3. To what temperature must $2000cm^3$ of a gas at $27°C$ be heated at constant pressure in order to raise its volume to $2500cm^3$

Soln

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

$V_1 = 2000\,cm^3$ $\quad$ $V_2 = 2500\,cm^3$

$T_1 = 27 + 273$ $\quad$ $T_2 = ?$

$= 300K$

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{2500\,cm^3 \times 300K}{2000\,cm^3}$$

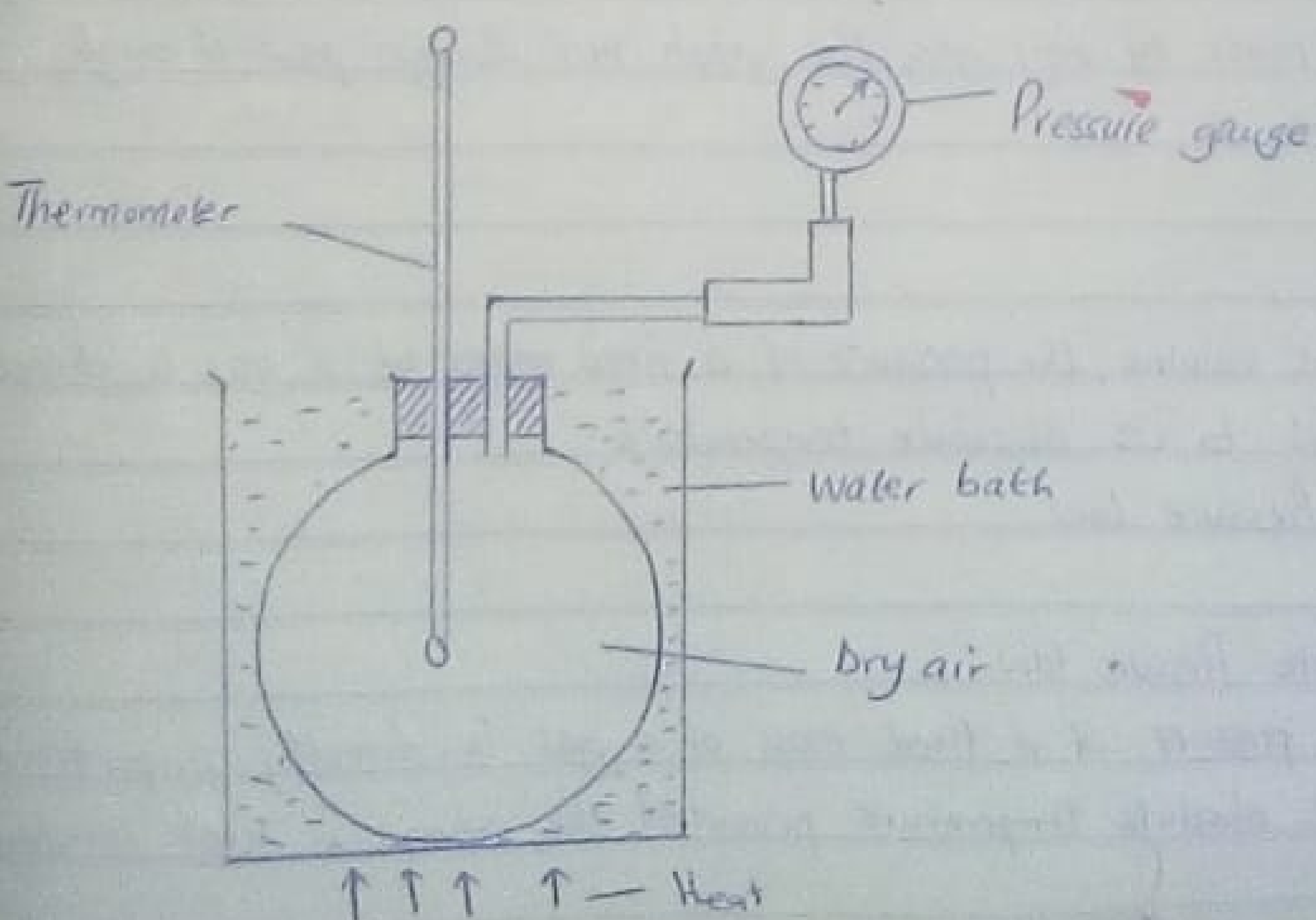
$= 375K$

$T°C = 375 - 273$

$T = 102°C$

PRESSURE LAW

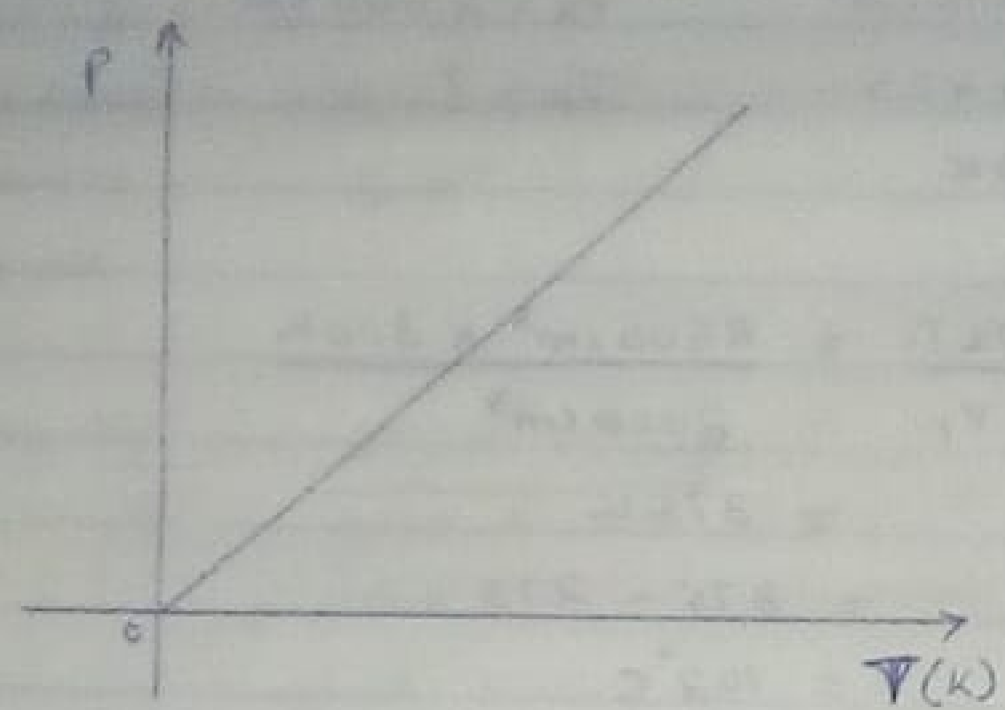
- The law relates pressure of a fixed mass of a gas to its absolute temperature at constant volume.



Experimental Description:

- Dry air is enclosed in a flask and therefore fixed mass and volume
- The water bath is slowly and steadily heated
- At some convinient temperature, pressure readings are taken.
- The graph of pressure against absolute temperature is then plotted

Graph of Pressure against Absolute Temperature



- The graph is a straight line passing through the origin
- This shows that the gas pressure is proportional to its absolute temperature

Comments

- With any mass of any gas, the graph will always pass through absolute zero

Conclusion:

- At constant volume, the pressure of a fixed mass of a gas is directly proportional to its absolute temperature.
- This is Pressure law

Quiz: State Pressure law

Ans: The pressure of a fixed mass of a gas is directly proportional to its absolute temperature provided the volume is kept constant.

- In symbol form $P \alpha T$ or $P = kT$ where k is a constant

- From $P = kT$ it implies that $\frac{P}{T} = k =$ Constant

- Hence $\frac{P_1}{T_1} = \frac{P_2}{T_2} = \frac{P_3}{T_3} =$ Constant.

1. A container contains oxygen at $0°C$ and one atmosphere pressure. What will be the pressure in the container if the temperature rise to $100°C$.

Soln

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

$P_1 = 1$ atm $\quad T_1 = 0 + 273 = 273K$

$P_2 = ?$ $\quad T_2 = 100 + 273 = 373K$

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{1 \times 373}{273} = 1.37 \text{ atmospheres.}$$

2. At $30°C$, the pressure of a gas is 70cmHg. At what temperature would the pressure of the gas be 20cmHg

Soln

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $\quad P_1 = 70cmHg$ $\quad P_2 = 20cmHg$

$T_1 = 30 + 273 = 303K$ $\quad T_2 = ?$

$$T_2 = \frac{P_2 T_1}{P_1} = \frac{20cmHg \times 303K}{70cmHg}$$

$$= \frac{20 \times 303}{70} = 86.6K \text{ or } \underline{359.6°C} \quad -186.4°C$$

3. A cylinder contains oxygen at $0°C$ and pressure 2 atmospheres what will be the pressure if the gas is heated to $100°C$ at constant volume

<u>Soln</u>

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad P_1 = 2 \text{ atm} \qquad T_1 = 0+273 = 273K$$

$$P_2 = ? \qquad T_2 = 100+273 = 373K$$

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{2 \times 373}{273} = 2.73 \text{ atmospheres}$$

EQUATION OF STATE

i) Boyle's law $\quad PV = \text{constant}$

ii) Charles law $\quad \frac{V}{T} = \text{constant}$

iii) Pressure law $\quad \frac{P}{T}$ constant

- Combining the three $\quad \frac{PV}{T} = \text{constant}$

ie $\quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} = \text{constant}$

- In general $\frac{PV}{T} = k$ where k is a constant. This is the equation of state where k depends on the type and quantity of the gas.
- The equation changes to $\frac{PV}{T} = R$ when the amount of gas is 1 mole.
- The constant R is the same for all gases and is called Universal gas Constant

1. A mass of $1200cm^3$ of oxygen at $27°C$ and pressure 1.2 atmosphere is compressed until its volume is $600cm^3$ and its pressure 3 atmospheres. What is its temperature in degrees celsius after compression

Soln

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

$P_1 = 1.2\ atm$ $\quad V_1 = 1200cm^3$ $\quad T_1 = 27+273 = 300K$

$P_2 = 3\ atm$ $\quad V_2 = 600cm^3$ $\quad T_2 = ?$

$$T_2 = \frac{P_2V_2T_1}{P_1V_1} = \frac{3 \times 600 \times 300}{1.2 \times 1200} = 375K$$

$$T°C = 375 - 273 = 102°C$$

2. $100cm^3$ of nitrogen is collected at $20°C$ and $75cmHg$ pressure. What is its volume at s.t.p.

Soln

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

$P_1 = 75cmHg$ $\quad T_1 = 293K$ $\quad V_1 = 100cm^3$

$P_2 = 76cmHg$ $\quad T_2 = 273K$ $\quad V_2 = ?$

$$V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{75\cancel{cmHg} \times 100cm^3 \times 273K}{76\cancel{cmHg} \times 293K} = 91.95\ cm^3$$

3. The volume of a mass of air at $27°C$ and $75cmHg$ pressure is $200cm^3$. Find the volume of air at $-73°C$ and $80cmHg$ pressure.

Soln

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

$P_1 = 75cmHg$ $\quad T_1 = 300K$ $\quad V_1 = 200cm^3$

$P_2 = 80cmHg$ $\quad T_2 = 200K$ $\quad V_2 = ?$

$$V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{75\cancel{cmHg} \times 200cm^3 \times 200k}{80\cancel{cmHg} \times 300k} = 125\ cm^3$$

GAS LAWS AND KINETIC THEORY

- The main assumptions made when explaining gas laws in terms of Kinetic Theory are
  - (i) Gases are made up of particles which are usually molecules.
  - (ii) Gas molecules are in constant random motion
  - (iii) Gas molecules collide elastically with each other and with the walls of the container
  - (iv) The intermolecular forces of attraction between molecules is negligible.
  - (v) The ~~total~~ volume of all gas molecules is negligible compared with the volume of the container.

1. BOYLE'S LAW ($V \propto 1/P$ at constant temperature)

- Reducing the volume means
  - (i) reducing surface area
  - (ii) Increasing the frequency of collisions
- Higher frequency of collisions implies bigger force
- Bigger force with a small surface area means higher pressure
- Thus the pressure has increased as the volume decreases.
- So volume of a gas at constant temperature is inversely proportional to the pressure.

2. CHARLES LAW ($V \propto T$ at constant pressure)

- Increasing temperature implies bigger molecular force.
- To keep the pressure constant, the bigger force must be exerted on a bigger surface area.
- A bigger surface area means the volume should be increased.
- So the volume of the gas at constant pressure increases with its temperature.

3. PRESSURE LAW ($P \propto T$ at constant volume)

- Increasing temperature increases average molecular kinetic energy
- Bigger kinetic energy means bigger force exerted by molecules
- But constant volume means constant surface area
- Thus a bigger force with the same area implies a bigger pressure
- Hence the pressure of a gas at a constant volume increases with increase in temperature

LIMITATIONS OF GAS LAWS

1. The laws assume the volume and intermolecular forces of the molecules to be zero, yet real gases have definite volumes.
2. Real gases liquify before zero volume is reached and the laws would become invalid

NB:

A gas that would obey the gas laws completely is called ideal or perfect gas.