Solutions to Workbook-1 [Chemistry] | States of Matter

Daily Tutorial Sheet	**Level - 0**

Very Short Answer Type (1 Mark)

1. $b = 4V$ or $V = \frac{b}{4} = \frac{0.0318}{4} = 7.95\times10^{-3}\,\text{L mol}^{-1} = 7.95\,\text{cm}^3\text{mol}^{-1}$

$\therefore$ Volume occupied by one O_2 molecule $= \frac{7.95}{6.02\times10^{23}} = 1.32\times10^{-23}\,\text{cm}^3$

Considering the molecule to be spherical, $\frac{4}{3}\pi r^3 = 1.32\times10^{-23}$ or $r^3 = 3.15\times10^{-24}$

$\therefore$ $3\log r = \log(3.15\times10^{-24}) = -24 + 0.4983 = -23.5017$ or $\log r = -7.8339 = \bar{8}.1661$

$r = \text{Antilog } \bar{8}.1661 = 1.466\times10^{-8}\,\text{cm}$

$\therefore$ Diameter of oxygen molecule = $2 \times r = 2 \times 1.466 \times 10^{-8}$ cm

$= 2.932 \times 10^{-8}$ cm = 2.932 Å

2. As level in the open arm of the manometer is lower than that in the arm connected to the gas bulb, this means that atmospheric pressure is greater than pressure of the gas by difference of the two levels. Hence, pressure of gas = 740 – 21 = 719 mm.

3. Size of molecule of He and H_2 is extremely small hence force of attraction between He atoms or H_2 molecules is negligible.

4. Triple point of a substance represents the conditions at which all the three phases of the substance, i.e., solid, liquid and gas exist together, e.g., triple point of water is 0.01°C at 4.58 mm pressure where ice, liquid water and water vapour coexist.

5. The temperature at which a real gas behaves like an ideal gas over an appreciable pressure range is called Boyle temperature or Boyle point.

6. Both decrease with increase of temperature.

Short Answer Type-I (2 Marks)

7. $P_1 = 250$ k Pa, $T_1 = 300$ K ; $P_2 = ?$ $T_2 = 1800$ K

Applying pressure – temperature law, $\frac{P_1}{T_1} = \frac{P_2}{T_2}$; $\frac{250}{300} = \frac{P_2}{1800}$ or $P_2 = 1500$ kPa

As the cylinder can withstand a pressure of 10^6 Pa = 10^3 kPa = 1000 kPa, hence it will blow up.

8. Mass of water filling the flask = (1067.9 – 134.567)g = 933.333 g

$\therefore$ Volume of flask = Volume of water filling the flask = 933.3 cm^3

($\because$ Density of H_2O = 1 g cm^{-3})

Now, P = 735 mm, T = 31 + 273 K = 304 K, V = 933.3 cm^3

Applying $PV = nRT$, i.e., $\left(\frac{735}{760}\text{atm}\right)\left(\frac{933.3}{1000}\text{L}\right) = n\times0.0821\,\text{L atm K}^{-1}\text{mol}^{-1}\times304\text{K}$

This given $n = 0.036$ mol

Mass of 0.036 mol of the gas = (137.456 – 134.567) g = 2.889 g

$\therefore$ Mass of 1 mole of the gas $= \frac{2.889}{0.036} = 80.25$ g

9 According to van der Waals equation, $\left(P+\frac{an^2}{V^2}\right)(V-nb)=nRT$ or $P=\frac{nRT}{V-nb}-\frac{an^2}{V^2}$

Here, $n=\frac{110}{44}=2.5$ moles. Substituting the given values, we get

$$P=\frac{(2.5\,\text{mol})(0.0821\,\text{L atm K}^{-1}\text{ mol}^{-1})(310\text{ K})}{(2\text{ L}-2.5\text{ mol}\times 0.0427\text{ L mol}^{-1})}-\frac{(3.59\,\text{L}^2\text{ atm mol}^{-2})\,(2.5\text{ mol})^2}{(2\,\text{L})^2}$$

$$= 33.61\text{ atm} - 5.61\text{ atm} = 28.0\text{ atm}$$

If the gas were considered as ideal gas, applying ideal gas equation, PV = nRT, we get

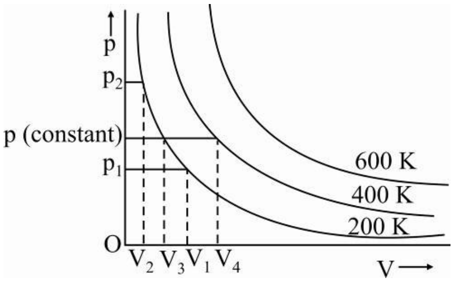
$$P=\frac{nRT}{V}=\frac{(2.5\text{mol})(0.0821\,\text{L atm K}^{-1}\text{ mol}^{-1})(310\,\text{K})}{2\text{L}} = 31.8\text{ atm}$$

10. **(i)** In accordance to Boyle's law, pressure of a gas is inversely proportional to its volume if temperature is kept constant. Thus, the volume of a gas will decrease if the pressure on the gas in increased keeping the temperature constant. e.g., at 200 K when pressure increases from p_1 to p_2, volume of the gas decreases, $V_2 < V_1$.

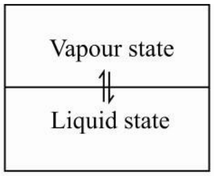
(ii) In accordance to Charles law, volume of a gas is directly proportional to its temperature if pressure is kept constant.

Thus, on increasing temperature, the volume of a gas will increase if pressure is kept constant.

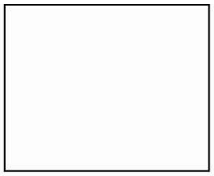
At constant p when the increase in the temperature is from 200 K to 400 K, the volume of the gas increases $V_4 > V_3$.



11. In a closed vessel, it is essential to know that below the critical point (i.e., critical temperature and critical pressure), the surface of separation between the liquid and its vapour is clearly visible. As we approach towards the critical point, the density of the liquid decreases while that of the vapour increases due to compression.



Below critical point
(Meniscus clearly visible)



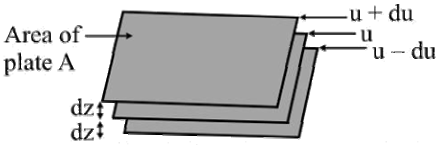
Above critical point
(Meniscus disappears)

At the critical point, the densities of the liquid and that of the vapour becomes equal and the surface of separation disappears i.e., the liquid and the gaseous state become non separable. In other words, the meniscus is no longer visible.

This fluid which is now a homogenous mixture is called supercritical fluid. Hence, any fluid above its critical temperature and pressure is called a supercritical fluid.

These supercritical fluids dissolve many organic substances. They are used for quick separation of a mixture into its components. e.g., CO_2 above $31.1^\circ C$ and above 600 bar pressure has a density of about $1 g/cm^3$.It is used to dissolve out caffeine from coffee beans as it is a better substitute than chlorofluorocarbons which are harmful for the environment.

12. When a liquid flows over a fixed surface, the layer of molecules in the immediate contact of surface is stationary. The velocity of the upper layers increase as the distance of layers from the fixed layer increases.



Gradation of velocity in the laminar flow

This type of flow in which there is a regular gradation of velocity in passing from one layer to the next is called laminar flow.

In laminar flow, the velocity of molecules is not same in all the layers because every layer offers some resistance or friction to the layer immediately below it.

13. Volume of 3.5 g He at 25°C and pressure P,

$$V = \frac{nRT}{P} = \frac{w}{M}\frac{RT}{P} = \frac{3.5}{4} \times \frac{R \times 298}{P} \qquad \textbf{........(i)}$$

To fill the balloon with H_2 to double this volume means volume of H_2 = 2V, T = 373 K. Hence,

$$2V = \frac{w}{M}\frac{RT}{P} = \frac{w}{2} \times \frac{R \times 373}{P}$$

Dividing (ii) by (i) we get : $2 = \frac{w \times 373}{2} \times \frac{4}{3.5 \times 298}$ or $w = 2.796\,g$

Short Answer Type-II (3 Marks)

14. Volume of the liquid $= \frac{(148-50)g}{0.98 g\,mol^{-1}} = 100\,ml = 0.1\,litre$

This is the volume of the vessel and hence the volume of the gas.

For ideal gas, $PV = nRT = \frac{w}{M}RT$

Or $M = \frac{wRT}{PV} = \frac{0.5g \times 0.082L\ atm\ K^{-1}\ mol^{-1} \times 300K}{1\,atm \times 0.1L} = 123\,g\,mol^{-1}$

15. As $P_1 = P_2$ and $V_1 = V_2$, But $PV = nRT$

$\therefore$ $P_1V_1 = P_2V_2$, i.e., $n_1RT_1 = n_2RT_2$ $\quad\therefore$ $n_1T_1 = n_2T_2$ or $\frac{w_1}{M_1}T_1 = \frac{w_2}{M_2}T_2$

i.e., $\frac{2.9}{M_x} \times (95+273) = \frac{0.184}{2} \times (17+273)$ or $M_x = \frac{2.9 \times 368 \times 2}{0.184 \times 290} = 40\ g\ mol^{-1}$

16. From the information and data given in the question, we concluded that

(a) In HCl, HBr and HI, dipole-dipole and London forces are present because molecules possess permanent dipole. In HF dipole-dipole. London forces and hydrogen bonding are present.

(b) Electronegativity of chlorine, bromine and iodine decreases in the order Cl > Br > I

Therefore, dipole moment should decreases from HCl to HI. Thus, dipole-dipole interaction should decrease from HCI to HI. But boiling point increase on moving from HCl to HI. This means that London forces are predominant.

This is so because London forces increases as the number of electrons in a molecule increases and in this case number of electrons is increasing from HCl towards HI.

(c) Hydrogen fluoride has highest dipole moment attributes due to highest electronegativity of fluorine as well as presence of hydrogen bonding in HF. Therefore, HF has highest boiling point.

17. **(i)** As we go to higher altitudes, the atmospheric pressure decreases. Thus, the pressure outside the balloon decreases. To regain equilibrium with the external pressure, the gas inside expands to decrease its pressure. Hence, the size of the balloon increases.

(ii) In summer, due to higher temperature, the average kinetic energy of the air molecules inside the type increases, i.e., molecules start moving faster. Hence, the pressure on the walls of the tube increases. If pressure inside is not kept low at the time of inflation, at higher temperature, the pressure may become so high that the tyre may burst.

18. **(i)** Molar volume occupied by the gas molecules $\propto$ size of the molecules and van der Waals' constant 'b' represents molar volume of the gas molecules. Hence, value of 'b' increases in the following order $H_2 < He < O_2 < CO_2$

(ii) van der Waals constant 'a' is the measure of magnitude of intermolecular attraction. The magnitude of intermolecular attractions increases with increase in size of electron cloud in a molecule. Hence, for the given gases magnitude of 'a' decreases in the following order

$$CH_4 > O_2 > H_2$$

Greater the size of electron cloud, greater is the polarisability of the molecule and greater is the dispersion forces or London forces.

19. Given that, $p_{ideal} = p_{real} + \frac{an^2}{V^2}$

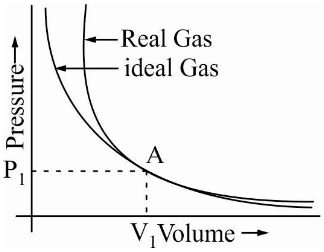
(i) $a = \frac{pV^2}{n^2}$ If units of $p = Nm^{-2}$, Units of $V = m^3$, units of n = mol

Then, units of $a = \frac{Nm^{-2}(m^3)^2}{(mol)^2} = Nm^4\ mol^{-2}$

(ii) If units of p = atm, units of $V = dm^3$, units n = mol

Then, units of $a = \frac{pV^2}{n^2} = \frac{atm.(dm^3)^2}{(mol)^2} = atm\ dm^6\ mol^{-2}$

Long Answer Type (5 Marks)



20. **(i)** At low pressure, the real gas shows very small deviation from ideal behaviour because the two curves almost coincide at low pressure.

(ii) At high pressure, the real gas show large deviations from ideal behaviour as the curves are far apart.

(iii) At point ' A ', both the curves intersect each other. At this point real gas behaves as an ideal gas. P_1 and V_1 are the pressure and volume which corresponds to this point A.

21. **(i)** In gaseous state, CO_2 will exist between the points a and b at temperature T_1.

(ii) At point b, the plot becomes linear, this shows the phase transition, i.e., liquification of CO_2 starts and at point c, it gets completely liquefied.

(iii) Similarly, at temperature T_2, g is the point at which CO_2 will be completely liquefied.

(iv) Condensation will not take place at T_3 temperature because $T_3 > T_c$ (critical temperature).

(v) Between b and c, liquid and gaseous CO_2 are in equilibrium.

22. **(i)** Boiling point of A = approximately 315 K, B = approximately 345 K,

(ii) In a closed vessel, liquid C will not boil because pressure inside keeps on increasing.

(iii) Temperature corresponding to 60 mm = 313 K.

(iv) A liquid boils when vapour pressure becomes equal to the atmospheric pressure.

However at high altitudes i.e., on, hills, water boils at low temperature due to low atmospheric pressure. But when pressure cooker is used, the vapour pressure of water is increased due to which water boils at even lower temperature within a short period of time.

23. Since both the containers are in the same conditions of P, V and T,

$$\frac{r_{O_2}}{r_{mix}} = \sqrt{\frac{M_{mix}}{M_{O_2}}}$$

As the mixture contains three moles of He and 2 moles of N_2, the effective molecular weight of the mixture would be

$$\frac{3}{5}\times 4+\frac{2}{5}\times 28=13.6 \qquad \therefore \qquad \frac{r_{O_2}}{r_{mix}}=\sqrt{\frac{13.6}{32}}=0.652$$

Though this solution looks OK, there is one big flaw in it.

The error is that we have assumed that He and N_2 from vessel B would effuse out with the same rate. This assumption was made in because we have taken the composition of the gas mixture coming out of the vessel to be same as that of the mixture that was inside the vessel. It should be duly noted that the two mixtures (inside and the are that effused out) have different compositions. Therefore first we must find the composition of the gas mixture coming out of the vessel B.

$$\frac{r_{N_2}}{r_{He}}=\frac{2}{3}\sqrt{\frac{4}{28}}=\frac{2}{3}\sqrt{\frac{1}{7}}=0.252$$

This means that initially the ratio of moles of N_2 to the moles of He coming out of the vessel are in the molar ratio of 0.252 and not $\frac{2}{3}$.

Let moles of the He coming out to be x

∴ Moles of N_2 coming out is 0.252 x

$$\therefore \qquad \frac{n_{N_2}}{n_{total}}=\frac{0.252\,X}{1.252\,X}=0.2$$

$$\frac{n_{He}}{n_{total}}=0.8 \Rightarrow M_{mix}=0.2\times 28+0.8\times 4=8.85 \qquad \therefore \qquad \frac{r_{O_2}}{r_{mix}}=\sqrt{\frac{8.8}{32}}=0.52$$

24. Weight balloon = 100 kg $=10\times 10^4\,g$

Volume of balloon $=\frac{4}{3}\pi r^3$

$$\frac{4}{3}\times\frac{22}{7}\times\left(\frac{20}{2}\times 100\right)^3=4190\times 10^6 cm^3=4190\times 10^3 litre$$

Weight of gas (He) in balloon $=\frac{PV}{RT}=\frac{1\times 4190\times 10^3\times 4}{0.082\times 300}=68.13\times 10^4\,g$

∴ Total weight of gas and balloon $=68.13\times 10^4+10\times 10^4=78.13\times 10^4\,g$

Weight of air displaced $=\frac{1.2\times 4190\times 10^6}{10^3}=502.8\times 10^4\,g$

∴ Pay load = wt. of air displaced – (wt. of balloon + wt. of gas)

∴ Pay load $=502.8\times 10^4-78.13\times 10^4=424.67\times 10^4\,g$

25. One should clearly note the fact that on heating a gas in a vessel there are the number of moles of gas which go out, the volume of vessel remains constant.

Let initial moles of gas at 300 K be ‘n’. On heating 3/5 moles of air are escaped out at temperature T.

∴ Moles of air left at temperature T = $\left(n-\frac{3}{5}n\right)=\frac{2n}{5}$

(a) Under similar conditions of P and V

$n_1T_1 = n_2T_2$

$n\times 300=\frac{2n}{5}\times T \quad \Rightarrow \quad T=750\text{ K}$

(b) On heating vessel to 900 K, let n_1 moles be left again $n_1T_1 = n_2T_2$

$n_1 \times 900 = 300 \times n$

$\Rightarrow \quad n_1 = \frac{1}{3}n$

$\therefore \quad$ Moles escaped out $= n - \frac{n}{3} = \frac{2}{3}n$ moles

(c) Let n/2 moles are escaped out at temperature T then

$n_1T_1 = n_2T_2$

$\frac{n}{2} \times T = n \times 300$

$T = 600$ K