STEPPING STONE SCHOOL (HIGH)

CLASS :IX

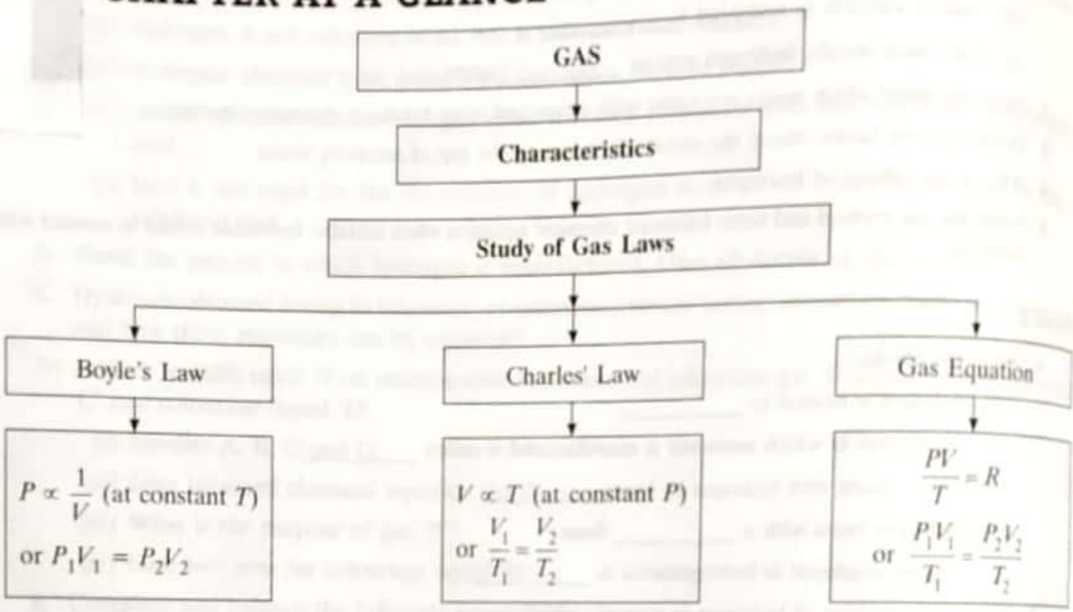
Subject:Chemistry **Date:02/06/2020**

Topic:Study of gas laws **Time Limit:40 min.**

Worksheet No. 7

Study of Gas Laws

CHAPTER AT A GLANCE



IMPORTANT TERMS AND DEFINITIONS

1. **Matter:** Anything that has weight and occupies space is called matter. Gas is also a matter or we can say that gas is a state of matter.
2. **States of Matter:** There are three states of matter.
   (*i*) Solid (*ii*) Liquid (*iii*) Gas.
3. **Comparison in the properties of solid, liquid and gas.**

Solid	*Liquid*	*Gas*
(*i*) Solids have definite shape and definite volume.	(*i*) Liquids have no definite shape. They take the shape of the container but they have definite volume.	(*i*) Gases have neither definite shape nor definite volume.
(*ii*) In solids, the molecules are closely packed.	(*ii*) In liquids, the molecules are loosely packed.	(*ii*) In gases, the molecules are far apart from each other.
(*iii*) In solids, the intermolecular space is minimum.	(*iii*) In liquids, the intermolecular space is more than solids.	(*iii*) In gases, the intermolecular space is maximum.

(iv) In solids, the intermolecular force of attraction is maximum.	(iv) In liquids, the intermolecular force of attraction is less than solids.	(iv) In gases, the intermolecular force of attraction is minimum or negligible.
(v) Solids cannot flow.	(v) Liquids flow from higher level to lower level.	(v) Gases flow freely in all directions.

4. **Characteristics of Gases:** The general characteristics of gases can be explained on the basis of **kinetic theory of gases** as follows:

(i) **Gases have neither definite shape nor definite volume:** The molecules in gases are far apart from each other, therefore, intermolecular force of attraction is minimum and hence gases occupy the entire space in the container.

(ii) **Gases are highly compressible:** As the gases have maximum intermolecular space, therefore, on compressing, the gas molecules come closer to each other and thereby decreasing the volume.

(iii) **Gases have minimum density:** As gases have the smallest mass per unit volume, therefore, they have the minimum density.

(iv) **Gases easily undergo diffusion:** Gases readily undergo intermixing when kept in contact with each other to form homogeneous mixture as they have maximum intermolecular spaces.

5. **Gas Laws:** Gas laws describe the behaviour of a gas under the conditions of pressure, temperature and volume.

The variables used during gas laws are the pressure (P), temperature (T) and volume (V).

(i) **Units of Temperature:**

(a) Celsius (°C) (b) Kelvin (K)

Relationship between Celsius and kelvin:

$$K = °C + 273$$

$$°C = K - 273$$

For example; Conversion of temperature on the Celsius scale to the Kelvin scale:

(a) 0 °C = 0 + 273 = 273 K (b) –273 °C = –273 + 273 = 0 K

(c) 100 °C = 100 + 273 = 373 K (d) 200 °C = 200 + 273 = 473 K

(ii) **Units of Volume:**

(a) Millilitre (mL) (b) Cubic centimetre (cm^3)

(c) Litre (L)

Relationship between litre, millilitre and cubic centimetre:

$$1 \text{ litre} = 1000 \text{ mL} = 1000 \text{ cm}^3$$

$$1 \text{ mL} = 1 \text{ cm}^3$$

(iii) **Units of Pressure:**

(a) Atmosphere (atm) (b) cm of Mercury (Hg) (cm of Hg)

(c) mm of Mercury (Hg) (mm of Hg)

Relationship between Atmosphere and Mercury:

1 atmosphere = 76 cm of Hg = 760 mm of Hg = 760 of Hg

6. **Boyle's law:** Boyle's law states that at constant temperature, the volume of a given mass of a dry gas is inversely proportional to pressure.

$$V \propto \frac{1}{P} \quad \text{(at constant } T\text{)}$$

where V = Volume of the dry gas, P = Pressure on the gas

$\Rightarrow \quad V = K \frac{1}{P}$ (where K is constant)

$\Rightarrow \quad PV = K$

Hence, **Boyle's law equation** is $P_1 V_1 = P_2 V_2$

where P_1 = Initial pressure, V_1 = Initial volume, P_2 = Final pressure, V_2 = Final volume

7. Charles' law

Pressure of an enclosed mass of a dry gas remaining constant, the volume of the gas is directly proportional to absolute temperature. This law is known as Charles' law.

$$V \propto T$$ (at constant P)

where V = Volume of the dry gas and T = Temperature of the gas

$\Rightarrow \quad V = KT$ (where K is constant)

$\Rightarrow \quad \frac{V}{T} = K$

Hence, **Charles' law equation** is $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

where V_1 = Initial volume, V_2 = Final volume, T_1 = Initial temperature, T_2 = Final temperature

8. **Kelvin Scale:** The new temperature scale on which the zero is at – 273 °C, such that each degree on it is equal to one degree on the Celsius is called **the Kelvin scale**.
9. **Absolute zero:** It is the last or the lowest limit of temperature at which the volume becomes theoretically zero. The temperature for absolute zero is – 273 °C.
10. The standard temperature is 0 °C or 273 K.
11. The standard pressure is 760 mm of Hg or 76 cm of Hg or 1 atmosphere.
12. **Gas Equation:** By combining Boyle's law and Charles' law, the perfect gas equation can be derived as follows:

According to Boyle's law

$$V \propto \frac{1}{P} \quad ...(i)$$

According to Charles' law

$$V \propto T \quad ...(ii)$$

Combining Boyle's law (*i*) and Charles' law (*ii*), we get

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

$\Rightarrow \quad V \propto \frac{T}{P}$

$\Rightarrow \quad V = K \frac{T}{P}$

$\Rightarrow \quad \frac{PV}{T} = K$ (where K is constant)

Hence, **Perfect Gas Equation** is $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

where P_1 = Initial pressure, P_2 = Final pressure, V_1 = Initial volume, V_2 = Final volume, T_1 = Initial temperature, T_2 = Final temperature.

SOLVED QUESTIONS

Q.1. At constant temperature a gas occupies a volume of 2000 cm^3 at a pressure of 740 mm of mercury. Find at what pressure its volume will be 500 cm^3.

Ans. Initial volume of the gas, V_1 = 2000 cm^3

Initial pressure of the gas, P_1 = 740 mm Hg

Final volume of the gas, V_2 = 500 cm^3

Final pressure of the gas, P_2 = ?

$\therefore$ According to Boyle's law, $P_1V_1 = P_2V_2$

$\Rightarrow$ $740 \times 2000 = P_2 \times 500$

$\Rightarrow$ $P_2 = \frac{2000 \times 740}{500} = 2960$ mm Hg.

Q.2. A gas occupies the initial volume of 400 cm^3 at a pressure Z. If the pressure is changed to 5 atmosphere, the volume of the gas was found to be 200 cm^3. Calculate the value of Z.

Ans. Given, $P_1 = Z$, $P_2 = 5$ atm, $V_1 = 400$ cm^3, $V_2 = 200$ cm^3

$\therefore$ Using Boyle's law, $P_1 V_1 = P_2 V_2$

$\Rightarrow$ $Z \times 400 = 5 \times 200$

$\Rightarrow$ $Z = \frac{5 \times 200}{400} = 2.5$ atm

Q.3. Calculate the pressure of 2.5 litre of dry hydrogen gas, if it occupies a volume of 3 litres at 1.2 atmosphere. Assume that the temperature remains constant.

Ans. Here, $P_1 = ?$, $V_1 = 2.5$ litres, $P_2 = 1.2$ atm, $V_2 = 3.0$ litres

Now, $P_1 V_1 = P_2 V_2$

$\Rightarrow$ $P_1 \times 2.5 = 1.2 \times 3.0$

$\Rightarrow$ $P_1 = \frac{1.2 \times 3.0}{2.5} = 1.44$ atm

Q.4. At constant temperature, a gas is at a pressure of 540 mm of mercury. At what pressure its volume decreases by 60%.

Ans. Let the initial volume of gas $(V_1) = x$

$\therefore$ 60% of initial volume $= \frac{60}{100}x = 0.6x$

$\therefore$ The final volume of gas $(V_2) = x - 0.6x = 0.4x$

The initial pressure of gas (P_1) = 540 mm Hg

Final pressure of gas (P_2) = ?

$\therefore$ $P_1 V_1 = P_2 V_2$

$\Rightarrow$ $P_2 = \frac{P_1V_1}{V_2} = \frac{540 \times x}{0.4\,x} = 1350$ mm Hg

Q.5. The volume of certain gas was found 400 cm^3, when pressure was 520 mm of Hg. If the pressure is increased by 30%, find the new volume of the gas.

Ans. Initial volume of gas, V_1 = 400 cm^3

Initial pressure of gas, P_1 = 520 mm Hg

30% of initial pressure $= 520 \times \frac{30}{100} = 156$ mm Hg

$\therefore$ Final pressure, $P_2 = 156 + 520 = 676$ mm Hg

Final volume of gas, $V_2 = ?$

Now,

$$P_1 V_1 = P_2 V_2$$

$\Rightarrow$ $$520 \times 400 = 676 \times V_2$$

$\Rightarrow$ $$V_2 = \frac{520 \times 400}{676} = 307.69 \text{ cm}^3.$$

Q.6. The volume occupied by a certain gas was found 5.6 dm^3 when the pressure was 2 atmosphere. If the pressure is increased by 20%, find the new volume of the gas.

Ans. Initial volume of gas, $V_1 = 5.6$ dm^3

Initial pressure of gas, $P_1 = 2$ atm

20% of initial pressure $= 2 \times \frac{20}{100} = \frac{4}{10} = 0.4$

$\therefore$ Final pressure, $P_2 = 0.4 + 2 = 2.4$ atm

Final volume, $V_2 = ?$

$\therefore$ $$P_1 V_1 = P_2 V_2$$

$\Rightarrow$ $$2 \times 5.6 = 2.4 \times V_2$$

$\Rightarrow$ $$V_2 = \frac{5.6 \times 2}{2.4} = 4.67 \text{ dm}^3$$

Q.7. 100 cm^3 of a gas at 27 °C is cooled to 20 °C at constant pressure. Calculate the volume of gas at 20 °C.

Ans. Initial volume $(V_1) = 100$ cm^3

Initial temperature $(T_1) = 27 + 273 = 300$ K

Final volume $(V_2) = ?$

Final temperature $(T_2) = 20 + 273 = 293$ K

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

$\Rightarrow$ $$\frac{100}{300} = \frac{V_2}{293}$$

$\Rightarrow$ $$V_2 = \frac{100 \times 293}{300} = 97.67 \text{ cm}^3$$

Q.8. Hydrogen gas occupies a volume of 400 cm^3 at a temperature of 27 °C and normal atmospheric pressure. Find the volume of the gas at 10 °C at constant pressure.

Ans. Initial volume $(V_1) = 400$ cm^3

Initial temperature $(T_1) = 27 + 273$ K $= 300$ K

Final volume $(V_2) = ?$

Final temperature $(T_2) = 10 + 273 = 283$ K

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

$\Rightarrow$ $$\frac{400}{300} = \frac{V_2}{283}$$

$\Rightarrow$ $$V_2 = \frac{400 \times 283}{300} = 377.33 \text{ cm}^3$$

Q.9. Carbon dioxide occupies a volume of 336 cm³ at S.T.P. Find its volume at 20 °C and at a pressure of 700 mm Hg.

Ans. Given, $P_1 = 760$ mm Hg, $P_2 = 700$ mm Hg, $V_1 = 336\ cm^3$, $V_2 = ?$, $T_1 = 273$ K,
$T_2 = 20 + 273 = 293$ K

According to Perfect Gas equation

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\Rightarrow \quad \frac{760 \times 336}{273} = \frac{700 \times V_2}{293}$$

$$\therefore \quad V_2 = \frac{760 \times 336 \times 293}{273 \times 700}$$

$$\Rightarrow \quad V_2 = \frac{74820480}{191100} = 391.525\ cm^3.$$

Q.10. 2.5 dm³ of dry nitrogen gas is collected at a temperature of 27 °C and a pressure of 740 mm Hg. Find the volume of gas at S.T.P.

Ans. Given, $P_1 = 740$ mm Hg, $P_2 = 760$ mm Hg, $V_1 = 2.5\ dm^3$, $V_2 = ?$, $T_1 = 27 + 273$ K $= 300$ K,
$T_2 = 273$ K

$$\therefore \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\Rightarrow \quad \frac{740 \times 2.5}{300} = \frac{760 \times V_2}{273}$$

$$\Rightarrow \quad V_2 = \frac{740 \times 2.5 \times 273}{760 \times 300}$$

$$\Rightarrow \quad V_2 = \frac{505050}{228000} = 2.215\ dm^3$$

Q.11. 6 dm³ of a dry gas at temperature of 27 °C has pressure of 700 mm Hg. Find the volume of ga[s] at S.T.P.

Ans. Given: $P_1 = 700$ mm Hg, $P_2 = 760$ mm Hg, $V_1 = 6\ dm^3$, $V_2 = ?$, $T_1 = 27 + 273$ K $= 300$ K
$T_2 = 273$ K

$$\therefore \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\Rightarrow \quad \frac{700 \times 6}{300} = \frac{760 \times V_2}{273}$$

$$\Rightarrow \quad V_2 = \frac{700 \times 6 \times 273}{300 \times 760} = \frac{1146600}{228000} = 5.03\ dm^3.$$

Q.12. Moist nitrogen at a pressure of 700 mm Hg and temperature 27 °C is found to occupy a volu[me] of 100 cm³. Find the volume of dry nitrogen gas at S.T.P. (Aqueous tension at 27 °C is 15 mm H[g])

Ans. Given: $P_1 = 700 - 15 = 685$ mm Hg, $P_2 = 760$ mm Hg, $V_1 = 100\ cm^3$, $V_2 = ?$,
$T_1 = 27 + 273 = 300$ K, $T_2 = 273$ K

$$\therefore \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\Rightarrow \quad \frac{685 \times 100}{300} = \frac{760 \times V_2}{273}$$

$$\Rightarrow \quad V_2 = \frac{685 \times 100 \times 273}{300 \times 760} = \frac{187005}{2280} = 82.01 \text{ cm}^3.$$

Q.13. Convert the following temperature (in °C) to the Kelvin temperature.

(*i*) –100 °C (*ii*) 273 °C (*iii*) 20 °C (*iv*) 5 °C (*v*) 10 °C

Ans. (*i*) 173 K (*ii*) 546 K (*iii*) 293 K (*iv*) 278 K (*v*) 283 K

Q.14. State Boyle's law. What happens when pressure in doubled?

Ans. At constant temperature, pressure of a gas is inversely proportional to the volume.

$$P \propto \frac{1}{V} \quad \text{(At constant } T\text{)}$$

or

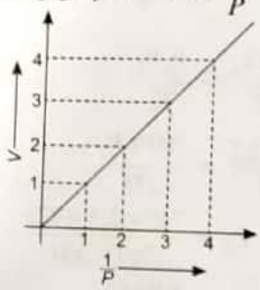
$$P = K \cdot \frac{1}{V}$$

$$\Rightarrow \quad PV = K$$

When pressure is doubled, then volume becomes half.

Q.15. Plot a graph showing the verification of Boyle's law.

Ans. Boyle's law can be verified by plotting graph of V vs. $\frac{1}{P}$.



Q.16. A gas occupies 400 cm³ under 760 mm Hg pressure. Find under what pressure the gas will occupy 380 cm³, the temperature remains constant.

Ans. Given, $P_1 = 760$ mm Hg, $V_1 = 400$ cm³, $P_2 = ?$, $V_2 = 380$ cm³.

Using Boyle's law, $P_1 V_1 = P_2 V_2$

$$\Rightarrow \quad 760 \times 400 = P_2 \times 380$$

$$\Rightarrow \quad P_2 = \frac{760 \times 400}{380} = 800 \text{ mm Hg.}$$

∴ The required pressure is 800 mm Hg or 80 cm Hg.

Q.17. Each question has four options, out of which only one option is correct. Write the correct option.

(*i*) According to Boyle's law, as the pressure increases volume

(*a*) increases **(*b*) decreases**

(*c*) remains same **(*d*) first increases and then decreases.**

(*ii*) According to Charles' law, volume of a dry gas is directly proportional to

(*a*) pressure **(*b*) absolute temperature**

(*c*) Both of these **(*d*) None of these**

(*iii*) The standard pressure is

(*a*) 760 mm Hg **(*b*) 760 cm Hg**

(*c*) 760 cm³ Hg **(*d*) None of these**

(*iv*) **The standard temperature is**

(*a*) **273 °C** (*b*) **273 K**

(*c*) **Both of these** (*d*) **None of these**

(*v*) **The temperature for absolute zero is**

(*a*) **–273 °C** (*b*) **–270 °C**

(*c*) **–273 K** (*d*) **–270 K**

Ans. (*i*) (*b*) (*ii*) (*b*) (*iii*) (*a*) (*iv*) (*b*) (*v*) (*a*)

Q.18. Account how temperature and molecular motion are inter-related?

Ans. As the temperature increases the molecules gain K.E. (kinetic energy) and start moving faster.

Q.19. Convert: (*i*) 285 °C in kelvin (*ii*) 365 K in °C.

Ans. (*i*) 285 + 273 = 558 K

(*ii*) 365 – 273 = 92 °C.

Q.20. Discuss the relationship between kelvin and Celsius scales of temperature?

Ans. K = °C + 273.

Q.21. What is S.T.P. or N.T.P. and what are its values?

Ans. It is the standard or normal condition of temperature and pressure.

Temperature = 273 K

Pressure = 760 mm Hg or 76 cm Hg.

Q.22. Define the behaviour of gases in terms of molecular motion?

Ans. The molecules of gases are far apart from each other, therefore, the intermolecular force of attraction is minimum or negligible. Hence the molecules move in all possible directions.

Q.23. Why pressure and temperature should be given while providing the volume of a gas?

Ans. Volume is inversely related to pressure and directly related to absolute temperature.

Q.24. State your answer.

(*a*) **Gases are highly compressible.**

(*b*) **Pressure cookers are widely used in hilly areas.**

(*c*) **Pressure is exerted by gas in all direction.**

(*d*) **Gases easily under go diffusion.**

(*e*) **Solids and liquids have higher density compared to gases.**

(*f*) **Gases have neither definite shape nor definite volume.**

Ans. (*a*) In the case of gases, the molecules are far apart from each other, therefore, the intermolecular space is maximum thus, gases can be compressed.

(*b*) As on higher altitudes or in hilly areas, the pressure decreases. So, the boiling point of the liquid decreases, therefore, pressure cooker is used for cooking of food.

(*c*) The molecules of gases move randomly in all possible directions, thus exerting pressure as pressure is defined as force acting per unit area. Hence pressure of a gas or its impact can be recorded on the walls of container per unit area.

(*d*) It is so because gases have maximum intermolecular space.

(*e*) In case of solids, the molecules are closely packed. In the case of liquids, the molecules are loosely packed, whereas in gases, the molecules are far apart from each other. Thus, it is observed that the molecules per unit volume decrease and hence the density also decreases.

(*f*) In the case of gases, the intermolecular space is maximum and intermolecular force of attraction is minimum or negligible. Hence the molecules do not experience any kind of attraction, therefore, they neither have definite shape nor definite volume.

Q.25. Convert the following in Celsius:

(*a*) **287 K** (*b*) **33 K** (*c*) **185 K** (*d*) **368 K**

Ans. (*a*) 287 – 273 = 14 °C (*b*) 33 – 273 = –240 °C (c) 185 – 273 = –88 °C (*d*) 368 – 273 = 95 °C

PRACTICE QUESTIONS

1. Calculate the pressure of a gas, when its volume is 250 mL initially, the gas is expanded to volume of 1000 mL and the pressure of 0.4 atmosphere. The temperature during the reaction remains constant.

2. At a constant temperature, a gas at a pressure of 750 mm of mercury occupies a volume of 1000 cm^3. If volume is decreased by 40%, find the new pressure.

3. A gas is enclosed in a vessel at standard temperature. At what temperature, the volume of enclosed gas will be 1/6 of its initial volume, given that the pressure remains constant.

4. Match the following:

Column I	Column II
(*i*) Boyle's law	(*a*) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
(*ii*) Charles' law	(*b*) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
(*iii*) Perfect gas equation	(*c*) $P_1V_1 = P_2V_2$

5. Fill in the blanks.

(*i*) 1 Atmosphere = ________ cm Hg = ________ mm Hg.

(*ii*) 1 litre = ________ mL = ________ cm^3.

(*iii*) Normal temperature – 273 K = ________ °C.

(*iv*) Gases have ________ density.

(*v*) Gases have neither definite ________ nor definite ________.

6. A sample of a gas has a volume of 160 mL at a pressure of 864 mm Hg at a certain temperature. What will be the volume if the pressure is changed to 1440 mm Hg keeping temperature constant.

7. Convert the following temperature on the Kelvin Scale to the Celsius Scale.

(*i*) 150 K (*ii*) 335 K (*iii*) 250 K (*iv*) 100 K (*v*) 446 K

8. Convert the following in kelvin:

(*a*) 25 °C (*b*) 95 °C (*c*) 218 °C (*d*) –102 °C

9. The pressure of a gas at S.T.P. is tripled when temperature is raised to 546 °C. What will be the change volume?

10. Why Kelvin temperature is always positive?

11. Define diffusion.

12. Explain why absolute zero is a theoretical concept?

Self Evaluation Test

Level 1

1. State
   (*i*) Boyle's law
   (*ii*) Charles' law
2. Name the quantity which is constant in (*i*) Boyle's law (*ii*) Charles' law.
3. What will be the pressure required to reduce 600 mL of a dry gas at 750 mm pressure to 500 mL at the same temperature.
4. Match the following:

Column I (Temperature in Celsius)	Column II (Temperature in Kelvin)
(*i*) 0 °C	(*a*) 546 K
(*ii*) 273 °C	(*b*) 293 K
(*iii*) –273 °C	(*c*) 290 K
(*iv*) 20 °C	(*d*) 0 K
(*v*) 17 °C	(*e*) 273 K

Level 2

5. Write the value of standard pressure in
   (*i*) atm (*ii*) mm Hg (*iii*) cm Hg
6. The volume of a sample of gas is 12.5 mL at a pressure of 38 cm Hg. At what pressure will the volume be 7.5 mL, keeping temperature constant?
7. Convert the following temperature to kelvin.
   (*i*) 15 °C (*ii*) –200 °C
   (*iii*) 40 °C (*iv*) 25 °C
   (*v*) 173 °C
8. Convert the following temperature to Celsius.
   (*i*) 486 K (*ii*) 209 K
   (*iii*) 590 K (*iv*) 789 K
   (*v*) 150 K

Level 3

9. State absolute zero.
10. A 226 mL of oxygen gas is heated from 18.5 °C to 96 °C at constant pressure. Calculate the new volume o oxygen.
11. Gas 'A' occupies 55 mL at 91 °C and 6 atm. What will be the volume of the gas 'A' at S.T.P.?
12. Why does the size of a weather balloon become larger and larger as it ascends into higher space?
13. Kelvin scale has been majorly adopted for the chemical calculation. Why?
14. Write the importance of STP.