Chapter: States of Matter

Intermolecular forces

Question 1

How does the molecular shape of a molecule affect the strength of Dispersion forces?

Ans.

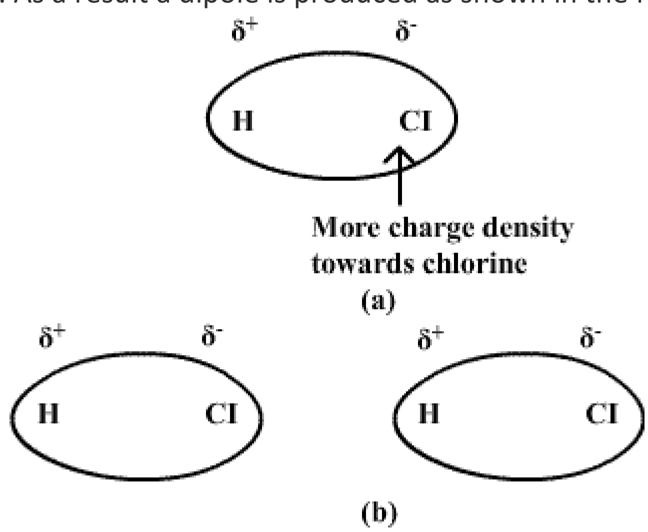
The shapes of the molecules affect the strength of dispersion forces. Long thin molecules can develop bigger temporary dipoles due to electron movement than the short molecules containing same number of electrons. Long thin molecules also lie closer together. For example butane and 2-methyl propane have a molecular formula C_4H_{10} but the atoms are arranged differently in both. In butane the carbon atoms are arranged in a single chain, but 2-methyl propane is a shorter chain with a branch. So butane has a higher boiling point because the dispersion forces are greater. The molecules are larger so they set up temporary dipole and can lie closer together than the shorter and fatter 2-methyl propane molecules.

Question 2

What types of forces are present in HCl molecule? Explain.

Ans.

HCl molecule is made up of H atom and Cl atom. Chlorine atom is more electronegative than the hydrogen atom so it attracts the electron cloud of hydrogen atom towards itself and acquires a partial negative charge leaving a partial positive charge on the hydrogen atom. As a result a dipole is produced as shown in the following figure.



Question 3

Non-polar molecules do not have dipoles like polar molecules but still they form solids or liquids. Explain

Ans.

Atoms of non-polar molecules are electrically symmetrical. But due to the rapid motion of electrons a momentary accumulation of electron density occurs on one side of the atom causing unsymmetrical charge distribution which causes the development of temporary instantaneous dipole on the atom. This temporary dipole formed in one atom or molecules induces a dipole in the other atom. The temporary dipoles of both the atoms attract each other and this temporary force of attraction between two temporary dipoles is known as London force. As a result of this force, the non-polar molecules also form solids or liquids.

Question 4

What is the other name for Intermolecular Forces?

Ans.

The Intermolecular Forces are also known as Vander Waals forces.

Question 5

What types of intermolecular forces exist between the molecules of acetic acid (CH_3COOH) and carbon tetrachloride (CCl_4)?

Ans.

In CH_3COOH, hydrogen bonding, dipole-dipole interactions and dispersion force are present whereas in CCl_4 only dispersion (non-polar) forces are present.

Question 6

Differentiate between Dipole-dipole forces and Dipole-induced dipole forces.

Ans.

Dipole-dipole forces	**Dipole-induced dipole forces**
i) These forces act between molecules with permanent dipole.	i) This type of attractive force is present between the polar molecule having permanent dipole and the molecule lacking permanent dipole.
ii) In this type of force, greater the dipole moment of polar molecule greater is the magnitude of dipole-dipole forces. This effect is known as Orientation Effect.	ii) In this type of force, as the size of the molecule or atom increases, the influence of permanent electrical dipole on it will also increase, resulting in the increase in magnitude of these forces. This effect is termed as Induction Effect.

Question 7

Name the type of forces present in CH_3Cl and PCl_3 molecule.

Ans.

CH_3Cl and PCl_3 molecules have permanent net dipoles so they have dipole-dipole interactions.

Question 8

Name the type of forces present in Cl_2 and H_2 molecules.

Ans.

Cl_2 and H_2 molecules are non-polar molecules so London forces are present in them.

Question 9

Arrange the following forces in increasing order of their strength -

Dipole-dipole interaction, hydrogen bond and dispersion forces.

Ans.

Hydrogen bond > Dipole-dipole interaction >Dispersion force

Question 10

Which substances among the following experiences dipole-dipole intermolecular forces?

SiF_4, $CHCl_3$, CO_2, SO_2

Ans.

SO_4 and $CHCl_3$ experience dipole-dipole intermolecular forces.

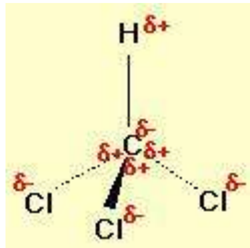
Effect of Heat on Matter

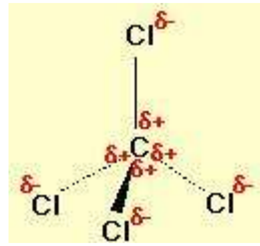
Question 1

Which one has the highest boiling point $CHCl_3$ or CCl_4?

Ans.

The molecule of $CHCl_3$ is highly polar because it contains three chlorine atoms which are highly electronegative and have strong Dipole-dipole attractions. CCl_4 molecule is nonpolar and it has uniform partial negative charge in all directions. The molecule of CCl_4 is also bigger than $CHCl_3$ so it has a strong dispersion force which leads to higher boiling point than $CHCl_3$.





Question 2

What is the freezing and boiling points of water at 1atm pressure in Fahrenheit scale?

Ans.

According to the Fahrenheit scale the freezing and boiling points of water at 1atm are $32^{o}F$ and $212^{o}F$ respectively.

Question 3

What is the SI unit of temperature?

Ans.

The S.I unit of temperature is Kelvin.

Question 4

Which should have a lower boiling point H_2O or H_2S?

Ans.

H_2S have a lower boiling point i.e. $-70^{o}C$ because no hydrogen bonding is present in liquid H_2S whereas the boiling point of water is $100^{o}C$ due to the presence of very strong hydrogen bonding.

Question 5

Which has a higher boiling point I_2 or Br_2?

Ans.

The atomic weights of Br and I are 80 and 127 respectively. Since I_2 has higher molecular weight, it has stronger London dispersion forces so it has a higher boiling point than Br_2.

Question 6

Out of fluorine and nitrogen monoxide which one has the higher melting and boiling points explain

Ans.

Out of fluorine and nitrogen monoxide, nitrogen monoxide has higher melting and boiling points because nitrogen monoxide is a polar molecule with strong Dipole-Dipole attraction forces.

Question 7

Convert 120 Fahrenheit into Celsius scale.

Ans.

$$^{\circ}C = \frac{5}{9}(^{\circ}F - 32) = \frac{5}{9}(120 - 32) = 48.8^{\circ}C$$

Question 8

Convert 25°C into Kelvin scale.

Ans.

K= °C + 273.15 = 25°C + 273 = 298.15K

Question 9

How gases can be liquefied?

Ans.

Gases can be liquefied by compression and by decreasing the thermal energy of their molecules by lowering the temperature.

Question 10

What factors are responsible for the existence of matter in three states?

Ans.

The existence of matter in three states depends upon the balance between intermolecular forces and the thermal energy of the molecules.

Gas laws

Question 1

A gas tanker carries helium gas at a pressure of 2.5 atmospheres at 25°C.The tanker can withstand a maximum pressure of 10 atmospheres. It collides with a truck and catches fire. According to the above information the tanker will blow up after the collision or it will catch fire. Explain. (Melting point of iron - 1535°C)

Ans.

The pressure built up in the tanker at melting point of iron is:

P_1 = 2.5 atm, P_2 = ? , T_1 = 25°C, T_2 = 1535°C = 1808K

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \text{ or } P_2 = \frac{P_1T_2}{T_1} = \frac{2.5 \times 1808}{298} = 15.16 \text{ atm}$$

Since, the pressure of the gas in the tank is much more than 10 atm at the melting point. Thus, the tank will blow up before reaching the melting point.

Question 2

A flask containing 250 mg of air at 27°C is heated till 25% of air is expelled from it. Calculate the final temperature of the gas?

Ans.

Let the Volume of the flask be V and final temperature be T (K)

So Mass of air expelled at T (K) =

$$\frac{250 \times 25}{100} = 62.5\,\text{mg}$$

Mass of air contained in flask = 250 − 62.5 = 187.5 mg

Now, the volume of total air (250 mg) at higher temperature

$$(V_2) = \frac{V \times 250}{187.5}$$

$$\frac{V_2}{T} = \frac{V}{300} = \frac{V_2 \times 300}{V} = \frac{V \times 250 \times 300}{187.5} = 400\,\text{K or } 127^\circ\text{C}$$

Question 3

What is the temperature at which 80 cm³ of a gas should be heated to increase its volume by 20% without changing the pressure? (Given that the initial temperature of the gas is 25°C)

Ans.

The desired increase in the volume of the gas

$$= 20\%\text{ of } 80\,\text{cm}^3 = \frac{80}{100} \times 20 = 16\,\text{cm}^3$$

$$\text{Final volume of the gas} = 80 + 16 = 96\,\text{cm}^3$$

$$V_1 = 80\,\text{cm}^3 \quad ; \quad V_2 = 96\,\text{cm}^3$$

$$T_1 = 25^\circ\text{C} = 298\,\text{K} \; ; \quad T_2 = ?$$

Applying Charles law

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{96\,\text{cm}^3 \times 298\,\text{K}}{80\,\text{cm}^3} = 357.6\,\text{K or } 84.6^\circ\text{C}$$

Question 4

A student filled a balloon with hydrogen at room temperature. The balloon will burst if pressure exceeds 0.2 bars. If at 1 bar pressure the gas occupies 0.27L volume; up to what volume can the balloon be expanded?

Ans.

Given that $P_1 = 1$ bar

$_2 = 0.2$ bar

$V_1 = 0.27$ L

$V_2 = ?$

According to Boyles law

$P_1V_1 = P_2V_2$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{1 \times 0.27}{0.2} = 1.35\,L$$

Question 5

A sample of gas is found to occupy a volume of 900cm^3 at 27^{o}C. Calculate the temperature at which it will occupy a volume of 300cm^3, provided the pressure is kept constant?

Ans.

Given that $V_1 = 900\ cm^3$

$V_2 = 300\ cm^3$

$T_1 = (27 + 273)\ K = 300\ K$, $T_2 = ?$

Applying Charles law

$$T_2 = \frac{V_2 \times T_1}{V_1} = \frac{300\,cm^3 \times 300K}{900\,cm^3} = 100\ K = 100 - 273 = -173^\circ C$$

Question 6

A gas cylinder contains air at a pressure of 15 bars at 20^{o}C. The cylinder is provided with a safety valve which can withstand a pressure of 35 bars. Calculate the temperature to which the tank can be safely heated?

Ans.

Given that P_1=15 bar

P_2 = 35 bar

$T_1 = 20^oC = 293\ K$

$T_2 = ?$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \text{ or } T_2 = \frac{P_2T_1}{P_1} = \frac{35 \times 293}{15} = 683.67\,K \text{ or } 410.52^\circ\ C$$

The safety valve will blow up when the temperature will exceed 683.67 K.

Question 7

Define absolute zero.

Ans.

The lowest imaginary temperature at which gases are supposed to occupy zero volume is called absolute zero.

Question 8

What is the relationship between pressure and density of a gas?

Ans.

According to the Boyles law, at constant temperature the pressure is directly proportional to the density of a fixed mass of the gas.

Question 9

What is each line of volume v/s temperature graph known as?

Ans.

Each line of Volume v/s temperature graph is called Isobar.

Question 10

If a graph is plotted between volume V v/s temperature ^{o}C at constant pressure. At what temperatures will it cut the volume and temperature axis?

Ans.

The graph cuts the volume axis at $0^{o}C$ but it cuts the temperature axis at $-273.15\ ^{o}C$, which is also known as the absolute temperature**.**

Ideal gas equation.

Question 1

How many grams of potassium chlorate must be decomposed to produce 4.8 L of oxygen at 740 torr and $25^{o}C$?

Ans.

$2\ KClO_3 \rightarrow 2\ KCl + 3O_2$

Number of moles of oxygen:
P = 740 torr = 740/760 atm
V = 4.8 L
R = 0.0821 L atm $mol^{-1}\ K^{-1}$
T = 25 + 273 = 298 K
n = ?

From Ideal gas equation:
n = PV/RT
n = 740 x 4.8/ 760 x 0.0821 x 298
n = 0.191 mol

Now, 3 moles of oxygen are produced from 2 moles of $KClO_3$
0.191 moles of oxygen = 2 x 0.191 /3
= 0.127 mol of $KClO_3$

Now 1 mol of $KClO_3$ = 122.5 g
0.127 mol of $KClO_3$ = 122.5 x 0.127
= 15.6 g

Question 2

Calculate the pressure of 1×10^{21} molecules of nitrogen dioxide when enclosed in a vessel of capacity of 2.5 L capacity at temperature 27ºC?

Ans.

Calculation of number of moles of nitrogen dioxide = $1 \times 10^{21} / 6.023 \times 10^{23}$
= 0.166×10^{-2} mol
= 1.66×10^{-3} mol

Now, PV = nRT
P = ? atm
V = 2.5 L
R = 0.0821 L atm mol^{-1} K^{-1}
T = 27 + 273 = 300 K
n = 1.66 x 10^{-3} mol
P = 1.66 x 10^{-3} x 0.0821 x 300 / 2.5
P = 1.6 35 x 10^{-2} atm

Question 3

A gas system has pressure, moles and temperature of 745torr, 0.425moles and -69^{o}C respectively. What is the volume in mL?

Ans.

P = 745 torr = 745/760 atm

V = ?

R = 0.0821 L atm mol^{-1} K^{-1}

T = -69 +273 = 204

n = 0.425 mol

We know, PV = nRT

V = [(0.425) (0.0821) (204) (760)] / [(745)]

V = 7.26 L

V = 7260 mL

Question 4

A closed gas system initially has pressure and temperature of 86.6torr and 424K with the volume unknown. If the same closed system has values of 597torr, 1240mL and 455K, what was the initial volume in mL?

Ans.

P_1 = 86.6 torr
V_1 = ?
T_1= 424K
P_1= 597 torr
V_2 = 1240 mL
T_2 = 455K
Using relation: $P_1V_1/T_1 = P_2V_2/T_2$
86.6 X V_1/ 424 = 597 X 1240 / 455
V_1 = 597 X 1240 x 424 / 455 x 86.6
V_1 = 7965 mL

Question 5

If 9.006 grams of a gas are enclosed in a 50.00 liter vessel at 273.15 K and 2.000 atmospheres of pressure, what is the molar mass of the gas? What gas is this?

Ans.

P = 2.000 atm

V = 50.00L

R = 0.0821 L atm mol^{-1} K^{-1}

T = 273 K

We know, n = PV / RT

n = [(2.000 atm) (50.00 L)] / [(0.0821 L atm mol^{-1} K^{-1}) (273 K)]

n = 4.461 mol

Molecular weight = weight / number of moles

Molecular weight = 9.006 / 4.461

Molecular weight = 2.019 g mol^{-1}

The answer (2.019 g mol^{-1}) is approximately that of hydrogen gas, H_2.

Question 6

5.0g of an ideal gas occupies 9.2 L at STP. What volume would it occupy at 120°C and 92 mm Hg?

Ans.

PV = nRT

At STP, P= 760mm Hg, T = 273 K

P_1 = 760 mm

V_1 = 9.2L

T_1= 273K

P_1= 92 mm

V_2 = ?

T_2 = 120 +273 = 393K

Using relation: $P_1V_1/T_1 = P_2V_2/T_2$

760 X 9.2/ 273 = 92 X V_2 / 393

V_2 = 760 X 9.2 X 393 / 273 X 92

V_2 = 109 L

Question 7

A 30.0 g gas sample occupies 11.2 L at STP. Find the molecular weight of this gas.

Ans.

11.2 L at STP is one-half molar volume; therefore there is 0.5 mol of gas present.

Thus, the molecular weight of the gas is 80.0 g mol^{-1}.

Question 8

At what pressure would 0.450 mole of nitrogen gas at 23.0 °C occupy 8.90 L?

Ans.

PV = nRT

P = nRT / V

P =?

V = 8.90 L

n = 0.450 mol

R = 0.0821 L atm mol^{-1} K^{-1}

T = 23 + 273 = 296 K

P = [(0.450 mol) (0.0821 L atm mol^{-1} K^{-1}) (296.0 K)] / 8.90 L

P = 1.23 atm

Question 9

A sample of ideal gas occupies a volume of 238 mL at STP. To what temperature must the sample be heated if it is to occupy a volume of 185 mL at 2.25 atm?

Ans.

At STP, P= 1 atm, T = 273 K

P_1 = 1

V_1 = 238 mL

T_1= 273K

P_1= 2.25 atm

V_2 = 185 mL

T_2 = ?

Using relation: $P_1V_1/T_1 = P_2V_2/T_2$

1 X 238/ 273 = 2.25 X 185 / T_2

T_2 = 2.25 x 185 x 273 / 238

T_2 = 477 K

Question 10

What volume is needed to store 0.050 moles of helium gas at 202.6 kPa and 127ºC?

Ans.

We know that, PV = nRT

P = 202.6 kPa

n = 0.050 mol

T = 127 + 273 = 400K

V = ? L

R = 8.314 J K^{-1} mol^{-1}

202.6 x V=0.050 x 8.314 x 400

202.6 V = 166.28

V = 166.28 / 202.6

V = 0.821 L or 821mL

Kinetic theory

Question 1

Which postulates of kinetic theory are not valid at high pressure and low temperature? Give reasons to justify their invalidity?

Ans.

The postulates of the kinetic theory that are not valid at high pressure and low temperature are:

i) There is no force of attraction between the molecules of a gas.

ii) Volume of the molecules of a gas is negligibly small in comparison to the space occupied by the gas.

According to the first assumption the gas will never liquefy but the gases do liquefy when cooled and compressed.

According to the second assumption the plot of P Vs V at constant temperature based on the experimental data and that based on theoretical calculations from Boyle's law should coincide. But at high pressures deviations are observed which confirms that these postulates of the kinetic theory are invalid.

Question 2

Why do gases deviate from ideal behaviour?

Ans.

Real gases deviate from ideal gas law because their molecules interact with each other. At high pressure the molecules of gases are very close to each other so the molecular interactions start operating and these molecules do not strike the walls of the container with full impact. Thus the pressure exerted by the gas is lower than the pressure exerted by the ideal gas. At high pressure the repulsive forces also come into action .So the constants of pressure and volume are corrected and the equation is written as:

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

This equation is known as Vander Waals equation.

Question 3

What is the relation between the deviations shown by the molecules of a gas and their molecular volume and attraction?

Ans.

The gases show positive deviations ($Z > 1$) when the effect of molecular volume dominates. Similarly negative deviations ($Z < 1$) are shown when the effect of molecular attraction predominates.

Question 4

In the Vander Waal equation what do the constants 'a' and 'b' represent?

Ans.

In the van der Waal's equation the constant 'a' gives the idea of the magnitude of attractive forces between the molecules of the gas and 'b' is the measure of effective volume occupied by the gas molecules. It is also called co-volume or excluded volume.

Question 5

Calculate the pressure of 2 mol of ammonia at 27^{o}C when its volume is 5l according to van der Waal equation? (Given that a = 4.17, b = 0.03711)

Ans.

$$\left[P+\frac{n^2}{V^2}a\right](V-nb)=nRT \quad \text{or} \quad P=\frac{nRT}{(V-nb)}-\frac{an^2}{V^2}$$

$$=\frac{2\times 0.082\times 300}{5-2\times 0.03771}-\frac{4.17\times 4}{25}$$

$$=\frac{2\times 0.082\times 300}{4.9258}-0.667=9.33\,\text{atm}$$

Question 6

The average velocity of carbon dioxide gas at T_1K and its most probable velocity at T_2K is 9.0 x 10^4 cm sec^{-1}. Calculate the value of $T_1$and T_2?

Ans.

$$\alpha=0.9213\times u_{rms}=0.9213\times\sqrt{\frac{3RT}{M}}$$

$$9\times 10^4=0.9213\times\sqrt{\frac{3\times 8.31\times 10^7\times T_1}{44}}$$

$$T_1=1691\,K$$

$$9\times 10^4=\sqrt{\frac{2RT_2}{M}} \quad \text{or} \quad T_2=2147\,K$$

Question 7

Give reason for the high compressibility of gases on the basis of kinetic molecular theory?

Ans.

According to the kinetic theory high compressibility of gases is due to large empty spaces between the molecules.

Question 8

What would happen if the molecular collisions in the kinetic theory are inelastic?

Ans.

If the molecular collisions are inelastic, there would be a constant loss of energy. Due to this loss of energy, the molecular motion will slow down and ultimately they will settle down at the bottam.

Question 9

What is the relationship between three types of molecular speeds at a given temperature?

Ans.

At a given temperature three type of molecular speeds which are Most probable speed, Average speed and Root mean square speed are related as $\alpha : \bar{v} : u_{rms} :: 1 : 1.128 : 1.224$

Question 10

How can we liquefy a gas, for which the value of α is 0?

Ans.

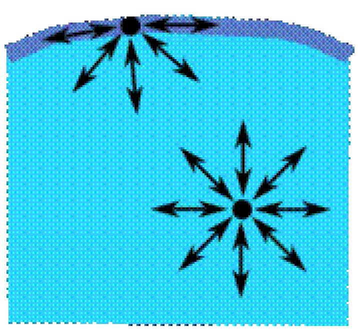
If the value of α is 0, it means that intermolecular forces are absent so the gas cannot be liquefied.

Properties of liquid

Question 1

What is surface tension? How does surface tension arise out of intermolecular forces? How is it related to the strength of intermolecular forces?

Ans.



IMBALANCE OF THE FORCES AT THE SURFACE OF THE LIQUID
(SURFACE TENSION)

Surface tension is the tendency of liquids to minimize their surface area. Molecules at the surface have relatively fewer neighbours with which to interact, because there are no molecules above it. Consequently, molecules at the surface are inherently less stable

- they have higher potential energy - than those in the interior. In order to increase the surface area of the liquid, some molecules from the interior have to be moved to the surface, a process requiring energy. The surface tension of a liquid is the energy required to increase the surface area by a unit amount. Surface tension decreases with decreasing intermolecular forces.

Question 2

Give reasons for the following:

(i) Glycerine is more viscous than water

(ii) Evaporation causes cooling

Ans.

(i) Glycerine has stronger intermolecular forces than water so it is more viscous than water.

(ii) Evaporation causes cooling because the molecules that undergo evaporation are high energy molecules so the kinetic energy of molecules which are left behind is less. Since the average kinetic energy of the remaining molecules is less the temperature of these molecules is also lower. If temperature is kept constant the distribution of kinetic energy will be same. The high energy molecules keep on escaping from the liquid into the gas phase. This phenomenon brings a cooling effect.

Question 3

What is Clausius-Clapeyron equation and what is its importance?

Ans.

The following equation is known as Clausius-Clapeyron equation

$$\frac{\log P_2}{\log P_1} = \frac{\Delta H_{vap}}{2.303R}\left[\frac{T_2 - T_1}{T_1 T_2}\right]$$

The Clausius – Clapeyron equation is the relationship between Vapour pressure and temperature. It gives a relationship between the natural log of vapour pressure and the inverse of temperature. It is a convenient way to measure the heat of vaporization in laboratory and to measure vapour pressure of a liquid at a temperature if the heat of Vaporization and Vapour pressure at one temperature are known.

Question 4

Name the factors that affect the Viscosity of a substance?

Ans.

The viscocity of a substance depends on its molar mass, intermolecular forces, molecular shape and its temperature.

Question 5

What is Capillary action Explain?

Ans.

Capillary action is the ability of a substance to flow up in a narrow tube against the force of gravity. It results from the combination of two forces the attraction force between molecules in a liquid called cohesive force and the attraction between the molecules in a liquid and the molecules of the surface of the tube called as adhesive force.

Question 6

What is the relationship between the volatility of a substance and the intermolecular forces present in it?

Ans.

The volatility of a substance increases with decrease in intermolecular forces. As the intermolecular forces become weaker, more number of molecules are allowed to evaporate at a given temperature making the liquid more volatile.

Question 7

Explain why water has higher vapour pressure than mercury

Ans.

Water has a higher vapour pressure than mercury because water has weaker interparticle force

Question 8

Define coefficient of Viscosity

Ans.

Co-efficient of viscosity is the force of friction required to maintain velocity difference of 1cm sec^{-1} between two parallel layers 1cm apart and having an area of $1cm^2$.

Question 9

Why does mercury have concave–downward meniscus?

Ans.

Mercury have concave-downward meniscus because in mercury the cohesive forces are stronger than adhesive forces.

Question 10

Why do the falling liquid drops assume a spherical shape?

Ans.

The molecules of a liquid tend to minimize the surface area due to surface tension. Since a sphere has the minimum surface area so they assume a spherical shape

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