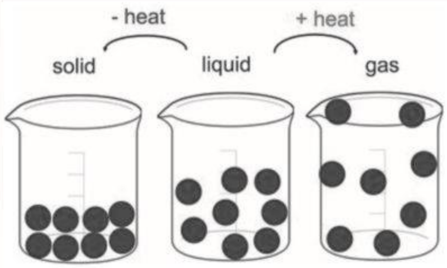



# CHAPTER 5

# PHYSICAL STATES OF MATTER

# INTRODUCTION

**Q.1 Define matter.** ***(K.B)***

**Ans:** **MATTER**

**Definition:**

*"Anything that has **mass** and **occupies space** is called matter".*

**Examples:**

Air, water, table, book etc.

**Q.2 What are physical states of matter?** ***(K.B)***

**Ans:** **PHYSICAL STATES OF MATTER**

Matter exist in three physical state i.e. gas, liquid and solid. The simplest form of mater is gaseous state. Liquid are less common and most of the matter exist as solid. These states are classified by means of two properties.

- Shape
- Volume

# 5.1 GASEOUS STATE (TYPICAL PROPERTIES)

**Q.1 Write down the general properties of gaseous state.**

**(SWL 2016, 17, MTN 2016, 17, DGK 2017)*(U.B+K.B)***

**Ans:** **GASES**

*"The state of matter that has **indefinite shape** and **indefinite volume** is called gas".*

**Examples:**

- Hydrogen ($H_2$)
- Oxygen ($O_2$)
- Carbon dioxide ($CO_2$)

**TYPICAL PROPERTIES OF GASES**

Gases have similar physical properties. A few typical properties are as follows:

**DIFFUSION**

*"The **spontaneous mixing up of molecules by random motion and collisions to form a homogeneous mixture** is called diffusion".*

**Examples:**

- Spreading of fragrance of flower
- Spreading of fragrance of perfume

**Dependence:**

Rate of diffusion depends upon the **molecular mass** of the gases. **Lighter gases diffuse rapidly than heavier ones**. e.g. **$H_2$ diffuses four times faster** than **$O_2$ gas**.

**EFFUSION**

*"It **is escaping of gas molecules through a tiny hole into a space with lesser pressure**".*

**Example:**

When a tyre gets punctured, air effuses out.

**Dependence:**

Effusion depends upon **molecular masses** of the gases. **Lighter gases effuse faster** than heavier gases.

**PRESSURE**

Gas molecules are always in continuous state of motion. Hence when molecules strike with the walls of the container or any other surface, they exert pressure.

*"The **force (F) exerted per unit surface area (A)** is called pressure".*

**Formula:**

$$P = \frac{F}{A}$$

**SI Unit of Pressure:**

The SI unit of force is Newton and that of area is $m^2$. Hence pressure has **SI unit** of **$Nm^{-2}$**. It is also called **Pascal (Pa)**.

**One Pascal (Pa) = 1 $Nm^{-2}$**

**Pressure Measuring Devices:**

- **Barometer** is used to measure **atmospheric pressure**
- **Manometer** is used to measure **pressure in the laboratory**.

## STANDARD ATMOSPHERIC PRESSURE

It is the pressure exerted by the atmosphere at the sea level.

**Definition:**

*"It is defined as the **pressure exerted by a mercury column of 760 mm height at sea level**. It is **sufficient pressure to support a column of mercury 760mm in height at sea level**".*

**Different Units of Pressure:**

| | | |
|---|---|---|
| 1 atm | =760 mm of Hg = 760 torr | (1 mm of Hg = one torr) |
| 101325 $Nm^{-2}$ | = 101325 Pa | |

## COMPRESSIBILITY

Gases are **highly compressible due to empty spaces** between their molecules. When the gases are compressed, the molecules come closer to one another and occupy less volume as compared to the volume in uncompressed state.

## MOBILITY

**"***The **ease of flow of molecules** is called mobility".*

- Gas molecules are always in state of **continuous motion**.
- They can move from one place to another because gas molecules possess very **high kinetic energy**.
- They move through **empty spaces** that are available for the molecules to move freely.

**Significance:**

The mobility or random motion results in mixing" up of gas molecules to produce a **homogeneous mixture**.

## DENSITY OF GASES

**"***The **mass per unit volume** of a substance is called density".*

**Units of Measurement:**

**Gas** density is expressed in **grams per $dm^3$**, whereas, **liquid** and **solid** densities are expressed in **grams per $cm^3$** i.e. liquids and solids are **1000 times** denser than gases.

**Effect of Temperature:**

Gases have **low density than liquids and solids**. It is due to **light mass** and **more volume** occupied by the gas molecules.

The **density of gases increases by cooling** because their volume decreases.

**Example:**

At normal atmospheric pressure, the density of **oxygen gas** is **1.4$gdm^{-3}$** at **20ºC** and **1.5$gdm^{-3}$** at **0ºC**.

# 5.1 GASEOUS STATE (TYPICAL PROPERTIES)

## SHORT QUESTIONS

**Q.1 Define diffusion. Give example.** ***(K.B+A.B)***

**OR**

**What is meant by diffusion of gases?** ***(K.B)***

**Ans:** *Answer given on pg # 159*

**Q.2 What is effusion?** **(MTN 2016, BWP 2016, 17, FSD 2017, GRW 2017 G-II, RWP 2017 G-II)*(K.B)***

**Ans:** *Answer given on pg # 159*

**Q.3 Define pressure. Write its SI units.** ***(K.B)***

**Ans:** *Answer given on pg # 159*

**Q.4 What is standard atmospheric pressure?** **(SGD 2016, 17, RWP 2017, LHR 2016)*(K.B)***

**Ans:** *Answer given on pg # 160*

**Q.5 Write a short note on the density of gases.** **(BWP 2017)*(K.B)***

**Ans:** *Answer given on pg # 160*

**Q.6 What are pressure measuring devices?** ***(K.B)***

**Ans:** **PRESSURE MEASURING DEVICES**

The pressure measuring devices are as follows:

- **Barometer** is used to measure atmospheric pressure
- **Manometer** is used to measure pressure in the Laboratory.

# 5.1 GASEOUS STATE (TYPICAL PROPERTIES)

## MULTIPLE CHOICE QUESTIONS

**1. The liquid state has intermolecular forces:** ***(K.B)***
(A) Strong (B) Weak (C) Very weak (D) None of these

**2. Solids are _________ and denser than liquid and gases.** ***(K.B)***
(A) Rigid (B) Soft (C) Hard (D) Both A and C

**3. Simplest state of matter is:** **(LHR 2014)*( K.B)***
(A) Solid state (B) Liquid state (C) Gaseous state (D) Plasma state

**4. How many times Liquid are denser than gases?** ***(K.B)***
(A) 100 times (B) 1000 times (C) 10,000 times (D) 100,000 times

**5. Gases are the lightest form of matter and their densities are expressed in terms of:** ***(K.B)***
(A) mg $cm^{-3}$ (B) g $cm^{-3}$ (C) g $dm^{-3}$ (D) Kg $dm^{-3}$

**6. Density of a gas increases when its:** ***(U.B)***
(A) Temperature is increased (B) Pressure is increased
(C) Volume is kept constant (D) None of these

**7. One atmospheric pressure is equal to how many pascals?** **(FSD 2017 G-I)*(K.B)***
(A) 101325 (B) 10325 (C) 106075 (D) 10523

**8. 760 mmHg is equal to:** ***(K.B)***
(A) 266 torr (B) 2660 torr (C) 626 torr (D) 1atm

**9. The gas with maximum rate of diffusion is:** **(LHR 2017 G-II)*(U.B)***
(A) Helium (B) Fluorine (C) Chlorine (D) Hydrogen

**10. Rate of diffusion of gases depends upon:** ***(U.B)***
(A) Chemical formula (B) Number of electrons (C) Molecular mass (D) Pressure

**11. How many times hydrogen diffuses faster than $O_2$?** ***(K.B)***
(A) Two times (B) Three times (C) Four times (D) One time

**12. Barometer is used to measure:** ***(K.B)***
(A) Melting point (B) Boiling point
(C) Atmospheric pressure (D) Pressure in laboratory

**13. Which instrument is used to measure atmospheric pressure?** **(GRW 2016 G-I, SGD 2017 G-I)*(K.B)***
(A) Barometer (B) Manometer (C) Thermometer (D) None of these

# 5.1 TEST YOURSELF

**i. Why the rate of diffusion of gases is rapid than that of liquids?** ***(U.B)***

**Ans:** **RATE OF DIFFUSION**

The rate of diffusion of gases is rapid than that of liquids because, gas molecules have insignificant attractive forces, **low molecular masses, more kinetic energy and more empty spaces** are present between their molecules, as compare to liquids.

**ii. Why the gases are compressible? (BWP 2017, MTN 2017, SWL 2017, SGD 2016, GRW 2016 G-II)*(U.B)***

**iii. What do you mean by Pascal? How many Pascals are equal to 1 atm?**
**(DGK 2017, GRW 2016)*(K.B)***

**Ans:** **PASCAL**

*"Pascal is equal to a force of one Newton that acts upon an area of one metre square".*
It is unit for pressure.

$$1\text{atm} = 101325 \text{ Pa} = 101325\text{Nm}^{-2}$$

**iv. Whether the density of a gas decrease on cooling?** **(LHR 2015, 16 G-II)*(U.B)***

**Ans:** **DENSITY OF GASES ON COOLING**

No, the density of a gas does not decrease on cooling. It increases on cooling because on cooling their volume decreases and density is inverse to volume.

As $$d = \frac{m}{v}$$

**Example:**

At normal atmospheric pressure the density of oxygen gas is **1.4g $dm^{-3}$ at 20°C and 1.5g$dm^{-3}$ at 0°C**.

**v. Why is the density of gas measured in g $dm^{-3}$ while that of a liquid is expressed in g $cm^{-3}$?**
**(SGD 2016, 17, FSD 2017)*(U.B)***

**Ans:** **MEASUREMENT OF DENSITY OF GASES AND LIQUID**

Gases have low densities due to small mass and more volume occupied by the gas molecules. Therefore gas density is expressed in grams per $dm^3$, whereas liquid and solid densities are expressed in gram per $cm^3$ because liquids and solids are 1000 times denser than gases.

**vi. Convert the followings** ***(U.B)***

**(a) 70 cm Hg to atm** **(b) 3.5 atm to torr** **(c) 1.5 atm to Pa**

**Solution:**

**(a) 70 cm Hg to atm:**

We know that:

760 cm Hg = 1 atm (As 760mmHg=76cmHg)

1 cm Hg $= \frac{1}{760}$

70 cm Hg $= \frac{1}{760} \times 70 = 0.0921$ atm

70 cm Hg = 0.0921 atm

**(b) 3.5 atm to torr:**

We know that:

1 atm = 760 torr

3.5 atm = 760 × 3.5

= 2660

3.5 atm = 2660 torr

**(c) 1.5 atm to Pa**

We know that

1 atm = 101325 Pa

1.5 atm = 101325 × 1.5

= 151987.5

1.5 atm is = 151987.5 Pa

# 5.2 LAWS RELATED TO GASES

## 5.2.1 BOYLE'S LAW

**Q.1 State Boyle's Law. Give the experimental verification of Boyle's Law.**

**(GRW 2015,17 G-II LHR 2015, BWP 2016, SGD 2016, FSD 2017, RWP 2017)** ***(U.B+K.B+A.B)***

**OR**

**Define Boyle's Law and verify it with an example** **(Ex –Q.1) (LHR 2016 G-I, 17 G-I)**

**Ans:**

**BOYLE'S LAW**

**Introduction:**

In **1662 Robert Boyle** studied the **relationship between the volume and pressure of a gas at constant temperature**. Robert Boyle (1627-1691) was natural philosopher, chemist, physicist and inventor. He is famous for Boyle's Law of gases.

**Robert Boyle (1627-1691) was natural philosopher, chemist, physicist and inventor. He is famous for Boyle's law of gases".**

**Statement 1:**

*"The **volume of a given mass of a gas is inversely proportional to its pressure** provided the **temperature remains constant**".*

**Mathematical Representation:**

According to this law the volume (V) of a given mass of a gas decreases with the increase of pressure (P) and vice versa.

It can be written as:

$$\text{Volume} \propto \frac{1}{\text{Pressure}}$$

$$V \propto \frac{1}{P}$$

$$V = \frac{k}{P}$$

$$PV = k = \text{constant}$$

Where, **k is proportionality constant**. The value of **k is same for the same amount of a given gas**.

**Statement 2:**

Boyle's Law can also be stated as:

*"The **product of pressure and volume** of a fixed mass of a gas is **constant at a constant temperature**".*

| | | | | | |
|---|---|---|---|---|---|
| When | $P_1V_1$ | = k | Then | $P_2V_2$ | = k |
| Where | $P_1$ | = Initial pressure | | $P_2$ | = Final pressure |
| | $V_1$ | = Initial volume | | $V_2$ | = Final volume |

As both equations have same constant, therefore their variables are also equal to each other.

$$P_1V_1 = P_2V_2$$

This equation establishes the relationship between pressure and volume of the gas.

## EXPERIMENTAL VERIFICATION OF BOYLE'S LAW

The relationship between volume and pressure can be verified experimentally by the following series of experiments. Let us take some mass of a gas in a cylinder having a movable piston and observe the effect of increase of pressure on its volume.

- The phenomenon is represented when the pressure of **2 atm** is applied, the volume of the gas reads as **1 $dm^3$**.
- When pressure is increased equivalent to **4 atm**, the volume of the gas reduces to **0.5 $dm^3$**.
- When pressure is increased three times i.e. **6 atm**, the volume reduces to **0.33 $dm^3$**.
- Similarly, when pressure is increased up to **8 atm** on the piston, volume of the gas decreases to **0.25 $dm^3$**

Where 'k' is proportionality constant. The value of k is same for the same amount of a given gas.

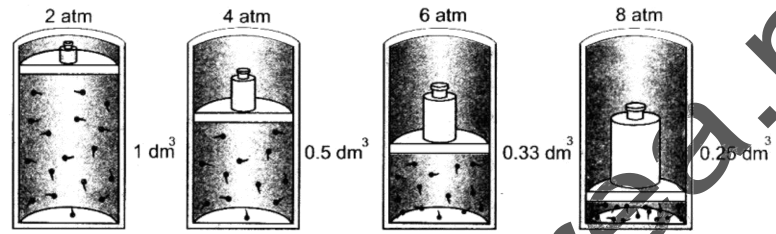



**Figure: The Decrease of Volume With Increase of Pressure**

**Calculations:**

When we calculate the product of volume and pressure for this experiment, the product of all these experiments is constant i.e 2 atm $dm^3$.1t proves the Boyle's law

$$P_1V_1 = 2\text{ atm} \times 1\text{ dm}^3 = \mathbf{2\text{ atm dm}^3}$$
$$P_2V_2 = 4\text{ atm} \times 0.5\text{ dm}^3 = \mathbf{2\text{ atm dm}^3}$$
$$P_3V_3 = 6\text{ atm} \times 0.33\text{ dm}^3 = \mathbf{2\text{ atm dm}^3}$$
$$P_4V_4 = 8\text{ atm} \times 0.25\text{ dm}^3 = \mathbf{2\text{ atm dm}^3}$$

**Conclusion:**

Hence, product of pressure and volume of fixed amount of gas is constant at constant temperature.

**Q.2 Explain the absolute temperature scale with example.** ***(U.B+K.B)***

**Ans:**

## ABSOLUTE TEMPERATURE SCALE

**Introduction:**

**Lord Kelvin** introduced **absolute temperature scale** or **Kelvin scale**. This scale of temperature starts from **0 K** or **–273.15ºC**, which is given the name of **absolute zero**.

**Absolute Zero:**

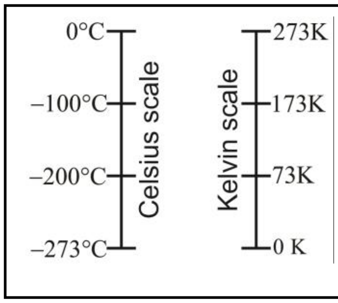
*"It is the **temperature at which an ideal gas would have zero volume**".*

**Absolute Temperature Scale or Kelvin scale:**

*"A **scale of temperature that starts from zero Kelvin** or **–273.15ºC** is called absolute temperature scale or Kelvin scale".*

As both scales have equal degree range, therefore, when 0 K is equal to -273°C then 273 K is equal to 0°C. Conversion of Kelvin temperature to Celsius temperature and vice versa can be carried out as follows:

$$\mathbf{T(K) = T(°C) + 273}$$
$$\mathbf{T(°C) = T(K) - 273}$$




**Remember:**

Always convert temperature scale from °C to K scale while solving problems.

K = 273 + °C

# 5.2 LAWS RELATED TO GASES
## 5.2.1 BOYLE'S LAW
### SHORT QUESTIONS

**Q.1 State Boyle law.** **(MTN 2016, SGD 2016, RWP 2016, LHR 2015, GRW 2017 G-I, II)*(K.B)***

**Ans:** *Answer given on pg # 163*

**Q.2 How can we measure blood pressure?** **(Do you know Pg. # 79)*(K.B)***

**Ans:** **<u>MEASUREMENT OF BLOOD PRESSURE</u>**


**<u>Instrument:</u>**
Blood pressure is measured using a pressure gauge it may be a mercury manometer or some other device.

**<u>Representation:</u>**
Blood pressure is reported by two values such as 120/80 which is a normal blood pressure.

**<u>Systolic Pressure:</u>**
The first measurement shows the maximum pressure when the heart is pumping it is called systolic pressure.

**<u>Diastolic Pressure:</u>**
When the heart is in resting position pressure decreases and it is the second value called diastolic.

**Q.3 In which unit blood pressure is measured?** **(Do you know Pg. # 79)*(K.B)***

**Ans:** **<u>UNIT OF BLOOD PRESSURE</u>**

Systolic and diastolic both of these pressure are measured in **torr** unit.

**Q.4 What is hypertension?** **(Do you know Pg. # 79)*(K.B)***

**Ans:** **<u>HYPERTENSION</u>**

**<u>Cause:</u>**
Hypertension is because of high blood pressure due to tension and worries in daily life.

**<u>Criteria:</u>**
The usual criteria of hypertension is a blood pressure greater than 140/90.

**<u>Disadvantage:</u>**
Hypertension raise the level of stress on the heart and on the blood vessels. This stress increase the susceptibility of heart attacks and strokes.

# 5.2 LAWS RELATED TO GASES
## 5.2.1 BOYLE'S LAW
### MULTIPLE CHOICE QUESTIONS

**1. Blood pressure of a healthy person is:** **(GRW 2014)*(K.B)***
(A) $\frac{120}{80}$ *mmHg* (B) $\frac{140}{90}$ *mmHg* (C) $\frac{110}{100}$ *mmHg* (D) $\frac{150}{70}$ *mmHg*

**2. When volume of a gas is increased two times its pressure becomes:** ***(U.B)***
(A) Double (B) Four times (C) Half (D) Zero

**3. Which quantity is kept constant in Boyle's law?** ***(K.B)***
(A) Temperature (B) Pressure (C) Volume (D) Amount of gas

**4. Which of the following statements is true for Boyle's law?** ***(U.B)***
(A) When volume increases pressure increases (B) When volume increases pressure decreases
(C) When volume decrease pressure increases (D) Both B and C

**5. The value of absolute zero is:** **(GRW 2017 G-I)*(K.B)***
(A) –273.15°C (B) 273.15°C (C) 0°C (D) 100°C

# 5.2 TEST YOURSELF

**i. Is the Boyle's Law of gases applicable to liquids?** **(MTN 2017)*(K.B)***

**Ans:** **BOYLE'S LAW FOR LIQUID**

Boyle's Law is not applicable to liquids rather it is only applicable to gases.

$$PV = \text{constant}$$

**ii. Is the Boyle's Law valid at very high temperature?** ***(U.B)***

**Ans:** **VALIDITY OF BOYLE'S LAW**

Yes, the Boyle's law is valid or applicable at very high but constant temperature.

**iii. What will happen if the pressure on a sample of gas is raised three times and its temperature is kept constant?** **(SWL 2016)*(U.B)***

**Ans:** **RAISE OF TEMPERATURE**

If the pressure on a sample of gas is raised three times its temperature is kept constant then according to Boyle's Law the volume will also decrease three times of its original volume.

## NUMERICAL EXAMPLE 5.1

**A gas with volume 350 $cm^3$ has a pressure of 650 mm of Hg. If its pressure is reduced to 325 mm of Hg, calculate what will be its new volume?** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

$$V_1 = 350\ cm^{-3}$$
$$P_1 = 650\ \text{mm of Hg}$$
$$P_2 = 325\ \text{mm of Hg}$$

**To Find:**

$$V_2 = ?$$

**Calculations:**

By using the Boyle's equation:

$$P_1V_1 = P_2V_2$$

or

$$V_2 = \frac{P_1V_1}{P_2}$$

By putting the values,

$$V_2 = \frac{650 \times 350}{325} = 700\ cm^3$$

$$V_2 = 700 cm^3$$

**Result:**

**Thus volume of the gas is doubled by reducing its pressure to half.**

## NUMERICAL EXAMPLE 5.2

**785 $cm^3$ of a gas was enclosed in a container under a pressure of 600 mm Hg. If volume is reduced to 350 $cm^3$, what will be the pressure?** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

$$V_1 = 785\ cm^3$$
$$P_1 = 600\ \text{mm of Hg}$$
$$V_2 = 350\ cm^3$$

**To Find:**

$$P_2 = ?$$

**Calculations:**

By using the Boyle's equation:

$$P_1V_1 = P_2V_2$$

$$P_2 = \frac{P_1V_1}{V_2}$$

By putting the values:

$$P_2 = \frac{785 \times 600}{350} = 1345.7\ \text{mm of Hg}$$

or

$$P_2 = \frac{1345.7}{760} = 1.77\ \text{atm}$$

$$P_2 = 1.77 \text{atm}$$

**Result:**

**If pressure is reduced to 350 mm Hg the volume of gas will be 1.77 atm.**

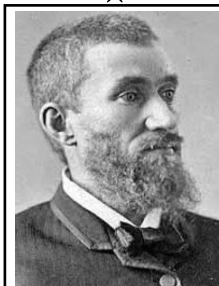
# 5.2.2 CHARLES LAW

**Q.1 Define and explain Charles Law of gases.**

**(Ex - Q.2) (MTN 2016, DGK 2016, SWL 2017, SGD 2017)*(U.B+K.B)***

**Ans:**

**CHARLES LAW**



**J. Charles in 1787. J. Charles (1746-1823) was a French inventor scientist, mathematician and balloonist. He described in 1802 how gases tend to expand when heated.**

**Introduction:**

The **relationship between volume and temperature keeping the pressure constant** was also studied by French scientist. **J. Charles** (1746-1823).

He was a French inventor, scientist, mathematician and balloonist. He described **in 1802 how gases tend to expand when heated**.

**Statement:**

*"The **volume of a given mass of a gas is directly proportional to the absolute temperature** if the **pressure is kept constant**".*

**Mathematical Representation:**

When pressure P is constant, the volume V of a given mass of a gas is proportional to absolute temperature T.

**Mathematically:**

It is represented as:

$$\text{Volume} \propto \text{temperature}$$

$$V \propto T$$

$$V = kT$$

$$\text{Or} \quad \frac{V}{T} = k$$

Where ***k* is proportionality constant**.

**Another Form of Charles's Law:**

If **temperature** of the gas is **increased** its **volume** also **increases**. When **temperature** is changed from $T_1$ **to** $T_2$, the **volume** will change from $V_I$ **to** $V_2$. The mathematical form of Charles' Law will be:

$$\frac{V_1}{T_1} = k, \frac{V_2}{T_2} = k$$

As both equations have same value of constant, therefore their variables are also equal to each other. So

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

**EXPERIMENTAL VERIFICATION OF CHARLES'S LAW**

Let us take a certain amount of gas enclosed in a cylinder having a movable piston. If the initial volume of the gas $V_I$ is **50 cm$^3$** and initial temperature $T_I$ is **25ºC**. On heating the cylinder up to **100 ºC** ($T_2$) its new volume $V_2$ is about **62.5 cm$^3$**. The **increase in temperature increases the volume** that can be observed as elaborated.

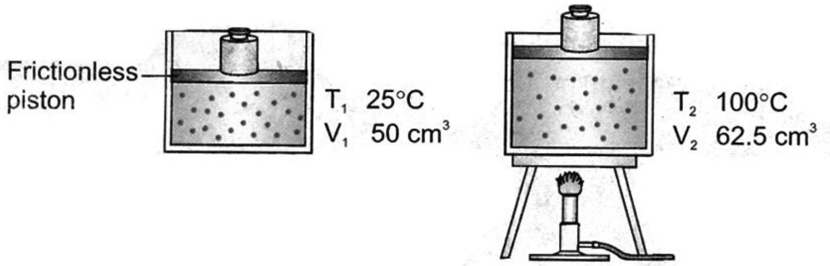



**Figure: Representation of Increase of Volume With The Increase in Temperature**

According to Charles's Law:

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

Putting the values in equation:

$$\frac{50}{25+273} = \frac{62.5}{100+273}$$

$$\frac{50}{298} = \frac{62.5}{373}$$

$$0.167 = 0.167$$

**Conclusion:**

Hence, volume of fixed amount of gas increased with increase in temperature at constant pressure.

**Q.2 In which units body temperatures is measured?** **(Do you know Pg. # 83)*(K.B)***

**Ans:** **MEASURING UNIT OF BODY TEMPERATURE**

Body temperature is measured in **Fahrenheit scale**. Normal body temperature is **98.6°F,** it is equivalent to **37ºC**. This temperature is close to average normal atmospheric temperature.

**Q.3 Explain the physical states of matter and role of intermolecular forces.** ***(U.B)***

**OR**

**Describe relationship between physical states of matter and intermolecular forces.*(U.B)***

**Ans:** **PHYSICAL STATES OF MATTER AND ROLE OF INTERMOLECULAR FORCES**

Matter exists in three physical states:

- Gas
- Liquid
- Solid.

**(i) Gaseous State of Matter:**

In the gaseous state, the molecules are far apart from each other. Therefore, **intermolecular forces** are **very weak** in them.

**(ii) Liquid State of Matter:**

In the liquid state molecules are much closer to each other as compared to gases. As a result liquid molecules develop **stronger intermolecular forces**, which affect their physical properties like diffusion, evaporation, vapour pressure and boiling point.

Compounds having **stronger intermolecular forces** have **higher boiling points**.

**(iii) Solid State of Matter:**

The **intermolecular forces become so dominant** in solid state that the **molecules look motionless**. They arrange in a regular pattern therefore they are **denser than** molecules of **liquids**.

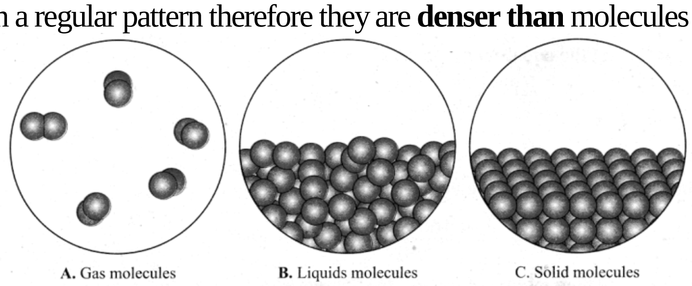



**Figure: Three States of Matter Showing Intermolecular Forces**

## 5.2.2 CHARLES LAW

## SHORT QUESTIONS

**Q.1 State Charles's Law.** **(BWP 2017, FSD 2016, GRW 2015, 16, LHR 2015,16, 17 G-I)*(K.B)***

**Ans:** *Answer given on pg # 167*

## 5.2.2 CHARLES LAW

## MULTIPLE CHOICE QUESTIONS

1. **Normal body temperature of human beings is:** **(GRW 2014)*(K.B)***
   (A) $37°C$ (B) $38°C$ (C) $39°C$ (D) $40°C$
2. **In Charles's Law 'k' is equal to:** **(LHR 2015)*(K.B)***
   (A) $\frac{T}{V}$ (B) TV (C) $\frac{V}{T}$ (D) $\frac{V}{P}$
3. $\frac{V}{T} = k$ **is the mathematical form of:** ***(K.B)***
   (A) Boyle's Law (B) Charles's Law (C) Avogadro's Law (D) Dalton Law
4. **Mathematical representation of Charles's Law is:** ***(K.B)***
   (A) $V \propto \frac{1}{P}$ (B) $V \propto \frac{1}{T}$ (C) $V \propto T$ (D) $V \propto P$

## 5.3 TEST YOURSELF

**i. Which variables are kept constant in Charles's Law?** ***(K.B)***

**Ans:** **CONSTANT VARIABLES OF CHARLES'S LAW**

Mass and pressure are kept constant in Charle's Law while volume and temperature are variable parameters. $\frac{V}{T} = \text{Constant}$

**ii. Why volume of a gas decreases with increase of pressure?** ***(U.B)***

**Ans:** **DECREASE IN VOLUME WITH PRESSURE**

Volume of gas decreases with increase of pressure because according to Boyle's Law volume and pressure both are inversely proportional to each other. So when we increase pressure, the gas molecules inter into the intermolecular spaces and come closer to one another and volume of a gas decreases.

**iii. What is absolute zero?** **(SWL 2016,17, FSD 2016, 17, GRW 2015)*(K.B)***

**Ans:** **ABSOLUTE ZERO**

*"Absolute zero is the temperature at which an ideal gas would have zero volume"*. Kelvin scale starts from absolute zero, represented as 0 K (Zero Kelvin). It is equal to -273°C.

**iv. Does Kelvin scale show a negative temperature?** ***(K.B)***

**Ans:** **NEGATIVE TEMPERATURE OF KELVIN**

The Kelvin scale does not show negative value, as $0\ K = -273.15°C$

**v. When a gas is allowed to expand, what will be its effect on its temperature?** ***(U.B)***

**Ans:** **EFFECT OF EXPANSION ON TEMPERATURE**

When a gas is allowed to expand, its temperature decreases because gas molecules consume energy for expansion by the gas molecules on its own. This decreases their temperature.

**vi. Can you cool a gas by increasing its volume?** ***(U.B)***

**Ans:** **COOLING OF GAS BY INCREASING VOLUME**

Yes, when a highly compressed gas is allowed to expand into a region of high pressure to low pressure, it consumes energy for the expansion by the gas molecules on its own this decreases their temperature.

| NUMERICAL EXAMPLE 5.3 | NUMERICAL EXAMPLE 5.4 |
|---|---|
| **A sample of oxygen gas has a volume of 250 $cm^3$ at -30°C. If gas is allowed to expand up to 700 $cm^3$ at constant pressure, find out its final temperature.** ***(U.B+K.B)*** | **A sample of hydrogen gas occupies a volume 160 $cm^3$ at 30°C. If its temperature is raised to 100°C, calculate what will be its volume if the pressure remains constant.** ***(U.B+A.B)*** |
| **NUMERICAL** | **NUMERICAL** |
| **Solution:** | **Solution:** |
| **Given Data:** $V_1 = 250\ cm^3$, $T_1 = -30^0C = 243\ K$, $V_2 = 700\ cm^3$ | **Given Data:** $V_I = 160\ cm^3$, $T_I = 30+273=303K$ (as $0^oC=273$ K), $T_2 = 100+273=373$ K |
| **To Find:** $T_2 = ?$ | **To Find:** $V_2 = ?$ |
| **Calculations:** By using the equation: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ or $T_2 = \frac{V_2 T_1}{V_1}$ | **Calculations:** By using the equation of Charles's Law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ Or $V_2 = \frac{V_1 T_2}{T_1}$ |
| By the values in equation: $T_2 = \frac{700 \times 243}{250} = 680.4\,K$; $T_2 = 680.4 - 273$; $T_2 = 407.4^oC$ | By Putting the values in equation: $V_2 = \frac{160 \times 373}{303} = 196.9\,cm^3$; $V_2 = 196.9cm^3$ |
| **Result:** **The final temperature of oxygen gas is 407.4°C.** | **Result** **The final volume of gas is 196.9 $cm^3$ if the pressure remains constant.** |

## 5.3 LIQUID STATE (TYPICAL PROPERTIES)
## 5.3.1 EVAPORATION, 5.3.2 VAPOUR PRESSURE,

**Q.1 What are liquids? Name some important properties of liquids.**

**(DGK 2017, FSD 2016)*(K.B)***

**Ans:** **LIQUID STATE**

*"The state of matter that has **indefinite shape** but **definite volume** is called liquid".*

**TYPICAL PROPERTIES OF LIQUIDS**

Typical properties of liquids are as follows:

- Evaporation
- Vapour pressure
- Boiling point
- Freezing point
- Diffusion
- Density

Liquids have a definite volume but their shape is not definite. A **liquid attains shape of the container** in which it is put.

**Q.2 Write a detailed note on evaporation. Which factors affect the evaporation?**
**(LHR 2014, 16 G-I, MTN 2016, BWP 2017, FSD 2017)*(U.B)***

**Ans:**

**EVAPORATION**

**Definition:**

*"The process of **changing of a liquid into a gas phase** is called evaporation".*

The **molecules having more than average kinetic energy** overcome the attractive forces among the molecules and **escape from the surface** is called as evaporation.

**Properties:**

**(i)** It is **reverse to condensation** in which a gas changes into liquid.
**(ii)** Evaporation is an **endothermic process (heat is absorbed)**.

**Example:**

When **one mole of water** in liquid state is converted into vapour form, it requires **40.7 kJ** of energy.

$$H_2O_{(l)} \longrightarrow H_2O_{(g)} \qquad \Delta H^o_{vap} = 40.7 \text{ KJ/mol}$$

**Mechanism of Evaporation:**

In the liquid state, molecules are in a continuous state of motion. They possess kinetic energy but all the molecules do not have same kinetic energy. Majority of the molecules have average kinetic energy and a few have more than average kinetic energy. The molecules having more than average kinetic energy, overcome the attractive forces among the molecules and escape from the surface. It is called as evaporation.

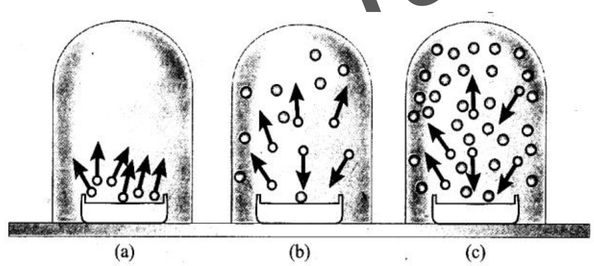



**Figure: A State of Dynamic Equilibrium Between Liquid and Its Vapours**

**Evaporation and Temperature:**

Evaporation is a **continuous process** taking place at **all temperatures**. **The rate of evaporation is directly proportional to temperature**. It increases with the increase in temperature because of increase in kinetic energy of the molecules.

**Evaporation is a Cooling Process:**

When the high kinetic energy molecules vaporize, the temperature of remaining molecules falls down. To compensate this deficiency of energy, the molecules of liquid absorb energy from the surroundings. As a result the temperature of surroundings decreases and we feel cooling.

**Example:**

When we put a drop of alcohol on palm, the alcohol evaporates and we feel cooling effect.

**FACTORS AFFECTING EVAPORATION**

Evaporation depends upon following factors:

**(i)** Surface area
**(ii)** Temperature
**(iii)** Intermolecular forces

**(i) Surface Area:**

Evaporation is a **surface phenomenon. Greater is surface area, greater is evaporation** and vice versa.

**Example:**

Sometimes a saucer is used if tea is to be cooled quickly. This is because evaporation from the larger surface area of saucer is more than that from the smaller surface area of a tea cup.

**(ii) Temperature:**

**At high temperature, rate of evaporation is high** because at high temperature kinetic energy of the molecules increases so high that they over- come the intermolecular forces and evaporate rapidly.

**Example:**

Hot water will evaporate faster than the cold water in containers of same capacity.

**(iii) Intermolecular Forces:**

**The stronger the intermolecular attractive forces, the lower is the evaporation.**

**Example:**

Water has stronger intermolecular forces than alcohol, therefore, alcohol evaporates faster than water.

**Q.3 What is vapour pressure and how it is affected by inter molecular forces?** **(Ex – Q.3)**

**(SWL 2016, BWP 2016, 17, MTN 2017, RWP 2017 G-II)*(U.B+K.B)***

**Ans:** **VAPOUR PRESSURE**

**Definition:**

*The **pressure exerted by the vapours of a liquid at equilibrium with the liquid at** a **particular temperature** is called vapour pressure of a liquid.*

**State of Equilibrium:**

*"The equilibrium is a state **when rate of vaporization and rate of condensation is equal to each other but in opposite directions**".*

**Formula:**

$$\text{liquid} \underset{\text{condense}}{\overset{\text{vapourize}}{\rightleftharpoons}} \text{vapours}$$

**Dynamic Equilibrium:**

*"The **state at which two opposing processes take places in the opposite direction simultaneously at equal rates** is called dynamic equilibrium".*

The **number of molecules evaporating** will be **equal to** the **number of molecules** coming back **(condensing)** to liquid. This state is called dynamic equilibrium.

**Explanation:**

From the open surface of a liquid, molecules evaporate and mix up with the air but when we close a system, evaporated molecules start gathering over the liquid surface. Initially the vapours condense slowly to return to liquid. After sometime condensation process increases and a stage reaches when the rate of evaporation becomes equal to rate of condensation. At this stage the number of molecules evaporating will be equal to the number of molecules coming back (condensing) to liquid. This is called dynamic equilibrium state.

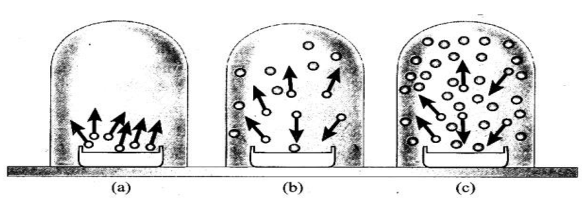



**Figure: A State of Dynamic Equilibrium Between Liquid and Its Vapours**

## FACTOR AFFECTING VAPOUR PRESSURE

Vapour pressure of a liquid depends upon the following factors:

**(i)** Nature of liquid

**(ii)** Size of molecule

**(iii)**Temperature

**(i) Nature of Liquid:**

Vapours pressure depends upon the nature of liquid.

**Polar liquids have low vapour pressure** than non-polar liquids at the same temperature. This is because of **strong intermolecular forces between the polar molecules** of liquids.

**Example:**

**Water** has **less vapour pressure than** that of **alcohol at same temperature**.

**(ii) Size of Molecules:**

**Small size molecules can easily evaporate than big size molecules**. Hence small size molecular liquids exert more vapour pressure.

**Examples:**

Hexane ($C_6H_{14}$) is a small sized molecule as compared to decane ($C_{10}H_{22}$).

$C_6H_{14}$ evaporates rapidly and exerts more pressure than $C_{10}H_{22}$).

**(iii) Temperature:**

At **high temperature, vapour pressure is higher than at low temperature**. At elevated temperature, the kinetic energy of the molecules increases enough to enable them to vaporize and exert pressure.

**Example:**

Vapour pressure of **water** at **0°C** is **4.58 mmHg** and at **100ºC** it is **760 mmHg**.

| Temp | Vapour Pressure | Temp | Vapour Pressure |
|---|---|---|---|
| °C | mmHg | °C | mmHg |
| 0 | 4.58 | 60 | 149.4 |
| 20 | 17.5 | 80 | 355.1 |
| 40 | 55.3 | 100 | 760.0 |

**Table: Relationship of Vapour Pressure of Water With Temperature**

**Q.4 Define boiling point and also explain how it is affected by different factors?**

**(Ex-Q.4)(LHR 2015, GRW 2016 G-II, SGD 2016, 17 G-II, RWP 2017 G-II)*(U.B+K.B)***

**Ans:**

## BOILING POINT

**Definition:**

*"The **temperature at which the vapour pressure of a liquid becomes equal to the atmospheric pressure or any external pressure** is called boiling point".*

**Example:**

- Boiling of **water** = **100ºC**
- Boiling point of **acetic acid** = **118ºC**

**Mechanism of Boiling**

When a liquid is heated, its molecules gain energy and the number of molecules which have more than average kinetic energy increases. More and more molecules become energetic, enough to overcome the intermolecular forces. Due to this, rate of evaporation increases which results in increase of vapour pressure until a stage reaches where the **vapour pressure of a liquid becomes equal to atmospheric pressure**. At this stage the **liquid starts boiling**.

## Relationship between Boiling Point and Vapour Pressure:

The increase of vapour pressure of diethyl ether, ethyl alcohol and water with the increase of temperature. At **0ºC** the vapour pressure of **diethyl ether** is **200 mm Hg**, of **ethyl alcohol 25 mm Hg** while that of **water** is about **5 mm Hg**. When they are **heated**, vapour pressure of **diethyl ether increases** rapidly and becomes equal to atmospheric pressure at **34.6°C**, while **vapour pressure of water increases slowly because intermolecular forces of water are stronger**.

The vapour pressure increases very rapidly when the liquids are near to boiling point.

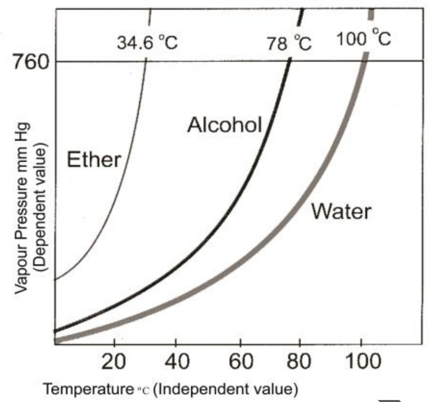



**Figure: Boiling Point Curves of Ether Alcohol and Water**

## Factors Affecting the Boiling Point:

The boiling point of the liquid depends upon the following factors.

**(i)** Nature of liquid

**(ii)** Intermolecular forces

**(iii)** External pressure

### (i) Nature of Liquid:

The **polar liquids have high boiling points than that of non-polar liquids** because polar liquids have strong intermolecular forces.

**Examples:**

Boiling point of **water (more polar)** is **100°C** while that of **ethyl alcohol (less polar)** is **78°C**.

### (ii) Intermolecular Forces:

The **stronger the intermolecular forces, the higher is the boiling point of liquid**.

Intermolecular forces play a very important role on the boiling point of liquids.

Substances having stronger intermolecular forces have high boiling points, because such liquids attain a level of vapour pressure equal to external pressure at high temperature.

**Example:**

Boiling point of **water (100°C)** is greater than that of **alcohol (78°C)** due to stronger intermolecular forces of attraction.

### (iii) External Pressure:

Boiling point of a liquid **depends upon external pressure**. Boiling point of a liquid is controlled by external pressure in such a way, that it can be increased by **increasing external pressure** and vice versa. This principle is used in the working of **'Pressure Cooker'**.

**Q.5 What is meant by freezing point?** **(LHR 2016 G-I, DGK 2016, SGD 2016)(U.B+K.B)**

**Ans:**

**FREEZING POINT**

*"The **temperature at which vapour pressure of a liquid state becomes equal to the vapour pressure of the solid state and liquid and solid coexist in dynamic equilibrium** is called freezing point".*

**Explanation:**

When liquids are cooled the vapour pressure of liquid decreases and when vapour pressure of a liquid state becomes equal to the vapour pressure of the solid state. At this temperature **liquid and solid coexist in dynamic equilibrium** with one another and this is called the freezing point of a liquid.

**Examples:**

Freezing point of **water** is **0ºC** and that of **acetic acid** is **16.6ºC** due to attractive forces respectively.

| Sr. No | Liquid | Freezing Point ºC | Boiling Point ºC |
|---|---|---|---|
| 1 | Diethyl ether | –116 | 34.6 |
| 2 | Ethyl alcohol | –115 | 78 |
| 3 | Water | 0.0 | 100 |
| 4 | n-Octane | –57 | 126 |
| 5 | Acetic acid | 16.6 | 118 |

**Q.6 Describe the phenomenon of diffusion in liquids along with factors which influence it.**
**(Ex-Q.5)(SGD 2016, RWP 2016, FSD 2017)(U.B+K.B)**

**Ans:**

**DIFFUSION**

*"The **spontaneous mixing up of molecules by random motion and collisions to form homogeneous mixture** is called diffusion".*

**Explanation:**

The liquid molecules are always in a state of **continuous motion**. They move from **higher concentration to lower concentration**. They mix up with the molecules of other liquids, so that they form a **homogeneous mixture**.

**Example:**

When a few drops of ink are added in a beaker of water, ink molecules move around and after a while spread in whole of the beaker. Thus diffusion has taken place.

**Figure: Diffusion in Liquid**

**Comparison of Rate of Diffusion of Liquids and Gases:**

Liquids diffuse like gases but the rate of diffusion of liquids is **very slow**.

**Factors Affecting Diffusion:**

The diffusion of liquids depends upon the following factors:

**(i)** Intermolecular forces
**(ii)** Size of molecules
**(iii)** Shapes of molecules
**(iv)** Temperature

**(i) Intermolecular Forces:**

**Liquids having weak intermolecular forces diffuse faster** than those of liquids having strong intermolecular forces.

**Example:**

Rate of diffusion of alcohol is greater than that of water.

**(ii) Size of Molecules:**

**Big sized molecules diffuse slowly.**

**Example:**

Honey diffuses slowly in water than that of alcohol in water.

**(iii) Shapes of Molecules:**

**Regular shaped molecules diffuse faster than irregular shaped molecules** because they can easily slip over and move faster.

**(iv) Temperature:**

**Diffusion increases by increasing temperature** because at high temperature the intermolecular forces are weak.

**Example:**

Rate of diffusion of **water** is **higher at 25ºC than** that of **0ºC**.

**Q.7 Explain comparison between densities of gases and liquids.** **(LHR 2014)*(U.B)***

**OR**

**Describe density of liquids in detail.** ***(U.B+K.B)***

**Ans:** **DENSITY**

**Definition:**

*"The **mass per unit volume of a substance** is called density."*

**Dependence of Density of Liquids:**

The density of liquids depends upon its **mass and volume**.

**Comparison between Densities of Gases and Liquids:**

Liquids are denser than gases because molecules of a liquid are closely packed and the spaces between their molecules are negligible. As the liquid molecules have strong intermolecular forces hence they cannot expand freely and have a fixed volume. Unlike gases, they cannot occupy all the available volume of the container that is the reason why densities of liquids are high.

**Examples:**

Density of **water** is **1.0 g cm$^{-3}$** while that of **air** is **0.001 g cm$^{-3}$** that is the reason why **drops of rain fall downward**.

**Variation in Densities of Liquids:**

The densities of liquids also vary. You can observe **kerosene oil floats over water** while **honey settles down in the water**.

## 5.3 LIQUID STATE (TYPICAL PROPERTIES)
## 5.3.1 EVAPORATION, 5.3.2 VAPOUR PRESSURE,
## SHORT QUESTIONS

**Q.1 How evaporation causes cooling?** **(SWL 2016, MTN 2017, BWP 2016, FSD 2016)*(U.B)***
**Ans:** *Answer given on pg # 171*
**Q.2 How surface area affects evaporation?** **(LHR 2016 G-I, FSD 2016,17)*(U.B)***
**Ans:** *Answer given on pg # 172*
**Q.3 How size of molecules affect the vapour pressure?** **(LHR 2016)*(U.B)***
**Ans:** *Answer given on pg # 173*
**Q.4 Define boiling point.** **(SWL 2016, MTN 2016, SGD 2017, RWP 2017)*(K.B)***
**Ans:** *Answer given on pg # 173*
**Q.5 How external pressure affects the boiling point?** **(FSD 2016, SGD 2016, 17 G-I)*(U.B)***
**Ans:** *Answer given on pg # 174*
**Q.6 Define freezing point.** **(GRW 2017 G-I)*(K.B)***
**Ans:** *Answer given on pg # 175*
**Q.7 What is the freezing point of diethyl ether and ethyl alcohol?** ***(K.B)***
**Ans:** **FREEZING POINTS**

**Diethyl Ether:**
Freezing point of diethyl ether is –116°C.
**Ethyl Alcohol:**
Freezing point of ethyl alcohol is –115°C.

## 5.3 LIQUID STATE (TYPICAL PROPERTIES)
## 5.3.1 EVAPORATION, 5.3.2 VAPOUR PRESSURE,
## MULTIPLE CHOICE QUESTIONS

1. **At which temperature rate of evaporation of water is minimum?** ***(K.B)***
(A) 50°*C* (B) 40°*C* (C) 90°*C* (D) 70.5°*C*
2. **Evaporation is reverse to:** ***(U.B)***
(A) Boiling (B) Freezing (C) Melting (D) Condensation
3. **Evaporation is __________ process.** ***(U.B)***
(A) Endothermic (B) Cooling (C) Continuous (D) All of these
4. **Heat of vapourization of water is:** ***(K.B)***
(A) 407kJ/mol (B) 40kJ/mol (C) 4.07kJ/mol (D) 40.7kJ/mol
5. **Evaporation increases with:** ***(U.B)***
(A) Intermolecular force (B) Temperature (C) Pressure (D) All of these
6. **On which factors evaporation depends?** ***(U.B)***
(A) Surface area (B) Temperature
(C) Intermolecular forces (D) All of these
7. **The vapour pressure of a liquid increases with:** **(Ex-11)*(U.B)***
(A) Increase of pressure (B) Increase of temperature
(C) Increase of intermolecular forces (D) Increase of polarity of molecules
8. **Which of the following has maximum vapour pressure at given temperature?** ***(U.B+K.B)***
(A) $C_5H_{12}$ (B) $C_6H_{14}$ (C) $C_7H_{10}$ (D) $C_8H_{18}$

**9. At which temperature vapour pressure of water is 760mmHg?** ***(K.B)***

(A) 20°C (B) 50°C (C) 100°C (D) 149.4°C

**10. Boiling point of alcohol is:** **(GRW 2016)*(K.B)***

(A) 68°C (B) 78°C (C) 88°C (D) 98°C

**11. Boiling point of water is:** ***(K.B)***

(A) 32°C (B) 78°C (C) 100°C (D) 20°C

**12. Boiling point of liquid depends upon:** ***(U.B)***

(A) Nature of liquid (B) Intermolecular forces
(C) External pressure (D) All of these

**13. Which of the following has highest boiling point?** ***(K.B)***

(A) Water (B) Ether (C) Alcohol (D) Benzene

**14. Freezing point of acetic acid is:** ***(K.B)***

(A) 16.5°C (B) 16.6°C (C) 16.3°C (D) 16.2°C

**15. Diffusion is faster in:** ***(U.B)***

(A) Liquids (B) Solids (C) Gases (D) None of these

**16. Spreading of ink in water is due to:** ***(U.B)***

(A) Effusion (B) Diffusion (C) Evaporation (D) Freezing

**17. Which shaped molecules diffuse faster?**

(A) Irregular (B) Regular (C) Uneven (D) Non-uniform

**18. Diffusion increases by increasing:** ***(U.B)***

(A) Temperature (B) Intermolecular forces
(C) Size of molecule (D) All of these

**19. The density of water is:** ***(K.B)***

(A) $1.0 gcm^{-3}$ (B) $1.3\ gcm^{-3}$ (C) $1.4\ gcm^{-3}$ (D) $1.2\ gcm^{-3}$

**20. Vapour pressure of water at 100°C is:** **(GRW 2017 G-II)*(K.B)***

(A) 140 mmHg (B) 300 mmHg (C) 580 mmHg (D) 760 mmHg

**21. Freezing point of water is:** **(GRW 2017 G-II, LHR 2016 G-I)*(K.B)***

(A) 0°C (B) 100°C (C) 34–4°C (D) 4°C

## 5.4 TEST YOURSELF

**i. Why does evaporation increase with the increase of temperature?** **(GRW 2017 G-I)*(U.B)***

**Ans:** **<u>INCREASE IN EVAPORATION WITH TEMPERATURE</u>**

Evaporation increases with increase of temperature because kinetic energy of the molecules increases to such an extent that they overcome the intermolecular forces and rapidly evaporate.

**ii. What do you mean by condensation?** **(SGD 2016)*(K.B)***

**Ans:** **<u>CONDENSATION</u>**

*"The process of changing of gas or vapour into liquid is called condensation. It is reverse of evaporation".*

$$\text{Liquid} \underset{Condense}{\overset{Vapourize}{\rightleftharpoons}} \text{vapours (gas)}$$

**iii. Why is vapour pressure higher at high temperature?** ***(U.B)***

**Ans:** **<u>TEMPERATURE AND VAPOUR PRESSURE</u>**

The vapour pressure is higher at high temperature than at low temperature because at elevated temperature, the kinetic energy of the molecules increases enough to enable them to vapourize and exert more pressure.

**iv. Why is the boiling point of water higher than that of alcohol?** **(SGD 2016, SWL 2016, RWP 2016, 17)*(U.B)***

**Ans:** **BOILING POINT OF WATER AND ALCOHOL**

Boiling point of water is higher than that of alcohol because water is a polar liquid and has high intermolecular forces than alcohol.

**v. What do you mean by dynamic equilibrium?** **(SGD, LHR, GRW, FSD, RWP 16,17)*(K.B)***

**Ans:** **DYNAMIC EQUILIBRIUM**

*"The state at which the rate of evaporation becomes equal to the rate of condensation is called dynamic equilibrium".*

$$\text{Liquid} \underset{Condense}{\overset{Vapourize}{\rightleftharpoons}} \text{Vapours.}$$

**vi. Why are the rates of diffusion in liquids slower than that of gases?** ***(U.B)***

**Ans:** **RATE OF DIFFUSION**

The rate of diffusion in liquids is slower than that of gases because liquids have stronger intermolecular forces than gases and very less empty spaces and kinetic energies.

**vii. Why does rate of diffusion increase with increase of temperature?** ***(U.B)***

**Ans:** **RATE OF DIFFUSION**

The rate of diffusion increases with increase in temperature because at high temperature the kinetic energy of molecules increases and intermolecular forces decrease. As a result gas molecules can move freely and fastly.

**viii. Why are the liquids mobile?** **(LHR, GRW 2014,15)*(U.B)***

**Ans:** **MOBILITY**

*"The ease of flow of a liquid is called mobility"*. The mobility of liquids depends upon the intermolecular forces and K.E of molecules. Liquids are mobile because liquid molecules possess high kinetic energy and weak intermolecular forces.

## 5.4 SOLID STATE (TYPICAL PROPERTIES)

**Q.1 Explain typical properties of solid state.** ***(U.B+K.B)***

**Ans:** **SOLID STATE**

*"The state of matter which has **definite shape** and **definite volume** is called solid".*

**Examples:**

- Sugar
- Common salt
- Iron
- Gold

In solid state the molecules are very close to one another and they are closely packed. The intermolecular forces are so strong that particles become almost motionless. Hence they cannot diffuse. Solid particles possess only vibrational motion.

**TYPICAL PROPERTIES OF SOLIDS**

Some typical properties of solids are as follows:

**(i)** Melting point
**(ii)** Rigidity
**(iii)** Density

**(i) Melting Point:**

*"The **temperature at which the solid starts melting and coexists in dynamic equilibrium with liquid state** is called melting point".*

**Examples:**

Melting point of **sodium chloride** is **801°C**.

**Explanation:**

The solid particles possess only **vibrational kinetic energy**. When solids are heated, their vibrational energies increase and particles vibrate at their mean position with a higher speed. If the heat is supplied continuously, a stage reaches at which the particles leave their fixed positions and then become mobile. At this temperature solid melts.

$$\textit{solid} \rightleftharpoons \textit{liquid}$$

**Melting Points of Ionic and Covalent Solids:**

The ionic and covalent solids make network structure to form macromolecules so all such solids have **very high melting points**.

**(ii) Rigidity:**

The particles of solids are not mobile. They have fixed position. Therefore solids are rigid in their structure.

**(iii) Density**

*"**Mass per unit volume of a substance** is called density".*

**Comparison between densities of solids, liquids and gases:**

Solids are denser than liquids and gases because solid particles are closely packed and do not have empty spaces between their particles. Therefore, they have the **highest densities among the three states** of matter.

**Examples:**

Density of **aluminum is 2.70 g $cm^{-3}$, iron is 7.86 g $cm^{-3}$** and **gold is 19.3 g $cm^{-3}$**.

## 5.4 SOLID STATE (TYPICAL PROPERTIES)

## SHORT QUESTIONS

**Q.1 What is solid state of matter?** **(MTN 2017)*(K.B)***

**Ans:** *Answer given on pg # 179*

**Q.2 Define melting point. Give an example.** **(RWP 2016)*(K.B)***

**Ans:** *Answer given on pg # 179*

**Q.3 What is meant by rigidity?** **(FSD 2017 G-I)*(U.B+K.B)***

**OR**

**Why solids are rigid in structure?** ***(U.B)***

**Ans:** *Answer given on pg # 180*

**Q.4 What is density?** ***(K.B)***

**Ans:** *Answer given on pg # 180*

## 5.4 SOLID STATE (TYPICAL PROPERTIES)

## MULTIPLE CHOICE QUESTIONS

**1. The density of gold is:** ***(K.B)***

(A) 2.70 g $cm^{-3}$ (B) 7.86 g $cm^{-}$ (C) 19.3 g $cm^{-3}$ (D) 1.4 g $cm^{-3}$

**2. The density of iron is:** ***(K.B)***

(A) 2.70 g $cm^{-3}$ (B) 7.86 g $cm^{-3}$ (C) 19.3 g $cm^{-3}$ (D) 1.4 g $cm^{-3}$

## 5.5 TYPES OF SOLIDS

**Q.1 Differentiate between crystalline and amorphous solids.** **(GRW 2017 G-I)(U.B)**

**OR**

**Explain the types of solids in detail?** **(U.B+K.B)**

**Ans:**

**TYPES OF SOLIDS**

According to their general appearance solids can be classified into two types:

**(i)** Amorphous solids:

**(ii)** Crystalline solids:

**(i) Amorphous Solids:** (Greek word **amorphous means without shape or shapeless**)

*"**Solids in which the particles are not arranged in a regular repeating pattern** are called amorphous solids".*

**Properties:**

- They **do not have sharp melting points**.
- They **do not form crystals**.

**Examples:**

- Plastic rubber
- Glass
- Coal tar etc.

**(ii) Crystalline Solids:**

*"**Solids in which particles are arranged in a definite three-dimensional pattern** are called crystalline solids".*

**Properties:**

- They **have definite surfaces or faces**.
- Each **face has definite angle** with the other.
- They have **sharp melting points**.

**Examples:**

- Diamond
- Sodium chloride
- Sugar
- Ammonium chloride etc.

## 5.5 TYPES OF SOLIDS

## SHORT QUESTIONS

**Q.1 What is the meaning of word amorphous. Give its properties.** **(MTN 2016, SWL 2017, FSD)*(K.B)***

**Ans:** *Answer given on pg # 180*

**Q.2 Differentiate between crystalline and amorphous solids.** ***(U.B)***

**Ans:** **DIFFERENTIATION**

The differences between crystalline and amorphous solids are as follows:

| Amorphous Solids | Crystalline Solids |
|---|---|
| **Definition** | |
| • Solids in which the particles are not regularly arranged or their regular shapes are destroyed, are called amorphous solids. | • Solids in which particles are arranged in a definite three dimensional pattern are called crystalline solids. |
| **Melting Point** | |
| • They do not have sharp melting point. | • They have sharp melting point. |
| **Examples** | |
| • Plastic<br>• Rubber<br>• Glass<br>• Coal tar | • Diamond<br>• Sodium chloride<br>• Sugar<br>• Ammonium chloride |

## 5.5 TYPES OF SOLIDS

## MULTIPLE CHOICE QUESTIONS

1. **Which one of the following is not amorphous?** **(LHR 2016 G-II)(Ex-5)*(K.B)***
   (A) Rubber (B) Plastic (C) Glass (D) Glucose
2. **The solid in which particles are arranged in definite three dimensional pattern are:** ***(K.B)***
   (A) Solids (B) Crystalline solids (C) Amorphous solids (D) Both B and C
3. **Plastic, glass, rubber etc. are the examples of:** ***(K.B)***
   (A) Crystalline solids (B) Super cooled liquid (C) Amorphous solids (D) Ionic solids
4. **Diamond is an example of:** ***(K.B)***
   (A) Amorphous solids (B) Ionic bond
   (C) Crystalline solids (D) Both B and C
5. **Which one of the following is amorphous solid?** **(RWP 2017 G-II)*(K.B)***
   (A) Glucose (B) Sodium chloride (C) Glass (D) Diamond

## 5.6 ALLOTROPY

**Q.1 Define Allotropy. Explain its conditions and properties.** ***(U.B+K.B)***

**Ans:**

**ALLOTROPY**

*"The **existence of an element in more than one form, in same physical state** is called allotropy".*

**Reasons:**

**(i) Different Number of Atoms in a Molecule:**

The existence of two or more kinds of molecules of an element each having different number of atoms such as allotropes of oxygen are **oxygen ($O_2$)** and **ozone ($O_3$)**.

**(ii) Different Arrangement of Atoms in a Molecule:**

Different arrangement of two or more atoms or molecules in a crystal of the element

**Examples:**

- **Sulphur** shows allotropy due to **different arrangement of molecules ($S_8$)** in the crystals.
- Due to different arrangement of **carbon (C)** atoms in the crystals carbon has **three allotropes**. **Diamond, Graphite, Bucky balls**
- Due to **different arrangement of $P_4$ molecules** in the crystals, phosphorous exists in the **three allotropes** i.e. **White, Red, Black**

**Properties of allotropes:**

They always show **different physical properties** but may have **same chemical properties**.

**Effect of temperature:**

Allotropes of solids have different arrangement of atoms in space at a given temperature. The arrangement of atoms also changes with the change of temperature and new allotropic form is produced.

**TRANSITION TEMPERATURE**

*"The **temperature at which one allotrope changes into another** is called transition temperature".*

**Examples:**

- Transition temperature of **sulphur** is **96°C**, below this temperature rhombic form is stable. If rhombic form is heated up to 96°C, its molecules rearrange themselves to give monoclinic form.

$$S_8(\text{rhombic}) \xrightarrow{96°C} S_8\ (\text{monoclinic})$$

- Transition temperature for allotropic forms of **tin** is **13.2°C**.

$$Sn_{(Grey)} \xrightarrow{13.2°C} Sn_{(White)}$$

- Transition temperature for allotropic forms of **phosphorous** is **250°C**.

$$P_{4(White)} \xrightarrow{250°C} P_{4(Red)}$$

**White Phosphorous:**

Is a **very reactive**, **poisonous** and **waxy**, **soft solids**. It exists as **tetra-atomic molecules**.

**Red Phosphorous:**

Is **less reactive**, **non-poisonous** and **brittle powder.**

## 5.6 ALLOTROPY

## SHORT QUESTIONS

**Q.1 Define and give example of transition temperature.** ***(K.B)***

**Ans:** *Answer given on pg # 182*

**Q.2 Define the term allotropy with examples.** ***(K.B)***

**Ans:** *Answer given on pg # 182*

**Q.3 What are properties of white phosphorous and red phosphorous?** ***(K.B)***

**Ans:** **PROPERTIES OF WHITE AND RED PHOSPHOROUS**

**White Phosphorous:**

Is a very reactive, poisonous, soft and waxy solid. It exists as tetra-atomic molecules.

**Red Phosphorous:**

Is less reactive, poisonous and brittle powder.

## 5.6 ALLOTROPY

## MULTIPLE CHOICE QUESTIONS

1. **The crystal structure of white tin is:** ***(K.B)***
(A) Cubic (B) Tetragonal (C) Monoclinic (D) None of these
2. **250° C is the transition temperature of which element?** ***(K.B)***
(A) Tin (B) Carbon (C) Phosphorus (D) Sulphur
3. **The existence of solid in different physical forms is called:** ***(K.B)***
(A) Crystals (B) Allotropy (C) Evaporation (D) Transition
4. **Red phosphorus is:** ***(K.B)***
(A) Less reactive (B) Non-poisonous (C) Brittle (D) All of above
5. **Allotropes of oxygen are:** ***(K.B)***
(A) 2 (B) 3 (C) 4 (D) 5

# 5.5 TEST YOURSELF

**i. Which form of sulphur exists at room temperature?** **(LHR 2017 G-I)*(K.B)***

**Ans:** **FORM OF SULPHUR AT ROOM TEMPERATURE**

Rhombic form of sulphur exists at room temperature.

**ii. Why is white tin available at room temperature?**

**(SGD 2016, GRW 2017, LHR 2014, RWP 2015)*(U.B)***

**Ans:** **AVAILABILITY OF WHITE TIN**

White tin is available at room temperature because it is stable above 13.2°C, which is transition temperature of grey and white tin.

$$\underset{\text{Cubic}}{S(\text{grey})} \xrightleftharpoons{13.2^\circ C} \underset{\text{Tetragonal}}{Sn(\text{white})}$$

**iii. Why is the melting point of a solid considered its identification characteristic?** ***(U.B)***

**Ans:** **IDENTIFICATION BY MELTING POINT**

The solid particles possess only vibrational kinetic energy. Melting point is the temperature at which the solid starts melting and co-exists in dynamic equilibrium with liquid state. Therefore, melting point of a solid is considered its identification characteristic.

**Example:**

- Melting point of NaCl is 801°C.

**iv. Why amorphous solids do not have sharp melting points while crystalline solids do have?** ***(U.B)***

**Ans:** **SHARP MELTING POINT**

Amorphous solids do not have sharp melting points because in these solids particles are not held in a regular three dimensional arrangement. On the other hand crystalline solids have sharp melting points because in these solids particles are held in a regular three dimensional arrangement.

**v. Which is lighter one, aluminum or gold?** ***(K.B)***

**Ans:** **LIGHT WEIGHT METAL**

Aluminium is lighter than gold because the density of aluminium (2.70 g $cm^{-3}$) is less than gold (19.3g$cm^{-3}$).

**vi. Write the molecular formula of a sulphur molecule?** ***(K.B)***

**Ans.** **MOLECULAR FORMULA OF SULPHUR**

Molecular formula of sulphur molecule is $S_8$.

**vii. Which allotropic form of carbon is stable at room temperature (25°C)?** ***(K.B)***

**Ans:** **STABILITY OF ALLOTROPE OF CARBON**

There are three allotropic forms of carbon i.e. diamond, graphite and bucky balls, which are stable at room temperature. Among these allotropic forms graphite is energetically slightly more stable than diamond.

**viii. State whether allotropy is shown by elements or compounds or both?** ***(U.B)***

**Ans:** **ALLOTROPY OF ELEMENT OR COMPOUND**

Allotropy is shown by elements only. It is the existence of an element in more than one forms in same physical state.

**Examples:**

- Allotropic forms of carbon are diamond, graphite and bucky balls.
- Allotropes of oxygen are $O_2$ and $O_3$.

# ANSWER KEYS

## 5.1 GASEOUS STATE (TYPICAL PROPERTIES)

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | A | 3 | C | 4 | B | 5 | C | 6 | B | 7 | A | 8 | D | 9 | D | 10 | C | 11 | C | 12 | C | 13 | A |

## 5.2 LAWS RELATED TO GASES

### 5.2.1 BOYLE'S LAW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 2 | C | 3 | A | 4 | B | 5 | A |

### 5.2.2 CHARLES LAW

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | A | 2 | C | 3 | B | 4 | C |

## 5.3 LIQUID STATE (TYPICAL PROPERTIES)

### 5.3.1 EVAPORATION, 5.3.2 VAPOUR PRESSURE,

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | D | 3 | A | 4 | D | 5 | B | 6 | D | 7 | B | 8 | A | 9 | C | 10 | B | 11 | C |
| 12 | D | 13 | A | 14 | B | 15 | C | 16 | B | 17 | B | 18 | A | 19 | A | 20 | D | 21 | A | | |

## 5.4 SOLID STATE (TYPICAL PROPERTIES)

| | | | |
|---|---|---|---|
| 1 | C | 2 | B |

## 5.5 TYPES OF SOLIDS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 2 | B | 3 | C | 4 | C | 5 | C |

## 5.6 ALLOTROPY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | C | 3 | B | 4 | A | 5 | A |

# EXERCISE SOLUTION

## MULTIPLE CHOICE QUESTIONS

1. **How many times liquids are denser than gases?**
**(GRW 2016 G-I, SGD 2017 G-II, BWP 2017 G-I, SWL 2016 G-II)*(K.B)***
(a) 100 times (b) 1000 times (c) 10,000 times (d) 100,000 times

2. **Gases are the lightest form of matter and their densities are expressed in terms of:**
**(RWP 2017 G-I, MTN 2016 G-I, BWP 2017 G-II, SWL 2017 G-I, II, DGK 2016 G-I)*(K.B)***
(a) mg $cm^{-3}$ (b) g $cm^{-3}$ (c) g $dm^{-3}$ (d) kg $dm^{-3}$

3. **At freezing point which one of the following coexists in dynamic equilibrium?** ***(K.B)***
(a) Gas and solid (b) Liquid and gas (c) Liquid and solid (d) All of these.

4. **Solid particles possess which one of the following motions?** ***(K.B)***
(a) Rotational motions (b) Vibrational motions
(c) Translational motions (d) Both translational and vibrational motions

5. **Which one of the following is not amorphous?**
**(LHR 2017 G-I, LHR 2016 G-II, DGK 2017 G-II, MTN 2017 G-I, II)*(K.B)***
(a) Rubber (b) Plastic (c) Glass (d) Glucose

6. **One atmospheric pressure is equal to how many Pascals?**
**(FSD 2017 G-I, SWL 2017 G-II, SWL 2016 G-1, RWP 2016 G-1, FSD 2016 G-1, BWP 2016 G-I,)*(K.B)***
(a) 101325 (b) 10325 (c) 106075 (d) 10523

7. **In the evaporation process, liquid molecules which leave the surface of the liquid have:** ***(U.B)***
(a) Very low energy (b) Moderate energy (c) Very high energy (d) None of these

8. **Which one of the following gas diffuses faster?(LHR 2017 G-II, SGD 2016 G-I, FSD 2016 G-II)*(U.B)***
(a) Hydrogen (b) Helium (c) Fluorine (d) Chlorine

9. **Which one of the following does not affect the boiling point?** ***(U.B)***
(a) Intermolecular forces (b) External pressure
(c) Nature of liquid (d) Initial temperature of liquid

10. **Density of a gas increases, when its:** ***(U.B)***
(a) Temperature is increased (b) Pressure is increased
(c) Volume is kept constant (d) None of these

11. **The vapour pressure of a liquid increases with the:** ***(U.B)***
(a) Increase of pressure (b) Increase of temperature
(c) Increase of intermolecular forces (d) Increase of polarity of molecules

## ANSWER KEY

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 2 | C | 3 | C | 4 | B | 5 | D | 6 | A | 7 | C | 8 | A | 9 | D | 10 | B | 11 | B |

# EXERCISE SHORT QUESTIONS

**1. What is diffusion? Explain with an example?** **(LHR 2017 G-I, RWP 2017 G-I)*(K.B+A.B)***

**Ans:** **DIFFUSION**

*"The spontaneous mixing of particles of a substance by random motion and collisions, to form a homogeneous mixture is called diffusion".*

***OR***

*"Movement of molecules of a substance from the region of higher concentration to the region of lower concentration is called diffusion".*

**Example:**

When a few drops of ink are added in beaker of water, ink molecules move around and after a while spread in whole of the beaker. Thus diffusion has taken place.

**2. Define standard atmospheric pressure. What are its units? How it is related to Pascal?**

**(GRW 2017 G-I, SGD 2016 RWP 2017, LHR 2016 G-I, II)*(U.B+K.B)***

**Ans:** **STANDARD ATMOSPHERIC PRESSURE**

**Definition:**

*It is the pressure exerted by the atmosphere at the sea level. "It is defined as the pressure exerted by a mercury column of 760mm height at sea level". It is sufficient pressure to support a column of mercury 760mm in height at sea level.*

**Units:**

- Atmosphere
- Pascal
- mmHg
- Torr
- $Nm^{-2}$

1atm = 760mmHg = 760torr = $101325Nm^{-2}$ = 101325Pa

**Relation with Pascal:**

1atm = 101325Pa = $101325Nm^{-2}$

**3. Why are the densities of gases lower than that of liquids?** **(RWP 2017 G-I)*(U.B)***

**Ans:** **LOWER DENSITIES OF GASES**

Gases have lower densities than densities of liquids. It is due to the light mass and more volume occupied by the gases. Another reason for lower densities of gases is negligible intermolecular forces among the gases molecules. On the other hand liquid molecules are closely spaced and have strong intermolecular forces.

**4. What do you mean by evaporation, how it is affected by surface area?** ***(U.B)***

**Ans:** **EVAPORATION**

"*The process of changing of a liquid into a gas phase is called evaporation."*

**Effect of Surface Area on Evaporation:**

Evaporation is a surface phenomenon. Greater is surface area, greater is evaporation and vice versa.

**5. Define the term allotropy with examples.** ***(K.B+A.B)***

**Ans:** **ALLOTROPY**

**Definition:**

*"The existence of an element in more than one forms in same physical state is called allotropy."*

**Examples:**

- Oxygen has two allotropic forms: Oxygen ($O_2$) and ozone ($O_3$).
- Three allotropic forms of carbon are: Diamond, graphite and bucky balls.

**6. In which form sulphur exists at 100°C?** **(LHR 2017 G-I)*(K.B)***

**Ans:** **EXISTANCE OF SULPHUR**

Sulphur exists in monoclinic form at $100^oC$

**7. What is the relationship between evaporation and boiling point of a liquid?** ***(U.B)***

**Ans:** **RELATIONSHIP BETWEEN EVAPORATION AND B.P**

If the boiling point of a liquid is high, its evaporation is slow because intermolecular forces are high in the liquid which have high boiling points. If boiling point is low then evaporation is high.

## EXERCISE LONG QUESTIONS

**1. Define Boyle's Law and verify it with an example.**

**Ans:** *Answer given on pg #* 163 (Topic 5.2; 5.2.1)

**2. Define and explain Charles's Law of gases.**

**Ans:** *Answer given on pg #* 167 (Topic 5.2; 5.2.2)

**3. What is vapour pressure and how it is affected by intermolecular forces?**

**Ans:** *Answer given on pg #* 172 (Topic 5.3; 5.3.2)

**4. Define boiling point and also explain, how it is affected by different factors?**

**Ans:** *Answer given on pg #* 173 (Topic 5.3; 5.3.3)

**5. Describe the phenomenon of diffusion in liquids along with factors which influence it.**

**Ans:** *Answer given on pg #* 175 (Topic 5.3; 5.3.5)

**6. Differentiate between crystalline and amorphous solids.**

**Ans:** *Answer given on pg #* 181 (Topic 5.5)

# EXERCISE SOLVED NUMERICALS

**1. Convert the following units:** ***(U.B+A.B)***

**(a) 850 mm Hg to atm**

**(b) 205000 Pa to atm**

**(c) 560 torr to cm Hg**

**(d) 1.25 atm to Pa**

**Solution:**

**(a) 850 mmHg to atm:**

760 mm of Hg = 1atm

$$1 \text{ mm of Hg} = \frac{1}{760} atm$$

$$850 \text{ mm of Hg} = \frac{1}{760} \times 850\, atm$$

= 1.12 atm

**(b) 205000 Pa to atm:**

101325Pa = 1atm

$$1\text{Pa} = \frac{1}{101325} atm$$

$$205000\text{Pa} = \frac{1}{101325} \times 205000 \text{ atm}$$

= 2.02 atm

**(c) 560 torr to cm Hg:**

760 torr = 760 mm of Hg

= 76 cm of Hg

$$1 \text{ torr} = \frac{76}{760} \text{cm of Hg}$$

$$560 \text{ torr} = \frac{76}{760} \times 560 cm \text{ of } Hg$$

= 56 cm of Hg

**(d) 1.25 atm to Pa:**

1 atm = 101325Pa

1.25 atm = 1.25×101325Pa

= 126656 Pa

---

**2. Convert the following units.** ***(U.B+A.B)***

**(a) 750°C to K** **(b) 150°C to K**

**(c) 100 K to °C** **(d) 172 K to °C**

**Solution:**

**(a) 750°C to K:**

T (°C) = 750 °C

T (K) = ?

T (K) = T(°C)+ 273

= 750 + 273

= 1023K

**(b) 150°C to K:**

T(°C) = 150 °C

T (K) = ?

T (K) = T(°C) + 273

= 150 + 273

= 423K

**(c) 100 K to °C:**

T (K) = 100 K

T (°C) = ?

T(°C) = T(K) – 273.15

= 100 – 273

= –173°C

**(d) 172 K to °C:**

T (K) = 172 K

T (°C) = ?

T(°C) = T(K) – 273

= 172 – 273

= – 101°C

---

**3. A gas at pressure 912 mm of Hg has volume 450cm³? What will be its volume at 0.4 atm?** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

$$\text{Initial pressure} = P_1 = 912 \text{ mm Hg} = \frac{912 \text{ mm Hg}}{760 \text{ mm Hg}}$$

= 1.2 atm

Initial volume of gas = $V_1$ = 450 $cm^3$

Final pressure of gas = $P_2$ = 0.4 atm

**To Find:**

Volume of gas at 0.4 atm. = $V_2$ = ?

**Calculations:**

Using the equation of Boyle's Law:

$$P_1V_1 = P_2V_2$$

**Solution:**

By putting the values:

$$1.2 \text{ atm} \times 450 \text{ cm}^3 = 0.4 \text{ atm} \times V_2$$

$$V_2 = \frac{1.2\text{atm} \times 450\text{cm3}}{0.4\text{atm}}$$

$$V_2 = 3 \times 450 \text{ cm}^3$$

$$V_2 = 1350 \text{ cm}^3$$

**Result:**

**The volume of gas at 0.4 atm is 1350 cm³.**

**4. A gas occupies a volume of 800 $cm^3$ at 1 atm, when it is allowed to expand up to 1200 $cm^3$ what will be its pressure in mm of Hg.** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

Initial pressure of gas = $P_1$ =1 atm
Initial volume of gas = $V_1$ = 800 $cm^3$
Final volume of gas = $V_2$ = 1200 $cm^3$

**To Find:**

Final pressure of gas = $P_2$ = ?

**Calculations:**

Using the equation of Boyle's Law:

$$P_1V_1 = P_2V_2$$

By putting the values:

$$1\text{ atm} \times 800\text{ cm}^3 = P_2 \times 1200\text{ cm}^3$$

$$P_2 = \frac{1\text{ atm} \times 800\text{ cm}^3}{1200\text{ cm}^3}$$

$$P_2 = \frac{2}{3}\text{ atm}$$

$$P_2 = 0.667\text{ atm}$$

As 1 atm = 760mmHg

So 0.66 atm = 760×0.66mmHg
= 506.66mmHg

**Result:**

**The pressure of gas at 1200 $cm^3$ volume is 506.66 mm of Hg.**

---

**5. It is desired to increase the volume of a fixed amount of gas from 87.5 to 118 $cm^3$ while holding the pressure constant. What would be the final temperature if the "initial temperature is 23°C.*(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

Initial volume of gas = $V_1$ = 87.5 $cm^3$
Final volume of gas = $V_2$ = 118 $cm^3$
Initial temperature of gas = $T_1$ = 23°C
= (23+273) K
= 296K

**To Find:**

Final temperature of gas = $T_2$ = ?

**Calculations:**

By using the equation of Charles's Law:

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

$$T_2V_1 = V_2 \times T_1$$

Or

$$T_2 = \frac{V_2T_1}{V_1}$$

By putting the values

$$T_2 = \frac{118\text{cm}^3 \times 296\text{K}}{87.5\text{ cm}^3}$$

$$T_2 = 399\text{K}$$

$T_2$ can be converted into Celsius scale as:

$$T_2 = 299 – 273 = 126^oC$$

**Result:**

**Final temperature of gas is 126°C.**

---

**6. A sample of gas is cooled at constant pressure from 30°C to 10°C. Comment:** ***(U.B+A.B)***

**a. Will the volume of the gas decrease to one third of its original volume?**

**b. If not, then by what ratio will the volume decrease?**

**NUMERICAL**

**Solution:**

**Given Data:**

**a.**

Initial temperature of gas = $T_1$ = 30°C
= (30+273) K
= 303K
Final temperature of gas = $T_2$ = 10°C
= (10+273)K
= 283K
Initial volume of gas = $V_1$ = 1 $dm^3$

**To Find:**

Final volume of gas = $V_2$ = ?
Ratio of volume decreases = ?

**Calculations:**

By using the equation of Charles's Law:

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

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

$$V_2 = \frac{V_1}{T} \times T_2$$

By putting the values:

$$V_2 = \frac{1\text{dm}^3}{303\text{K}} \times 283\text{K}$$

$$V_2 = 0.93\text{dm}^3$$

**Results:**

**(a) The volume of gas will not decrease to one third of its original volume.**

**(b) The volume decreases in the ratio 1:0.93.**

**7. A balloon that contains 1.6 $dm^3$ of air at standard temperature and pressure is taken under water to a depth at which its pressure increases to 3.0 atm. Suppose that temperature remain unchanged, what would be the new volume of the balloon. Does it contract or expand?** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

Initial pressure of balloon = $P_1$ = 1 atm
Balloons contain air = $V_1$= 1.6 $dm^3$
Final pressure of balloon = $P_2$ = 3.0 atm

**To Find:**

New volume of balloon = $V_2$ = ?

**Calculations:**

By using the equation of Boyle's Law:

$$P_1V_1 = P_2V_2$$

By putting the values

$$1 \text{ atm} \times 1.6 \text{ dm}^3 = 3 \text{ atm} \times V_2$$

$$V_2 = \frac{1 \text{ atm} \times 1.6 \text{ dm}^3}{3 \text{ atm}}$$

$$V_2 = 0.53 \text{ dm}^3$$

**Result:**

- **The new volume of balloon is 0.53 $dm^3$.**
- **The gas will contract**

---

**8. A sample of neon gas occupies 75.0 $cm^3$ at very low pressure of 0.4 atm. Assuming temperature remain constant what would be the volume at 1.0 atm pressure?** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

Initial pressure of neon = $P_1$ = 0.4 atm
Initial volume of neon = $V_1$ = 75.0 $cm^3$
Final pressure of neon = $P_2$ = 1 atm

**To Find:**

Volume of neon at 1.0 atm. =$V_2$ = ?

**Calculations:**

By using the equation of Boyle's Law:

$$P_1V_1 = P_2V_2$$

By putting the values

$$0.4 \text{ atm} \times 75 \text{ cm}^3 = 1 \text{ atm} \times V_2$$

$$V_2 = \frac{0.4 \text{ atm} \times 75 \text{ cm}^3}{1 \text{ atm}}$$

$$V_2 = 30 \text{ cm}^3$$

**Result:**

**Thus at 1 atm pressure the volume of neon is 30 $cm^3$.**

**9. A gas occupies a volume of 35.0 $dm^3$ at 17°C. If the gas temperature rises to 34°C at constant pressure, would you expect the volume to double? If not calculate the new volume.** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

Initial temperature of gas = $T_1$ = 17 °C
= 273 + 17 = 290 K
Initial volume of gas =$V_1$ = 35 $dm^3$
Final temperature of gas =$T_2$ = 34 °C
= 273 + 34 = 307 K

**To Find:**

New volume of gas = $V_2$ = ?

**Calculations:**

By using the equation of Charles's Law:

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

By putting the values:

$$\frac{35 \text{ dm}^3}{290 \text{ K}} = \frac{V_2}{307 \text{ K}}$$

$$V_2 = \frac{35 \text{ dm}^3 \times 307 \text{ K}}{290 \text{ K}}$$

$$V_2 = 37 \text{ dm}^3$$

**Result:**

- **Volume will not be doubled because the absolute temperature is not doubled**
- **New volume of gas is 37 $dm^3$.**

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**10. The largest moon of Saturn, is Titan. It has atmospheric pressure of 1.6xl0$^5$ Pa. What is the atmospheric pressure in atm? Is it higher than Earth's atmospheric pressure?** ***(U.B+A.B)***

**NUMERICAL**

**Solution:**

**Given Data:**

The atmospheric pressure of Titan = $1.6 \times 10^5$ Pa

**To Find:**

Atmospheric pressure in atm = ?

**Calculations:**

We know that,

1atm = 101325 Pa

Atmospheric pressure of Titan in Pascal
= $1.6\times10^5$Pa.

Atmospheric pressure of Titan in atm.

$$= \frac{1.6\times10^5}{101325}$$

= 1.58 atm

**Result:**

**Thus the atmosphere pressure of Titan (1.58 atm) is greater than the atmospheric pressure of Earth (1.0atm).**

# ADDITIONAL CONCEPTUAL QUESTIONS

**Q.1 Why the densities of gases are lower than that of liquids?** ***(U.B)***

**Ans:** **DENSITY OF GASES AND LIQUIDS**

Gases have lower densities than densities of liquid. It is due to the light mass and more volume occupied by the gases. Another reason for lower densities of gases is negligible intermolecular forces among the gas molecules. On the other hand, liquid molecules are closely packed and have strong intermolecular forces.

**Q.2 What is molar heat of evaporation**

**Ans:** **MOLAR HEAT OF EVAPORATION**

*"The **amount of heat required to convert 1 mole of a liquid into gaseous state under standard conditions of temperature and pressure** is called molar heat of evaporation".*

**Q.3 Why does tea get cool in saucer quickly then in a tea cup?** ***(U.B)***

**Ans:** Evaporation increases with increase of surface area. Since surface area of saucer is greater than the surface area of a tea cup, evaporation from a saucer is more than a tea cup and tea gets cool down quickly.

**Q.4 Why does hot water evaporate quickly than cold water?** ***(U.B)***

**Ans:** Evaporation increases with increase of temperature that is why hot water evaporates quickly than cold water.

**Q.5 Why hexane ($C_6H_{14}$) has more vapour pressure than decane ($C_{10}H_{22}$)?** ***(U.B)***

**Ans:** Hexane has small sized molecule as and has weak intermolecular forces as compared to decane. There hexane a evaporates quickly and exerts more pressure than decane.

**Q.6 Why drops of rain fall downward?** ***(U.B)***

**Ans:** Density of **water** is **1.0 g $cm^{-3}$** while that of **air** is **0.001 g $cm^{-3}$** that is the reason why **drops of rain fall downward**.

**Q.7 Why the densities of liquids are high?** **(GRW 2014)*(U.B)***

**Ans:** **HIGH DENSITY OF LIQUID**

The liquid molecules have strong intermolecular forces hence they cannot expand freely and have a fixed volume. Like gases, they cannot occupy all the available volume of the container that is the reason why densities of liquids are high.

**Q.8 Write two properties of liquid state of water.** **(GRW 2016 G-II)*(K.B)***

**Ans:** **PROPERTIES OF LIQUID STATE OF WATER**

- The liquid state of matter has indefinite shape but definite volume
- The attractive forces between particles are stronger than that of gases but weaker than that of solids.

**Q.9 Why kerosene oil floats over water and honey settles down?** **(GRW 2017)*(U.B)***

**Ans:** **FLOATS OVER WATER AND HONEY SETTLES DOWN**

The kerosene oil floats over water because its density is lower than that of water whereas honey settles down due to its higher density than water.

## TERMS TO KNOW

| Terms | Definitions |
|---|---|
| **Diffusion** | *"The* ***spontaneous mixing up of molecules by random motion and collisions to form a homogeneous mixture*** *is called diffusion".* |
| **Effusion** | *"It is* ***escaping of gas molecules through a tiny hole into a space with lesser pressure****".* |
| **Pressure** | *"The* ***force (F) exerted per unit surface area (A)*** *is called pressure".* |
| **Strandard Atmospheric Pressure** | *"It is defined as the* ***pressure exerted by a mercury column of 760 mm height at sea level****. It is* ***sufficient pressure to support a column of mercury 760mm in height at sea level****".* |
| **Compressibility** | Gases are **highly compressible due to empty spaces** between their molecules. When the gases are compressed, the molecules come closer to one another and occupy less volume as compared to the volume in uncompressed state. |
| **Boyle's law** | *"The* ***volume of a given mass of a gas is inversely proportional to its pressure*** *provided the* ***temperature remains constant****".* |
| **Charle's law** | *"The* ***volume of a given mass of a gas is directly proportional to the absolute temperature*** *if the* ***pressure is kept constant****".* |
| **Evaporation** | *"The process of* ***changing of a liquid into a gas phase*** *is called evaporation".* |
| **Vapour Pressure** | *The* ***pressure exerted by the vapours of a liquid at equilibrium with the liquid at*** *a* ***particular temperature*** *is called vapour pressure of a liquid.* |
| **Boiling Point** | *"The* ***temperature at which the vapour pressure of a liquid becomes equal to the atmospheric pressure or any external pressure*** *is called boiling point".* |
| **Freezing point** | *"The* ***temperature at which vapour pressure of a liquid state becomes equal to the vapour pressure of the solid state and liquid and solid coexist in dynamic equilibrium*** *is called freezing point".* |
| **Melting point** | *"The* ***temperature at which the solid starts melting and coexists in dynamic equilibrium with liquid state*** *is called melting point".* |
| **Amorphous solids** | Solids in which the particles are not regularly arranged or their regular shapes are destroyed, are called amorphous solids. |
| **Crystalline solids** | Solids in which particles are arranged in a definite three dimensional pattern are called crystalline solids. |
| **Allotropy** | *"The* ***existence of an element in more than one form, in same physical state*** *is called allotropy".* |
| **Transition Temperature** | *"The* ***temperature at which one allotrope changes into another*** *is called transition temperature".* |

## SELF TEST

**Time: 35 Minutes** **Marks: 25**

**Q.1 Four possible answers (A), (B), (C) and (D) to each question are given, mark the correct answer. (6×1=6)**

**1. Boiling point of alcohol is:**

(A) 58ºC (B) 87ºC (C) 78ºC (D) 68ºC

**2. At some temperature which of the following will have high vapour pressure:**

(A) Deithyl Ether (B) Alcohol (C) Water (D) Honey

**3. Which one of the following gases will diffuse faster?**

(A) Oxygen (B) Fluorine (C) Nitrogen (D) Chlorine

**4. Transition temperature of tin is:**

(A) 12.3ºC (B) 13.2ºC (C) 96ºC (D) 250ºC

**5. Density of Iron is:**

(A) $2.70 gcm^{-3}$ (B) $7.86 gcm^{-3}$ (C) $19.3 gcm^{-3}$ (D) $8.76 gcm^{-3}$

**6. When volume of a gas increased two times its pressure becomes:**

(A) Double (B) Four times (C) Half (D) Zero

**Q.2 Give short answers to the following questions. (5×2=10)**

**(i)** Differentiate between Diffusion and Effusion.

**(ii)** Why gases are highly compressible?

**(iii)** Can you cool a gas by increasing its volume.

**(iv)** Define the term Allotropy with example.

**(v)** Why does evaporation increase with increase of temperature.

**Q.3 Answer the following questions in detail. (5+4=9)**

(i) Define Boyle's law and verify with an example. (5)

(ii) Define Evaporation. Explain factor affecting evaporation. (4)

**Note:**

Parents or guardians can conduct this test in their supervision in order to check the skill of students.