# **Topic 1 Gaseous State**

Objective Questions I (Only one correct option)

 Points I, II and III in the following plot respectively correspond to (v<sub>mp</sub> : most probable velocity) (2019 Main, 10 April II)



- (a)  $v_{mp}$  of H<sub>2</sub>(300 K);  $v_{mp}$  of N<sub>2</sub>(300 K);  $v_{mp}$  of O<sub>2</sub>(400 K) (b)  $v_{mp}$  of O<sub>2</sub>(400 K);  $v_{mp}$  of N<sub>2</sub>(300 K);  $v_{mp}$  of H<sub>2</sub>(300 K)
- (c)  $v_{\rm mp}$  of N<sub>2</sub>(300 K);  $v_{\rm mp}$  of O<sub>2</sub>(400 K);  $v_{\rm mp}$  of H<sub>2</sub>(300 K)
- (d)  $v_{\rm mp}$  of N<sub>2</sub>(300 K);  $v_{\rm mp}$  of H<sub>2</sub>(300 K);  $v_{\rm mp}$  of O<sub>2</sub>(400 K)
- **2.** Consider the following table.

Gas	$a/(k Pa dm^6 mol^{-1})$	$b/(\mathrm{dm}^3\mathrm{mol}^{-1})$
Α	642.32	0.05196
В	155.21	0.04136
С	431.91	0.05196
D	155.21	0.4382

*a* and *b* are van der Waals' constants. The correct statement about the gases is (2019 Main, 10 April I)

- (a) gas *C* will occupy lesser volume than gas *A*; gas *B* will be lesser compressible than gas *D*
- (b) gas *C* will occupy more volume than gas *A*; gas *B* will be more compressible than gas *D*
- (c) gas *C* will occupy more volume than gas *A*; gas *B* will be lesser compressible than gas *D*
- (d) gas *C* will occupy more volume than gas *A*; gas *B* will be lesser compressible than gas *D*

**3.** At a given temperature *T*, gases Ne, Ar, Xe and Kr are found to deviate from ideal gas behaviour. Their equation of state is given as,  $p = \frac{RT}{V - b}$  at *T*.

Here, b is the van der Waals' constant. Which gas will exhibit steepest increase in the plot of Z (compression factor) vs p? (2019 Main, 9 April II) (a) Xe (b) Ar

**4.** Consider the van der Waals' constants, *a* and *b*, for the following gases.

Gas	Ar	Ne	Kr	Xe
$a/(atm dm^6 mol^2)$	1.3	0.2	5.1	4.1
$b/(10^{2} \text{ dm}^{3} \text{ mol}^{-1})$	3.2	1.7	1.0	5.0
$b/(10^{2} \text{ dm}^{3} \text{ mol}^{-1})$	3.2	1.7	1.0	5.

Which gas is expected to have the highest critical temperature? (2019 Main, 9 April I) (a) Kr (b) Xe

(c) .	Ar	(d) Ne

**5.** The combination of plots which does not represent isothermal expansion of an ideal gas is

(2019 Main, 12 Jan II)



**6.** An open vessel at 27°C 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

(2019 Main, 12 Jan II)

(a)	750 K	(b)	500 K
(c)	750°C	(d)	500°C

7. The volume of gas A is twice than that of gas B. The compressibility factor of gas A is thrice than that of gas B at same temperature. The pressures of the gases for equal number of moles are (2019 Main, 12 Jan I)

(a) $p_A$	$2p_B$	(b) $2p_A$	$3p_B$
(c) $p_A$	$3p_B$	(d) $3p_A$	$2p_B$

**8.** A 10 mg effervescent tablet containing sodium bicarbonate and oxalic acid releases  $0.25 \text{ mL of } \text{CO}_2$  at T = 298.15 K and p = 1 bar. If molar volume of  $\text{CO}_2$  is 25.0 L under such condition, what is the percentage of sodium bicarbonate in each tablet?

[Molar mass of NaHCO<sub>3</sub> 84 g mol<sup>1</sup>] (2019 Main, 11 Jan I) (a) 8.4 (b) 0.84 (c) 16.8 (d) 33.6

- **9.** 0.5 moles of gas A and x moles of gas B exert a pressure of 200 Pa in a container of volume  $10\text{m}^3$  at 1000 K. Given R is the gas constant in JK  $^1$  mol  $^1$ , x is (2019 Main, 9 Jan I) (a)  $\frac{2R}{4R}$  (b)  $\frac{4R}{2R}$  (c)  $\frac{4R}{2R}$  (d)  $\frac{2R}{4R}$
- **10.** Two closed bulbs of equal volume (*V*) containing an ideal gas initially at pressure  $p_i$  and temperature  $T_1$  are connected through a narrow tube of negligible volume as shown in the figure below. The temperature of one of the bulbs is then raised to  $T_2$ . The final pressure  $p_f$  is (2016 Main)

(a) 
$$2p_i \frac{T_1}{T_1 T_2}$$
 (b)  $2p_i \frac{T_2}{T_1 T_2}$   
(c)  $2p_i \frac{T_1 T_2}{T_1 T_2}$  (d)  $p_i \frac{T_1 T_2}{T_1 T_2}$ 

**11.** If *Z* is a compressibility factor, van der Waals' equation at low pressure can be written as (2014 Main)

(a) Z	1	$\frac{RT}{pb}$	(b) Z	1	$\frac{a}{VRT}$
(c) Z	1	$\frac{pb}{RT}$	(d) Z	1	$\frac{pb}{RT}$

**12.** For gaseous state, if most probable speed is denoted by  $C^*$ , average speed by  $\overline{C}$  and root square speed by C, then for a large number of molecules, the ratios of these speeds are

(a)  $C^* : \overline{C} : C$  1.225 : 1.128 : 1 (b)  $C^* : \overline{C} : C$  1.128 : 1.225 : 1 (c)  $C^* : \overline{C} : C$  1 : 1.128 : 1.225 (d)  $C^* : \overline{C} : C$  1 : 1.225 : 1.128 **13.** 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<sup>-2</sup>) (2012)



- **14.** The term that corrects for the attractive forces present in a real gas in the van der Waals' equation is (2009) (a) nb (b)  $n^2a/V^2$ (c)  $(n^2a/V^2)$  (d) nb
- **15.** The given graph represent the variations of Z (compressibility factor (Z)  $\frac{pV}{nRT}$ ) *versus p*, for three real gases A, B and C. Identify the only incorrect statement.



- (a) For the gas A, a 0 and its dependence on p is linear at all pressure
- (b) For the gas *B*, *b* 0 and its dependence on *p* is linear at all pressure
- (c) For the gas C, which is typical real gas for which neither a nor b 0. By knowing the minima and the point of intersection, with Z 1, a and b can be calculated
- (d) At high pressure, the slope is positive for all real gases
- 16. If helium and methane are allowed to diffuse out of the container under the similar conditions of temperature and pressure, then the ratio of rate of diffusion of helium to methane is (2005)

$$\begin{array}{c} (a) \ 2.0 \\ (c) \ 0.5 \end{array} \qquad \begin{array}{c} (b) \ 1.0 \\ (d) \ 4.0 \end{array}$$

**17.** For a monatomic gas kinetic energy *E*. The relation with rms velocity is (2004, 1M)

(a) 
$$u = \frac{2E}{m}^{1/2}$$
 (b)  $u = \frac{3E}{2m}^{1/2}$   
(c)  $u = \frac{E}{2m}^{1/2}$  (d)  $u = \frac{E}{3m}^{1/2}$ 

- **18.** Positive deviation from ideal behaviour takes place because of (2003.1M)
  - (a) molecular interaction between atom and pV/nRT 1
  - (b) molecular interaction between atom and pV / nRT = 1
  - (c) finite size of atoms and pV/nRT 1
  - (d) finite size of atoms and pV/nRT = 1
- **19.** Which of the following volume (V) temperature (T) plots represents the behaviour of one mole of an ideal gas at the atmospheric pressure? (2002, 3M)



- **20.** The root mean square velocity of an ideal gas at constant pressure varies with density (d) as (2001, S, 1M) (a)  $d^2$ (b) *d* (c)  $\sqrt{d}$ (d)  $1/\sqrt{d}$
- **21.** The compressibility of a gas is less than unity at STP. Therefore, (2000, 1M)

(b)  $V_m < 22.4 \text{ L}$ (d)  $V_m = 44.8 \text{ L}$ (a)  $V_m > 22.4 \text{ L}$ (c)  $V_m = 22.4 \text{ L}$ 

- **22.** The rms velocity of hydrogen is  $\sqrt{7}$  times the rms velocity of nitrogen. If T is the temperature of the gas (2000.1M) (a)  $T(H_2) = T(N_2)$ (b)  $T(H_2) > T(N_2)$ (c)  $T(H_2) < T(N_2)$ (d)  $T(H_2) = \sqrt{7} T(N_2)$
- **23.** A gas will approach ideal behaviour at (1999, 2M) (a) low temperature and low pressure
  - (b) low temperature and high pressure
  - (c) high temperature and low pressure
  - (d) high temperature and high pressure

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24. According to Graham's law, at a given temperature the ratio of the rates of diffusion  $\frac{r_A}{r_A}$  of gases A and B is given by  $r_R$ 

(where, p and M are pressures and molecular weights of gases A and B respectively) (1998, 2M)

(a) 
$$\frac{p_A}{p_B} = \frac{M_A}{M_B}^{\frac{1}{2}}$$
 (b)  $\frac{M_A}{M_B} = \frac{p_A}{p_B}^{\frac{1}{2}}$   
(c)  $\frac{p_A}{p_B} = \frac{M_B}{M_A}^{\frac{1}{2}}$  (d)  $\frac{M_A}{M_B} = \frac{p_B}{p_A}^{\frac{1}{2}}$ 

- **25.** The compressibility factor for an ideal gas is (1997, 1M) (a) 1.5 (b) 1.0 (c) 2.0 (d)
- **26.** The ratio between the root mean square speed of  $H_2$  at 50 K and that of O<sub>2</sub> at 800 K is (1996, 1M) (d)  $\frac{1}{4}$ (a) 4 (b) 2 (c) 1

- **27.** Equal weights of ethane and hydrogen are mixed in an empty container at 25 C. The fraction of the total pressure exerted by hydrogen is (1993, 1M) (a) 1 : 2 (b) 1 : 1 (c) 1 : 16 (d) 15 : 16
- **28.** At constant volume, for a fixed number of moles of a gas the pressure of the gas increases with rise of temperature due to (a) increase in average molecular speed (1992.1M) (b) increase rate of collisions amongst molecules
  - (c) increase in molecular attraction
  - (d) decrease in mean free path
- **29.** According to kinetic theory of gases, for a diatomic molecule (1991, 1M)
  - (a) the pressure exerted by the gas is proportional to mean velocity of the molecule
  - (b) the pressure exerted by the gas is proportional to the root mean velocity of the molecule
  - (c) the root mean square velocity of the molecule is inversely proportional to the temperature
  - (d) the mean translational kinetic energy of the molecule is proportional to the absolute temperature
- **30.** The rate of diffusion of methane at a given temperature is twice that of a gas X. The molecular weight of X is (1990, 1M)

- **31.** The density of neon will be highest at (1990, 1M) (a) STP (b) 0 C, 2 atm (d) 273 C, 2 atm (c) 273 C, 1 atm
- **32.** The value of van der Waals' constant *a* for the gases  $O_2$ ,  $N_2$ ,  $NH_3$  and  $CH_4$  are 1.360, 1.390, 4.170 and 2.253L<sup>2</sup> atm mol<sup>2</sup> respectively. The gas which can most easily be liquefied is (a)  $O_2$ (b)  $N_2$  $(c) NH_3$ (d) CH<sub>4</sub>
- 33. A bottle of dry ammonia and a bottle of dry hydrogen chloride connected through a long tube are opened simultaneously at both ends the white ammonium chloride ring first formed will be (1988, 1M)
  - (a) at the centre of the tube
  - (b) near the hydrogen chloride bottle
  - (c) near the ammonia bottle
  - (d) throughout the length of the tube
- **34.** In van der Waals' equation of state for a non-ideal gas, the term that accounts for intermolecular forces is (1988, 1M)

(a) 
$$(V \ b)$$
 (b)  $RT$  (c)  $p + \frac{a}{V^2}$  (d)  $(RT)^{-1}$ 

- **35.** The average velocity of an ideal gas molecule at 27 C is 0.3 m/s. The average velocity at 927 C will be (1986, 1M) (a) 0.6 m/s (b) 0.3 m/s (c) 0.9 m/s(d) 3.0 m/s
- **36.** Rate of diffusion of a gas is (1985, 1M) (a) directly proportional to its density (b) directly proportional to its molecular weight
  - (c) directly proportional to the square root of its molecular weight
  - (d) inversely proportional to the square root of its molecular weight

- **37.** Equal weights of methane and hydrogen are mixed in an empty container at 25 C. The fraction of the total pressure exerted by hydrogen is (1984, 1M)
  - (a)  $\frac{1}{2}$  (b)  $\frac{8}{9}$  (c)  $\frac{1}{9}$  (d)  $\frac{16}{17}$
- 38. When an ideal gas undergoes unrestrained expansion, no cooling occurs because the molecules (1984, 1M) (a) are above the inversion temperature
  - (b) exert no attractive forces on each other
  - (c) do work equal to loss in kinetic energy
  - (d) collide without loss of energy
- **39.** Helium atom is two times heavier than a hydrogen molecule. At 298 K, the average kinetic energy of a helium atom is
  - (a) two times that of a hydrogen molecule (1982, 1M)
  - (b) same as that of a hydrogen molecule
  - (c) four times that of a hydrogen molecule
  - (d) half that of a hydrogen molecule
- **40.** Equal weights of methane and oxygen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by oxygen is (1981, 1M)
  - (a)  $\frac{1}{3}$  (b)  $\frac{1}{2}$  (c)  $\frac{2}{3}$  (d)  $\frac{1}{3}$   $\frac{273}{298}$
- 41. The temperature at which a real gas obeys the ideal gas laws over a wide range of pressure is (1981, 1M)
  (a) critical temperature (b) Boyle temperature
  (c) inversion temperature (d) reduced temperature
- 42. The ratio of root mean square velocity to average velocity of a gas molecule at a particular temperature is (1981, 1M)
  (a) 1.085 : 1 (b) 1 : 1.086 (c) 2 : 1.086 (d) 1.086 : 2

#### **Objective Questions II**

(One or more than one correct option)

**43.** One mole of a monoatomic real gas satisfies the equation  $p(V \ b) = RT$  where, b is a constant. The relationship of interatomic potential V(r) and interatomic distance r for gas is given by (2015 Adv.)



- **44.** According to kinetic theory of gases (2011) (a) collisions are always elastic
  - (b) heavier molecules transfer more momentum to 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

- 45. A gas described by van der Waals' equation (2008, 4M)(a) behaves similar to an ideal gas in the limit of large molar volumes
  - (b) behaves similar to an ideal gas in the limit of large pressures
  - (c) is characterised by van der Waals' coefficients that are dependent on the identity of the gas but are independent of the temperature
  - (d) has the pressure that is lower than the pressure exerted by the same gas behaving ideally
- **46.** If a gas is expanded at constant temperature (1986, 1M) (a) the pressure decreases
  - (b) the kinetic energy of the molecules remains the same
  - (c) the kinetic energy of the molecules decreases
  - (d) the number of molecules of the gas increases

#### **Numerical Value Based Question**

**47.** A closed tank has two compartments A and B, both filled with oxygen (assumed to be ideal gas). The partition separating the two compartments is fixed and is a perfect heat insulator (Fig. 1). If the old partition is replaced by a new partition which can slide and conduct heat but does not allow the gas to leak across (Fig. 2), the volume (in m<sup>3</sup>) of the compartment A after the system attains equilibrium is \_\_\_\_\_.



#### Assertion and Reason

*Read the following questions and answer as per the direction given below* :

- (a) Statement I is correct; Statement II is correct; Statement II is the correct explanation of Statement I
- (b) Statement I is correct; Statement II is correct; Statement II is not the correct explanation of Statement I
- (c) Statement I is correct; Statement II is incorrect
- (d) Statement I is incorrect; Statement II is correct
- **48. Statement I** The pressure of a fixed amount of an ideal gas is proportional to its temperature.

**Statement II** Frequency of collisions and their impact both increase in proportion to the square root of temperature.

- (2000)
- **49.** Statement I The value of van der Waals' constant '*a*' is larger for ammonia than for nitrogen.

Statement II Hydrogen bonding is present in ammonia.

(1998)

(1993, 1M)

#### **Passage Based Questions**

#### Passage

X and Y are two volatile liquids with molar weights of  $10 \text{ g} \mod ^{1}$  and 40 gmol <sup>1</sup> respectively. Two cotton plugs, one soaked in X and



the other soaked in Y, are simultaneously placed at the ends of a tube of length L = 24 cm, as shown in the figure.

The tube is filled with an inert gas at 1 atm pressure and a temperature of 300 K. Vapours of X and Y react to form a product which is first observed at a distance d cm from the plug soaked in X. Take X and Y to have equal molecular diameters and assume ideal behaviour for the inert gas and the two vapours. (2014 Adv.)

- **50.** The experimental value of d is found to be smaller than the estimate obtained using Graham's law. This is due to
  - (a) larger mean free path for X as a compared of that of Y
  - (b) larger mean free path for Y as compared to that of X
  - (c) increased collision frequency of *Y* with the inert gas as compared to that of *X* with the inert gas
  - (d) increased collision frequency of *X* with the inert gas as compared to that of *Y* with the inert gas
- **51.** The value of *d* in cm (shown in the figure), as estimated from Graham's law, is

(a) 8	(b) 12	(c) 16	(d) 20
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#### Match the Columns

**52.** Match the gases under specified conditions listed in Column I with their properties/laws in Column II.

	Column I		Column II
А.	Hydrogen gas ( $p$ 200 atm, T 273 K)	p.	compressibility factor 1
В.	Hydrogen gas ( $p \sim 0, T$ 273 K)	q.	attractive forces are dominant
C.	$CO_2(p \ 1 \text{ atm}, T \ 273 \text{ K})$	r.	pV nRT
D.	Real gas with very large molar volume	s.	p(V nb) nRT

#### **Fill in the Blanks**

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(2007, 6M)
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- **53.** The absolute temperature of an ideal gas is ..... to/than the average kinetic energy of the gas molecules. (1997, 1M)
- 54. 8 g each of oxygen and hydrogen at 27°C will have the total kinetic energy in the ratio of ...... (1989, 1M)
- **55.** The value of pV for 5.6 L of an ideal gas is ...... RT, at NTP. (1987, 1M)
- **56.** The rate of diffusion of a gas is ...... proportional to both ......... and square root of molecular mass. (1986, 1M)
- **57.**  $C_p$   $C_V$  for an ideal gas is ..... (1984, 1M)
- **58.** The total energy of one mole of an ideal monoatomic gas at 27 C is ..... cal. (1984, 1M)

#### True / False

- **59.** A mixture of ideal gases is cooled up to liquid helium temperature (4.22 K) to form an ideal solution. (1996, 1M)
- **60.** In the van der Waals' equation,  $p = \frac{n^2 a}{V^2} (V nb) nRT$

the constant '*a*' reflects the actual volume of the gas molecules. (19

- **61.** A gas in a closed container will exert much higher pressure due to gravity at the bottom than at the top. (1985, 1/2 M)
- 62. Kinetic energy of a molecule is zero at 0°C. (1985, 1/2 M)

#### **Integer Answer Type Questions**

- 63. The diffusion coefficient of an ideal gas is proportional to its mean free path and mean speed. The absolute temperature of an ideal gas is increased 4 times and its pressure is increased 2 times. As a result, the diffusion coefficient of this gas increases *x* times. The value of *x* is ... (2016 Adv.)
- **64.** A closed vessel with rigid walls contains 1 mole of  ${}^{238}_{92}$  U and 1 mole of air at 298 K. Considering complete decay of  ${}^{238}_{92}$  U to  ${}^{206}_{82}$  Pb, the ratio of the final pressure to the initial pressure of the system at 298 K is (2015 Adv.)
- **65.** If the value of Avogadro number is  $6.023 ext{ 10}^{23} ext{ mol}^{1}$  and the value of Boltzmann constant is  $1.380 ext{ 10}^{23} ext{ JK}^{1}$ , then the number of significant digits in the calculated value of the universal gas constant is (2014 Adv.)
- **66.** To an evacuated vessel with movable piston under external pressure of 1 atm, 0.1 mole of He and 1.0 mole of an unknown compound (vapour pressure 0.68 atm at 0 C) are introduced. Considering the ideal gas behaviour, the total volume (in litre) of the gases at 0 C is close to (2011)

#### **Subjective Questions**

- **67.** At 400 K, the root mean square (rms) speed of a gas X (molecular weight = 40) is equal to the most probable speed of gas Y at 60 K. The molecular weight of the gas Y is (2009)
- 68. The average velocity of gas molecules is 400 m s<sup>-1</sup>, find the rms velocity of the gas.
  (2003, 2M)
- **69.** The density of the vapour of a substance at 1 atm pressure and 500 K is  $0.36 \text{ kg m}^{-3}$ . The vapour effuses through a small hole at a rate of 1.33 times faster than oxygen under the same condition.
  - (i) Determine, (a) molecular weight (b) molar volume(c) compression factor (Z) of the vapour and (d) which forces among the gas molecules are dominating, the attractive or the repulsive?
  - (ii) If the vapour behaves ideally at 1000 K, determine the average translational kinetic energy of a molecule.

(2002, 5M)

**70.** The compression factor (compressibility factor) for one mole of a van der Waals' gas at 0 C and 100 atm pressure is found to be 0.5. Assuming that the volume of a gas molecule is negligible, calculate the van der Waals' constant 'a'.

(2001, 5M)

- **71.** Calculate the pressure exerted by one mole of  $CO_2$  gas at 273 K if the van der Waals' constant a = 3.592 dm<sup>6</sup> atm mol<sup>2</sup>. Assume that the volume occupied by  $CO_2$  molecules is negligible. (2000)
- **72.** (i) One mole of nitrogen gas at 0.8 atm takes 38 s to diffuse through a pin-hole, whereas one mole of an unknown compound of xenon with fluorine at 1.6 atm takes 57 s to diffuse through the same hole. Calculate the molecular formula of the compound.
  - (ii) The pressure exerted by 12 g of an ideal gas at temperature t C in a vessel of volume V litre is one atm. When the temperature is increased by 10°C at the same volume, the pressure increases by 10%. Calculate the temperature t and volume V.
    (Malaminiation of the state of the same 120)

(Molecular weight of the gas = 120) (1999, 5M)

- **73.** Using van der Waals' equation, calculate the constant *a* when two moles of a gas confined in a four litre flask exert a pressure of 11.0 atm at a temperature of 300 K. The value of *b* is  $0.05 \text{ L mol}^{-1}$ . (1998, 4M)
- **74.** An evacuated glass vessel weighs 50.0 g when empty 148.0 g when filled with a liquid of density 0.98 g  $mL^{-1}$  and 50.5 g when filled with an ideal gas at 760 mm Hg at 300 K. Determine the molar mass of the gas. (1998, 3M)
- **75.** A mixture of ideal gases is cooled up to liquid helium temperature (4.22 K) to form an ideal solution. Is this statement true or false ? Justify your answer in not more than two lines. (1996, 1M)
- **76.** The composition of the equilibrium mixture  $(Cl_2 \implies 2Cl)$  which is attained at 1200 C, is determined by measuring the rate of effusion through a pin-hole. It is observed that at 1.80 mm Hg pressure, the mixture effuses 1.16 times as fast as krypton effuses under the same conditions. Calculate the fraction of chlorine molecules dissociated into atoms (atomic weight of Kr = 84) (1995, 4M)
- **77.** A mixture of ethane  $(C_2H_6)$  and ethene  $(C_2H_4)$  occupies 40 L at 1.00 atm and at 400 K. The mixture reacts completely with 130 g of  $O_2$  to produce  $CO_2$  and  $H_2O$ . Assuming ideal gas behaviour, calculate the mole fractions of  $C_2H_4$  and  $C_2H_6$  in the mixture. (1995, 4M)
- **78.** An LPG (liquefied petroleum gas) cylinder weighs 14.8 kg when empty. When full it weighs 29.0 kg and shows a pressure of 2.5 atm. In the course of use at 27 C, the weight of the full cylinder reduces to 23.2 kg. Find out the volume of the gas in cubic metres used up at the normal usage conditions, and the final pressure inside the cylinder. Assume LPG to the *n*-butane with normal boiling point of 0 C. (1994, 3M)
- **89.** A 4 : 1 molar mixture of He and  $CH_4$  is contained in a vessel at 20 bar pressure. Due to a hole in the vessel, the gas mixture leaks out. What is the composition of the mixture effusing out initially? (1994, 2M)
- **80.** A gas bulb of 1 L capacity contains 2.0  $10^{21}$  molecules of nitrogen exerting a pressure of 7.57  $10^3$  Nm<sup>-2</sup>. Calculate

the root mean square (rms) speed and the temperature of the gas molecules. If the ratio of the most probable speed to root mean square speed is 0.82, calculate the most probable speed for these molecules at this temperature. (1993, 4M)

**81.** At room temperature, the following reaction proceed nearly to completion.  $2NO + O_2$   $2NO_2$   $N_2O_4$ The dimer,  $N_2O_4$ , solidifies at 262 K. A 250 mL flask and a 100 mL flask are separated by a stopcock. At 300 K, the nitric oxide in the larger flask exerts a pressure of 1.053 atm and the smaller one contains oxygen at 0.789 atm.

The gases are mixed by opening the stopcock and after the end of the reaction the flasks are cooled to 220 K. Neglecting the vapour pressure of the dimer, find out the pressure and composition of the gas remaining at 220 K. (Assume the gases to behave ideally). (1992, 4M)

- **82.** At 27 C, hydrogen is leaked through a tiny hole into a vessel for 20 min. Another unknown gas at the same temperature and pressure as that of hydrogen is leaked through same hole for 20 min. After the effusion of the gases the mixture exerts a pressure of 6 atm. The hydrogen content of the mixture is 0.7 mole. If the volume of the container is 3 L. What is the molecular weight of the unknown gas? (1992, 3M)
- 83. Calculate the volume occupied by 5.0 g of acetylene gas at 50 C and 740 mm pressure. (1991, 2M)
- **84.** The average velocity at  $T_1$  K and the most probable at  $T_2$  K of CO<sub>2</sub> gas is 9.0  $10^4$  cm s<sup>-1</sup>. Calculate the value of  $T_1$  and  $T_2$  (1990, 4M)
- **85.** A spherical balloon of 21 cm diameter is to be filled up with hydrogen at NTP from a cylinder containing the gas at 20 atm at 27 C. If the cylinder can hold 2.82 L of water, calculate the number of balloons that can be filled up. (1987, 5M)
- Calculate the root mean square velocity of ozone kept in a closed vessel at 20 C and 82 cm mercury pressure. (1985, 2M)
- **87.** Give reasons for the following in one or two sentences.
  - (i) Equal volumes of gases contain equal number of moles. (1984, 1M)
  - (ii) A bottle of liquor ammonia should be cooled before opening the stopper. (1983, 1M)
- 88. Oxygen is present in one litre flask at a pressure of 7.6 10<sup>-10</sup> mm Hg. Calculate the number of oxygen molecules in the flask at 0 C. (1983, 2M)
- **89.** When 2 g of a gas A is introduced into an evacuated flask kept at 25 C, the pressure is found to be one atmosphere. If 3 g of another gas B is then added to the same flask, the total pressure becomes 1.5 atm. Assuming ideal gas behaviour, calculate the ratio of the molecular weights  $M_A : M_B$ .

(1983, 2M)

**90.** At room temperature, ammonia gas at 1 atm pressure and hydrogen chloride gas at *p* atm pressure are allowed to effuse through identical pin holes from opposite ends of a glass tube of one metre length and of uniform cross-section.

Ammonium chloride is first formed at a distance of 60 cm from the end through which HCl gas is sent in. What is the value of p? (1982, 4M)

- **91.** Calculate the average kinetic energy, in joule per molecule in 8.0 g of methane at 27°C. (1982, 2M)
- **92.** The pressure in a bulb dropped from 2000 to 1500 mm of mercury in 47 min when the contained oxygen leaked through a small hole. The bulb was then evacuated. A mixture of oxygen and another gas of molecular weight 79 in the molar ratio of 1 : 1 at a total pressure of 4000 mm of mercury was introduced. Find the molar ratio of the two gases remaining in the bulb after a period of 74 min.

(1981, 3M)

# Topic 2 Liquid State

**Objective Questions I** (Only one correct option)

The qualitative sketches I, II and III given below show the variation of surface tension with molar concentration of three different aqueous solutions of KCl, CH<sub>3</sub>OH and CH<sub>3</sub>(CH<sub>2</sub>)<sub>11</sub>OSO<sub>3</sub>Na<sup>+</sup> at room temperature. (2016 Adv.)



Topic 1

1.	(c)	<b>2.</b> (b)	<b>3.</b> (a)	<b>4.</b> (a)
5.	(c)	<b>6.</b> (b)	<b>7.</b> (b)	<b>8.</b> (a)
9.	(b)	<b>10.</b> (b)	<b>11.</b> (b)	<b>12.</b> (c)
13.	(c)	14. (b)	15. (b)	<b>16.</b> (a)
17.	(a)	<b>18.</b> (a)	<b>19.</b> (c)	<b>20.</b> (d)
21.	(b)	<b>22.</b> (c)	<b>23.</b> (c)	<b>24.</b> (c)
25.	(b)	<b>26.</b> (c)	<b>27.</b> (d)	<b>28.</b> (a)
29.	(d)	<b>30.</b> (a)	<b>31.</b> (b)	<b>32.</b> (c)
33.	(b)	<b>34.</b> (c)	<b>35.</b> (a)	<b>36.</b> (d)
37.	(b)	<b>38.</b> (b)	<b>39.</b> (b)	<b>40.</b> (a)
41.	(b)	<b>42.</b> (a)	<b>43.</b> (c)	<b>44.</b> (a)
45.	(a,c)	<b>46.</b> (a,b)	<b>47.</b> (2.22)	<b>48.</b> (d)
49.	(a)	<b>50.</b> (d)	<b>51.</b> (c)	
52.	A p,s; B	r; C p, q; D	r	

- **93.** A hydrocarbon contains 10.5 g of carbon per gram of hydrogen. 1 L of the vapour of the hydrocarbon at 127°C and 1 atm pressure weighs 2.8 g. Find the molecular formula of the hydrocarbon. (1980, 3M)
- **94.** 3.7 g of a gas at 25°C occupied the same volume as 0.184 g of hydrogen at 17°C and at the same pressure. What is the molecular weight of the gas ? (1979, 2M)
- 95. 4.215 g of a metallic carbonate was heated in a hard glass tube, the CO<sub>2</sub> evolved was found to measure 1336 mL at 27°C and 700 mm of Hg pressure. What is the equivalent weight of the metal ? (1979, 3M)
- **96.** Calculate the density of  $NH_3$  at 30°C and 5 atm pressure. (1978, 2M)
  - (d)  $CH_3OH$  KCl  $CH_3(CH_2)_{11}OSO_3 Na^+$
- At 100°C and 1 atm if the density of the liquid water is 1.0 g cm<sup>-3</sup> and that of water vapour is 0.0006 g cm<sup>-3</sup>, then the volume occupied by water molecules in 1 L of steam at this temperature is (2000, 1M)
  (a) 6 cm<sup>3</sup>
  (b) 60 cm<sup>3</sup>
  (c) 0.6 cm<sup>3</sup>
  (d) 0.06 cm<sup>3</sup>
- 3. The critical temperature of water is higher than that of O<sub>2</sub> because the H<sub>2</sub>O molecule has (1997)
  (a) fewer electrons than O<sub>2</sub>
  (b) two covalent bonds
  (c) V-shape
  (d) dipole moment
- A liquid is in equilibrium with its vapour at it's boiling point. On the average, the molecules in the two phases have equal

  (a) inter-molecular forces
  (b) potential energy
  (c) kinetic energy
  (d) total energy

# Answers

53.	less	<b>54.</b>	1:16	55.	0.25	
56.	inversely, tin	ıe		57.	R	<b>58.</b> 900
59.	F	60.	F	61.	F	<b>62.</b> F
63.	(4)	64.	(9)	65.	(4)	<b>66.</b> (7 L)
67.	(4)	<b>68.</b>	$435~{ m ms}^{-1}$	70.	(1025)	<b>71.</b> (0.99 atm)
73.	(6.46)	74.	(123 g mol	$^{1})$		<b>76.</b> (0.14)
78.	$(2.46 \text{ m}^3)$	79.	(8:1)	80.	$(407 \text{ ms}^{-1})$	<b>81.</b> (0.221 atm)
82.	$(1020 \text{ g mol}^{-1})$	83.	(5.23 L)	85.	(10)	
86.	$(390.2 \text{ ms}^{-1})$	88.	$(2.7  10^{10} \text{ g})$	mol	1)	
89.	(1:3)	90.	(2.20 atm)	91.	(6.2 10 21	J/molecule)
94.	(41.32g)	95.	(12.15)	96.	$(3.42 \text{ gL}^{-1})$	
Гор	ic 2					
1.	(d)	2.	(c)	3.	(d)	<b>4.</b> (c)

# **Hints & Solutions**

А

#### **Topic 1 Gaseous State**

1.	Key Idea From kinetic gas equation,								
	Most probable velocity $(v_{\rm mp}) = \sqrt{\frac{2RT}{M}}$								
	where, $R$ gas constant, $T$ temperature,								
		М	molecu	ılar mass					
	$v_{\rm mp} = \sqrt{\frac{2RT}{M}}$ , i.e. $v_{\rm mp} = \sqrt{\frac{T}{M}}$								
-	Gas	М	$T(\mathbf{K})$	$\sqrt{T / M}$					
-	$H_2$	2	300	$\sqrt{300/2}$ $\sqrt{150}$ III (Highest)					
	N <sub>2</sub>	28	300	$\sqrt{300/28}$ $\sqrt{10.71}$ I (Lowest)					
	O <sub>2</sub>	32	400	$\sqrt{400/32}$ $\sqrt{12.5}$ II					
	с								

So,

- I. corresponds to  $v_{\rm mp}$  of  $\rm N_2$  (300 K)
- II. corresponds to  $v_{\rm mp}$  of  $O_2$  (400 K)
- III. corresponds to  $v_{\rm mp}$  of H<sub>2</sub> (300 K)
- 2. For 1 mole of a real gas, the van der Waals' equation is

$$p = \frac{a}{V^2} (V = b) RT$$

The constant 'a' measures the intermolecular force of attraction of gas molecules and the constant 'b' measures the volume correction by gas molecules after a perfectly inelastic binary collision of gas molecules.

For gas A and gas C given value of 'b' is  $0.05196 \,\mathrm{dm^3} \,\mathrm{mol}^{-1}$ . Here,

intermolecular force of attraction а

compressibility real nature 1

volume occupied

Value of  $a/(kPa dm^6 mol^{-1})$  for gas A(642.32) > gas C(431.91)So, gas C will occupy more volume than gas A. Similarly, for a given value of a say 155.21 kPa dm<sup>6</sup> mol<sup>-1</sup> for gas B and gas D

intermolecular force of attraction  $\overline{b}$ compressibility real nature 1

volume accupied

 $b/(\text{dm}^3 \text{ mol}^{-1})$  for gas B (0.04136) < Gas D (0.4382) So, gas B will be more compressible than gas D.

3. Noble gases such as Ne, Ar, Xe and Kr found to deviate from ideal gas behaviour.

Xe gas will exhibit steepest increase in plot of Z vs p. Equation of state is given as:

$$p = \frac{RT}{(V = b)} = p(V = b) = RT$$

$$pV \quad pb \quad RT \qquad pV \quad RT \quad pb$$

$$\frac{pV}{RT} \quad 1 \quad \frac{pb}{RT}$$
As,  $Z \quad \frac{pV}{RT}$ 
so,  $Z \quad 1 \quad \frac{pb}{RT} \quad y \quad c \quad mx$ 

The plot of z vs p is found to be



The gas with high value of b will be steepest as slope is directly proportional to b. b is the van der Waals' constant and is equal to four times the actual volume of the gas molecules. Xe gas possess the largest atomic volume among the given noble gases (Ne, Kr, Ar). Hence, it gives the steepest increase in the plot of Z(compression factor) vsp.

4. Critical temperature is the temperature of a gas above which it cannot be liquefied what ever high the pressure may be. The kinetic energy of gas molecules above this temperature is sufficient enough to overcome the attractive forces. It is represented as  $T_c$ . 0.0

	$T_c$	$\frac{3u}{27Rb}$	
For Ar,	$T_c$	8 1.3	0.0144
	-	27 8.314 3.2	
For Ne,	$T_c$	$\frac{8 \ 0.2}{27 \ 8.314 \ 1.7}$	0.0041
For Kr,	$T_c$	8 5.1 27 8.314 1.0	0.18
For Xe,	$T_c$	8 4.1 27 8.314 5.0	0.02

The value of  $T_c$  is highest for Kr (Krypton).

**5.** In isothermal expansion,  $pV_m = K$  (constant)

This relation is plotted in graph 'C'  $\frac{K}{V_m}$ 

Likewise,

This relation is plotted in graph "A". Thus, graph B and D are incorrect. For them the correct graphs are:



6. Given, temperature  $(T_1)$  27 C 273 27 300 K Volume of vessel constant Pressure in vessel constant Volume of air reduced by  $\frac{2}{5}$  so the remaining volume of air is  $\frac{3}{5}$ .

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

$$n T_1 = \frac{3}{5} n T_2$$
 ...(i)

...(ii)

...(i)

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

 $n \quad 300 \quad \frac{3}{5}n \quad T_2$  $T_2 \quad 300 \quad \frac{5}{3} \quad 500 \,\mathrm{K}$ 

**7.** Given,  $Z_A = 3Z_B$ 

or

Compressibility factor (*Z*) =  $\frac{pV}{nRT}$  [for real gases] On substituting in equation (i), we get

$$\frac{p_A V_A}{n_A R T_A} = \frac{3 p_B V_B}{n_R R T_R}$$

Also, it is given that

Eq. (ii)

$$V_A = 2V_B$$
,  $n_A = n_B$  and  $T_A = T_B$   
becomes  
$$\frac{p_A \quad 2V_B}{n_B R T_B} \quad \frac{3p_B V_B}{n_B R T_B}$$

$$2p_A = 3p_B$$

8.  $2NaHCO_3 H_2C_2O_4 2CO_2 Na_2C_4O_4 H_2O_2$   $2 \mod 1 \mod 2 \mod$ In the reaction, number of mole of  $CO_2$  produced.

$$n \quad \frac{pV}{RT} \quad \frac{1 \text{ bar } 0.25 \quad 10^{-5} \text{ L}}{0.082 \text{ L atm K}^{-1} \text{ mol}^{-1} \quad 298.15 \text{ K}}$$
  
1.02 \quad 10^{-5} \text{ mol}^{-5} \text{ mol}^{-1} \text{} 10^{-5} text{} 10^{-5} text{}

Number of mole of NaHCO<sub>3</sub>  $\frac{\text{Weight of NaHCO}_3}{\text{Molecular mass of NaHCO}_3}$ 

$$w_{\text{NaHCO}_3}$$
 1.02 10 <sup>5</sup> 84 10<sup>3</sup> mg  
0.856 mg  
NaHCO<sub>3</sub>%  $\frac{0.856}{10}$  100 8.56%

9. From the ideal gas equation,

$$pV nRT$$
  
Given:  $p = 200 \text{ Pa}, V = 10 \text{ m}^3, T = 1000 \text{ K}$ 

 $n_A = 0.5$  moles,  $n_B = x$  moles

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

$$200 \quad 10 \quad (n_4 \quad n_B) \quad R \quad 1000$$

10. Initially,

Number of moles of gases in each container  $\frac{p_i V}{RT_1}$ Total number of moles of gases in both containers  $2\frac{p_i V}{RT_1}$ After mixing, number of moles in left chamber  $\frac{p_f V}{RT_1}$ Number of moles in right chamber  $\frac{p_f V}{RT_2}$ Total number of moles  $\frac{p_f V}{RT_1} = \frac{p_f V}{RT_2} \frac{p_f V}{R} = \frac{1}{T_1} = \frac{1}{T_2}$ As total number of moles remains constant. Hence,  $\frac{2p_i V}{RT_1} = \frac{p_f V}{RT_1} = \frac{p_f V}{RT_2} = p_f = 2p_i = \frac{T_2}{T_1 = T_2}$ 

- **11. PLAN** To solve this problem, the stepwise approach required, i.e.
  (*i*) Write the van der Waals' equation, then apply the condition that at low pressure, volume become high, i.e.
  V b~V
  - (ii) Now calculate the value of compressibility factor (Z).  $[Z \quad pV / RT]$

According to van der Waals' equation,

$$p = \frac{a}{V^2} (V = b) RT$$

At low pressure,  $p = \frac{a}{V^2} V RT$ 

$$pV \quad \frac{a}{V} \quad RT \text{ or } pV \quad RT \quad \frac{a}{V}$$

Divide both side by RT,  $\frac{pV}{RT} = 1 - \frac{a}{RTV}$ 

**12.** 
$$C^*$$
 Most probable speed  $\sqrt{\frac{2RT}{M}}$ 

C Average speed  $\sqrt{\frac{3KT}{M}}$ 

*C* Root square speed corrected as root means square speed, i.e.

rms 
$$\sqrt{\frac{3RT}{M}}$$
 and as we know  $\overset{*}{C}$   $\overline{C}$   $C$   
 $\overset{*}{C}:\overline{C}:C$   $1: \sqrt{\frac{4}{p}}:\sqrt{\frac{3}{2}}$   $1:1.128:1.225$ 

NOTE

As no option correspond to root square speed, it is understood as misprint. It should be root mean square speed.

13. The van der Waals' equation of state is

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

For one mole and when b = 0, the above equation condenses to

$$p = \frac{a}{V^2} V RT$$

 $pV RT \frac{a}{V}$ ...(i)

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

a'. Equating with slope of the straight line given in the graph.

 $a \quad \frac{20.1 \quad 21.6}{3 \quad 2} \quad 1.5$ a 1.5

14. In the van der Waals' equation

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

The additional factor in pressure, i.e.  $\frac{n^2 a}{V^2}$  corrects for intermolecular force while b corrects for molecular volume.

**15.** Option (b) is incorrect statement because at high pressure slope of the line will change from negative to positive.

**16.** 
$$\frac{r_{(\text{He})}}{r_{(\text{CH}_4)}} = \sqrt{\frac{16}{4}} = 2:1$$

- **17.** Kinetic energy (E)  $\frac{3}{2}kT$ RMS speed (u)  $\sqrt{\frac{3kT}{m}}$  $u \sqrt{\frac{2E}{m}}$
- **18.** Positive deviation corresponds to Z = 1

$$\therefore Z \quad \frac{pV}{nRT}, \text{ for positive deviation}, \frac{pV}{nRT} \quad 1.$$

19. Option (b) and (d) are ruled out on the basis that at the initial point of 273 K, 1 atm, for 1.0 mole volume must be 22.4 L, and it should increase with rise in temperature. Option (a) is ruled out on the basis that initial and final points are not connected by the ideal gas equation V = T, i.e. V/T do not have the same value at the two points.

In option (c), at the initial point, the volume is 22.4 L as required by ideal gas equation and (V/T) have the same value at both initial and final points.

**20.** Root mean square velocity  $(u_{\rm rms}) = \sqrt{\frac{3RT}{M}}$ p M dRT

Also,

Substituting for RT/M in  $u_{\rm rms}$  expression gives,

$$u_{\rm rms} \quad \sqrt{\frac{3p}{d}} \qquad u_{\rm rms} \quad \frac{1}{\sqrt{d}}$$

**21.** Compressibility factor (Z)  $\frac{V}{V_{id}}$  1 (given) V 22.4 L  $\therefore$   $V_{id}$  (1 mol) 22.4 L at STP

**22.** Root mean square speed 
$$u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$
  
$$\frac{u_{\text{rms}}(\text{H}_2)}{u_{\text{rms}}(\text{N}_2)} = \sqrt{7} = \sqrt{\frac{T(\text{H}_2)}{2}} = \frac{28}{T(\text{N}_2)}$$

7 
$$\frac{14T (H_2)}{T (N_2)}$$
  
T (N<sub>2</sub>) 2T (H<sub>2</sub>) i.e. T (H<sub>2</sub>) T (N<sub>2</sub>)

- 23. At high temperature and low pressure, the gas volume is infinitely large and both intermolecular force as well as molecular volume can be ignored. Under this condition postulates of kinetic theory applies appropriately and gas approaches ideal behaviour.
- **24.** Rate of effusion  $p_i$ ;  $p_i$  Partial pressure of *i*th component

$$\sqrt{\frac{1}{M}}$$
**25.** Compressibility factor (Z)  $\frac{V}{V_{\text{ideal}}}$  1  
 $\therefore$  For ideal gas  $V$   $V_{\text{ideal}}$   
**26.** Expression of rms is,  $u_{\text{rms}} \sqrt{\frac{3RT}{M}}$   
 $\frac{u_{\text{rms}} (\text{H}_2 \text{ at } 50 \text{ K})}{u_{\text{rms}} (\text{O}_2 \text{ at } 800 \text{ K})} \frac{\sqrt{\frac{3R}{2}}}{\sqrt{\frac{3R}{32}}} \sqrt{\frac{3R}{800}}}{\sqrt{\frac{50}{2}} \frac{32}{800}}$   
**27.** Let  $x$  g of each gas is mixed.

Mole of ethane 
$$\frac{x}{30}$$
  
Mole of hydrogen  $\frac{x}{2}$   
Mole fraction of hydrogen  $\frac{\frac{x}{2}}{\frac{x}{2} + \frac{x}{30}} = \frac{\frac{15}{16}}{\frac{16}{16}}$   
Partial pressure of H<sub>2</sub>  
Total pressure Mole fraction of hydrogen  
15:16

1

**28.** Average speed 
$$\sqrt{\frac{8RT}{M}}$$

i.e. at constant volume, for a fixed mass, increasing temperature increases average speeds and molecules collide more frequently to the wall of container leading to increase in gas pressure.

29. The mean translational kinetic energy ( ) of an ideal gas is  $\frac{3}{2}k_BT$ ; T Absolute temperature, i.e. T

**30.** 
$$\frac{r_{\text{CH}_4}}{r_X}$$
 2  $\sqrt{\frac{M_X}{16}}$   $M_X$  64

**31.** The ideal gas equation,  $pV \quad nRT \quad \frac{w}{M}RT$ 

$$pM = \frac{w}{V} RT \quad dRT \qquad (d \text{ density})$$
$$d = \frac{pM}{RT}$$

i.e. density will be greater at low temperature and high pressure.

**32.** The ease of liquefication of a gas depends on their intermolecular force of attraction which in turn is measured in terms of van der Waals' constant *a*. Hence, higher the value of *a*, greater the intermolecular force of attraction, easier the liquefication.

In the present case,  $NH_3$  has highest *a*, can most easily be liquefied.

**33.** HCl will diffuse at slower rate than ammonia because rate of effusion  $\frac{1}{\sqrt{M}}$ .

Therefore, ammonia will travel more distance than HCl in the same time interval and the two gas will first meet nearer to HCl end.

**34.** In van der Waals' equation of state

$$p = \frac{a}{V^2}$$
 (V b) RT (For 1 mole)

1

The first factor  $(p \ a/V^2)$  correct for intermolecular force while the second term  $(V \ b)$  correct for molecular volume.

**35.** Expression for average velocity is  $u_{av} = \sqrt{\frac{8R}{M}}$ 

For the same gas but at different temperature

$$\frac{u_{\text{avg}}(T_1)}{u_{\text{avg}}(T_2)} \quad \sqrt{\frac{T_1}{T_2}} \quad \sqrt{\frac{300}{1200}} \quad \frac{1}{2}$$
$$u_{\text{av}} (927 \text{ C}) \quad 2 \quad u_{\text{av}} (27 \text{ C}) \quad 0.6 \text{ ms}$$
**36.** Rate of effusion  $\frac{1}{\sqrt{M}}$ ,

**37.** Let *x* grams of each hydrogen and methane are mixed,

Moles of H<sub>2</sub> 
$$\frac{x}{2}$$
  
Moles of CH<sub>4</sub>  $\frac{x}{16}$   
Mole fraction of H<sub>2</sub>  $\frac{\frac{x}{2}}{\frac{x}{2} + \frac{x}{16}} = \frac{8}{9}$   
Partial pressure of H<sub>2</sub>  
Total pressure Mole fraction of H<sub>2</sub>  $\frac{8}{9}$ 

- **38.** According to postulates of kinetic theory, there is no intermolecular attractions or repulsions between the molecules of ideal gases.
- **39.** According to kinetic theory, average kinetic energy (E)  $\frac{3}{2}k_BT$

where,  $k_B$  is Boltzmann's constant. Since, it is independent of molar mass, it will be same for He and H<sub>2</sub> at a given temperature.

**40.** If x g of both oxygen and methane are mixed then :

Mole of oxygen 
$$\frac{x}{32}$$
  
Mole of methane  $\frac{x}{16}$ 

Mole fraction of oxygen 
$$\frac{\frac{x}{32}}{\frac{x}{32} \frac{x}{16}} = \frac{1}{3}$$

According to law of partial pressure

Partial pressure of oxygen  $(p_{O_2})$  Mole fraction Total pressure

$$\frac{p_{O_2}}{p} \quad \frac{1}{3}$$

**41.** It is the Boyle temperature  $T_B$ . At Boyle temperature, the first virial coefficient (*B*) vanishes and real gas approaches ideal behaviour.

$$T_B = \frac{a}{Rb}$$

Here, a and b are van der Waals' constants.

**42.** The two types of speeds are defined as;

Root mean square speed 
$$(u_{\rm rms}) = \sqrt{\frac{3RT}{M}}$$
  
Average speed  $(u_{\rm av}) = \sqrt{\frac{8RT}{M}}$ 

For the same gas, at a given temperature, M and T are same, therefore

$$\frac{u_{\text{rms}}}{u_{\text{av}}} = \sqrt{\frac{3RT}{M}} : \sqrt{\frac{8RT}{M}}$$
$$\sqrt{3} : \sqrt{\frac{8}{3}} = \sqrt{3} : \sqrt{2.54} = 1.085 : 1$$

- **43.** Equation of state  $p(V \ b) \ RT$  indicates absence of intermolecular attraction or repulsion, hence interatomic potential remains constant on increasing ' ' in the beginning. As the molecules come very close, their electronic and nuclear repulsion increases abruptly.
- **44.** (a) According to a postulate of kinetic theory of gases, collision between the molecules as well as with the wall of container is perfectly elastic in nature.
  - (b) If a gas molecule of mass *m* moving with speed *u* collide to the wall of container, the change in momentum is p = -2mu. Therefore, heavier molecule will transfer more momentum to the wall as there will be greater change in momentum of the colliding gas molecule. However, this is not postulated in kinetic theory.
  - (c) According to Maxwell-Boltzmann distribution of molecular speed, very few molecules have either very high or very low speeds. Most of the molecules moves in a specific, intermediate speed range.
  - (d) According to kinetic theory of gases, a gas molecule moves in straight line unless it collide with another molecule or to the wall of container and change in momentum is observed only after collision.
- **45.** Option (a) is correct because in the limit of large volume, both intermolecular force and molecular volume becomes negligible in comparison to volume of gas.

Option (b) is wrong statement because in the limit of large pressure Z = 1.

Option (c) is correct statement. For a van der Waals' gas, van der Waals' constants a and b are characteristic of a gas, independent of temperature.

Option (d) is wrong statement because Z can be either less or greater than unity, hence real pressure can be less or greater than ideal pressure.

- 46. Pressure is inversely proportional to volume at constant temperature, hence (a) is correct.
  Average kinetic energy of a gas is directly proportional to absolute temperature, hence (b) is correct.
  Expansion at constant temperature cannot change the number of molecules, hence (d) is incorrect.
- **47.** Given  $p_1$  5 bar,  $V_1$  1 m<sup>3</sup>,  $T_1$  400 K

So,

So,

$$n_1 \quad \frac{5}{400R} \qquad \qquad (\text{from } pV \quad nRT)$$

Similarly,  $p_2$  1 bar,  $V_2$  3 m<sup>3</sup>,  $T_2$  300 K,  $n_2 \frac{3}{300R}$ 

Let at equilibrium the new volume of A will be  $(1 \ x)$ So, the new volume of B will be  $(3 \ x)$ Now, from the ideal gas equation.

$$\frac{p_1 V_1}{n_1 R T_1} \quad \frac{p_2 V_2}{n_2 R T_2}$$

and at equilibrium (due to conduction of heat)

$$\frac{\frac{p_1}{T_1}}{\frac{p_2}{n_1}} \frac{\frac{p_2}{T_2}}{\frac{V_1}{n_1}}$$

$$\frac{\frac{V_1}{n_1}}{\frac{V_2}{n_2}} \text{ or } V_1 n_2 \quad V_2 n_1$$

After putting the values

$$(1 \ x) \ \frac{3}{300R} \ (3 \ x) \ \frac{5}{400R} \text{ or } (1 \ x) \ \frac{(3 \ x)5}{4}$$
  
or  $4(1 \ x) \ 15 \ 5x \text{ or } 4 \ 4x \ 15 \ 5x \text{ or } x \ \frac{11}{9}$   
Hence, new volume of *A* i.e.,  $(1 \ x)$  will comes as  $1 \ \frac{11}{9} \ \frac{20}{9}$  or 2.22.

- **48.** Assertion is incorrect because besides amount, pressure also depends on volume. However, reason is correct because both frequency of collisions and impact are directly proportional to root mean square speed which is proportional to square root of absolute temperature
- **49.** *a* is the measure of intermolecular force of attraction. Greater the intermolecular force of attraction (H-bond in the present case) higher the value of *a*.
- **50.** X is a lighter gas than Y, hence X has greater molecular speed. Due to greater molecular speed of X, it will have smaller mean free path and greater collision frequency with the incrt gas molecules. As a result X will take more time to travel a given distance along a straight line. Hence X and Y will meet at a distance smaller than one calculated from Graham's law.

Hence, (d) is the correct choice.

**51. PLAN** This problem can be solved by using the concept of Graham's law of diffusion according to which rate of diffusion of non-reactive gases under similar conditions of temperature and pressure are inversely proportional to square root of their density.

Rate of diffusion  $\frac{1}{\sqrt{\text{molar weight of gas}}}$ 

Let distance covered by X is d, then distance covered by Y is 24 - d.

If  $r_X$  and  $r_Y$  are the rate of diffusion of gases X and Y,

$$\frac{\dot{X}}{\dot{Y}} = \frac{d}{24} \frac{d}{d} \sqrt{\frac{40}{10}} 2$$
[:: Rate of diffusion distance travelled]

d 48 2d

3*d* 48 *d* 16 cm

Hence, (c) is the correct choice.

**52.** A. At p = 200 atm, very high pressure, Z = 1. Also, at such a high pressure, the pressure correction factor  $\frac{n^2 a}{V^2}$  can be

ignored in comparison to p.

- B. At  $P \sim 0$ , gas will behave like an ideal gas, pV = nRT.
- C.  $\operatorname{CO}_2(p \ 1 \operatorname{atm}, T \ 273 \operatorname{K}), Z \ 1.$
- D. At very large molar volume, real gas behaves like an ideal gas.

**53.** Less; 
$$E = \frac{3}{2} RT$$

**54.** 1 : 16, KE  $\frac{3}{2}$  *nRT*. At same temperature, KE (total) *n*.

- **55.** 0.25 *RT* because at NTP, 5.6 L  $\frac{1}{4}$  mole.
- 56. Inversely, time.
- **57.** For an ideal gas,  $C_p = C_V = R$

**58.** At 27°C, 
$$E = \frac{3}{2}RT = \frac{3}{2}$$
 2 300 900 cal

- **59.** An ideal gas cannot be liquefied because there exist no intermolecular attraction between the molecules of ideal gas.
- **60.** *a* is the measure of intermolecular force.
- **61.** In a close container, gas exert uniform pressure everywhere in the container.
- **62.** KE  $\frac{3}{2}$  *RT* where, *T* is absolute temperature (in Kelvin).
- **63.** (DC) Diffusion coefficient (mean free path)  $U_{\text{mean}}$ Thus (DC)  $U_{\text{mean}}$

But, 
$$\frac{RT}{\sqrt{2} N_0 p} = \frac{T}{P}$$
  
and 
$$U_{\text{mean}} = \sqrt{\frac{8RT}{M}}$$
$$U_{\text{mean}} = \sqrt{T}$$
$$DC = \frac{(T)^{3/2}}{p}$$

$$\frac{(DC)_2}{(DC)_1}(x) = \frac{p_1}{p_2} - \frac{T_2}{T_1}^{3/2} = \frac{p_1}{2p_1} - \frac{4T_1}{T_1}^{3/2}$$
$$\frac{1}{2} \quad (8) \quad 4$$

**64.** 
$$_{92}U^{238}$$
  $_{82}Pb^{206}$  8  $_{2}He^{4}(g)$  6  $_{1}$ 

n(gas)[Initial] 1 (air)

n(gas)[Final] 8(He) 1(air) 9

At constant temperature and volume;

So, 
$$\frac{p}{p_f} \frac{n_f}{n_i} \frac{9}{1} = 9$$

65. PLAN This problem can be solved by using the concept involved in calculation of significant figure.

Universal gas constant,  $R = kN_A$ 

- where, k Boltzmann constant
- and  $N_A$  Avogadro's number
  - R 1.380 10<sup>23</sup> 6.023 10<sup>23</sup> J/Kmol 8.31174 ~ 8.312

Since, k and  $N_A$  both have four significant figures, so the value of R is also rounded off upto 4 significant figures.

[When number is rounded off, the number of significant figure is reduced, the last digit is increased by 1 if following digits 5 and is left as such if following digits is 4.] Hence, correct integer is (4).

**66.** Since, the external pressure is 1.0 atm, the gas pressure is also 1.0 atm as piston is movable. Out of this 1.0 atm partial pressure due to unknown compound is 0.68 atm.

Therefore, partial pressure of He

Volume 
$$\frac{n(\text{He})RT}{p(\text{He})} = \frac{0.32 \text{ atm.}}{0.32 \text{ atm.}} 7 \text{ L}$$

 $u_{\rm rms}$   $u_{\rm mps}$ 

Volume of container = Volume of He.

$$\begin{cases}
 \sqrt{\frac{3RT}{M(X)}} & \sqrt{\frac{2RT}{M(Y)}} \\
 \frac{3R}{M(X)} & \sqrt{\frac{2RT}{M(Y)}} \\
 \frac{3R}{400} & \frac{2R}{M(Y)} \\
 \frac{3R}{400} & \frac{2R}{M(Y)} \\
 \frac{3R}{M(Y)} & \sqrt{\frac{3}{400}} \\
 \frac{3R}{$$

(c) 
$$Z \quad \frac{pV}{RT} \quad \frac{1}{0.082} \frac{50}{500} \quad 1.22$$
  
(d)  $\because Z \quad 1$ , repulsive force is dominating.  
(ii)  $\overline{E}_k \quad \frac{3}{2} k_B T \quad \frac{3}{2} \quad 1.38 \quad 10^{-23} \quad 1000 \text{ J} \quad 2.07 \quad 10^{-20} \text{ J}$ 

**70.** In case of negligible molecular volume, b = 0. For 1 mole of gas

$$p \quad \frac{a}{V^{2}} \quad V \quad RT$$

$$pV \quad \frac{a}{V} \quad RT$$

$$\frac{pV}{RT} \quad \frac{a}{VRT} \quad 1 \qquad \because \frac{pV}{RT} \quad Z$$

$$Z \quad \frac{a}{\frac{ZRT}{p}} \quad RT \quad 1 \qquad Z \quad \frac{ap}{ZR^{2}T^{2}} \quad 1$$

$$a \quad \frac{ZR^{2}T^{2}(1 \quad Z)}{p} \quad \frac{0.5 (0.082 \quad 273)^{2} (1 \quad 0.5)}{100}$$

$$a \quad 1.25 \text{ atm } L^{2} \text{ mol }^{2}$$

**71.** In case of negligible molecular volume, b = 0 and van der Waals' equation reduces to

$$p \quad \frac{n^2 a}{V^2} \quad V \quad nRT$$

$$p \quad \frac{RT}{V} \quad \frac{a}{V^2} \qquad (n \quad 1 \text{ mole})$$

$$\frac{0.082 \quad 273}{22.4} \quad \frac{3.592}{(22.4)^2} \quad 0.99 \text{ atm}$$

72. (i) For the same amount of gas being effused

$$\frac{r_1}{r_2} \quad \frac{t_2}{t_1} \quad \frac{p_1}{p_2} \sqrt{\frac{M_2}{M_1}} \\ \frac{57}{38} \quad \frac{0.8}{1.6} \sqrt{\frac{M_2}{28}} \\ M_2 \quad 252 \text{ g mol}^{-1}$$

Also, one molecule of unknown xenon-fluoride contain only one Xe atom [M (Xe) = 131], formula of the unknown gas can be considered to be  $XeF_n$ .

131 19*n* 252; *n* 6.3, hence the unknown gas is  $XeF_6$ . (ii) For a fixed amount and volume, p = T

$$\frac{1}{1.1} \quad \frac{T}{T \quad 10} \quad \text{where, } T \quad \text{Kelvin temperature} \\ T \quad 100 \text{ K} \quad t \quad 273 \\ t \quad 173 \text{ C} \\ \text{Volume} \quad \frac{nRT}{p} \quad \frac{12}{120} \quad \frac{0.082 \quad 100}{1} \quad 0.82 \text{ L}$$

73. The van der Waals' equation is

$$p \quad \frac{n^2 a}{V^2} \quad (V \quad nb) \quad nRT$$

$$a \quad \frac{V^2}{n^2} \frac{nRT}{V \ nb} \quad p \quad \frac{(4)^2}{(2)^2} \quad \frac{2 \ 0.082 \ 300}{4 \ 2 \ (0.05)} \quad 11$$
  
6.46 atm L<sup>2</sup> mol<sup>-2</sup>

**74.** Mass of liquid 148 50 98 g

Volume of liquid  $\frac{98}{0.98}$  100 mL = volume of flask mass of gas 50.5 50 = 0.50 g

Now applying ideal gas equation :  $pV = \frac{w}{M} RT$ 

$$M = \frac{wRT}{pV} = \frac{0.5 \quad 0.082 \quad 300}{1 \quad 0.1} = 123 \text{ g mol}^{-1}$$

- **75.** False, ideal gas cannot be liquefied as there is no intermolecular attraction between the molecules of ideal gas. Hence, there is no point of forming ideal solution by cooling ideal gas mixture.
- **76.** If ' ' is the degree of dissociation, then at equilibrium

$$\begin{array}{c} \mbox{Cl}_2 \rightleftharpoons 2\mbox{Cl}\\ \mbox{Moles} & 1 & 2 & \mbox{Total} & 1 \end{array}$$

From diffusion information

$$\frac{r_{(\text{mix})}}{r_{(\text{Kr})}} = 1.16 \quad \sqrt{\frac{84}{M(\text{mix})}}$$
$$\frac{M_{(\text{mix})}}{M_{(\text{mix})}} = \frac{62.4}{1}$$
$$\frac{71}{1} = 62.4$$
$$0.14$$

**77.** The total moles of gaseous mixture 
$$\frac{pV}{RT} = \frac{1 \quad 40}{0.082 \quad 400}$$
  
1.22

Let the mixture contain x mole of ethane. Therefore,

$$C_{2}H_{6} + \frac{7}{2}O_{2} \qquad 2CO_{2} + 3H_{2}O$$

$$C_{2}H_{4} + 3O_{2} \qquad 2CO_{2} + 2H_{2}O$$

$$1.22 x$$
Total moles of O<sub>2</sub> required  $\frac{7}{2}x \quad 3(1.22 \quad x) \quad \frac{x}{2} \quad 3.66$ 

$$\frac{130}{32} \quad \frac{x}{2} \quad 3.66$$
x 0.805 mole ethane and 0.415 mole ethene.  
Mole fraction of ethane  $\frac{0.805}{1.22} \quad 0.66$ 

Mole fraction of ethene 1 0.66 0.34

**78.** Weight of butane gas in filled cylinder 29 14.8 kg 14.2 kg During the course of use, weight of cylinder reduces to 23.2 kg

Weight of butane gas remaining now

23.2 14.8 = 8.4 kg  
Also, during use, V (cylinder) and T remains same.  
Therefore, 
$$\frac{p_1}{p_2} = \frac{n_1}{n_2}$$
  
 $p_2 = \frac{n_2}{n_1} p_1 = \frac{8.4}{14.2} = 2.5$  Here,  $\frac{n_2}{n_1}$   
1.48 atm

Also, pressure of gas outside the cylinder is 1.0 atm.

$$\begin{array}{cccc} pV & nRT \\ V & \frac{nRT}{p} & \frac{(14.2 & 8.4) & 10^3}{58} & \frac{0.082 & 30}{1} \\ 2460 \text{ L} & 2.46 \text{ m}^3 \end{array}$$

**79.** 
$$\frac{r_{\text{He}}}{r_{\text{CH}_4}} = \frac{n_{\text{He}}}{n_{\text{CH}_4}} \sqrt{\frac{M_{\text{CH}_4}}{M_{\text{He}}}} = \frac{4}{1} \sqrt{\frac{16}{4}} = 8$$

Initial ratio of rates of effusion gives the initial composition of mixture effusing out. Therefore,  $n(\text{He}): n(\text{CH}_4) = 8:1$ 

80. Number of moles 
$$\frac{2}{6} \frac{10^{21}}{10^{23}} = 0.33 = 10^{-2}$$
  
 $p = 7.57 = 10^{3} \text{ Nm}^{-2}$   
Now,  $pV = nRT$   
 $T = \frac{pV}{nR} = \frac{7.57 = 10^{3}}{0.33 = 10^{-2}} \frac{10^{-3}}{8.314} = 276 \text{ K}$   
 $u_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 = 8.314}{28 = 10^{-3}}} \text{ m s}^{-1} = 496 \text{ ms}^{-1}$   
Also,  $\frac{u_{\text{mps}}}{u_{\text{rms}}} = 0.82$   
 $u_{\text{mps}} = 0.82 = u_{\text{rms}} = 0.82 = 496 \text{ ms}^{-1} = 407 \text{ ms}^{-1}$ 

2.1

**81.** First we calculate partial pressure of NO and  $O_2$  in the combined system when no reaction taken place.

$$pV \quad \text{constant} \qquad p_1V_1 \quad p_2V_2$$

$$p_2(\text{NO}) \quad \frac{1.053 \quad 250}{350} \quad 0.752 \text{ atm}$$

$$p_2(\text{O}_2) \quad \frac{0.789 \quad 100}{350} \quad 0.225 \text{ atm}$$

Now the reaction stoichiometry can be worked out using partial pressure because in a mixture.

$$\begin{array}{cccccccc} & p_i & n_i \\ 2NO & + & O_2 & 2NO_2 & N_2O_4 \\ \text{(nitial} & 0.752 \text{ atm} & 0.225 \text{ atm} & 0 & 0 \\ \text{Final} & 0.302 & 0 & 0 & 0.225 \text{ atm} \end{array}$$

Now, on cooling to 220 K,  $N_2O_4$  will solidify and only unreacted NO will be remaining in the flask.

$$p T$$

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

$$\frac{0.302}{p_2} \frac{300}{220}$$

$$p_2(\text{NO}) \quad 0.221 \text{ atm}$$

**82.** Total moles of gas in final mixture  $\frac{pV}{RT} = \frac{6}{0.082} \frac{3}{300} = 0.731$ 

 $\therefore$  Mole of H<sub>2</sub> in the mixture 0.70

÷

 $\frac{w_2}{w_1}$ 

Mole of unknown gas (X) 0.031

Because both gases have been diffused for same time

$$\frac{r(H_2)}{r(X)} = \frac{0.70}{0.031} \sqrt{\frac{M}{2}}$$
$$\frac{M}{1020 \text{ g mol}^{-1}}$$

83. 
$$V \quad \frac{nRT}{p}$$
For acetylene gas,  $5 \text{ g} \quad \frac{5}{26} \text{ mol}$ 

$$p \quad 740 \text{ mm} = \frac{740}{760} \text{ atm}$$

$$T \quad 50 \text{ C} = 323 \text{ K}$$
Substituting in ideal gas equation
$$V \quad \frac{5}{26} \quad \frac{0.082 \quad 323}{74} \quad 76 \quad 5.23 \text{ L}$$
84.  $u_{av}$  (average velocity)  $\sqrt{\frac{8RT_1}{M}}$ 

$$\frac{9 \quad 10^4}{100} \text{ ms}^{-1} \quad \sqrt{\frac{8 \quad 8.314 \ T_1}{3.14} \quad 44 \quad 10^{-3}}$$

$$T_1 \quad 1682.5 \text{ K}$$
Also, for the same gas
$$\frac{u_{av}}{u_{mps}} \quad \sqrt{\frac{8RT_1}{M}} : \sqrt{\frac{2RT_2}{M}} \quad \sqrt{\frac{8T_1}{2T_2}}$$

$$1 \quad \sqrt{\frac{4T_1}{T_2}}$$

$$T_2 \quad \frac{4T_1}{4} \quad \frac{4 \quad 1682.5}{3.14} \quad 2142 \text{ K}$$
Hence,  $T_1 \quad 1682.5 \text{ K}, \ T_2 \quad 2142 \text{ K}$ 

**85.** Volume of balloon  $\frac{4}{3} r^3 \frac{4}{3} 3.14 \frac{21}{2} cm^3$  $= 4847 \text{ cm}^3 \quad 4.85 \text{ L}$ 

Now, when volume of  $H_2(g)$  in cylinder is converted into NTP volume, then ... т7

$$\frac{\frac{p_1 V_1}{T_1} + \frac{p_2 V_2}{T_2}}{\frac{20}{300} + \frac{1}{273}}, V_2 \text{ NTP volume}$$

$$\frac{V_2}{V_2} = 51.324 \text{ L}$$

Also, the cylinder will not empty completely, it will hold 2.82 L of  $H_2(g)$  when equilibrium with balloon will be established. Hence, available volume of  $H_2(g)$  for filling into balloon is

$$51.324$$
  $2.82 = 48.504$  L

Number of balloons that can be filled  $\frac{48.504}{4.85}$  10

**86.** 
$$u_{\rm rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.314 \times 293}{48 \times 10^{-3}}} = 390.2 \,{\rm ms}^{-1}$$

- 87. (i)  $NH_3(l)$  is highly volatile, a closed bottle of  $NH_3(l)$  contains large number of molecules in vapour phase maintaining high pressure inside the bottle. When the bottle is opened, there is chances of bumping of stopper. To avoid bumping, bottle should be cooled that lowers the pressure inside.
  - (ii) According to Avogadro's hypothesis, "Under identical conditions of pressure and temperature, equal volume of ideal gases contain equal number of molecules."

**88.** Number of moles (n) 
$$\frac{pV}{RT}$$
  
and n  $\frac{N$  (Number of molecules)  
 $N_A$  (Avogadro number)  
N  $nN_A = \frac{pV}{RT} = N_A$   
 $\frac{7.6 \times 10^{-10}}{760} = \frac{1}{0.082 \times 273} = 6.023 \times 10^{23}$   
2.7  $\times 10^{10}$  molecules

89. From the given information, it can be easily deduced that in the final mixture,

partial pressure of 
$$A$$
 1.0 atm  
partial pressure of  $B$  0.5 atm  
Also
$$n_{A} \quad \frac{p_{A}V}{RT} \quad \frac{V}{RT}$$

$$n_{B} \quad \frac{p_{B}V}{RT} \quad \frac{0.5 V}{RT}$$

$$\frac{n_{B}}{n_{A}} \quad \frac{1}{2} \quad \frac{w_{B}}{M_{B}} \quad \frac{M_{A}}{w_{A}} \quad \frac{3}{2} \quad \frac{M_{A}}{M_{B}}$$

$$M_{A}:M_{B} \quad 1:3$$
**90.** Rate of effusion  $(r) \quad \frac{p}{\sqrt{M}}$ 

$$\frac{r(\text{NH}_{3})}{r(\text{HCl})} \quad \frac{1}{\sqrt{17}} \quad \frac{\sqrt{36.5}}{p} \qquad \frac{40}{60} \quad \frac{1}{p} \sqrt{\frac{3}{2}}$$

$$\frac{r(\text{NH}_3)}{r(\text{HCl})} = \frac{1}{\sqrt{17}} \frac{\sqrt{36.5}}{p} = \frac{40}{60} = \frac{1}{p} \sqrt{\frac{36.5}{17}}$$
$$p = \frac{3}{2} \sqrt{\frac{36.5}{17}} = 2.20 \text{ atm}$$

**91.** KE 
$$\frac{3}{2}k_BT : k_B$$
 Boltzmann's constant

$$\frac{3}{2}$$
 1.38 10 <sup>23</sup> 300 J 6.21 10 <sup>21</sup> J/molecule

**92.** Rate of effusion is expressed as  $\frac{dp}{dt} = \frac{kp}{\sqrt{M}}$ k constant, p instantaneous pressure

$$\frac{dp}{p} = \frac{k}{\sqrt{M}} \frac{dt}{dt}$$

kt Integration of above equation gives  $\ln \frac{p_0}{p}$  $\sqrt{M}$ р k47

Using first information : ln  $\frac{2000}{1500}$ 

$$\overline{00} \quad \overline{\sqrt{32}} \\
k \quad \frac{\sqrt{32}}{47} \ln \quad \frac{4}{3} \qquad \dots (i)$$

Now in mixture, initially gases are taken in equal mole ratio, hence they have same initial partial pressure of 2000 mm of Hg each.

After 74 min :

Also

 $\frac{4T_1}{T_2}$ 

For O<sub>2</sub> ln 
$$\frac{2000}{p_{O_2}} = \frac{74k}{\sqrt{32}}$$

Substituting k from Eq. (i) gives

$$\ln \frac{2000}{p_{O_2}} = \frac{74}{\sqrt{32}} = \frac{\sqrt{32}}{47} \ln \frac{4}{3}$$

$$\ln \frac{2000}{p_{O_2}} \quad \frac{74}{47} \ln \frac{4}{3}$$
Solving gives  $p(O_2)$  at 74 min 1271.5 mm  
For unknown gas :  $\ln \frac{2000}{p_g} \quad \frac{74}{\sqrt{79}}$ 
Substituting  $k$  from (i) gives  
 $\ln \frac{2000}{p_g} \quad \frac{74}{\sqrt{79}} \quad \frac{\sqrt{32}}{47} \ln \frac{4}{3}$ 
Solving gives :  $p_g$  1500 mm  
After 74 min,  $p(O_2): p(g)$  1271.5 : 1500

- Also, in a mixture, partial pressure number of moles  $n(O_2): n(g) = 1: 1.18$
- **93.** First we determine empirical formula as

	С	Н
Weight	10.5	1
Mole	$\frac{10.5}{12}$ 0.875	1
Simple ratio	1	1/0.875 = 1.14
Whole no.	7	8

Empirical formula C<sub>7</sub>H<sub>8</sub>

From gas equation :  $pV = \frac{w}{M} RT$ 

$$M \quad \frac{wRT}{pV} \quad \frac{2.8 \quad 0.082 \quad 400}{1 \quad 1} \quad 91.84 \quad 92$$

:. Molar mass (M) is same as empirical formula weight. Molecular formula = Empirical formula  $C_7H_8$ 

94. For same p and V, n 
$$\frac{1}{T}$$
  
 $\frac{n(\text{gas})}{n(\text{H}_2)} \frac{T(\text{H}_2)}{T(\text{gas})}$   
 $n(\text{H}_2) \frac{0.184}{2} \quad 0.092$   
 $n(\text{gas}) \frac{290}{298} \quad 0.092 = 0.0895$   
∴ 0.0895 mole of gas weigh 3.7 g  
1 mole of gas will weigh  $\frac{3.7}{0.0895} = 41.32$  g

**95.** Moles of  $CO_2$  can be calculated using ideal gas equation as :

$$n \quad \frac{pV}{RT} \quad \frac{700}{760} \quad \frac{1336}{1000} \quad \frac{1}{0.082} \quad \frac{1}{300} \quad 0.05$$

Also, the decomposition reaction is : MCO = MO

$$\begin{array}{ll} MCO_3 & MO + CO_2 \\ 0.05 \text{ mol} & 0.05 \text{ mol} \end{array}$$

$$\therefore \quad 0.05 \text{ mole } MCO_3 \quad 4.215 \text{ g}$$

$$1.0 \text{ mole } MCO_3 \quad \frac{4.215}{0.05} = 84.3 \text{ g (molar mass)}$$

$$84.3 \quad \text{MW of } M + 12 + 48$$

$$\text{Molecular weight of metal} \quad 24.3$$

$$\therefore \quad \text{Metal is bivalent, equivalent weight}$$

$$\frac{\text{Molecular weight}}{2} \quad 12.15$$

**96.** The ideal gas equation :

$$pV \quad nRT \quad \frac{w}{M} RT$$

$$pM \quad \frac{w}{V} RT \quad dRT \text{ where, 'd' is density}$$

$$d \quad \frac{pM}{RT} \quad \frac{5 \quad 17}{0.082 \quad 303} \quad 3.42 \text{ g L}^{-1}.$$

# **Topic 2** Liquid State

**1.** I (CH<sub>3</sub>OH) : Surface tension decreases as concentration increases.

II (KCl) : Surface tension increases with concentration for ionic salt.

III  $[CH_3(CH_2)_{11}OSO_3 Na^+]$ : It is an anionic detergent.

There is decrease in surface tension before micelle formation, and after CMC (Critical Micelle Concentration) is attained, no change in surface tension.



2. Let us consider, 1.0 L of liquid water is converted into steam . Volume of  $H_2O(l)$  1 L, mass 1000 g

Volume of 1000 g steam 
$$\frac{1000}{0.0006}$$
 cm<sup>3</sup>

: Volume of molecules in  $\frac{1000}{0.0006}$  cm<sup>3</sup> steam = 1000 cm<sup>3</sup>

Volume of molecules in

$$1000 \text{ cm}^3 \text{ steam} = \frac{1000}{1000} \quad 0.0006 \quad 1000 = 0.60 \text{ cm}^3$$

- **3.** Critical temperature is directly proportional to intermolecular force of attraction.  $H_2O$  is a polar molecule, has greater intermolecular force of attraction than  $O_2$ , hence higher critical temperature.
- **4.** At liquid-vapour equilibrium at boiling point, molecules in two phase posses the same kinetic energy.