=1atm\,;T_2=40^0C=313K\,;V_2\,\alpha\,r_2^{\,3}=(2)^3$

$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}=T_1=\frac{P_1r_1^{\,3}T_2}{P_2r_2^{\,3}}$

$$T_1 = \frac{1.2418 \times (1.8)^3 \times 313}{(2)^3 \times 1} = 283.35^0 K \Rightarrow T_1 = 10.2^0 C$$

11. A steel tank is filled with a gas at 150 atmospheres and at 20ºC. If the pressure rises to 250 atmospheres, the tank explodes. Find the temperature at which the tank explodes.

Sol: $T_1 = 20^0 C = 293^0 K \; ; T_2 = ?$

$P_1 = 150\, atm, \; P_2 = 250\, atm$

From Charles' law, $\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow T_1 = \frac{P_1 \times T_2}{P_2} = \frac{250 \times 293}{150} = 488.3^0 K$

$\Rightarrow T_1 = 215.3^0 C$

12. The mass of 1 litre of hydrogen gas at N.T.P. is 0.9 g. What is the mass of the gas of same volume at 27ºC and 75 cm of Hg pressure?

Sol: At NTP, $P_1 = 76\, mm\, of\ Hg \; ; T_1 = 0^0 C = 273 k$ V= 1 lit

$$\frac{P}{m_1 T_1} = \frac{P_2}{m_2 T_2} \Rightarrow \frac{76}{0.9 \times 273} = \frac{75}{m_2 \times 300}$$

$$m_2 = \frac{75 \times 0.9 \times 273}{76 \times 300} \Rightarrow m_2 = 0.8082\, g$$

ASSESS YOURSELF

1. **The definition of volume coefficient of a gas is different from the definitions of volume coefficient of a solid or a liquid. Why?**

Ans: In case of gas, the initial volume at $0^o C$ is to be taken where as in the case of solids and liquids the volume at the initial temperature is taken .This is due the more expansion of gases compared that of solids or liquids.

2. **A gas is taken in an enclosure. The pressure of a gas is reduced by pumping out some gas. Will you expect the temperature of the gas to decrease by Charles' law?**

Ans: No. Charles' law is applicable for the changes in pressure of the gas of constant mass.

3. **Boltzmann Constant $K = \frac{R}{N}$ where N is Avogadro's number. Which quantity does $\frac{PV}{KT}$ represent?**

Ans: Number of moles in the gas.

4. **If the gas in an open vessel is heated, what will be the relation between its temperature and mass of the gas in the container?**

Ans: Mass of the gas in the vessel is inversely proportional to its absolute temperature.

5. **When the gas from a cooking gas cylinder is used or when a gas stove is lighted what happens to the pressure of the gas in the cylinder?**

Ans: Decreases.

6. **In the expression for α, if the temperatures are expressed on Kelvin scale does it give the correct value of α?**

Ans: No. The temperatures are to be taken in Celsius scale only.