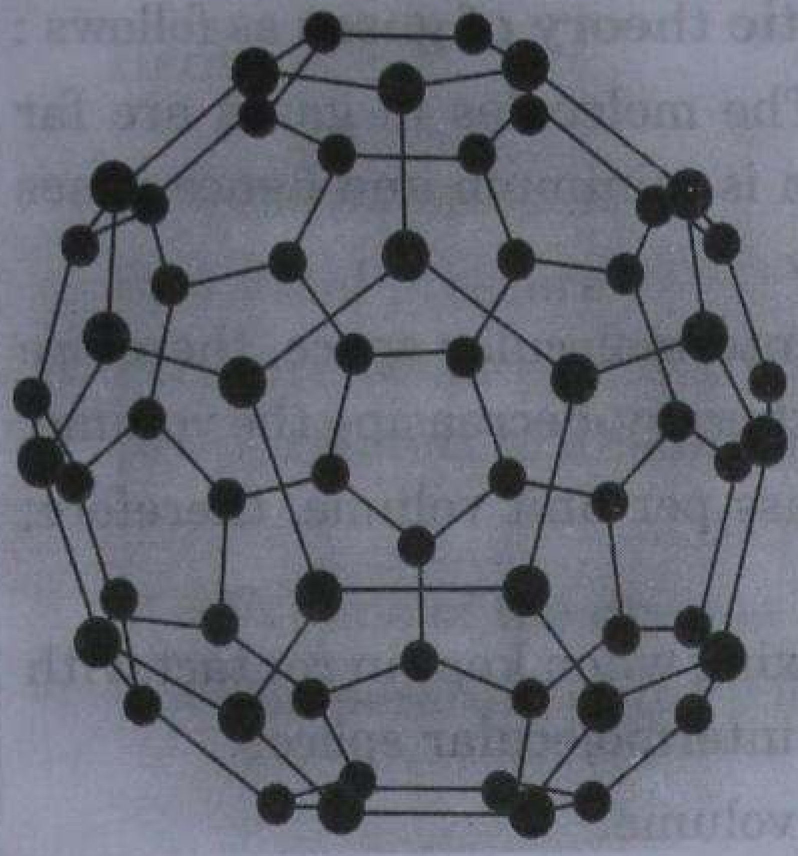

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STUDY OF GAS LAWS

SCOPE OF SYLLABUS

(i) The behaviour of gases under changes of temperature and pressure; explanation in terms of molecular motion (particles, atoms, molecules); Boyle's Law and Charles' Law; absolute zero; gas equation; simple relevant calculations.

The behaviour of gases under changes of temperature and pressure; explanation in terms of molecular motion (particles, atoms, molecules). Boyle's Law (statement, mathematical form, simple calculations).

Charles' Law; (statement, mathematical form, simple calculations). Absolute zero; Kelvin scale of temperature. Gas equation $P_1V_1/T_1 = P_2V_2/T_2$; simple relevant calculations based on gas equation.

(ii) Relationship between Kelvin Scale and Celsius Scale of temperature; Standard temperature and pressure.

Conversion of temperature from Celsius scale to Kelvin scale and vice versa. Standard temperature and pressure. (simple calculations)

IMPORTANT POINTS TO REMEMBER

1. Anything that has weight and occupies space is called **matter**.

2. 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. 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 the 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. The variables used during gas laws are the pressure, temperature and volume.

(i) **Units of Temperature**

(a) Celsius — °C

(b) Kelvin — K

(c) Normal temperature – 273 K = 0°C

Relationship between Celsius and Kelvin :

$$K = °C + 273$$

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 : 1 litre = 1000 ml = 1000 cm^3

1 ml = 1 cm^3

(iii) **Units of Pressure**

(a) Atmosphere — atm

(b) cm of Mercury (Hg) — cm Hg

(c) mm of Mercury (Hg) — mm Hg

Relationship between Atmosphere and Mercury :

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

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

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

V = Volume of the dry gas

P = Pressure on the gas

$$V = k\frac{1}{P} \quad \text{(where } k \text{ is constant)}$$

$$PV = k$$

Hence, $\boxed{\textbf{Boyle's law equation } P_1V_1 = P_2V_2}$

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

7. 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.**

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

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

$$V = kT \quad \text{(where } k \text{ is constant)}$$

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

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

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

8. 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** 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. **By combining Boyle's law and Charles' law the perfect gas equation can be derived as follows :**

According to Boyles' 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

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

$$V = k\frac{T}{P} \quad \Rightarrow \quad \frac{PV}{T} = k \quad \text{(where } k \text{ is constant)}$$

Hence, $\boxed{\textbf{Perfect gas equation } \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$

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

IMPORTANT QUESTIONS

Q1. 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, $P_2 = ?$

$$P_1V_1 = P_2V_2$$
$$740 \times 2000 = P_2 \times 500$$
$$P_2 = \frac{2000 \times 740}{500}$$
$$= 2960 \text{ mm Hg.}$$

Q2. 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. $P_1 = Z$ $\quad P_2 = 5$ atm

$V_1 = 400\ cm^3$ $\quad V_2 = 200\ cm^3$

$$P_1V_1 = P_2V_2$$
$$Z \times 400 = 5 \times 200$$
$$Z = \frac{5 \times 200}{400}$$
$$= 2.5 \text{ atm}$$

Q3. 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.

Ans. $P_1 = ?$ $\quad V_1 = 250$ ml

$P_2 = 0.4$ atm $\quad V_2 = 1000$ ml

$$P_1V_1 = P_2V_2$$
$$P_1 \times 250 = 0.4 \times 1000$$
$$P_1 = \frac{0.4 \times 1000}{250}$$
$$= 1.6 \text{ atm}$$

Q4. Calculate the pressure of 2.5 litre of dry hydrogen gas, if it occupies a volume of 3 litre at 1.2 atmosphere. Assume that the temperature remains constant.

Ans. $P_1 = ?$ $\quad V_1 = 2.5$ litre

$P_2 = 1.2$ atm $\quad V_2 = 3.0$ litre

$$P_1V_1 = P_2V_2$$
$$P_1 \times 2.5 = 1.2 \times 3.0$$
$$P_1 = \frac{1.2 \times 3.0}{2.5}$$
$$= 1.44 \text{ atm}$$

Q5. 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 $(V_1) = x$

$\therefore$ The 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 $(P_2) = ?$

$$P_1V_1 = P_2V_2$$
$$P_2 = \frac{P_1V_1}{V_2} = \frac{540 \times x}{0.4x}$$
$$= 1350 \text{ mm Hg}$$

Q6. 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.

Ans. $P_1 = 750$ mm Hg $\quad P_2 = ?$

$V_1 = 1000\ cm^3$

The 40% of initial volume $= \frac{40}{100} \times 1000$

$= 400\ cm^3$

$$V_2 = 1000 - 400 = 600\ cm^3$$
$$P_1V_1 = P_2V_2$$
$$750 \times 1000 = P_2 \times 600$$
$$P_2 = \frac{750 \times 1000}{600}$$
$$= 1250 \text{ mm Hg}$$

Q7. 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

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

Final pressure $P_2 = 156 + 520$

$= 676$ mm Hg

Final volume of gas $V_2 = ?$

$$P_1V_1 = P_2V_2$$

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

$$V_2 = \frac{520 \times 400}{676}$$

$$= 307.69 \text{ cm}^3.$$

Q8. 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

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

Final pressure $P_2 = 0.4 + 2 = 2.4$ atm

Final volume $V_2 = ?$

$$P_1V_1 = P_2V_2$$

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

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

Q9. 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

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

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

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

$$= 97.66 \text{ cm}^3$$

Q10. 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

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

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

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

Q11. 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.

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

Initial temperature of gas $(T_1) = 0°C$

$= 0 + 273$ K $= 273$ K

$$\text{Final volume } (V_2) = \frac{x}{6}$$

Final temperature $(T_2) = ?$

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

$$\frac{x}{273} = \frac{x}{6 \times T_2}$$

$$T_2 = \frac{273x}{6 \times x} = 45.5 \text{ K}$$

$$= 45.5 - 273$$

$$= -227.5°C.$$

Q12. Carbon dioxide occupies a volume of 336 cm^3 at S.T.P. Find its volume at 20°C and at a pressure of 700 mm Hg.

Ans. $P_1 = 760$ mm Hg $\quad P_2 = 700$ mm Hg

$V_1 = 336$ cm^3 $\quad V_2 = ?$

$T_1 = 273$ K $\quad T_2 = 20 + 273 = 293$ K

According to Perfect Gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

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

$$= \frac{74820480}{191100} = 391.525 \text{ cm}^3.$$

Q13. 2.5 dm^3 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. $P_1 = 740$ mm Hg $\quad P_2 = 760$ mm Hg

$V_1 = 2.5\ dm^3$ $\qquad V_2 = ?$

$T_1 = 27 + 273\ K = 300\ K$ $\qquad T_2 = 273\ K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

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

$$= \frac{505050}{228000} = 2.21 dm^3$$

Q14. 6 dm^3 of dry gas at temperature of 27°C and pressure of 700 mm Hg. Find the volume of gas at S.T.P.

Ans. $V_1 = 6\ dm^3$ $\qquad V_2 = ?$

$P_1 = 700$ mm Hg $\qquad P_2 = 760$ mm Hg

$T_1 = 27 + 273\ K = 300\ K$ $\qquad T_2 = 273\ K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

$$V_2 = \frac{700 \times 6 \times 273}{300 \times 760} = \frac{1146600}{228000}$$

$$= 5.02\ dm^3.$$

Q15. Moist nitrogen at a pressure of 700 mm Hg and temperature 27°C is found to occupy a volume of 100 cm^3. Find the volume of dry nitrogen gas at S.T.P.

(Aqueous tension at 27°C is 15 mm Hg)

Ans. $P_1 = 700 - 15 = 685$ mm Hg $\qquad P_2 = 760$ mm Hg

$V_1 = 100\ cm^3$ $\qquad V_2 = ?$

$T_1 = 27 + 273 = 300\ K$ $\qquad T_2 = 273\ K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

$$V_2 = \frac{685 \times 100 \times 273}{300 \times 760} = \frac{187005}{2280}$$

$$V_2 = 82.01\ cm^3.$$

Q16. Convert the following temperature (in °C) to the Kelvin temperature.

***(i)* –100°C** $\qquad$ ***(ii)* 273°C**

***(iii)* 20°C** $\qquad$ ***(iv)* 5°C**

***(v)* 10°C**

Ans. *(i)* 173 K $\qquad$ *(ii)* 546 K

(iii) 293 K $\qquad$ *(iv)* 278 K

(v) 283 K

LET'S RECALL

Fill Your Answer in the Space Given for Each Question.

Q1. Match the following :

A.

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

Ans. (*i*) ☐ (*ii*) ☐ (*iii*) ☐ (*iv*) ☐ (*v*) ☐

B.

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*) $P_1V_1 = P_2V_2$

Ans. (*i*) ☐ (*ii*) ☐ (*iii*) ☐

Q2. 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 _______________.

Q3. Each question has four options, out of which only one option is correct. Dark the bubble for correct answer.

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

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

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

Ans. (a) (b) (c) (d)

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

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

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

Ans. (a) (b) (c) (d)

(*iii*) The standard pressure is

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

(*c*) 760 cm^3 Hg (*d*) None of these

Ans. a b c d

(*iv*) The standard temperature is

(*a*) 273 °C (*b*) 273 K

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

Ans. a b c d

(*v*) The temperature for absolute zero is

(*a*) –273 °C (*b*) –270 °C

(*c*) –273 K (*d*) –270 K

Ans. a b c d

Answers

1. A. (*i*) *e*	(*ii*) *a*	(*iii*) *d*	(*iv*) *b*	(*v*) *c*
B. (*i*) *c*	(*ii*) *a*	(*iii*) *b*		
2. (*i*) 76, 760				
(*ii*) 1000, 1000				
(*iii*) 0				
(*iv*) low				
(*v*) shape, volume				
3. (*i*) *b*	(*ii*) *b*	(*iii*) *a*	(*iv*) *b*	(*v*) *a*

SELF EVALUATION TEST

Time : 30 minutes *Marks : 30*

Q1. State absolute zero. **1**

Q2. State **2**

(*i*) Boyles' law

(*ii*) Charles' law

Q3. 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 ? **4**

Q4. 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 ? **4**

Q5. A 226 ml of oxygen gas is heated from 18.5 °C to 96 °C at constant pressure. Calculate the new volume of oxygen. **4**

Q6. Convert the following temperature to Kelvin. **5**

(*i*) 15 °C

(*ii*) –200 °C

(*iii*) 40 °C

(*iv*) 25 °C

(*v*) 173 °C

Q7. Convert the following temperature on the Kelvin Scale to the Celsius Scale. **5**

(*i*) 150 K

(*ii*) 335 K

(*iii*) 250 K

(*iv*) 100 K

(*v*) 446 K

Q8. Gas 'A' occupies 55 ml at 91 °C and 6 atm. What will be the volume of the gas 'A' at S.T.P. ? **5**

ANSWERS

3. 96 ml				
4. 63.33 cm Hg				
5. 286.08 ml				
6. (*i*) 288 K	(*ii*) 73 K	(*iii*) 313 K	(*iv*) 298 K	(*v*) 446 K
7. (*i*) – 123°C	(*ii*) 62°C	(*iii*) 23°C	(*iv*) –173°C	(*v*) 173°C
8. 247.5 ml				