CHAPTER > 05

States of Matter

KEY NOTES

Solid, liquid and gases are three general states of **matter.** In this chapter, we will discuss different characteristics of gaseous and liquid states of matter.

Intermolecular Forces

- Intermolecular forces are the forces of attraction and repulsion between interacting particles (atoms and molecules).
- These are the weak forces and generally affect the physical properties and some chemical properties of matter.
- Attractive intermolecular forces are known as **van der Waals' forces.** van der Waals' forces vary considerably in magnitude. They include dispersion forces or London forces, dipole-dipole forces and dipole-induced dipole forces.

Dispersion or London Forces

- These forces exist in between neutral atoms and/or non-polar molecules, as in them electronic charge cloud is distributed symmetrically and, hence have no dipole moment.
- The interaction energy of these forces is proportional to $1/r^6$. (where r is the distance between two particles)

Dipole-Dipole Forces

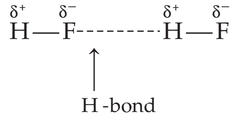
- These forces exists between dipole ends of polar molecules and are the strongest of all van der Waals' forces.
- Dipole-dipole interaction energy between stationary polar molecules is proportional to $1/r^3$ and that between rotating polar molecules is proportional to $1/r^6$.
  where, is distance between polar molecules.
- This interaction is stronger in London forces but weaker ion-ion interactions.

Dipole Induced Dipole Forces

- These forces exist between the polar molecules having permanent dipole and the molecules lacking permanent dipole.
- Permanent dipole of the polar molecule induces dipole on the electrically neutral molecule by deforming its electron cloud.

Hydrogen Bond

- It is a special case of dipole-dipole interaction. A hydrogen bond is formed (or such force exist) when a hydrogen is bonded to a more electronegative atom (like, N, O and F).



$$\overset{\delta^+}{\mathrm{H}}-\overset{\delta^-}{\mathrm{F}}\underset{\substack{\uparrow\\ \text{H -bond}}}{\cdots\cdots\cdots}\overset{\delta^+}{\mathrm{H}}-\overset{\delta^-}{\mathrm{F}}$$

- Energy of hydrogen bond varies between 10 to 100 kJ mol^{-1} i.e. these are strong forces and play a key role in determining the structure and properties of many compounds like proteins, nucleic acid etc.

Thermal Energy

- The energy of a body which arises because of the motion of its atoms or molecules, is called the thermal energy.
- It is infact, the measure of average kinetic energy of the particles of the matter and, hence is responsible for their motion.
- This movement of particles is called thermal motion.

Intermolecular Forces *vs* Thermal Interactions

- The intermolecular forces tend to keep the molecules together but thermal energy tend to keep them apart.
- Thus, these two compete and the competition between these two (i.e. intermolecular forces and thermal energy) results in three states of matter.

The Gaseous State

- Gases have neither definite shape nor definite volume.
- They are characterised by their high diffusibility, large intermolecular space, high kinetic energy, high compressibility and low density.

The Gas Laws

Gas laws are the relationships between measurable properties of gases.

Boyle's Law (Pressure-Volume Relationship)

- It states that "at constant temperature, the pressure of a given mass of a gas is inversely proportional to its volume."

i.e. $p \propto \frac{1}{V}$ (At constant T and n)

or $pV = \text{constant}$

or $p_1V_1 = p_2V_2 = \text{constant}$

- Graph between p *versus* V or pV *versus* p at constant temperature is called **isotherm**.

Charle's Law (Temperature-Volume Relationship)

- According to this law, "the volume of a given mass of a gas is directly proportional to the absolute temperature at constant pressure".

i.e. $V \propto T$

(at constant pressure or $\frac{V}{T} = \text{constant}$ or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$)

- A graph of V *versus* T at constant pressure is called **isobar.**

Gay-Lussac's Law
(Pressure-Temperature Relationship)

- According to this law, "at constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature".

i.e. $p \propto T$

or $\frac{p}{T} = \text{constant}$ (at constant V)

or $\frac{p_1}{T_1} = \frac{p_2}{T_2}$

- A graph of p *versus* T at constant volume is known as **isochore**.

Avogadro's Law (Volume-Amount Relationship)

- It states that, equal volumes of all gases under same conditions of temperature and pressure contain equal number of molecules."
i.e. $V \propto n$ (n = number of moles of gas)
- The volume of one mole of a gas at STP is known as **molar gas volume**.
- The number of molecules in one mole of a gas has been determined 6.022×10^{23}, is known as **Avogadro constant**.

Ideal Gas Equation

- A gas that follows Boyle's law, Charle's law and Avogadro's law strictly is called an **ideal gas**.
- The combination of various gas laws such as Boyle's law, Charles' law and Avogadro's law leads to the **ideal gas equation.**

At constant T and n; $V \propto 1/p$ (Boyle's law)

At constant p and n; $V \propto T$ (Charles' law)

At constant p and T; $V \propto n$ (Avogadro's law)

On combining the above three relations, we get

$$V \propto \frac{nT}{p} \text{ or } V = R\frac{nT}{p} \quad \ldots\text{(i)}$$

(Here, R = proportionality constant or gas constant)

On rearranging the equation (i), we get

$$pV = nRT \quad [\text{where, } n = w/M]$$

where, R is proportionality constant or **universal gas constant**.

The values of R are

$$R = 8.314 \text{ Pa m}^3\text{K}^{-1}\text{mol}^{-1}$$
$$= 8.314 \text{ J K}^{-1}\text{mol}^{-1}$$
$$= 8.20578 \times 10^{-2} \text{ L atm K}^{-1}\text{mol}^{-1}$$

- Ideal gas equation is a relation between four variables and it describes the state of any gas, therefore it is also called **equation of state.**
- **The combined gas law**
It is given by,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

- **Density and molar mass of a gaseous substance** is related as,

$$M = dRT/p$$

Dalton's Law of Partial Pressure

- It states that "the total pressure exerted by the mixture of non-reactive gases is equal to the sum of the partial pressure of each gas present in the mixture under the same conditions of $T$and V."

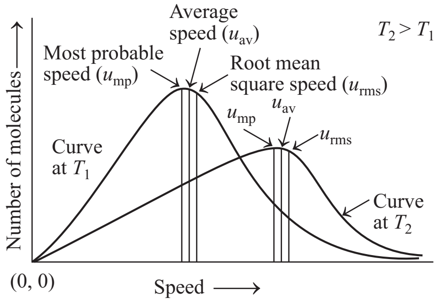
$$p_{\text{total}} = p_1 + p_2 + p_3 \text{ ....} \quad (\text{At constant } T \text{ and } V)$$

- **In terms of mole fraction**

Partial pressure, (p) = mole fraction $\chi \times p_{\text{total}}$

Kinetic Energy and Molecular Speeds

- Maxwell and Boltzmann have shown that actual distribution of molecular speeds depends on temperature and molecular mass of a gas.
- Maxwell derived a formula for calculating the number of molecules possessing a particular speed.



Maxwell Boltzmann distribution of speeds

- Kinetic energy of a particle is given by the expression.

$$\text{Kinetic energy} = \frac{1}{2} mu^2$$

Average Speed ($\bar{u}$ or u_{av})

It is the arithmetic mean of the various speeds of the molecules.
Let there be 'N' molecules of gas having velocities $u_1, u_2 \ldots\ldots\ldots, u_N$.

Then, average velocity,

$$\bar{u} \text{ or } u_{av} = \frac{u_1 + u_2 + \ldots\ldots + u_N}{N} = \sqrt{\frac{8RT}{\pi M}}$$

Most Probable Speed (u_{mp})

It is the velocity possessed by maximum number of molecules.

$$u_{mp} = \sqrt{2RT/M}$$

Root Mean Square Speed (u_{rms})

It is the square root of the mean of the squares of the velocity of molecules of the same gas.

$$u_{rms} = \sqrt{\frac{u_1^2 + u_2^2 + \ldots\ldots + u_N^2}{N}} = \sqrt{\frac{3RT}{M}}$$

Root mean square speed, average speed and the most probable speed have the following relationship.

$$u_{rms} > u_{av} > u_{mp}$$

The ratio between the three speeds are given below :

$$u_{mp} : u_{av} : u_{rms} :: 1 : 1.128 : 1.224$$

Kinetic Molecular Theory of Gases

Kinetic molecular theory of gases is based on the following assumptions :

- A gas consists of extremely small discrete molecules. These molecules are so small and so far apart that actual volume of the molecules is negligible as compared to the total volume of the gas.
- Gas molecules are in constant random motion with high velocities that moves in a straight line and changes their directions on collision with other molecules or walls of the container.
- The intermolecular forces are negligible and the effect of gravity on them is also negligible.
- The collisions are perfectly elastic, therefore there is no loss of kinetic energy during collision. However, there may be redistribution of energy during such a collision.
- The pressure of a gas is caused by the bombardment of moving molecules against the walls of the container.
- In a gas, different molecules have different kinetic energies but the average kinetic energy of molecules is proportional to absolute temperature of the gas.

Behaviour of Real Gases : Deviation from Ideal Gas Behaviour

- At constant temperature, pV *vs* p plot for real gases is not a straight line. There is significant deviation from ideal behaviour.
- At very low temperature and high pressure, **real gases** shows deviation from the ideal gas behaviour.

  The causes of deviation are given below :
  - At low temperature and high pressure, volume of a real gas is larger than that predicted for an ideal gas.
  - Intermolecular forces are not negligible.
- The pressure exerted by a real gas is lower than the pressure exerted by an ideal gas.

$$p_{\text{ideal}} = \underset{\substack{\text{Observed} \\ \text{pressure}}}{p_{\text{real}}} + \underset{\substack{\text{Correction} \\ \text{term}}}{\frac{an^2}{V^2}}$$

- With the help of kinetic theory of gases, behaviour of gases can be interpreted mathematically.
- The modified form of ideal gas equation is **van der Waals' equation** as shown below :

$$\left[p + \frac{n^2 a}{V^2}\right][V - nb] = nRT$$

  where, a and b are constants.
- 'a' is a measure of magnitude of attractive forces between gaseous molecules and 'b' is a measure of effective size of molecules.

Compressibility Factor

- The extent of deviation of a real gas from ideal behaviour is expressed in terms of compressibility factor.

$$Z = \frac{pV}{nRT}, \quad Z = \frac{V_{\text{real}}}{V_{\text{ideal}}}$$

- For ideal gas, $Z = 1$ at all temperatures and pressures.
  At very low pressure, all gases have $Z \approx 1$ and behave as ideal gas. At high pressure, all gases have $Z > 1$.
  At intermediate pressure, most gases have $Z < 1$.
- Gases show ideal behaviour when the volume occupied is large, so that the volume of the molecules can be neglected, as comparison to it.

Boyle Temperature or Boyle Point

It is the temperature at which a real gas obeys ideal gas law over an appreciable range of pressure.

Liquefaction of Gases

The phenomenon of converting a gas into liquid is known as **liquefaction**.

- **Critical temperature** (T_c) is the temperature for a gas below which a continuous increase in pressure will bring liquefaction of gas, while above which no liquefaction is noticed.
- **Critical pressure** (p_c) is the minimum pressure applied on 1 mole of gas placed at critical temperature to just liquefy the gas.
- **Critical volume** (V_c) is the volume occupied by 1 mole of gas at critical temperature.

Liquid State

The liquid state is the intermediate state between gas and solid. It has finite volume but does not have a definite shape.

Vapour Pressure

- Inside a closed vessel, the liquid and its vapours are in dynamic equilibrium. The pressure exerted by the vapours is known as **equilibrium vapour pressure or saturated vapour pressure.**
- The condition of free vaporisation throughout the liquid is called boiling. The temperature at which vapour pressure of liquid is equal to external pressure is called **boiling point.**
- At 1 atm pressure, boiling temperature is called **normal boiling point.** If pressure is 1 bar, then the boiling point is called **standard boiling point** of liquid.

Surface Tension

- The energy required to increase the surface area of liquid by one unit is called surface energy. It is defined as the force acting per unit length perpendicular to the line drawn on the surface. It has dimension of kg s^{-2}.
- The SI unit of surface tension is Nm^{-1}.
- Surface tension decreases with rise in temperature.
  Soaps and detergents decrease the surface tension.
- The energy required to increase the surface area of the liquid by one unit is known as **surface energy.**
  Its dimensions is Jm^{-2}.

Viscosity

- It is the measure of resistance to flow. It arises due to the internal friction between layers of fluids as they pass over each other.
  Mathematically, it is given as

$$F \propto A\frac{du}{dz} \Rightarrow F = \eta A\frac{du}{dz}$$

where, $F =$ force, $\frac{du}{dz} =$ velocity gradient

$A =$ area of contact.

- η is proportionality constant and is called **coefficient of viscosity**.
- Its SI unit is Nsm^{-2} or Pa s or $\text{kg m}^{-1}\text{s}^{-1}$.
- In CGS system, the unit of coefficient of viscosity is Poise (Poise $= 1\text{ g cm}^{-1}\text{ s}^{-1} = 10\text{ kg m}^{-1}\text{s}^{-1}$.
- Viscosity of liquid decreases with increase in temperature.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Intermolecular Forces and Thermal Energy*

1 Atoms and non-polar molecules are electrically symmetrical and have no dipole moment because

(a) their electronic charge cloud is symmetrically distributed
(b) their electronic charge cloud is unsymmetrically distributed
(c) electronic charge distributed momentarily
(d) All of the above

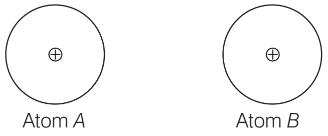
2 London or dispersion force is a/an

(a) attractive force that acts between two temporary dipoles
(b) attractive force that acts between two permanent dipoles
(c) repulsive force that acts between two permanent dipoles
(d) repulsive force that acts between two temporary dipoles

3 The partial charge(s) developed on the ends of dipoles is

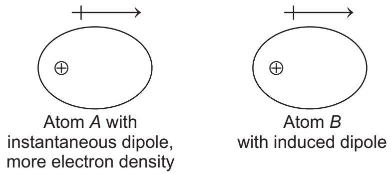
(a) $> 1.6 \times 10^{-19}$ C
(b) $< 1.6 \times 10^{-19}$ C
(c) equal to 1.6×10^{-19} C
(d) None of these

4 Pair of figures I, II, III represent the situation, when two atoms A and B are in close vicinity to each other.

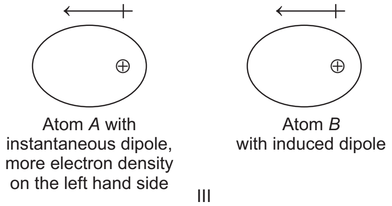


Symmetrical distribution of electronic charge cloud

I



II



III

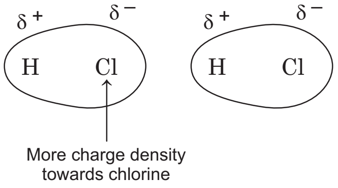
Which type of interaction is present between atom *A* and atom *B* as shown in the above pair of figures?

(a) London forces
(b) van der Waals' forces
(c) dipole-dipole forces
(d) dipole-induced dipole forces

5 The relative strength of interionic/intermolecular forces in decreasing order is ***JEE Main 2020***

(a) dipole-dipole > ion-dipole > ion-ion
(b) ion-ion > ion-dipole > dipole-dipole
(c) ion-dipole > ion-ion > dipole-dipole
(d) ion-dipole > dipole-dipole > ion-ion

6 Consider the following figure



Which one of the following interactions is shown between the two HCl molecules?

(a) Dipole-dipole interaction
(b) Ion-dipole interaction
(c) London forces
(d) Dipole-induced dipole interaction

7 The type of attractive forces operated between the polar molecules having permanent dipole and the molecules lacking permanent dipole is

(a) dipole-dipole
(b) London forces
(c) dipole-induced dipole
(d) H−bonding

8 On which of the following factors does induced dipole moment depends upon?

(a) Dipole moment present in the permanent dipole
(b) Polarisability of the electrically neutral molecules
(c) Both (a) and (b)
(d) None of the above

9 The predominant intermolecular forces present in ethyl acetate, a liquid, are : ***JEE Main 2020***

(a) London dispersion and dipole-dipole
(b) London dispersion, dipole-dipole and hydrogen bonding
(c) Dipole-dipole and hydrogen bonding
(d) Hydrogen bonding and London dispersion

10 Hydrogen bond is found between the molecules in which of the following bonds?

(a) Highly polar (b) Non-polar
(c) Less polar (d) Both (a) and (c)

11 Which type of intermolecular forces are present in the molecules of HF, HCl and HBr and HI?

(a) Dipole-dipole forces (b) Hydrogen bonding
(c) London forces (d) Both (a) and (c)

12 Why are liquids and solids hard to compress?

(a) Magnitude of the attractive forces increases with decreasing distance
(b) Magnitude of the attractive forces increases with increasing distance
(c) Magnitude of the repulsive forces increases with decreasing distance
(d) Magnitude of the repulsive forces decreases with decreasing distance

13 Thermal energy is directly proportional to the

(a) volume of the substance
(b) mass of the substance
(c) temperature of the substance
(d) Both (a) and (b)

14 The properties which tends to keep the molecules together and apart respectively?

(a) Intermolecular forces and potential energy
(b) Intermolecular forces and thermal energy
(c) Thermal energy and intermolecular forces
(d) Potential energy and intermolecular forces
(d) intermolecular forces and thermal energy of the molecules

15 The gases are easily liquefied when

(a) they are compressed at higher temperature
(b) they are compressed at lower temperature
(c) they are expanded at higher temperature
(d) they are expanded at lower temperature

TOPIC 2 ~ Gaseous State (Including Gas Laws) and Ideal Gas Equation

16 Boyle's law is expressed as follows

$$p = K_1 \cdot \frac{1}{V}$$

where, p = pressure,
V = volume
K_1 = proportionality constant

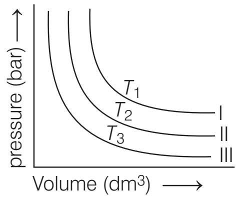
Which of the following option is true about constant (K_1)?

(a) Value of K_1 does not depend upon temperature of the gas
(b) Value of K_1 depends upon the amount of gas
(c) Value of K_1 is independent of the units of p and V
(d) All of the above

17 Boyle's law is valid, when a graph plotted against p *versus* $\frac{1}{V}$ is

(a) straight line passing through origin
(b) straight line passing through some intercept
(c) parabola passing through x-axis
(d) curved line passing through origin

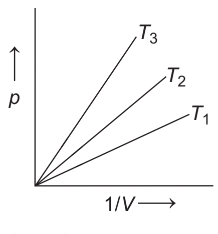
18 Consider the graph, which is given below :



Curves I, II, III are variations of pressure at temperatures T_1, T_2 and T_3. Arrange the temperature in the correct order.

(a) $T_1 < T_2 < T_3$ (b) $T_1 = T_2 = T_3$
(c) $T_1 > T_2 > T_3$ (d) $T_1 = T_2 > T_3$

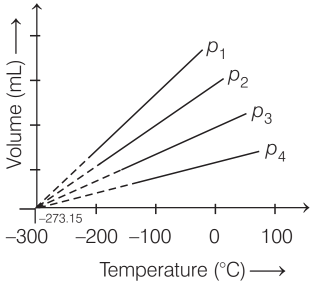
19 Consider a graph plotted between p and $\frac{1}{V}$ as shown below :



The correct order of temperature T_1, T_2, T_3 will be

(a) $T_3 > T_2 > T_1$
(b) $T_1 > T_2 > T_3$
(c) $T_1 = T_2 = T_3$
(d) $T_1 > T_2 = T_3$

20 Consider the following figure.



The above graph explains

(a) Boyle's law (b) Avogadro's law
(c) Charles' law (d) Graham's law

21 The gases become denser at

(a) low pressure (b) low temperature
(c) high pressure (d) (b) as well as (c)

22 A correct relationship between density and pressure of a gas is

(a) $d = K' \cdot p$ at constant volume
(b) $d = K' \cdot p$ at constant temperature
(c) $d = K' \cdot \frac{1}{p}$ at constant temperature
(d) $d = \frac{1}{K'} \cdot p$ at constant volume

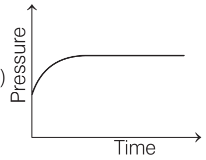
23 What will be the minimum pressure required to compress 2 L of gas at 1 bar to 1 L at 25°C?

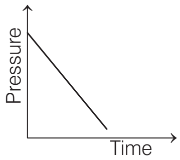
(a) 1 bar (b) 2 bar (c) 4 bar (d) 6 bar

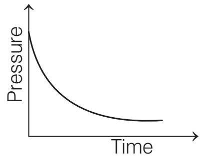
24 A balloon is filled with hydrogen at room temperature. It will burst, if pressure exceeds 0.2 bar. If at 1 bar pressure the gas occupied 2.27 L volume, up to what volume can the balloon be expanded?

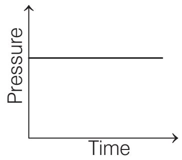
(a) 6.25 L (b) 11.35 L (c) 8.35 L (d) 10.50 L

25 A mixture of gases O_2, H_2 and CO are taken in a closed vessel containing charcoal. The graph that represents the correct behaviour of pressure with time is **JEE Main 2020**

(a)


(b)


(c)


(d)


26 Charles found that for all gases, at any given pressure, graph of volume *vs* temperature is a straight line and on extending to zero volume, each line intersects the temperature axis at

(a) 273.15°C (b) 273.15 K
(c) – 273.15° C (d) – 273.15 K

27 On a ship sailing in pacific ocean where temperature is 23.4°C, a balloon is filled with 2 L air. What will be the volume of the balloon when the ship reaches Indian ocean, where temperature is 26.1°C?

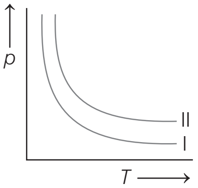
(a) 2.018 L (b) 2.8 L (c) 3.5 L (d) 1.5 L

28 A gas is heated from 273 K to 373 K at 1 atm pressure. If the initial volume of the gas is 10 L, its final volume would be

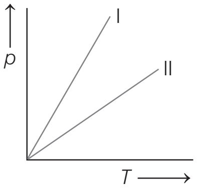
(a) 20 dm^3 (b) 13.66 dm^3 (c) 10 dm^3 (d) 7.32 dm^3

29 An ideal gas of given mass is heated first in a small vessel (I) and then in a large vessel (II). A plot between p *vs* T are plotted for (I) and (II).
The correct *p*-*T* curves in I and II conditions is

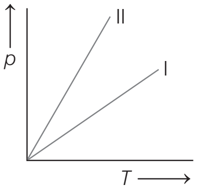
(a)



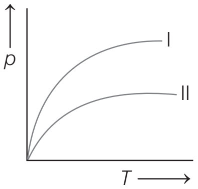
(b)



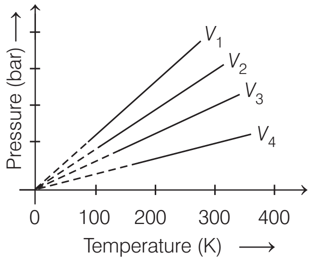
(c)



(d)



30 Consider the following figure, which shows the pressure *vs* temperature (in K) graph of a gas.



The above graph explains

(a) Boyle's law (b) Avogadro's law
(c) Charles' law (d) Gay Lussac's law

31 The pressure in well inflated tyres of automobiles is almost constant, but on a hot summer day this increases considerably and the tyre may burst. This phenomena is explained by

(a) Boyle's law (b) Charles' law
(c) Gay Lussac's law (d) Avogadro's law

32 Which of the following set of variables when plotted gives a straight line with a negative slope ?

(p = vapour pressure and T = temperature in Kelvin)

	***y*-axis**	***x*-axis**
(a)	p	T
(b)	$\log_{10} p$	T
(c)	$\log_{10} p$	$\frac{1}{T}$
(d)	$\log_{10} p$	$\log_{10} \frac{1}{T}$

33 Four 10 L flasks are separately filled with the gases CH_4, CO_2, H_2 and O_2 under the same conditions. The ratio of number of molecules in these gases respectively are

(a) 2:1:4:2 (b) 8:22:1:16
(c) 1:2:3:4 (d) 1:1:1:1

34 The value of universal gas constant (R) depends on

(a) the pressure of the gas
(b) the temperature of the gas
(c) the unit of measurement of pressure, temperature and volume
(d) the volume of the gas

35 Which one of the following is not the correct value of gas constant (R)?

(a) 0.0821 L atm K^{-1} mol^{-1}
(b) 1.99 cal K^{-1} mol^{-1}
(c) 8.3 JK^{-1} mol^{-1}
(d) 10.2 JK^{-1} mol^{-1}

36 An ideal gas equation is shown as $pV = nRT$ which is also termed as

(a) equation of state (b) equation of variable
(c) equation of parabola (d) None of these

37 Gas equation $pV = nRT$ is obeyed by a gas in

(a) adiabatic process (b) isothermal process
(c) Both (a) and (b) (d) None of these

38 An open vessel at 27ºC is heated until two fifth of the air (assumed as an ideal gas) in it has escaped from the vessel. Assuming that the volume of the vessel remains constant, the temperature at which the vessel has been heated is **JEE Main 2019**

(a) 750 K (b) 500 K (c) 750ºC (d) 500ºC

39 Which of the following is a constant in an ideal gas equation ? **JIPMER 2019**

(a) Temperature (b) Pressure
(c) Volume (d) Universal gas constant

40 40 L of a gas is stored under a pressure of 150 atm at 300 K. How many moles of the gas are present in the cylinder?

(a) 264 mol (b) 244 mol
(c) 225 mol (d) 2.5 mol

41 The volume occupied by 1.8 g of water vapour at 374°C and 1 bar pressure will be

[Use $R = 0.083$ bar L K^{-1} mol^{-1}] ***NEET (Odisha) 2019***

(a) 96.66 L (b) 55.87 L (c) 3.10 L (d) 5.3 L

42 If 10^{-4} dm^3 of water is introduced into a 1.0 dm^3 flask at 300 K, how many moles of water are in the vapour phase when equilibrium is established? (Given, vapour pressure of H_2O at 300 K is 3170 Pa, $R = 8.314$ JK^{-1} mol^{-1}).

(a) 5.56×10^{-3} mol (b) 1.53×10^{-2} mol
(c) 4.46×10^{-2} mol (d) 1.27×10^{-3} mol

43 At 25°C and 760 mm of Hg pressure, a gas occupies 600 mL volume. What will be its pressure at a height where temperature is 10°C and volume of the gas is 640 mL?

(a) 677 mm Hg (b) 600 mm Hg
(c) 700 mm Hg (d) 752 mm Hg

44 If $V = 1$ litre, 10 moles of H_2 and 10 moles of N_2 gas are mixed at temperature 26°C, then calculate pressure of the gas. ***JIPMER 2019***

(a) 491 atm (b) 300 atm (c) 550 atm (d) 600 atm

45 1000 mL of a gas collected at STP occupies some volume at 2 bar pressure and 127°C. The volume of gas at STP is

(a) $\dfrac{2 \times 273}{400}$ (b) $\dfrac{400 \times 2}{273}$ L
(c) $\dfrac{400}{2 \times 273}$ L (d) $400 \times 2 \times 273$ L

46 An open vessel containing air at 292 K was cooled to a certain temperature at which the number of moles of the gaseous molecules increased by 25%. The final temperature of the vessel is

(a) 234 K (b) 25 K (c) 210 K (d) – 40 K

47 There is 15 L of a gas at STP. At what other condition, volume of gas remains the same?

(a) 546°C and 0.5 atm (b) 273°C and 2 atm
(c) 273 K and 2 atm (d) 0°C and 0 atm

48 A bubble of volume V_1 is present in the bottom of a pond at 15°C and 1.5 atm pressure. When it comes at the surface, it observes a pressure of 1 atm at 25°C and has volume V_2. The value of V_2/V_1 is

(a) 15.5 (b) 0.155 (c) 155.0 (d) 1.55

49 Dalton's law of partial pressure is not applicable to a mixture of

(a) He and N_2 (b) Ar and He
(c) N_2 and O_2 (d) HCl and NH_3

50 Gases are generally collected over water. The pressure exerted by saturated water vapour on the gases is called

(a) vapour pressure (b) aqueous tension
(c) surface tension (d) osmotic pressure

51 Which of the following option is correct regarding partial pressure of gases when these are collected over water?

(a) $p_{\text{dry gas}} = p_{\text{total}}$ – surface tension
(b) $p_{\text{dry gas}} = p_{\text{total}}$ – osmotic pressure
(c) $p_{\text{dry gas}} = p_{\text{total}}$ – aqueous tension
(d) $p_{\text{dry gas}} = p_{\text{total}}$ – vapour pressure

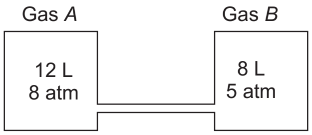
52 A neon dioxygen mixture contains 70.6 g of O_2 and 167.5 g neon. If pressure of the mixture of gases in the cylinder is 25 bar, what are the partial pressures of O_2 and Ne in the mixture, respectively?

(a) 5.25 bar, 10 bar (b) 19.75 bar, 5.25 bar
(c) 19.75 bar, 10 bar (d) 5.25 bar, 19.75 bar

53 Equal masses of H_2, O_2 and methane have been taken in a container of volume (V) at temperature 27°C in identical conditions. The ratio of the volumes of gases $H_2{:}O_2{:}CH_4$ would be ***CBSE AIPMT 2014***

(a) 8 : 16 : 1 (b) 16 : 8 : 1
(c) 16 : 1 : 2 (d) 8 : 1 : 2

54 Two vessels containing gases A and B are interconnected as shown in the figure. The stopper is opened, the gases are allowed to mix homogeneously. The partial pressures of A and B in the mixture respectively will be

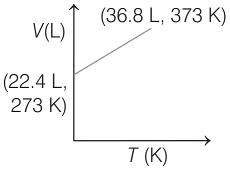


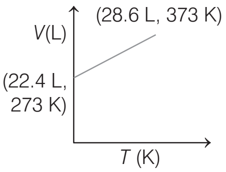
(a) 8 and 5 atm (b) 9.6 and 4 atm
(c) 4.8 and 2 atm (d) 6.4 and 4 atm

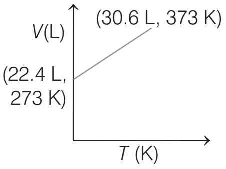
55 A closed vessel contains equal number of nitrogen and oxygen molecules at a pressure of p mm. If nitrogen is removed from the system then the pressure will be

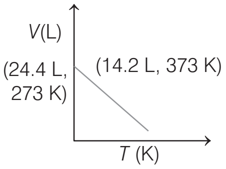
(a) p (b) $2p$
(c) p^2 (d) $p/2$

56 Which one of the following volume (V)-temperature (T) plots represents the behaviour of one mole of an ideal gas at one atmospheric pressure?

(a)


(b)


(c)


(d)


57 Two gases A and B having molar mass 60 and 45 g mol^{-1}, respectively are enclosed in a vessel. The weight of A is 0.5 g and that of B is 0.2 g. The total pressure of the mixture is 750 mm. The partial pressure of gas A and B respectively are

(a) 260 mm, 490 mm (b) 190 mm, 560 mm
(c) 490 mm, 260 mm (d) 520 mm, 290 mm

58 A gaseous mixture was prepared by taking equal moles of CO and N_2. If the total pressure of the mixture was found to be 1 atm, the partial pressure of the nitrogen (N_2) in the mixture is

CBSE AIPMT 2011

(a) 1 atm (b) 0.5 atm
(c) 0.8 atm (d) 0.9 atm

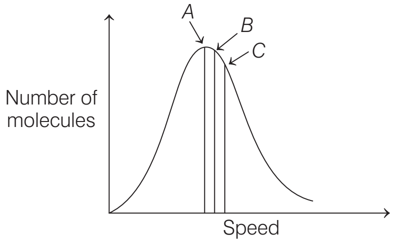
TOPIC 3 ~ *Kinetic Energy, Molecular Speeds and Kinetic Molecular Theory of Gases*

59 According to Maxwell and Boltzmann, the actual distribution of molecular speeds depends on

(a) temperature of a gas only
(b) temperature and molecular mass of a gas
(c) temperature and pressure of a gas
(d) pressure and molecular mass of a gas

60 Identify the correct labels of A, B and C in the following graph from the options given below :

JEE Main 2020



Root mean square speed (v_{rms}); most probable speed (v_{mp}); Average speed (v_{av})

(a) A - v_{rms}; B - v_{mp}; C - v_{av}
(b) A - v_{mp}; B - v_{rms}; C - v_{av}
(c) A - v_{mp}; B - v_{av}; C - v_{rms}
(d) A - v_{av}; B - v_{rms}; C - v_{mp}

61 The ratio between u_{mp}, u_{av} and u_{rms} is

(a) $u_{mp} : u_{av} : u_{rms} :: 1 : 1.28 : 1.224$
(b) $u_{rms} : u_{av} : u_{mp} :: 1 : 1.28 : 1.224$
(c) $u_{av} : u_{rms} : u_{mp} :: 1.224 : 1.28 : 1$
(d) $u_{rms} : u_{mp} : u_{av} :: 1 : 1.28 : 1.224$

62 The root mean square speed of O_2 gas at 27°C is

(a) $4.8 \times 10^2 \, ms^{-1}$ (b) $3.02 \times 10^3 \, ms^{-1}$
(c) $5.6 \times 10^4 \, ms^{-1}$ (d) $1.29 \times 10^2 \, ms^{-1}$

63 Points I, II and III in the following plot respectively correspond to (v_{mp} : most probable velocity)

JEE Main 2019

(a) v_{mp} of H_2 (300 K) ; v_{mp} of N_2 (300 K) ; v_{mp} of O_2 (400 K)
(b) v_{mp} of O_2 (400 K) ; v_{mp} of N_2 (300 K) ; v_{mp} of H_2 (300 K)
(c) v_{mp} of N_2 (300 K) ; v_{mp} of O_2 (400 K) ; v_{mp} of H_2 (300 K)
(d) v_{mp} of N_2 (300 K); v_{mp} of H_2 (300 K) ; v_{mp} of O_2 (400 K)

64 The ratio between the root mean square velocity of H_2 at 50 K and that of O_2 at 800 K is

(a) 4 (b) 2 (c) 1 (d) 0.25

65 According to kinetic theory of gases, ***JEE Main 2011***

(a) collisions are always elastic
(b) heavier molecules transfer more momentum of the wall of the container
(c) only a small number of molecules have very high velocity
(d) between collisions, the molecules move in straight lines with constant velocities

66 Gases consists of large number of identical particles (atoms or molecules) that are so small and so far apart on the average that the actual volume of the molecules is negligible in comparison to the empty space between them. This assumption explains the

(a) fixed volume of gases
(b) partial pressure exerted by the gases
(c) compressibility of gases
(d) All of the above

67 If a gas expands at constant temperature, it indicates that

(a) kinetic energy of molecules decreases
(b) pressure of the gas increases
(c) kinetic energy of molecules remains the same
(d) number of molecules of gas increase

TOPIC 4 ~ *Behaviour of Real Gases*

68 Maximum deviation from ideal gas is expected from **NEET 2013**

(a) $H_2(g)$ (b) $N_2(g)$

(c) $CH_4(g)$ (d) $NH_3(g)$

69 The negative deviation from an ideal behaviour means that

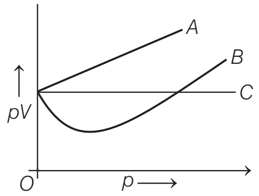
(a) value of pV decreases with decrease in pressure

(b) value of pV decreases with increase in pressure

(c) value of pV increases with increase in pressure

(d) value of pV remains constant with increase in pressure

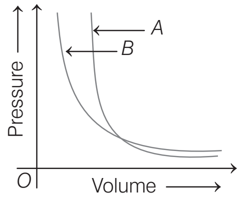
70 Consider the plot of pV *versus* p at constant temperature,



Which of the above slope shows real gas behaviour?

(a) A and C (b) Only B (c) A and B (d) A, B and C

71 Graph of pressure *versus* volume is given below.



The plot that represents an ideal gas behaviour is

(a) Only A (b) Only B

(c) A and B (d) Neither A nor B

72 At which of the following condition the measured volume is more than the calculated volume?

(a) Low pressure (b) Constant pressure

(c) High pressure (d) Partial pressure

73 The correction factor 'a' to the ideal gas equation corresponds to **NEET 2018**

(a) electric field present between the gas molecules

(b) volume of the gas molecules

(c) density of the gas molecules

(d) forces of attraction between the gas molecules

74 a and b are van der Waals' constants for gases. Chlorine is more easily liquefied than ethane because

(a) a and b for $Cl_2 >$ a and b for C_2H_6

(b) a and b for $Cl_2 <$ a and b for C_2H_6

(c) a for $Cl_2 >$ a for C_2H_6 but b for $Cl_2 > b$ for C_2H_6

(d) a for $Cl_2 >$ a for C_2H_6 but b for $Cl_2 < b$ for C_2H_6

75 Given van der Waals' constant of NH_3, H_2, O_2 and CO_2 are respectively 4.17, 0.244, 1.36 and 3.59. Which one of the following gases is most easily liquefied? **NEET 2018**

(a) O_2 (b) H_2 (c) NH_3 (d) CO_2

76 A gas such as carbon monoxide would be most likely to obey the ideal gas law at **CBSE AIPMT 2015**

(a) high temperatures and low pressures

(b) low temperatures and high pressures

(c) high temperatures and high pressures

(d) low temperatures and low pressures

77 Constant 'b' in van der Waals' equation represents

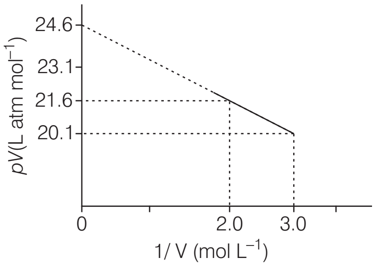
(a) volume occupied by the gaseous molecules

(b) intermolecular attraction between gaseous molecules

(c) intermolecular collision per unit volume

(d) None of the above

78 For one mole of a van der Waals' gas when $b = 0$ and $T = 300$ K, the pV vs $1/V$ plot is shown below. The value of the van der Waals' constant a (atm L mol^{-2}) is



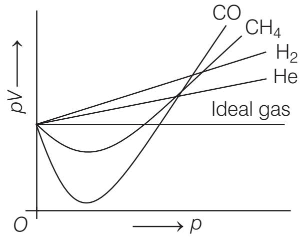
(a) 1.0 (b) 4.5 (c) 1.5 (d) 3.0

79 If Z is a compressibility factor, van der Waals' equation at low pressure can be written as **JEE Main 2014**

(a) $Z = 1 + \frac{RT}{pb}$ (b) $Z = 1 - \frac{a}{VRT}$

(c) $Z = 1 - \frac{pb}{RT}$ (d) $Z = 1 + \frac{pb}{RT}$

80 Consider the following figure.

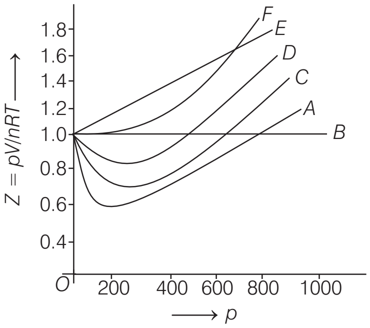


Which of the following gases show negative as well as positive deviation from the ideal gas behaviour?

(a) H_2 and CH_4 (b) CO and He

(c) CO and CH_4 (d) H_2, He and CH_4

81 The figure given below represents the variation of compressibility factor for some gases.



Which of the above graph shows, $Z = 1$ at all temperature and pressure?

(a) *A, B* and *C*
(b) *A* and *D*
(c) *C* and *D*
(d) Only *B*

82 The value of Z for real gases below Boyle's temperature initially

(a) increases
(b) decreases
(c) remain same
(d) increases then decreases

83 Which of the following option is correct about the type of deviations and value of Z, respectively for real gases which show deviations from ideality above the Boyle's point?

(a) negative and $Z < 1$ (b) negative and $Z > 1$
(c) positive and $Z > 1$ (d) positive and $Z < 1$

84 A gas at 350 K and 15 bar has molar volume 20 percent smaller than that for an ideal gas under the same conditions.

The correct option about the gas and its compressibility factor (Z) is **NEET (National) 2019**

(a) $Z > 1$ and repulsive forces are dominant
(b) $Z > 1$ and attractive forces are dominant
(c) $Z > 1$ and repulsive forces are dominant
(d) $Z > 1$ and attractive forces are dominant

85 Dominance of strong repulsive forces among the molecules of the gas

(a) depends on Z and indicated by $Z = 1$
(b) depends on Z and indicated by $Z > 1$
(c) depends on Z and indicated by $Z < 1$
(d) is independent of Z

86 The compressibility of a gas is less than unity at STP. Therefore

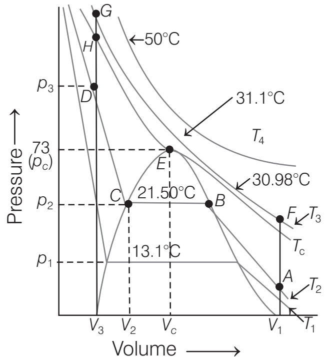
(a) $V_m >$ 22.4 L (b) $V_m <$ 22.4 L
(c) $V_m =$ 22.4 L (d) $V_m =$ 44.8 L

TOPIC 5 ~ *Liquefaction of Gases and Liquid States*

87 First complete data on pressure-volume-temperature relations of a substance in both gaseous and liquid state was obtained by

(a) Boyle (b) Charle's
(c) Avogadro (d) Thomas Andrews

88 The isotherms of CO_2 at various temperatures are represented in the figure.



At which point will CO_2 be completely liquefied when temperature is T_2?

(a) Point *A*
(b) Point *B*
(c) Point *C*
(d) Between the point *B* and point *C*

89 A gas and CO_2, that can be liquefied below the critical temperature by applying pressure separately are respectively called

(a) vapour and CO_2 gas
(b) vapour and CO_2 vapour
(c) fluid and CO_2 fluid
(d) fluid and dry CO_2

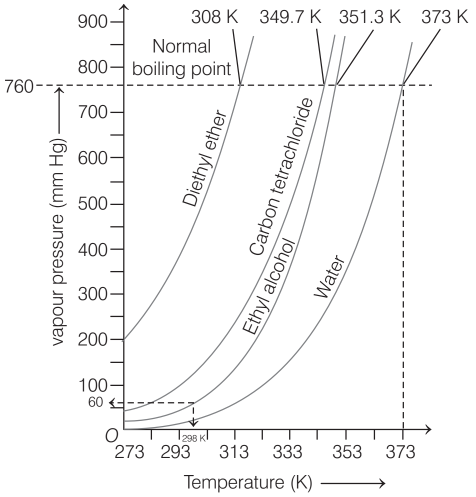
90 The liquefaction behaviour of the temporary gases like CO_2 approaches that of permanent gases like N_2, O_2 etc., as we go

(a) below critical temperature (b) above critical temperature
(c) above absolute zero (d) below absolute zero

91 When density of liquid and vapour becomes the same, the clear boundary between liquid and vapour disappears at the temperature.The temperature is called

(a) Boyle's temperature (b) melting point
(c) critical temperature (d) None of these

92 The figure given below shows the variation of vapour pressure of different liquids with temperature.



At high altitude, atmospheric pressure is low (say 60 mm Hg). At what temperature does liquid CCl_4 boils?

(a) 273 K (b) 281 K (c) 349 K (d) 373 K

93 Mercury drops are spherical in shape. Which of the following option explains it correctly?

(a) The minimum surface area of the liquids accommodate the lowest energy state
(b) The maximum surface area of liquids accommodate the lowest energy state
(c) The minimum surface area of liquids accommodate the higher energy state
(d) None of the above

94 Choose the correct relation between force and velocity gradient.

(a) $F = \frac{\eta}{A}\frac{du}{dz}$ (b) $F = \frac{A}{\eta}\frac{du}{dz}$

(c) $F = \eta A \frac{dz}{du}$ (d) None of these

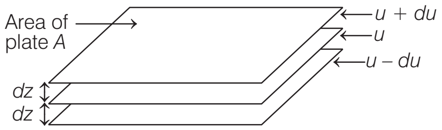
95 The increasing order of viscosity of the following compounds is given as

hexane < H_2O < glycerol

Which of the following is the correct reason?

(a) Hexane has strongest intermolecular forces
(b) H_2O has strongest intermolecular forces
(c) Glycerol has strongest intermolecular forces
(d) Weaker the intermolecular forces, greater is the viscosity

96 The figure given below shows a regular gradation of velocity in passing from one layer to the next?



It shows

(a) capillary action (b) laminar flow
(c) surface tension (d) viscosity

97 The viscous force which acts between two layers is proportional to

(a) area of contact
(b) velocity gradient
(c) Both (a) and (b)
(d) None of the above

SPECIAL TYPES QUESTIONS

I. Statement Based Questions

98 Which of the following statements is correct?

(a) The attractive force increases with the increase of distance between dipoles
(b) The attractive force decreases with the increase of distance between dipoles
(c) The attractive force decreases with the decrease of distance between dipoles
(d) The attractive force remains same with the decrease of distance between dipoles

99 The term intermolecular forces does not include

I. electrostatic forces that exist between two oppositely charged ions.
II. covalent bond.
III. van der Waals' forces.

Choose the correct option.

(a) I and II (b) II and III
(c) I and III (d) I, II and III

100 van der Waals' forces include

I. London forces II. dispersion forces
III. dipole-dipole forces
IV. dipole-induced dipole forces

Which of the following statement is correct?

(a) I, II and III (b) II, III and IV
(c) I and II (d) All of these

101 Select the correct statement from the following.

(a) London forces are repulsive
(b) London forces are neither attractive nor repulsive
(c) Interaction energy is inversely proportional to the sixth power of the distance between two interacting particles
(d) Interaction energy is directly proportional to the cubic power of the distance between two interacting particles

102 Choose the correct option from the following.
(a) Dipole-dipole interaction energy between the stationary polar molecules is related with distance as $1/r^3$
(b) Dipole-dipole interaction energy between the rotating polar molecules is related with distance as $1/r^6$
(c) Both (a) and (b)
(d) None of the above

103 Which of the following statement is incorrect regarding dipole-induced dipole forces?
(a) Interaction energy is proportional to $1/r^6$
(b) High polarisability increases the strength of attractive interactions
(c) Cumulative effect of dispersion forces and dipole induced dipole interactions exists
(d) None of the above

104 Strength of the hydrogen bond is determined by interaction between the
I. lone pair of the electronegative atom of one molecule and the hydrogen atom of other molecule.
II. bond pair of the electronegative atom of one molecule and the hydrogen atom of other molecule.

Identify the correct statement.
(a) Only I
(b) Only II
(c) Both I and II
(d) Neither I nor II

105 Consider the following statements :
I. Hydrogen bonds are powerful force in determining the structure and properties of many compounds.
II. When molecular interactions are very weak, molecules do not cling together to make solid or liquid unless thermal energy is reduced by lowering temperature.
III. Gases are highly compressible.

Choose the correct statements and select the correct option
(a) Both I and II
(b) Both II and III
(c) Both I and III
(d) I, II and III

106 Thermal energy of a substance is defined as the
I. sum of kinetic energy of the particles.
II. average kinetic energy of the particles.

Select the correct statement.
(a) Only I
(b) Only II
(c) Both I and II
(d) Neither I nor II

107 Which of the following factors determine the state of a substance?
I. The nature of intermolecular forces of the particles.
II. Molecular interaction between the particles.
III. Thermal energy of the particles.

The correct option is
(a) I and II
(b) Only III
(c) I, II and III
(d) Only I

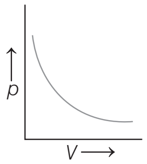
108 Consider the following orders.
I Gas > Liquid > Solid [Thermal energy]
II Gas > Liquid > Solid [Intermolecular energy]
III Solid > Liquid > Gas [Intermolecular energy]
IV Solid > Liquid > Gas [Thermal energy]

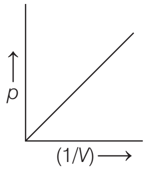
Choose the correct order and select the correct statement.
(a) I and III
(b) I and II
(c) II and IV
(d) III and IV

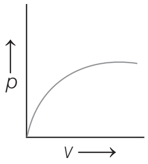
109 Which of the following statements are correct regarding the characteristic of gases?
I. Gases are highly compressible.
II. Gases exert pressure equally in all directions.
III. Gases have much higher density than the solids and liquids.
IV. Gases mix evenly and completely in all proportions without any mechanical aid.

Choose the correct statement.
(a) I, II and III
(b) II, III and IV
(c) I, II and IV
(d) I, II, III and IV

110 Some graphs are given below.

I.


II.


III.


Which of the above graph(s) represents Boyle's law ?
(a) I and II
(b) I and III
(c) II and III
(d) I, II and III

111 Avogadro's law is the combination of
I. Charles' law.
II. Boyle's law.
III. Dalton's atomic theory.
IV. Gay Lussac's law of combining volume.

Select the correct statement.
(a) I and II
(b) II and III
(c) III and IV
(d) I and IV

112 Which of the following data represents 1 mole of CO_2 gas at NTP?

I. 1 g of gas. II. 44 g of gas.

III. 22.7 L of gas. IV. 6.023×10^{23} gas molecules.

Choose the correct statement.

(a) I, II and IV (b) I, II and III
(c) II, III and IV (d) I, II, III and IV

113 Which of the following statement correctly represent the Avogadro's law?

I. $V = K \cdot n$ II. $M = K \cdot d$

where, K = constant, n = number of moles, M = molar mass, d = density

Identify the correct statement.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

114 Consider the following statements :

I. One mole of each gas at standard temperature and pressure will have same volume.

II. At STP, molar volume of an ideal gas or a combination of ideal gases is 22.7 L mol^{-1}.

III. The combined gas law is given by $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$.

IV. In ideal gas equation, R is called universal gas constant

Choose the correct statement and select the correct option.

(a) Both I and II (b) Both II and III
(c) Both I and IV (d) I, II, III and IV

115 Which of the following statement is correct regarding the changes which decreases the vapour pressure of water kept in a sealed vessel?

(a) Increasing the temperature of water
(b) Adding salt to water
(c) Decreasing the temperature of water
(d) Both (b) and (c)

116 The pressure p exerted by a mixture of three gases having partial pressure, p_1, p_2 and p_3 is given by

I. $p = p_1 + p_2 + p_3$

II. $p = \sqrt{p_1 + p_2 + p_3}$

III. $p = \sqrt{p_1} + \sqrt{p_2} + \sqrt{p_3}$

Identify the correct statement.

(a) Only I (b) Only II (c) Only III (d) I and II

117 Consider the following statement regarding Maxwell Boltzmann distribution curve

I. The fraction of molecules with very low or very high speeds is very small.

II. At higher temperatures, the curve near u_{mp} becomes narrower.

III. The speed possessed by maximum fraction of molecules is known as most probable speed.

Which of the above statement/s is/are incorrect?

(a) Only I (b) Only II (c) II and III (d) I and III

118 Consider the following statements :

I. The ratio of the average speed to the rms speed is independent of the temperature.

II. The square of the average speed of the molecules is equal to the square of the rms speed at a certain temperature.

III. Kinetic energy of the gas molecules at any given temperature is independent of the average speed.

Which of the above statements is/are correct?

(a) Only I (b) Only II (c) II and III (d) I and III

119 Which of the following is correct according to kinetic theory of gases?

I. Collision are always elastic.

II. Heavier molecules transfer more momentum to the wall of container.

III. Only a small number of molecules have very high velocity.

IV. Between collisions, the molecules move in straight line with constant velocities.

(a) I and II (b) I, III and IV
(c) II and III (d) I, II, III and IV

120 There are assumptions of the kinetic theory which do not hold good. These are

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

II. Volume of the molecules of a gas is negligibly small in comparsion to the space occupied by gas.

Choose the correct assumption and select the correct statement.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

121 Which of the following statement is incorrect?

(a) Real gases show deviations from ideal gas law because molecules interact with each other
(b) Repulsive interactions are significant at low pressure.
(c) van der Waals' equation is given as,

$$\left[p + \frac{an^2}{V^2}\right][V - nb] = nRT$$

(d) Real gases show ideal behaviour when conditions of temperature and pressure are such that the intermolecular forces are practically negligible

122 Consider the following statements :

I. Density and molar mass of gaseous substance are related as $M = dRT/p$.

II. Partial pressure in terms of mole fraction(χ_i) is related as $p_i = \chi_i p_{total}$.

III. At constant temperature, pV *vs* p plot for real gases is a straight line.

IV. Real gases do not follow ideal gas equation perfectly under all conditions.

Choose the correct statements and select the correct option

(a) Both I and II (b) Both II and III
(c) I, II and III (d) I, II and IV

123 At what condition, the measured and the calculated volume of gas approach each other?

I. Low pressure

II. High pressure

Identify the correct statement.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

124 The compressibility factor (Z) is the ratio of

I. pV and nRT

II. actual molar volume of gas to molar volume of ideal gas

Choose the correct statement.

(a) Only I (b) Only II
(c) Both I and II (d) None of these

125 Boyle point of a gas depends upon

I. nature of the gas.

II. critical temperature of gas.

Select the correct statement.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

126 Which of the following statement is correct?

(a) Molecules of liquids are held together by attractive intermolecular forces
(b) Molecules of liquids can move past one another freely
(c) Liquids can be poured and can assume the shape of container in which these are stored
(d) All of the above

127 Which of the following statement is correct ?

(a) Liquefaction of permanent gases require cooling as well as considerable compression.
(b) It is possible to change a gas into liquid or liquid into gas by a process in which always a single phase is present.
(c) A gas below the critical temperature can be liquefied by applying pressure and is called vapour of that substance.
(d) All of the above

128 Vapour pressure at the equilibrium state is known as

I. equilibrium vapour pressure

II. saturated vapour pressure

Choose the correct statement.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

129 Which of the following statement is incorrect?

(a) Liquids at high altitudes boil at lower temperatures in comparison to that at sea level.
(b) In hospitals surgical instruments are sterilised in autoclaves in which boiling point of water is increased by using a weight covering vent.
(c) Boiling does not occur when liquid is heated in a closed vessel
(d) Sharp glass edges are cooled for making them smooth.

130 Which of the following phenomenon takes place due to surface tension?

I. The particles of soil at the bottom of the river remain separated but they stick together when taken out.

II. A liquid rises (or falls) in a thin capillary as soon as the capillary touches the surface of the liquid.

The correct statement is

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

131 Consider the following statements regarding surface tension.

I. The magnitude of surface tension of a liquid depends on the attractive forces between the molecules.

II. Surface tension decrease with increase in temperature.

Which of the following statement is correct?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

II. Assertion and Reason

■ **Directions** (Q. Nos. 132-141) *In the following questions, an Assertion* (A) *is followed by a corresponding Reason* (R). *Use the following keys to choose the appropriate answer.*

(a) Both A and R are correct; R is the correct explanation of A.
(b) Both A and R are correct; R is not the correct explanation of A.
(c) A is correct; R is incorrect.
(d) A is incorrect; R is correct.

132 **Assertion** (A) Three states of matter are the result of balance between intermolecular forces and thermal energy of the molecules.

Reason (R) Intermolecular forces tend to keep the molecules together but thermal energy of molecules tends to keep them apart.

133 **Assertion** (A) London forces are applicable for short distances (~500 pm).

Reason (R) The magnitude of London forces depends on the polarisability of the particle.

134 **Assertion** (A) The graph between $p\,v/s\,\frac{1}{V}$ is a straight line.

Reason (R) For adiabatic process, $p \propto \frac{1}{V}$. ***AIIMS 2019***

135 **Assertion** (A) At constant temperature, *pV versus p* plot for ideal gas is a straight line.

Reason (R) At high pressure all gases have $Z < 1$ but at intermediate pressure most gases have $Z > 1$.

136 **Assertion** (A) At 300 K, kinetic energy of 16 g of methane is equal to the kinetic energy of 32 g of oxygen.

Reason (R) At constant temperature, kinetic energy of one mole of all gases is equal.

137 **Assertion** (A) Compressibility factor for the helium gas varies with pressure along with positive slope

Reason (R) Repulsive forces dominate in helium gas, even at low pressure.

138 **Assertion** (A) At high pressure, the compressibility factor Z is $\left(1 + \frac{pb}{RT}\right)$.

Reason (R) At high pressure, van der Waals' equation is modified as $p(V - b) = RT$.

139 **Assertion** (A) Critical temperature is the highest temperature at which condensation of a gas is possible.

Reason (R) Critical pressure is the highest pressure at which a liquid will boil when heated.

140 **Assertion** (A) A spherical water droplet gets flatened on a flat surface.

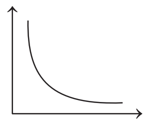
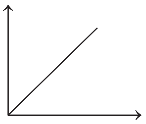
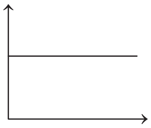
Reason (R) It becomes flat due to gravity. ***AIIMS 2019***

141 **Assertion** (A) Meniscus of a liquid disappears at the critical temperature.

Reason (R) Density of liquid and its gaseous phase become equal at the critical temperature.

III. Matching Type Questions

142 Match the following graphs of an ideal gas with their coordinates and choose the correct option from the codes given below.

Graphical representation	*x* and *y* coordinates
A. 	1. pV vs V
B. 	2. p vs V
C. 	3. p vs $\frac{1}{V}$

Codes

	A	B	C
(a)	3	2	1
(b)	2	3	1
(c)	1	2	3
(d)	2	1	3

143 Match the following columns including gas laws with the equation representing them and choose the correct option from the codes given below.

Column I	Column II
A. Boyle's law	1. $V \propto n$ at constant T and p
B. Charles' law	2. $p_{\text{total}} = p_1 + p_2 + p_3 + \dots$ at constant T, V
C. Dalton's law	3. pV/T = constant
D. Avogadro's law	4. $V \propto T$ at constant n and p
	5. $p \propto 1/V$ at constant n and T

Codes

	A	B	C	D
(a)	5	4	2	1
(b)	4	5	2	1
(c)	5	4	3	2
(d)	4	5	2	3

144 Match the column I with column II and choose the correct option using the codes given below

Column I	Column II
A. u_{av}	1. $\sqrt{\frac{3RT}{M}}$
B. u_{rms}	2. $\sqrt{\frac{8RT}{\pi M}}$
C. u_{mp}	3. $\sqrt{\frac{2RT}{\pi M}}$
	4. $\sqrt{\frac{2RT}{M}}$

Codes

	A	B	C
(a)	2	1	4
(b)	1	2	3
(c)	3	2	1
(d)	4	1	2

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

145 A vessel of 120 mL capacity contains a certain amount of gas at 35°C and 1.2 bar pressure. The gas is transferred to another vessel of volume 180 mL at 35°C. What would be its pressure?

(a) 0.8 bar (b) 1 bar (c) 0.6 bar (d) 0.2 bar

146 Critical temperature for carbon dioxide and methane are 31.1°C and − 81.9°C respectively. Which of these has stronger intermolecular forces?

(a) CO_2 (b) CH_4
(c) Same in CO_2 and CH_4 (d) Cannot be predicted

147 At 0°C, the density of a certain oxide of a gas at 2 bar is same as that of dinitrogen at 5 bar. What is the molecular mass of the oxide?

(a) 60 g mol^{-1} (b) 70 g mol^{-1} (c) 74 g mol^{-1} (d) 82 g mol^{-1}

148 Pressure of 1 g of an ideal gas A at 27°C is found to be 2 bar. When 2 g of another ideal gas B is introduced in the same flask at same temperature, the pressure becomes 3 bar. Find a relationship between their molecular masses.

(a) $M_B = 3M_A$ (b) $M_B = 4M_A$
(c) $M_B = 2M_A$ (d) $M_B = M_A$

149 34.05 mL of phosphorus vapour weighs 0.0625 g at 546°C and 0.1 bar pressure. What is the molar mass of phosphorus?

(a) $1204.6 \text{ g mol}^{-1}$ (b) $1284.3 \text{ g mol}^{-1}$
(c) $1250.4 \text{ g mol}^{-1}$ (d) $1124.6 \text{ g mol}^{-1}$

150 What would be the SI unit for the quantity pV^2T^2/n?

(a) $\text{Nm}^4 \text{K}^2 \text{mol}^{-1}$ (b) $\text{Nm}^2 \text{K mol}^{-2}$
(c) $\text{Nm}^3 \text{K}^3 \text{mol}^{-1}$ (d) $\text{Nm}^3 \text{K}^2 \text{mol}^{-2}$

151 What will be the pressure exerted by a mixture of 3.2 g of methane and 4.4 g of carbon dioxide contained in a 9 dm^3 flask at 27°C?

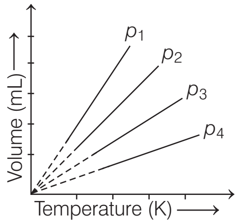
(a) 8.314×10^4 Pa (b) 8.314×10^2 Pa
(c) 8.314×10^3 Pa (d) 8.314×10^5 Pa

152 Pay load is defined as the difference between the mass of displaced air and the mass of the balloon. Calculate the pay load when a balloon of radius 10 m, mass 100 kg is filled with helium at 1.66 bar at 27°C. (Density of air = 1.2 kg m^{-3} and $R = 0.083 \text{ bar dm}^3 \text{ K}^{-1} \text{ mol}^{-1}$).

(a) 2814.61 kg (b) 3212.12 kg
(c) 4123.21 kg (d) 3811.11 kg

NCERT Exemplar

153 A plot of volume (V) *versus* temperature (T) for a gas at constant pressure is a straight line passing through the origin. The plots at different values of pressure are shown in figure. Which of the following order of pressure is correct for this gas?



(a) $p_1 > p_2 > p_3 > p_4$ (b) $p_1 = p_2 = p_3 = p_4$
(c) $p_1 < p_2 < p_3 < p_4$ (d) $p_1 < p_2 = p_3 < p_4$

154 The interaction energy of London force is inversely proportional to sixth power of the distance between two interacting particles but their magnitude depends upon

(a) charge of interacting particles
(b) mass of interacting particles
(c) polarisability of interacting particles
(d) strength of permanent dipoles in the particles

155 Dipole-dipole forces act between the molecules possessing permanent dipole. Ends of dipoles possess 'partial charges'. The partial charge is

(a) more than unit electronic charge
(b) equal to unit electronic charge
(c) less than unit electronic charge
(d) double the unit electronic charge

156 A person living in Shimla observed that cooking food without using pressure cooker takes more time. The reason for this observation is that at high altitude

(a) pressure increases
(b) temperature decreases
(c) pressure decreases
(d) temperature increases

157 Which of the following property of water can be used to explain the spherical shape of rain droplets?

(a) Viscosity (b) Surface tension
(c) Critical phenomena (d) Pressure

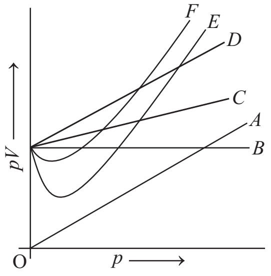
158 The pressure of a 1 : 4 mixture of dihydrogen and dioxygen enclosed in a vessel is one atmosphere. What would be the partial pressure of dioxygen?

(a) 0.8×10^5 atm (b) 0.008 Nm^{-2}
(c) $8 \times 10^4 \text{ Nm}^{-2}$ (d) 0.25 atm

159 As the temperature increases, average kinetic energy of molecules increases. What would be the effect of increase of temperature on pressure provided the volume is constant?

(a) Increases (b) Decreases
(c) Remains same (d) Becomes half

160 Which curve in figure represents the curve of ideal gas?



(a) Only *B* (b) *C* and *D* (c) *E* and *F* (d) *A* and *B*

161 Increase in kinetic energy can overcome intermolecular forces of attraction. How will the viscosity of liquid be affected by the increase in temperature?

(a) Increase
(b) No effect
(c) Decrease
(d) No regular pattern will be followed

162 Gases possess characteristic critical temperature which depends upon the magnitude of intermolecular forces between the particles. Following are the critical temperatures of some gases.

Gases	H_2	He	O_2	N_2
Critical temperature in (K)	33.2	5.3	154.3	126

From the above data what would be the order of liquefaction of these gases? Start writing the order from the gas liquefying first.

(a) H_2, He, O_2, N_2 (b) He, O_2, H_2, N_2
(c) N_2, O_2, He, H_2 (d) O_2, N_2, H_2, He

163 Atmospheric pressures recorded in different cities are as follows.

Cities	Shimla	Bangalore	Delhi	Mumbai
p (in N/m^2)	1.01×10^5	1.2×10^5	1.02×10^5	1.21×10^5

Consider the above data and mark the place at which liquid will boil first.

(a) Shimla (b) Bengaluru
(c) Delhi (d) Mumbai

164 How does the surface tension of a liquid vary with increase in temperature?

(a) Remains same
(b) Decreases
(c) Increases
(d) No regular pattern is followed

165 What is SI unit of viscosity coefficient (η)?

(a) Pascal (b) Nsm^{-2}
(c) km^{-2} s (d) Nm^{-2}

166 **Assertion** (A) The temperature at which vapour pressure of a liquid is equal to the external pressure is called boiling temperature.

Reason (R) At high altitude, atmospheric pressure is high.

167 Match the graphs between the following variables with their names.

	Graphs		Names
A.	Pressure *vs* temperature graph at constant molar volume	1.	Isotherm
B.	Pressure *vs* volume graph at constant temperature	2.	Constant temperature curve
C.	Volume *vs* temperature graph at constant pressure	3.	Isochore
		4.	Isobar

	A	B	C		A	B	C
(a)	1	2	3	(b)	2	4	3
(c)	3	1	4	(d)	4	2	13

Answers

> Mastering NCERT with MCQs

1 (a)	2 (a)	3 (b)	4 (a)	5 (b)	6 (a)	7 (c)	8 (c)	9 (a)	10 (a)
11 (d)	12 (c)	13 (c)	14 (b)	15 (b)	16 (b)	17 (a)	18 (c)	19 (a)	20 (c)
21 (c)	22 (b)	23 (b)	24 (b)	25 (c)	26 (c)	27 (a)	28 (b)	29 (b)	30 (d)
31 (c)	32 (c)	33 (d)	34 (c)	35 (d)	36 (a)	37 (c)	38 (b)	39 (d)	40 (b)
41 (d)	42 (d)	43 (a)	44 (a)	45 (a)	46 (a)	47 (b)	48 (d)	49 (d)	50 (b)
51 (c)	52 (d)	53 (c)	54 (c)	55 (d)	56 (c)	57 (c)	58 (b)	59 (b)	60 (c)
61 (a)	62 (a)	63 (c)	64 (c)	65 (a)	66 (c)	67 (c)	68 (d)	69 (b)	70 (c)
71 (b)	72 (c)	73 (d)	74 (d)	75 (c)	76 (a)	77 (a)	78 (c)	79 (b)	80 (c)
81 (d)	82 (b)	83 (c)	84 (b)	85 (b)	86 (b)	87 (d)	88 (c)	89 (b)	90 (b)
91 (c)	92 (b)	93 (a)	94 (c)	95 (c)	96 (b)	97 (c)			

> Special Types Questions

98 (b)	99 (a)	100 (d)	101 (c)	102 (c)	103 (d)	104 (a)	105 (d)	106 (b)	107 (c)
108 (a)	109 (c)	110 (a)	111 (c)	112 (c)	113 (c)	114 (d)	115 (d)	116 (a)	117 (b)
118 (d)	119 (d)	120 (c)	121 (b)	122 (d)	123 (a)	124 (c)	125 (a)	126 (d)	127 (d)
128 (c)	129 (d)	130 (c)	131 (c)	132 (a)	133 (b)	134 (c)	135 (c)	136 (a)	137 (a)
138 (a)	139 (c)	140 (a)	141 (a)	142 (b)	143 (a)	144 (a)			

> NCERT & NCERT Exemplar Questions

145 (a)	146 (a)	147 (b)	148 (b)	149 (c)	150 (a)	151 (a)	152 (d)	153 (c)	154 (c)
155 (c)	156 (c)	157 (b)	158 (c)	159 (a)	160 (a)	161 (c)	162 (d)	163 (a)	164 (b)
165 (b)	166 (c)	167 (c)							

3 (*b*) The partial charges (denoted by δ) which are developed on the ends of dipoles are always less than the unit electronic charge, i.e. 1.6×10^{-19}C.

4 (*a*) The given pair of figures represents London or dispersion forces between the molecules.

5 (*b*) Interionic (ion-ion) forces are stronger than ion-dipole, which in turn are stronger than intermolecular forces like dipole-dipole interaction.

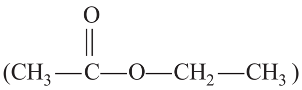
This is because in case of ion-ion interactions there is complete transfer of electrostatic charges from one atom to another. Whereas in dipole-dipole interactions, there is involvement of only partial charges.

The strength of ion-dipole interactions lies intermediate to that of ion-ion and dipole-dipole interactions.
Thus, the correct decreasing order of relative strength is :

Ion-ion > ion-dipole > dipole-dipole.

8 (*c*) Induced dipole moment depends upon the dipole moment present in the permanent dipole and the polarisability of the electrically neutral molecules. Molecules of larger size can be easily polarised.

High polarisability increases the strength of attractive interactions.

9 (*a*) Ethyl acetate ( $CH_3-\overset{O}{\overset{\|}{C}}-O-CH_2-CH_3$) molecules are polar. So, dipole-dipole interaction is present between its molecules. There are no such groups such as hydroxyl ($-OH$) which are capable of forming hydrogen bond.

London dispersion forces are present in all substances involving ethyl acetate also.

Thus in ethyl acetate, the predominant intermolecular forces are London dispersion and dipole-dipole forces.

10 (*a*) Hydrogen bond is found between the molecules in which highly polar bonds (like H—F, O—H, N—H) are present.

11 (*d*) H-bonding is present only in HF, but the other two dipole-dipole and the London forces are present in all the given molecules.

14 (*b*) The intermolecular forces tends to keep the molecules together but thermal energy of the molecules tend to keep them apart.

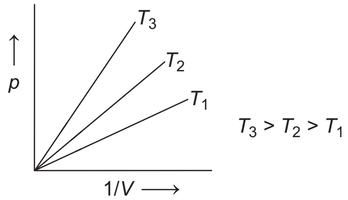
15 (*b*) Gases do not liquefy on compression only, although molecules come very close to each other and intermolecular forces operate to the maximum.

However, when the thermal energy of molecules is reduced by lowering of temperature, the gases can be very easily liquefied.

16 (*b*) In the given expression, value of K_1 depends upon the amount of gas, temperature of gas and units in which p and V are expressed.

17 (*a*) According to Boyle's law,

$$p \propto \frac{1}{V} \qquad \text{(at constant temperature)}$$



Above figure represents the graph between p and $1/V$.

It is a straight line passing through origin.

18 (*c*) In the graph, higher curves correspond to higher temperature, so order of temperatures is

$$T_1 > T_2 > T_3$$

19 (*a*) pV = constant at constant temperature.

Higher curves corresponds to higher temperature.

Hence, the correct order is

$$T_3 > T_2 > T_1$$

22 (*b*) A relationship can be obtained between density and pressure of a gas by using Boyle's law,

$$p = K_1 \cdot \frac{1}{V} \qquad \left(d = \frac{m}{V}, \text{ where } d = \text{density}\right)$$

$$\therefore \qquad V = \frac{m}{d}, \quad p = K_1 \cdot \frac{d}{m}$$

$$\therefore \qquad d = \left(\frac{m}{K_1}\right) \cdot p = K' p$$

This shows that, at a constant temperature, pressure is directly proportional to the density of a fixed mass of the gas.

23 (*b*) $p_1 = 1\text{ bar}, \ p_2 = ?, \ V_1 = 2\text{ L}, V_2 = 1\text{ L}$

From Boyle's law $\quad p_1V_1 = p_2V_2$

$$1 \times 2 = p_2 \times 1$$

$$p_2 = 2\text{ bar}$$

24 (*b*) According to Boyle's law,

$$p_1V_1 = p_2V_2$$

Given, $\quad p_1 = 1\text{ bar}, \ V_1 = 2.27\text{ L},$

$p_2 = 0.2\text{ bar}, \ V_2 = ?$

$$V_2 = \frac{p_1V_1}{p_2}$$

$$= \frac{1\text{ bar} \times 2.27\text{ L}}{0.2\text{ bar}} = 11.35\text{ L}$$

25 (*c*) Option (c) is the graph that represents correct behaviour of pressure with time. With passage of time, the pressure of the gases decreases and finally reach a constant value.

It is due to adsorption of gases by charcoal. The decrease in pressure is faster in the beginning, but as the adsorbent charcoal gets saturated, pressure attains constancy.

26 (*c*) Each line of the volume *vs* temperature graph intersects the temperature axis at − 273.15° C.

Slopes of lines obtained at different pressure are different but at zero volume all the lines meet the temperature axis at − 273.15° C.

27 (*a*) Given,

$$V_1 = 2\text{ L}, T_2 = (26.1 + 273)\text{ K} = 299.1\text{K}, V_2 = ?$$

$$T_1 = (23.4 + 273)\text{ K} = 296.4\text{ K}$$

From Charles' law,

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

$$\Rightarrow \qquad V_2 = \frac{V_1T_2}{T_1}$$

$$\Rightarrow \qquad V_2 = \frac{2\text{ L} \times 299.1\text{ K}}{296.4\text{ K}} = 2\text{L} \times 1.009$$

$$= 2.018\text{ L}$$

28 (*b*) Given,

$T_1 = 273\text{ K}, \quad T_2 = 373\text{ K}, \ p = \text{constant}, \ V_1 = 10\text{ L}, V_2 = ?$

From Charles' law,

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

$$\Rightarrow \qquad \frac{10}{273} = \frac{V_2}{373}$$

$$\Rightarrow \qquad V_2 = 373 \times \frac{10}{273}$$

$$= 13.66\text{ L}$$

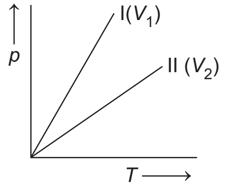
$$= 13.66\text{ dm}^3$$

29 (*b*) In vessel (I), volume is small (V_1), while in second vessel volume is large (V_2).

From Gay Lussac's law,

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

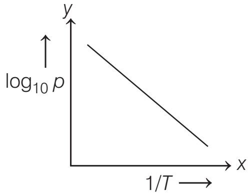
The correct *p*-*T* plot is given below.



30 (*d*) Graph follows Gay Lussac's law. Lower curves correspond to higher volume.

31 (c) Pressure in well inflated tyres of automobiles is almost constant, but on a hot summer day, this increases considerably and the tyre may burst. These phenomena are explained by Gay Lussac's law.

32 (c) A plot of $1/T$ on x-axis and $\log_{10} p$ on y-axis gives a straight line with a negative slope as shown below.



33 (d) According to the Avogadro's law, same volume of gases contain same number of molecules at same conditions. So, all the four gases (CH_4, CO_2, H_2, O_2) have same volume of 10 L under same conditions and hence as per Avogadro law, the ratio of number of molecules of gas will be equal. i.e. 1 : 1 : 1 : 1

35 (d) The different values of gas constant (R) are

$$R = 8.3\ \text{JK}^{-1}\ \text{mol}^{-1}$$
$$= 1.99\ \text{cal K}^{-1}\ \text{mol}^{-1}$$
$$= 0.0821\ \text{L atm K}^{-1}\ \text{mol}^{-1}$$

Thus, the option (d) is incorrect.

37 (c) Ideal gas equation, $pV = nRT$ is obeyed by an ideal gas in both adiabatic and isothermal process.

38 (b) Given, temperature $(T_1) = 27°\ \text{C} = 273 + 27 = 300\ \text{K}$

Volume of vessel = constant

Pressure in vessel = constant

Volume of air reduced by 2/5 so the remaining volume of air is 3/5.

Let at T_1 the volume of air inside the vessel is n so at T_2 the volume of air will be $\frac{3}{5}n$.

Now, as p and V are constant, so

$$n \cdot T_1 = \frac{3}{5} n\, T_2 \quad \text{...(i)}$$

Putting the value of T_1 in equation (i) we get,

$$n \times 300 = \frac{3}{5} n \times T_2$$

or $$T_2 = 300 \times \frac{5}{3} = 500\ \text{K}$$

39 (d) According to ideal gas equation,

$$pV = nRT$$

where, p = pressure, V = volume

n = no. of moles, T = temperature

R = universal gas constant

$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$

Hence, in ideal gas equation, universal gas constant is constant.

40 (b) According to ideal gas law,

$$pV = nRT$$

Given, $p = 150$ atm, $V = 40$ L, $T = 300$ K, n = ?

$$n = \frac{pV}{RT} = \frac{150 \times 40}{0.082 \times 300}$$
$$= 243.9 \approx 244\ \text{mol}$$

41 (d) According to ideal gas equation,

$$pV = nRT$$

or $$V = \frac{nRT}{p} = \frac{w}{M.wt}\frac{RT}{p} \quad \text{...(i)} \quad \left[\because n = \frac{w}{M.wt}\right]$$

Given, $w = 1.8$ g, $T = 374°$ C

$= (374 + 273)\ \text{K} = 647\ \text{K}$

$p = 1$ bar,

$R = 0.083\ \text{bar LK}^{-1}\ \text{mol}^{-1}$

On substituting the given values in Eq. (i), we get

$$V = \frac{1.8\ \text{g}}{18\ \text{g mol}^{-1}} \times \frac{0.082\ \text{bar LK}^{-1}\ \text{mol}^{-1} \times 647\ \text{K}}{1\ \text{bar}}$$
$$= 5.3\ \text{L}$$

42 (d) According to ideal gas equation,

$$pV = nRT$$

or $$n = \frac{pV}{RT} = \frac{3170 \times 10^{-3}}{8.134 \times 300}$$
$$= 1.27 \times 10^{-3}\ \text{mol}$$

43 (a) $p_1 = 760$ mm Hg, $V_1 = 600$ mL,

$T_1 = 25 + 273 = 298$ K

$V_2 = 640$ mL

and $T_2 = 10 + 273 = 283$ K

According to combined gas law,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\Rightarrow \quad p_2 = \frac{p_1V_1T_2}{T_1V_2}$$

$$\Rightarrow \quad p_2 = \frac{(760\ \text{mm Hg}) \times (600\ \text{mL}) \times (283\ \text{K})}{(640\ \text{mL}) \times (298\ \text{K})}$$
$$= 676.6\ \text{mmHg}$$
$$\approx 677\ \text{mm Hg}$$

44 (a) According to ideal gas equation, $pV = nRT$.

Given, $V = 1$L, $n_1 = 10$ moles, $n_2 = 10$ moles.

If moles of H_2 and N_2 gas are mixed, then

$$n = n_1 + n_2 = 10 + 10 = 20\ \text{mol}$$
$$T = 26°\ \text{C} = 299\ \text{K}.$$

$$\Rightarrow \qquad p = \frac{nRT}{V}$$

On substituting the given values in above equation, we get,

$$p = \frac{20 \text{ mol} \times 0.0821 \text{ L atm mol}^{-1}\text{K}^{-1} \times 299 \text{ K}}{1 \text{ L}}$$

$$= 490.9 \text{ atm} \sim 491 \text{ atm}$$

45 (*a*) $V_1 = 1000 \text{ mL} = 1 \text{ L}, p_1 = 2 \text{ bar},$

$T_1 = (127 + 273) \text{ K} = 400 \text{ K}$

At STP, $V_2 = ?, \ p_2 = 1 \text{ bar}, T_2 = 273 \text{ K}$

According to combined gas law,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\Rightarrow \qquad V_2 = \frac{p_1V_1T_2}{T_1p_2}$$

$$= \frac{2 \times 1 \times 273}{400 \times 1} = \frac{2 \times 273}{400} \text{ L}$$

46 (*a*) Suppose the volume of the container is V containing n moles at 292 K.

Let the temperature be T (K) when n moles increase to 1.25 n (i.e. by 25%).

$\because$ 1.25 n moles at T (K) occupy a volume, (V)

$\because$ n moles at T (K) occupy a volume $\frac{V}{1.25}$

$T_1 = 292 \text{ K}, V_1 = V, p_1 = p,$

$T_2 = T \text{ K}, V_2 = \frac{V}{1.25}$

$p_1 = p_2$ (constant)

From $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$

$$\frac{pV}{292} = \frac{p \times \frac{V}{1.25}}{T}$$

$$\Rightarrow \qquad T = 233.6 \text{ K} \approx 234 \text{ K}$$

47 (*b*) $V_1 = 15 \text{ L}, p_1 = 1 \text{ atm}, T_1 = 273 \text{ K}$

$V_2 = 15 \text{ L}$, Let, $p_2 = 2 \text{ atm}$ and

$T_2 = 273° \text{C} = (273 + 273) \text{ K} = 546 \text{ K}$

From gas law,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\Rightarrow \qquad \frac{1 \times V_1}{273} = \frac{2 \times V_2}{546}$$

$$\Rightarrow \qquad V_1 = V_2$$

So, at 273°C and 2 atm the volume of gas remains the same.

48 (*d*) $p_1 = 1.5 \text{ atm}, T_1 = 15° \text{C} = (15 + 273) \text{ K} = 288 \text{ K}$

$p_2 = 1 \text{ atm}, T_2 = 25° \text{C} = (25 + 273) = 298 \text{ K}$

According to combined gas law,

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\Rightarrow \qquad \frac{p_1T_2}{T_1p_2} = \frac{V_2}{V_1}$$

$$\Rightarrow \qquad \frac{V_2}{V_1} = \frac{1.5 \times 298}{288 \times 1} = 1.55$$

49 (*d*) HCl and NH_3 react with each other, whereas the gases given in the other options do not react with each other. The Dalton's law of partial pressure is applicable to non-reactive gases.

52 (*d*) We know that,

No. of moles $(n) = \frac{w}{M}$

For O_2, $w = 70.6 \text{ g}, M = 32 \text{ g mol}^{-1}$

No. of moles of O_2 $(n_1) = \frac{70.6 \text{ g}}{32 \text{ g mol}^{-1}} = 2.21 \text{ mol}$

For Ne, $w = 167.5 \text{ g}, M = 20 \text{ g mol}^{-1}$

No. of moles of Ne $(n_2) = \frac{167.5 \text{ g}}{20 \text{ g mol}^{-1}} = 8.375 \text{ mol}$

Mole fraction of O_2 $(\chi_1) = \frac{n_1}{n_1 + n_2}$

$$= \frac{2.21}{2.21 + 8.375} = 0.21$$

Mole fraction of Ne $(\chi_2) = 1 - \chi_1$

$= 1 - 0.21 \qquad [\because \chi_2 = 1 - \chi_1]$

$\chi_2 = 0.79$

Partial pressure of a gas = Mole fraction × total pressure

Partial pressure of $O_2 = 0.21 \times 25 = 5.25$ bar

Partial pressure of Ne $= 0.79 \times 25 = 19.75$ bar

53 (*c*) Equal masses of H_2, O_2 and CH_4 are taken in volume (V) of container and volume of gas $\propto$ number of moles (Avogadro's law)

Volume of H_2 : Volume of O_2 : Volume of CH_4

$$= \frac{w}{2} : \frac{w}{32} : \frac{w}{16} \quad (M_{H_2} = 2, M_{O_2} = 32, M_{CH_4} = 16)$$

$$= 16 : 1 : 2$$

54 (*c*) Moles of A $(n_A) = \frac{p_AV_A}{RT} = \frac{8 \times 12}{RT} = \frac{96}{RT}$

Moles of B $(n_B) = \frac{p_BV_B}{RT} = \frac{8 \times 5}{RT} = \frac{40}{RT}$

Total pressure × total volume = $(n_A + n_B) \times RT$

$$p \times (12 + 8) = \frac{1}{RT}(96 + 40)\,RT \;\Rightarrow p = 6.8$$

Partial pressure of $A = p \times$ mole fraction of A

$$= 6.8\left(\frac{96}{RT}\Big/\frac{96+40}{RT}\right)$$

$$= 4.8 \text{ atm}$$

Partial pressure of $B = 6.8 - 4.8 = 2$ atm.

55 (*d*) In the vessel,

Number of molecules of N_2 = Number of molecules of O_2

i.e. number of moles of N_2 = number of moles of O_2

Mole fraction of N_2 = Mole fraction of O_2

Partial pressure of N_2 = Partial pressure of $O_2 = \frac{p}{2}$ mm

When N_2 is removed then only O_2 molecules exert the pressure.

i.e., $$p_{\text{total}} = p_{O_2} = \frac{p}{2}\text{mm}$$

56 (*c*) *V-T* plot represents the behaviour of 1 mole of an ideal gas at 1 atm pressure.

Volume of 1 mole of an ideal gas at 273 K and 1 atm pressure is 22.4 L.

∴ Volume of 1 mole of an ideal gas at 373 K and 1 atm pressure will be,

$$V = \frac{RT}{p}$$

$$= \frac{0.082 \times 373}{1} = 30.58 \text{ L} \sim 30.6 \text{ L}$$

Hence, the plot given in option (c) is correct.

57 (*c*) Number of moles of A, $n_A = \frac{w_A}{M_A}$

$$= \frac{0.50}{60} = 0.0083$$

Number of moles of B, $n_B = \frac{w_B}{M_B} = \frac{0.20}{45} = 0.0044$

Total pressure $(p_T) = 750$ mm of Hg

p_A = mole fraction of $A\,(\chi_A) \times$ total pressure (p_T)

Mole fraction of $A, (\chi_A) = \frac{n_A}{n_A + n_B} \times p_T$

$$\chi = \frac{0.0083}{0.0083 + 0.0044} \times 750 = 490 \text{ mm}$$

$$p_B = 750 - 490 = 260 \text{ mm}$$

59 (*b*) According to Maxwell and Boltzmann, the actual distribution of molecular speeds depends on temperature and molecular mass of a gas. This is because on increasing the temperature, molecular motion increases. Therefore, the individual speeds of molecules also increases. Also, at the same temperature, the gas molecules with heavier mass have slower speed than the lighter gas molecules.

60 (*c*) The increasing order of molecular velocities of gas molecules is as follows :

Most probable velocity $(v_{\text{mp}}) <$ average velocity $(v_{\text{av}}) <$ rms velocity (v_{rms}).

Because,

$$v_{\text{mp}} = \sqrt{\frac{2RT}{M}}$$

$$v_{\text{av}} = \sqrt{\frac{8RT}{\pi M}}$$

and $$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

61 (*a*) The ratio between u_{mp}, u_{av} and u_{rms} can be calculated as shown below.

$$u_{\text{mp}} : u_{\text{av}} : u_{\text{rms}} = \sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{M\pi}} : \sqrt{\frac{3RT}{M}}$$

$$= \sqrt{2} : \sqrt{8/\pi} : \sqrt{3}$$

$$= 1 : 1.128 : 1.2248$$

62 (*a*) We know that, $u_{\text{rms}} = \sqrt{3RT/M}$

$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$,

$T = 27°\text{C} = 27 + 273 = 300$ K

$M_{O_2} = 32 \text{ g mol}^{-1} = 32 \times 10^{-3} \text{kg mol}^{-1}$

∴ $$u_{\text{rms}} = \sqrt{\frac{3 \times 8.314 \times 300}{32 \times 10^{-3}}}$$

$$= 4.8356 \times 10^2 \text{ ms}^{-1}$$

$$= 4.8 \times 10^2 \text{ ms}^{-1}$$

63 (*c*) $v_{\text{mp}} = \sqrt{\frac{2RT}{M}}$, i.e. $v_{\text{mp}} \propto \sqrt{\frac{T}{M}}$

Gas	***M***	***T*(K)**	$\sqrt{T/M}$
H_2	2	300	$\sqrt{300/2} = \sqrt{150}$ …III (Highest)
N_2	28	300	$\sqrt{300/28} = \sqrt{10.71}$ …I (Lowest)
O_2	32	400	$\sqrt{400/32} = \sqrt{12.5}$ … II

So,

I corresponds to v_{mp} of N_2 (300 K)

II corresponds to v_{mp} of O_2 (400 K)

III corresponds to v_{mp} of H_2 (300 K)

64 (*c*) Given, $T_1 = 50$ K for H_2

$T_2 = 800$K for O_2

We know that,

Root mean square velocity $(u_{\text{rms}}) = \sqrt{\dfrac{3RT}{M}}$

$$u \propto \frac{T}{M}$$

$$\frac{u_{H_2}}{u_{O_2}} = \sqrt{\frac{T_1}{M_1} \times \frac{M_2}{T_2}}$$

$$\Rightarrow \quad \frac{u_{H_2}}{u_{O_2}} = \sqrt{\frac{50}{2} \times \frac{32}{800}} = 1$$

65 (*a*) According to kinetic theory of gases, collision between the molecules as well as with the wall of the container is perfectly elastic in nature.

66 (*c*) The given assumption explains the compressibility of gases due to the empty space between them.

68 (*d*) Easily liquefiable gases like NH_3, SO_2 etc., exhibit maximum deviation from ideal gas as for them $Z <<< 1$. CH_4 also exhibits deviaton but it is less as compared to NH_3. Permanent gases like H_2, N_2 cannot be liquefied, thus they do not show deviation.

70 (*c*) Graphs *A* and *B* show real gas behaviour because at constant temperature, pV *versus* p plot is not a straight line.

71 (*b*) The pressure *versus* volume plot of experimental data (real gas) and theoretically calculated from Boyle's law (ideal gas) should coincide. At very high pressure, the measured volume is more than the calculated volume.

At low pressures, measured and calculated volumes approach each other.

Therefore, graph '*B*' shows ideal gas behaviour.

73 (*d*) According to van der Waals' equation,

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

where, *a* and *b* are called van der Waals' constant.

an^2/V^2 is called internal pressure of the gas where, '*a*' is a measure of forces of attraction between gas molecules.

'*b*' is also called co-volume or excluded volume.

The constants '*a*' and '*b*' are expressed in atm L^2 mol^{-2} and mol^{-1}, respectively.

74 (*d*) '*a*' for $Cl_2 >$ *a* for C_2H_6 but *b* for $Cl_2 <$ *b* for C_2H_6.

Since, there is stronger intermolecular interaction present in Cl_2, it is more easily liquefied.

75 (*c*) In the van der Waals' equation,

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

'*a*' and '*b*' are known as van der Waals' constant.
'*a*' is the measure of force of attraction between gas molecules. Greater the value of *a*, easier the liquefaction of the gas.

Among $NH_3(4.17)$, $H_2(0.244)$, $O_2(1.36)$ and $CO_2(3.59)$, the value of *a* is greatest for NH_3, hence it is most easily liquefied.

76 (*a*) Real gases show ideal gas behaviour at high temperatures and low pressures.

78 (*c*) van der Waals' equation of state is given below,

$$\left(p + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

For one mole, $n = 1$ and $b = 0$, the above equation becomes

$$\left(p + \frac{a}{V^2}\right)V = RT$$

$$\Rightarrow \quad pV = RT - \frac{a}{V} \quad \ldots\text{(i)}$$

Eq. (i) is a straight line equation between pV and $\dfrac{1}{V}$ whose slope is $-$'*a*'

Equate the value of '*a*' with slope of the straight line given in the graph as shown below.

$$-a = \frac{20.1 - 21.6}{3 - 2} = -1.5$$

$$\Rightarrow \quad a = 1.5$$

79 (*b*) van der Waals' equation is given by

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT$$

At low pressure, *V* decreases. Thus, a/V^2 increases.
However, *V* is still large enough in comparison to '*b*', hence, '*b*' can be neglected. Thus, van der Waals' equation becomes

$$\left(p + \frac{a}{V^2}\right)V = RT$$

$$\Rightarrow \quad pV + \frac{a}{V} = RT$$

$$\Rightarrow \quad pV = RT - \frac{a}{V}$$

$$\Rightarrow \quad \frac{pV}{RT} = 1 - \frac{a}{RTV}$$

$$Z = 1 - \frac{a}{RTV} \qquad \left[\because \frac{pV}{RT} = Z\right]$$

81 (*d*) The figure *B* shows ideal gas behaviour. For ideal gas, $Z = 1$ at all temperatures and pressure because $pV = nRT$.

82 (*b*) Below Boyle temperature, real gases first show decrease in *Z* value with increasing pressure, which reaches a minimum value.

83 (*c*) Above the Boyle point, real gases show positive deviations from ideality and $Z > 1$.

84 (*b*) Compressibility factor (Z) is the factor which decides the extent of deviation of real gases from ideal gases.

$$Z = \frac{V_{\text{real}}}{V_{\text{ideal}}}$$

Real gases deviate from ideal gas behaviour because for ideal gas it is considered that there is no force of attraction between gas molecules.

Also, for ideal gas, volume of gas molecules is negligible in comparison to volume of gas container.

$$\text{Given,} \qquad V_{\text{real}} < V_{\text{ideal}}$$
$$\therefore \qquad Z > 1$$

If $Z < 1$, the gas is more compressible than expected from ideal behaviour. As a result, attractive forces are present between molecules and are dominant.

85 (*b*) At high pressure, all the gases have $Z > 1$. These are most difficult to compress, i.e. dominance of strong repulsive forces among the molecules of the gas.

86 (*b*)
$$Z < 1$$
$$\Rightarrow \quad \frac{pV}{RT} < 1$$
$$\Rightarrow \quad \frac{p}{RT} = \frac{1}{0.0821 \times 273} = \frac{1}{22.4}$$
$$\Rightarrow \quad \frac{V_m}{22.4} < 1$$
$$\Rightarrow \quad V_m < 22.4 \text{ L}$$

87 (*d*) Thomas Andrews plotted isotherms of carbon dioxide at various temperatures. Later on, it was found that real gases behave in the same manner as carbon dioxide. Andrews noticed that at high temperatures, isotherms look like that of an ideal gas and the gas cannot be liquefied even at very high pressure.

88 (*c*) At point C (T_2 isotherm), CO_2 will be completely liquefied.

89 (*b*) A gas below its critical temperature can be liquefied by applying pressure and is called vapour of substance. CO_2 gas below its critical temperature is called CO_2 vapour.

90 (*b*) Critical temperature of a gas is highest temperature at which liquefaction of gas first occur. Liquefaction of so called permanent gases (i.e. gases which show continuous positive deviation in Z value) requires cooling as well as considerable compression.

But liquefaction of temporary gases like CO_2 and CH_4 approach that of permanent gases as we go above the critical temperature.

91 (*c*) The temperature at which density of liquid and vapour becomes the same and a clear boundary between liquid and vapour disappears is called critical temperature.

92 (*b*) When atmospheric pressure decreases to 60 mm of Hg, liquid boils below the boiling temperature. According to the graph, CCl_4 boils at 349 K, when atmospheric pressure approaches 760 mm of Hg.

At 60 mm of Hg, CCl_4 boils at temperature $\approx$ 281 K.

94 (*c*) The correct relation between force and velocity gradient is given below.

$$F = \eta A \frac{du}{dz}$$

where, du/dz = velocity gradient.
F = force, A = area of contact
η = coefficient of viscosity = Nsm^{-2} = Pa

95 (*c*) Stronger the intermolecular forces, greater will be the viscosity. Glycerol has strongest intermolecular forces due to hydrogen bonding (three H-bond per molecule).

Hence, the correct order is

$$\text{hexane} < H_2O < \text{glycerol}$$

96 (*b*) Laminar flow is the type of flow in which there is a regular gradation of velocity on passing from one layer to the next layer.

97 (*c*) The *viscous force* which acts between two layers is directly proportional to area of contact and velocity gradient.

$$F \propto A \qquad \text{(where, '}A\text{' is the area of contact)}$$
$$F \propto \frac{du}{dz} \qquad \left(\text{where, } \frac{du}{dz} \text{ is velocity gradient}\right)$$

99 (*a*) Intermolecular forces does not include the electrostatic forces that exist between the two oppositely charged ions and the forces that hold atoms of a molecule together, i.e. covalent bond.

Thus, the statement (a) is correct.

101 (*c*) Statement (c) is correct, while the other statements are incorrect. Corrected form are as follows :

(a) London forces are always attractive.
(c) Interaction energy is inversely proportional to the sixth power of the distance between two interacting particles.

104 (*a*) Strength of the hydrogen bond is determined by the coulombic interaction between the lone-pair electrons of the electronegative atom of one molecule and the hydrogen atom of other molecule.

H-bonding is shown as,

$$\overset{\delta^+}{H}—\overset{\delta^-}{F}\underset{\underset{\text{H-bond}}{\downarrow}}{- - -}\overset{\delta^+}{H}—\overset{\delta^-}{F}$$

Thus, the statement (I) is correct.

109 (*c*) Statements I, II and IV are correct, while the statement III is incorrect.
It's correct form is as follows :

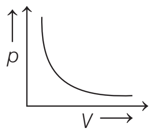
Gases have much lower density than the solids and liquids.

110 (*a*) From Boyle's law,

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

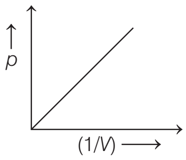
The correct graphs are shown below.

$\Rightarrow$



(I) Graph of p *vs* V

pV = constant



(II) Graph of p *vs* $1/V$

111 (*c*) In 1811, Italian scientist Avogadro combined conclusions of Dalton's atomic theory and Gay Lussac's law of combining volumes which is now known as Avogadro's law.

112 (*c*) 1 mol CO_2 gas can be represented as follows.

1 mol CO_2 gas = 44 g of CO_2 gas
1 mol CO_2 gas = 22.7 L (at STP or NTP)
1 mol CO_2 gas = 6.023×10^{23} molecules of gas

So, statements II, III and IV are correct, while I is incorrect.

115 (*d*) When salt is added, less surface area is available for the water molecules to vaporise because salt molecules occupy the position of water molecules on the surface. Hence, vapour pressure of the water decreases. Moreover, vapour pressure also decreases with decrease in temperature because kinetic energy of the molecules decrease.

Thus, the statement (d) is correct.

116 (*a*) Mathematically, Dalton's law of partial pressure is expressed as,

$$p_{\text{total}} = p_1 + p_2 + p_3 \qquad \text{(at constant } T, V)$$

Thus, the statement I is correct.

117 (*b*) Statement (b) is incorrect.
It's correct form is as follows :

In Maxwell-Boltzmann's distribution curve, on increasing the temperature, the curve near u_{mp} becomes broader, which indicates that more molecules possess speeds near to u_{mp}.

Rest other statements are correct.

118 (*d*) The given statements are explained as shown below.

I. $$\frac{u_{\text{av}}}{u_{\text{rms}}} = \sqrt{\frac{8RT}{\pi M}} \Big/ \sqrt{\frac{3RT}{M}} = \sqrt{\frac{8}{3\pi}}$$

So, the ratio of average speed to the rms speed is independent of the temperature.

II. $$(u_{\text{av}})^2 = \frac{8RT}{\pi M} \text{ and } (u_{\text{rms}})^2 = \frac{3RT}{M}$$

So, $(u_{\text{av}})^2 \neq (u_{\text{rms}})^2$

III. Average kinetic energy of the molecules at any temperature is given as,

$$\overline{\text{K} \cdot \text{E.}} = \frac{3}{2}RT$$

So, $\overline{\text{K} \cdot \text{E}}$ is independent of the average speed.

Thus, I and III are correct statements.

121 (*b*) Statement (b) is incorrect.

It's correct form is as follows :

Repulsive interactions are short range interactions and are significant when molecules are almost in contact. This situation occur at high pressure.

Rest other statements are correct.

122 (*d*) Statements I, II and IV are correct, while III is incorrect.
It's correct form is as follows :

At constant temperature, pV *vs* p plot for real gases is not a straight line. There is a significant deviation from ideal behaviour.

123 (*a*) At low pressure, measured and calculated volumes approach each other.

Thus, the statement I is correct.

128 (*c*) A dynamic equilibrium is established between the liquid phase and vapour phase. Vapour pressure at this stage is known as equilibrium vapour pressure or saturated vapour pressure.

Thus, statements I and II are correct.

129 (*d*) Statement (d) is incorrect.
It's correct form is as follows :

Sharp glass edges are heated for making them smooth. On heating, the glass melts and the surface of the liquid tends to take the rounded shape at the edges which make the edges smooth.

This is called fire polishing of glass.

Rest other statements are correct.

132 (*a*) Intermolecular forces tend to keep the molecules together but thermal energy tends to keep them apart. That's why, states of matter are the result of balance between intermolecular forces and the thermal energy of the molecules.

Thus, both A and R are correct and R is the correct explanation of A.

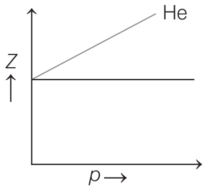
133 (*b*) London forces are applicable only for short distances (~500 pm) and its magnitude depends on the polarisability of the particle.

Thus, both A and R are correct but R is not the correct explanation of A.

135 (*c*) At high pressure, all gases have $Z > 1$ but at intermediate pressure most gases have $Z < 1$.

Thus, A is correct but R is incorrect.

137 (*a*) Compressibility factor for He > 1 (i.e. positive slope) because repulsive forces dominate in helium, even at low pressure as shown below.



Thus, both A and R are correct and R is the correct explanation of A.

139 (*c*) Critical pressure is the pressure at critical temperature.

Thus, A is correct but R is incorrect.

140 (*a*) Due to surface tension, liquid tends to have a minimum surface area. For a given volume of a liquid, sphere has the minimum surface area.

Therefore, the small spherical drops of liquids get slightly flatened by the effect of gravity.

Thus, both A and R are correct and R is the correct explanation for the A.

141 (*a*) At critical temperature, density of liquid and its gaseous phase become equal. At this point, there is no boundary between liquid and gaseous state, and hence meniscus of liquid disappears.

Thus, both A and R are correct and R is the correct explanation of A.

142 (*b*) The correct match is given below.

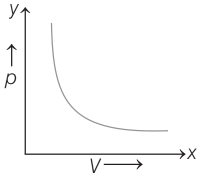
$$A \rightarrow 2, B \rightarrow 3, C \rightarrow 1$$

According to Boyle's Law,

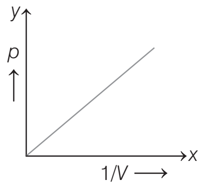
$$p \propto \frac{1}{V} \quad \text{[at constant } T\text{]}$$

$$\Rightarrow \quad pV = \text{constant}$$

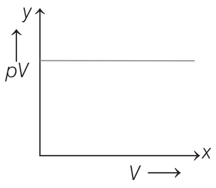
Graph *p vs V* ⟶



Graph *p vs* 1/*V* ⟶



Graph *pV vs V* ⟶



143 (*a*) The correct match is

$A \rightarrow 5, B \rightarrow 4, C \rightarrow 2, D \rightarrow 1$

A. Boyle's law $\rightarrow p \propto \frac{1}{V}$ at constant *n* and *T*

B. Charles' law $\rightarrow V \propto T$ at constant *n* and *p*

C. Dalton's law $\rightarrow p_{\text{total}} = p_1 + p_2 + \dots$ at constant *T, V*

D. Avogadro law $\rightarrow V \propto n$ at constant *T* and *p*.

144 (*a*) The correct match is

$$A \rightarrow 2, B \rightarrow 1, C \rightarrow 4$$

A. Average velocity (u_{av}) is the arithmetic mean of the velocities of different molecules of a gas. From kinetic gas equations,

$$u_{\text{av}} = \sqrt{\frac{8RT}{\pi M}}$$

B. Root mean square velocity (u_{rms}) is the square root of mean of the squares of the velocities of the different molecules of gas. From kinetic gas equation,

$$u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

C. Most probable velocity (u_{mp}) is the velocity possessed by the largest number of the molecules of gas from kinetic gas equation,

$$u_{\text{mp}} = \sqrt{\frac{2RT}{M}}$$

145 (*a*) $p_1 = 1.2\,\text{bar},\ p_2 = ?, V_1 = 120\,\text{mL}, V_2 = 180\,\text{mL}$

From Boyle's law,

$$p_1V_1 = p_2V_2$$

$$p_2 = \frac{p_1V_1}{V_2}$$

$$p_2 = \frac{1.2\ \text{bar} \times 120\ \text{mL}}{180\ \text{mL}}$$

$$= 0.8\ \text{bar}$$

146 (*a*) Critical temperature is the temperature above which a gas cannot be liquefied. Higher the critical temperature, more easily the gas can be liquefied, i.e. stronger the intermolecular forces.

Hence, CO_2 has stronger intermolecular forces than CH_4.

147 (*b*) Density, $d = Mp/RT$

When, *T* and *d* are same and *R* is constant,

Given, $p_1 = 2\ \text{bar}, M_1 = ?$

$p_2 = 5\ \text{bar}, M_2 = 28\,\text{g mol}^{-1}$

then p_1M_1 (gaseous oxide) $= p_2M_2$ (nitrogen).

$2\ \text{bar} \times M_1 = 5\,\text{bar} \times 28\,\text{g mol}^{-1}$

(molar mass of $N_2 = 28\,\text{g mol}^{-1}$)

Molecular mass of unknown oxide,

$$M_1 = \frac{5\ \text{bar} \times 28\ \text{g mol}^{-1}}{2\ \text{bar}}$$

$$= 70\,\text{g mol}^{-1}$$

148 (*b*) For an ideal gas,

$$pV = nRT$$

For gas A, $p_A V = n_A RT$ ...(i)

Similarly for gas B, $p_B V = n_B RT$ ...(ii)

Number of moles of A gas ;

$$n_A = \frac{1}{M_A}$$

(M_A = molar mass of gas A)

Number of moles of B gas;

$$n_B = \frac{2}{M_B} \quad (M_B = \text{ molar mass of gas } B)$$

Pressure of gas A, $p_A = 2\,\text{bar}$

Total pressure, $p_{\text{total}} = p_A + p_B = 3$ bar

Pressure of gas B, $p_B = p_{\text{total}} - p_A = 3 - 2 = 1\,\text{bar}$

V, R and T are same for both the gases.

Hence, from Eqs. (i) and (ii), we get

$$\frac{p_A}{p_B} = \frac{n_A}{n_B} = \frac{1 \times M_B}{M_A \times 2}$$

$$\frac{M_B}{M_A} = \frac{2p_A}{p_B} = \frac{2 \times 2}{1}$$

$$M_B = 4M_A$$

149 (*c*) $pV = nRT$

$$pV = \frac{mRT}{M} \qquad (m = \text{ mass of phosphorus and } M = \text{ molar mass of phosphorus})$$

$$M = \frac{mRT}{pV}$$

$$M = \frac{0.0625\text{ g} \times 0.0821\text{ L atm K}^{-1}\text{ mol}^{-1} \times 819\text{ K}}{0.1 \times 0.987\text{ atm} \times 0.03405\text{ L}}$$

$$M = 1250.4\text{ g mol}^{-1}$$

150 (*a*) The SI unit is calculated as follows :

$$\frac{pV^2T^2}{n} = \frac{(\text{Nm}^{-2})\ \{(\text{m})^3\}^2\ (\text{K})^2}{\text{mol}} = \text{Nm}^4\text{ K}^2\text{ mol}^{-1}$$

151 (*a*) Moles of CH_4, $n_{CH_4} = \frac{\text{Mass of } CH_4}{\text{Molar mass of } CH_4}$

[Molar mass of $CH_4 = 12 + 4 \times 1 = 16\text{ g mol}^{-1}$]

$$= \frac{3.2}{16} = 0.2\text{ mol}$$

Similarly, moles of CO_2, $n_{CO_2} = \frac{4.4}{44} = 0.1$ mol

[Molar mass of $CO_2 = 12 + 2 \times 16 = 44\text{ g mol}^{-1}$]

Total moles = 0.2 + 0.1 = 0.3 mol

$$pV = nRT$$

$$\Rightarrow \qquad p = \frac{nRT}{V}$$

In terms of SI units

$$\text{Pressure,} \quad p = \frac{0.3\text{ mol} \times 8.314\text{ Pa m}^3\text{ K}^{-1}\text{ mol}^{-1} \times 300}{9 \times 10^{-3}\text{ m}^3}$$

$$p = 8.314 \times 10^4\text{ Pa}$$

152 (*d*) $R_{\text{balloon}} = 10$ m

$$V_{\text{balloon}} = \frac{4}{3}\pi r^3 = \frac{4}{3} \times \frac{22}{7} \times (10)^3$$

$$= 4190.476\text{ m}^3.$$

$$V_{\text{balloon}} = V_{\text{displaced air (by balloon)}}$$

$\therefore$ Mass of displaced air = $V_{\text{displaced air}}$ × density of air

$$m_{\text{displaced air}} = 4190.476\text{ m}^3 \times 1.2\text{ kg m}^{-3}$$

$$m = 5028.57\text{ kg}$$

Mass of helium (He) filled in balloon,

$$m_{\text{He}} = \frac{pVM}{RT} \qquad \left(pV = \frac{mRT}{M}\right)$$

$$m_{\text{He}} = \frac{1.66\text{ bar} \times 4190.476 \times 10^3\text{ dm}^3 \times 4 \times 10^{-3}\text{ kg mol}^{-1}}{0.083\text{ bar dm}^3\text{ K}^{-1}\text{ mol}^{-1} \times 300\text{ K}}$$

$$m_{\text{He}} = 1117.46\text{ kg}$$

Total mass of filled balloon, (m_{balloon})

= mass of balloon + mass of He filled in the balloon

$$m_{\text{balloon}} = 100\text{ kg} + 1117.46\text{ kg} = 1217.46\text{ kg}$$

Pay load = mass of displaced air − mass of balloon

= 5028.57 kg − 1217.46 kg

= 3811.11 kg

153 (*c*) At a particular temperature, pV = constant

Thus, $p_1V_1 = p_2V_2 = p_3V_3 = p_4V_4$

As $V_1 > V_2 > V_3 > V_4$

Therefore, $p_1 < p_2 < p_3 < p_4$

154 (*c*) London dispersion forces operate only over very short distances. The energy of interaction is

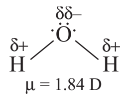
$$\frac{1}{(\text{distance between two interacting particles})^6}$$

Large or more complex is the molecule, greater is the magnitude of London forces. This is obviously due to the fact that the large electron clouds are easily distorted or polarised.

Hence, greater the polarisability of the interacting particles, greater is the magnitude of the interaction energy.

155 (*c*) Dipole-dipole forces act between the molecules possessing permanent dipole and ends of dipoles possess ‘partial charges’. Partial charges present on ends of a dipole are always less than unit electronic charge.

e.g.



156 (*c*) Pressure at the top of a mountain [or at high altitude] decreases. This suggests that, boiling takes place at lower temperature due to which, food takes more time to cool (boil). However, in a pressure cooker, pressure is increased and, hence boiling point increases.

Thus, food boils in a pressure cooker in a less period of time.

157 (*b*) The spherical shape of rain droplets is due to surface tension. The lowest energy state of a liquid will be observed when the surface area is minimum.

Surface tension tries to decrease the surface area of the liquid to the minimum. The rain droplets are spherical because for a given volume, a sphere has minimum surface area.

158 (*c*) Let number of mole of $H_2 = 1\,\text{mol}$

Number of moles of $O_2 = 4$ mol

$$\therefore \text{ Mole fraction of } O_2 = \frac{4}{1+4} = \frac{4}{5} = 0.8$$

$$\text{Mole fraction of } H_2 = \frac{1}{1+4} = \frac{1}{5} = 0.2$$

$$\text{Partial pressure of } O_2 = \text{mole fraction} \times p_{\text{total}}$$

$$= 0.8 \times 1 \text{ atm} = 0.8 \text{ atm}$$

$$= 0.8 \times 10^5 \text{ Nm}^{-2}$$

$$= 8 \times 10^4 \text{ Nm}^{-2}$$

159 (*a*) From Gay Lussac's law,

$$p \propto T \qquad \text{[volume constant]}$$

With increase of temperature, pressure increases.

160 (*a*) The graph given in the question depend upon the Boyle's law. At constant temperature, the graph between pV *vs* p at all pressures will be straight line parallel to x-axis for ideal gas. At constant temperature pV *vs* p plot for real gases is not straight line.

For ideal gas pV = constant at all pressures.

Therefore, only B represents ideal gas.

161 (*c*) With increase of temperature, the kinetic energy of the molecules of liquid increases which can overcome the intermolecular forces. Hence, the liquid starts flowing. In other words, the viscosity of a liquid decreases with increase in temperature.

It has been found that, the decrease is about 2% per degree rise in temperature.

Therefore, the correct option is (c).

162 (*d*) The gases which have higher critical temperature, liquefied first.

Hence, order of liquefaction is

$$O_2 > N_2 > H_2 > \text{He}$$

163 (*a*) In Shimla, atmospheric pressure is the lowest, therefore liquid will boil first at this place.

164 (*b*) The surface tension of liquids generally decreases with increase of temperature and becomes zero at the critical temperature. The decrease in surface tension with increase of temperature is due to the fact that with increase of temperature, the kinetic energy of the molecules increases and, therefore the intermolecular attraction decreases.

166 (*c*) At high altitude, atmospheric pressure is low.

Thus, A is correct but R is incorrect.

167 (*c*) The correct match is

$$A \rightarrow 3, B \rightarrow 1, C \rightarrow 4$$

A. When molar volume is constant, the p-T graph is called isochore.

B. When temperature is constant, the p-V graph is called isotherm.

C. When pressure is constant, V-T graph is called isobar.