Chapter 6

STATES OF MATTER (Gaseous States)

A — SINGLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

1. A gas distributes itself uniformly into the entire space available because of
(a) repulsive forces between molecules
(b) attractive forces between molecules
(c) ceaseless random motion of molecules
(d) random collisions amongst the molecules

2. According to the kinetic theory of gases, between two successive collisions gas molecule travels
(a) in a wrong path
(b) in a circular path
(c) in a rectilinear path
(d) with a retarded velocity

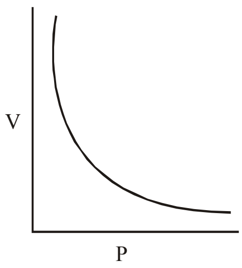
3. The postulates of the kinetic molecular theory of gases include all those that follow *except*
(a) no forces exist between molecules
(b) molecules are point masses
(c) molecules are in random motion
(d) molecules are repelled by the walls of the container

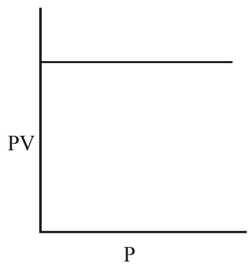
4. Equal volumes of two gases at the same temperature and pressure have
(a) equal masses
(b) Avogadro's number of molecules
(c) identical chemical composition
(d) the same number of molecules

5. Collapsible balloon is inflated to a volume of 10 L at a pressure of 1 atm. When the balloon is immersed to the bottom of a lake, its volume reduces to 1.25 L. Assuming 1 atm pressure to be equivalent to 10m column of water and no change in temperature, the depth of the lake will be
(a) 70m (b) 80m
(c) 90m (d) none of these

6. At a pressure of 760 torr and temperature of 273.15K, the indicated volume of which system is not consistent with the observation
(a) 14 g of N_2 + 16 g of O_2 ; volume = 22.4 L
(b) 4 g of He + 44 g of CO_2 ; volume = 44.8 L
(c) 7 g of N_2 + 36 g of O_3 ; volume = 22.4 L
(d) 17 g of NH_3 + 36.5 g of HCl, Volume = 44.8 L

7. For a fixed mass of a gas and at a given temperature, which of the following graphs is not consistent with the Boyle's law ?

(a)


(b)


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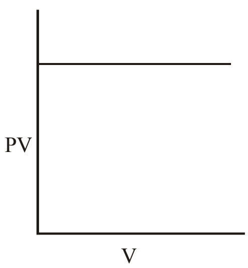
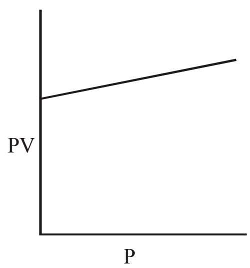


(d)


MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ			

8. The volume V (L) of 1 mol of a gas is plotted against temperature on celsius scale (abscissa) at two different constant pressures 1 atm and 2 atm. The two plots

(a) are rectangular hyperbolas
(b) are straight lines parallel to each other
(c) are straight lines with different slopes having intercepts to be 22.4 L and 11.2 L.
(d) will intersect at temperature 273.15 K.

9. Which of the following does not determine the translational kinetic energy of an ideal gas ?

(a) Temperature
(b) Amount of the gas
(c) Number of moles of gas
(d) Pressure of the gas

10. 190.0 ml of N_2 was collected in a jar over water at some temperature, water level inside and outside the jar standing at the same height. If barometer reads 740 mm Hg and aqueous tension at the temperature of the experiment is 20 mm Hg, the volume of the gas at 1 atm pressure and at the same temperature would be

(a) 185.0 mL (b) 180.0 mL
(c) 195.0 mL (d) 200 mL

11. The temperature of a gas placed in an open container is raised from 27°C to 227°C. The percent of the original amount of the gas expelled from the container will be

(a) 20 (b) 40
(c) 60 (d) 80

12. 14 g of N_2 and 36 g of ozone are at the same pressure and temperature . Their volumes will be related as

(a) $2V_{N_2} = 3V_{O_3}$ (b) $3V_{N_2} = 2V_{O_3}$
(c) $3V_{N_2} = 4V_{O_3}$ (d) $4V_{N_2} = 3V_{O_3}$

13. Equal masses of hydrogen gas and oxygen gas are placed in a closed container at a pressure of 3.4 atm. The contribution of hydrogen gas to the total pressure is

(a) 1.7 atm (b) 0.2 atm
(c) 3.2 atm (d) 3.02 atm

14. Helium gas at 1 atm and SO_2 at 2 atm pressure, temperature being the same, are released separately at the same moment into 1m long evacuated tubes of equal diameters. If helium reaches the other end of the tube in *t* s, what distance SO_2 would traverse in the same time interval in the other tube?

(a) 25 cm (b) 50 cm
(c) 60 cm (d) 75 cm

15. 2 mol of NH_3 and 1 mol of HCl are introduced into a 10 L evacuated closed container at 27°C. The pressure set up in the container will be

(a) $\frac{3\times 0.0821\times 300}{10}$ atm (b) $\frac{2\times 0.0821\times 300}{10}$ atm
(c) $\frac{1\times 0.0821\times 300}{10}$ atm (d) None of these

16. A mixture of 1 mol of H_2 and 1 mol of Cl_2 along with a little charcoal in a 10 L evacuated flask was irradiated to light till the reaction was complete. Subsequently 5L of water was introduced into the flask and the flask was cooled to 27°C. The pressure exerted by the system was approximately equal to

(a) $\frac{2\times 0.0821\times 300}{10}$ atm (b) $\frac{2\times 0.0821\times 300}{5}$ atm
(c) $\frac{4\times 0.0821\times 300}{5}$ atm (d) ≈ 26 mm Hg

17. Two flasks *A* and *B* of equal volumes maintained at temperatures 300K and 600K contain equal mass of H_2 and CH_4 respectively. The ratio of total translational kinetic energy of gas in flask *A* to that in flask *B* is

(a) unity (b) 2
(c) 4 (c) 0.25

18. By what amount the heat capacity of 160 g of oxygen under the condition of constant pressure exceeds that at constant volume

(a) *R* (b) 10 *R*
(c) 5 *R* (c) none of these

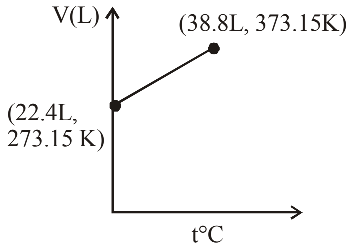
19. At what temperature, the translational kinetic energy of 14 g of nitrogen will be the same as that of 32 g of oxygen at 300 K

(a) 150 K (b) 300 K
(c) 600 K (c) 131.25 K

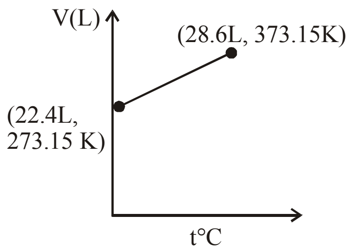
MARK YOUR RESPONSE					
	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ
	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ
	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ			

20. Which of the following volume versus temperature (celsius) plots represents the behavior of 1 mol of an ideal gas at a pressure of 1 atm?

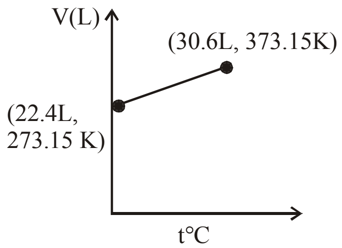
(a)



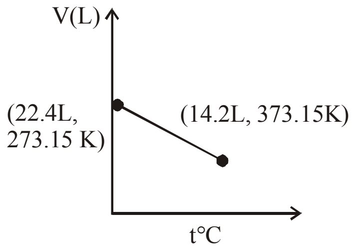
(b)



(c)



(d)



21. 0.40 g of helium in a bulb at a temperature of TK had a pressure of P atm. When the bulb was immersed in hotter bath at a temperature 50 K more than the first one, 0.08 g of gas had to be removed to restore the original pressure. T is:

(a) 100 K (b) 200 K
(c) 300 K (c) 500 K

22. Positive deviation of real gases from ideal behavior takes place because of

(a) molecular interactions and $\frac{PV}{nRT} > 1$

(b) molecular interactions and $\frac{PV}{nRT} < 1$

(c) finite size of molecules and $\frac{PV}{nRT} < 1$

(d) finite size of molecules and $\frac{PV}{nRT} > 1$

23. The false statement amongst the following is

(a) For every gas there exists a characteristic temperature, called Boyle temperature, at which the compressibility factor is unity over some range of pressure.

(b) For every gas there exists a characteristic temperature, inversion temperature, at which Joule-Thomson effect is zero.

(c) The extent of departure of compressibility factor $\left(\frac{PV}{nRT}\right)$ from unity is a measure of the extent of deviation from the ideal behavior.

(d) Amongst H_2, He and NH_3, NH_3 has the lowest value of a and He has the lowest value of b .

24. For a hypothetical gas containing molecules as point masses and having non-zero intermolecular forces, which of the following is correct

(a) The gas will show positive deviation from ideal behavior

(b) The compressibility factor $\frac{PV}{nRT} > 1$

(c) The gas is more compressible than the ideal gas under equivalent conditions

(d) The gas is difficult to be compressed compared to ideal gas.

25. Consider a hypothetical gas with no intermolecular forces but contains the molecules which are not point masses. During free expansion the gas will exhibit

(a) cooling effect at all temperatures

(b) heating effect at all temperatures

(c) neither cooling nor heating effect at all temperatures

(d) ideal behavior

MARK YOUR RESPONSE	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ	24. ⓐⓑⓒⓓ
	25. ⓐⓑⓒⓓ				

26. Amongst the following statements, the correct one is :

(a) The gas can not be compressed below the critical temperature.

(b) Below critical temperature thermal motion of the molecules is slow enough for the intermolecular forces to come into play leading to condensation of the gas.

(c) At critical temperature liquid and gaseous phase can be distinguished.

(d) An ideal gas has a characteristic critical temperature.

27. The van der Waal's equation for 1 mol of a real gas may be rearranged to give

$$V_m^3 - \left(b + \frac{RT}{P}\right)V_m^2 - \frac{a}{P}V_m - \frac{ab}{P} = O$$

V_m being the molar volume of the gas. Indicate the correct statement amongst the following

(a) At temperature greater than T_c, there are three values of V_m, one real and two imaginary.

(b) At temperature T_c, the three real values of V_m are identical.

(c) At temperature less than T_c there are three real values of V_m.

(d) All are correct.

28. The compressibility factor $Z = \frac{PV}{RT}$ for 1 mol of a real gas is greater than unity at a pressure of 1 atm and 273 .15 K. The molar volume of the gas at STP will be

(a) less than 22.4 L (b) greater than 22.4 L

(c) equal to 22.4 L (d) none of these

29. The van der Waals's constants for gases *A, B* and *C* are as follows

Gas	***a*** **(L^2 atm mol^{-2})**	***b*** **(L mol^{-1})**
A	0.024	0.027
B	4.17	0.037
C	3.59	0.043

Based upon the above data, which of the following statements is correct?

(i) The gas ***B*** has the highest critical temperature

(ii) The gas ***A*** has minimum departure from the ideal behavior

(iii) The gas ***C*** has largest molecular volume

(a) (i) (b) (i) and (ii)

(c) (ii) and (iii) (d) all the three

30. A gas has non-zero value of force of attraction between the molecules but has the molecules to be point masses. The van der Waal's equation for the gas will be

(a) $PV = nRT + nbP$

(b) $P(V - nb) = nRT$

(c) $PV = nRT$

(d) $PV = nRT - \frac{an^2}{V}$

31. The compressibility factor $Z = \left(\frac{\text{PV}}{n\text{RT}}\right)$ of a gas above $T = \frac{a}{Rb}$ will be

(a) less than unity (b) greater than unity

(c) equal to unity (d) none of these

32. The mean free path of a gas at constant volume

(a) increases with increase in temperature

(b) decreases with increase in pressure

(c) remains unchanged on changing pressure or temperature

(d) none is correct.

33. A balloon filled with air is placed in a tank of helium gas at the same temperature and pressure. If the balloon is pricked with a sharp point, after a short while the balloon will

(a) remain unchanged in size

(b) enlarge

(c) shrink

(d) collapse completely

34. Relative humidity of air is 80% at 27°C. If the aqueous tension at the same temperature is 27 mm Hg, partial pressure of water vapour in the air will be

(a) 27 mm Hg (b) 25 mm Hg

(c) 23 mm Hg (d) 21.60 mm Hg

MARK YOUR RESPONSE	26. ⓐⓑⓒⓓ	27. ⓐⓑⓒⓓ	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ	30. ⓐⓑⓒⓓ
	31. ⓐⓑⓒⓓ	32. ⓐⓑⓒⓓ	33. ⓐⓑⓒⓓ	34. ⓐⓑⓒⓓ	

35. At what temperature the average speed of helium molecule will be the same as that of oxygen molecule at 527°C

(a) 100 K (b) 200 K
(c) 273 K (d) 400 K

36. 1 L flask contains nitrogen along with a drop or two of water at 40°C, the total pressure being 760 torr. If all the contents are transferred to another flask of 0.5 L at the same temperature, the pressure set up in the second flask will be (aqueous tension at 40°C = 55 torr)

(a) 1410 torr (b) 1465 torr
(c) 1520 torr (d) none of these

37. 4g of H_2 effused through a pinhole in 10 s at some constant temperature and pressure. The amount of oxygen effused in the same time interval and at the same conditions of temperature and pressure would be

(a) 4 g (b) 8 g
(c) 16 g (d) 32 g

38. The rate of diffusion of methane at a given temperature is twice that of a gas *X*. The molecular mass of *X* is

(a) 4.0 (b) 8.0
(c) 32.0 (d) 64.0

39. *X* ml of H_2 gas effuses through a pin hole in a container in 5 s, the time taken for the effusion of the same volume of the gas specified below under identical conditions is

(a) 10 s : He (b) 20 s : O_2
(c) 25 s : CO (d) 55 s : CO_2

40. Two flasks *X* and *Y* of volumes 250 ml and 300 ml respectively at the same temperature are connected by a stop cock of negligible volume. The flask *X* contains nitrogen gas at a pressure of 660 torr and the flask *Y* contains neon at a pressure of 825 torr. If the stop cock is opened to allow the two gases to mix, the partial pressure of neon and total pressure of the system will be

(a) 300 torr, 700 torr (b) 400 torr, 700 torr
(c) 450 torr, 750 torr (d) 300 torr, 750 torr

41. SO_2 and He are kept in a container at partial pressures P_1 and P_2 . A thin perforation is made in the wall of the container and it is observed that the two gases effuse out at the same rate. The ratio $P_1 : P_2$ will be

(a) 16:1 (b) 1 : 16
(c) 1 : 4 (d) 4 : 1

42. 2 moles of N_2 and 1 mole of CO_2 are placed is a container at 25°C. Compared to nitrogen molecule , the CO_2 molecule will strike the wall of the container with

(a) greater average speed
(b) smaller average speed
(c) greater average K.E.
(d) smaller average K.E.

43. The translational kinetic energy of 80 g of methane at 127°C will be (R = 2 cal $K^{-1}mol^{-1}$)

(a) 6.0 k cal (b) 96 k cal
(c) 1.905 k cal (d) 3.048 k cal

44. A gaseous mixture of NH_3 gas and H_2S gas contains 20 mol % of NH_3. The vapour density of the mixture is

(a) 20.4 (b) 30.6
(c) 10.2 (d) 15.3

45. A closed vessel contains helium and ozone at a pressure of *P* atm. The ratio of He and oxygen atoms is 1 : 1. If helium is removed from the vessel , the pressure of the system will reduce to?

(a) 0.5 *P* atm (b) 0. 75 *P* atm
(c) 0.25 *P* atm (d) 0.33 *P* atm

46. If for two gases of molecular masses M_A and M_B at temperatures T_A and T_B, $T_A M_B = T_B M_A$, then which of the following properties has the same magnitude for both the gases

(a) Pressure (b) Density
(c) Molar K.E. (d) rms velocity

47. The reciprocal of compressibility factor of a real gas in the critical state is

(a) $\frac{3}{8}$ (b) $\frac{3}{4}$

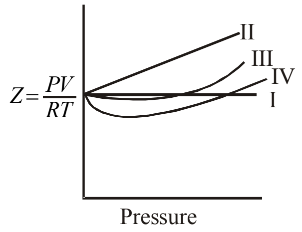
(c) $\frac{8}{3}$ (d) $\frac{1}{3}$

48. Consider a real gas placed in a container. If the intermolecular attractions are supposed to disappear suddenly which of the following would happen?

(a) The pressure decreases
(b) The pressure increases
(c) The pressure remains unchanged
(d) The gas collapses

MARK YOUR RESPONSE					
	35. ⓐⓑⓒⓓ	36. ⓐⓑⓒⓓ	37. ⓐⓑⓒⓓ	38. ⓐⓑⓒⓓ	39. ⓐⓑⓒⓓ
	40. ⓐⓑⓒⓓ	41. ⓐⓑⓒⓓ	42. ⓐⓑⓒⓓ	43. ⓐⓑⓒⓓ	44. ⓐⓑⓒⓓ
	45. ⓐⓑⓒⓓ	46. ⓐⓑⓒⓓ	47. ⓐⓑⓒⓓ	48. ⓐⓑⓒⓓ	

49. For the non-zero volume of molecules having no forces of attraction, the variation of compressibility factor $Z = \frac{PV}{RT}$ with pressure is given by the graph



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

50. Which of the following statements is correct at a fixed temperature?

(a) The translational K.E. of all molecules in a gas is the same.

(b) The translational K.E. varies from molecule to molecule .

(c) The average translational K.E. of a molecule is greater in heavier gas than the lighter one.

(d) The average translational K.E. of a molecule is the function of pressure.

51. Number of atoms in 230g of sodium (atomic mass 23) is

(a) twice that in 80g of oxygen

(b) half that in 20g of hydrogen

(c) both are correct

(d) none is correct

52. The compressibility factor of helium as a real gas is

(a) unity (b) $1 - \frac{a}{RTV}$

(c) $1 + \frac{Pb}{RT}$ (d) $\frac{RTV}{1-a}$

53. Pick out the false statement of the following

(a) Average translational K.E. per molecule is the same for all gases at a given temperature

(b) The equation $PV = nRT$ is not applicable to real gases, particularly at high pressures and low temperatures

(c) $\frac{PV}{RT}$ is independent of the amount of the gas

(d) $\frac{PV}{RT} > 1$ for H_2 and He for all values of pressure and temperature

54. The ratio $\frac{a}{b}$ (*a* and *b* being the van der Waal's constants of real gases) has the dimensions of

(a) atm mol^{-1} (b) L mol^{-1}

(c) atm L mol^{-1} (d) atm L mol^{-2}

55. A graph is plotted between PV_m (along *Y*-axis) and *P* (along *X*–axis) at 27° (V_m being the molar volume of an ideal gas). The intercept of the graph at *Y*–axis is (R = 0.082 atm L $K^{-1}mol^{-1}$)

(a) 22.4 atm L mol^{-1} (b) 24.6 atm L mol^{-1}

(c) 24.6 atm L $K^{-1}mol^{-1}$ (d) none of these

56. Volume of 14 g of nitrogen gas (assume ideal gas) at a pressure of 0.5 atm is plotted against temperature on Celsius scale along *X*–axis). The intercept of the graph on the *Y*–axis is

(a) 22.4 L (b) 11.2 L
(c) 5.6 L (d) None of these

57. A manometer is connected to a flask containing a gas. The open arm reads 36.2 cm whereas the arm connected to the flask reads 15.5 cm . If the barometric pressure is 743 mm Hg, the gas pressure in atm is

(a) 1.0 atm (b) 1.25 atm
(c) 1.30 atm (d) 1.45 atm

58. Consider the reaction $2\underset{(g)}{X} + 3\underset{(g)}{Y} \rightarrow Z(g)$ where gases *X* and *Y* are insoluble and inert to water and *Z* forms a basic solution. In an experiment, 3 mol each of *X* and *Y* are allowed to react in 15 L flask at 500K. When the reaction is complete, 5L of water is added to the flask and temperature is reduced to 300K. The pressure in the flask is (neglect aqueous tension)

(a) 1.64 atm (b) 2.46 atm
(c) 4.92 atm (d) 3.28 atm

MARK YOUR RESPONSE					
	49. ⓐⓑⓒⓓ	50. ⓐⓑⓒⓓ	51. ⓐⓑⓒⓓ	52. ⓐⓑⓒⓓ	53. ⓐⓑⓒⓓ
	54. ⓐⓑⓒⓓ	55. ⓐⓑⓒⓓ	56. ⓐⓑⓒⓓ	57. ⓐⓑⓒⓓ	58. ⓐⓑⓒⓓ

59. 0.75 mol of solid X_4 and 2 mol of O_2 are heated in a closed container to form only one gaseous compound. The ratio of final pressure at 327°C to the initial pressure at 27°C in the flask is

(a) 0.75 (b) 1
(c) 1.5 (d) 2

60. For 10 minutes each, at 27°C, from two identical holes helium and an unknown gas X at equal pressures are leaked into a common vessel of 3L capacity. The resulting pressure is 4.1 atm and the mixture contains 0.4 mol of helium. The molar mass of gas X is

(a) 16 (b) 32
(c) 64 (d) None of these

61. A mixture of 16 g CH_4 and 64 g of O_2 is ignited in a sealed bulb of 3L and then cooled to 27°C. The pressure in the bulb will be

(a) 0.82 atm (b) 8.2 atm
(c) 24.6 atm (d) 2.46 atm

62. A sealed flask contains a gas and a few drops of water at TK. The pressure in the flask is 1030 mm Hg . The temperature of the flask is reduced by 1%. If the aqueous tension at two temperatures are 30 and 25 mm Hg, the final pressure in the flask would be

(a) 1019.7 mm (b) 1020 mm
(c) 1015 mm (d) None of these

63. There are 100 persons sitting at equal distances in a row XY. N_2O gas (laughing gas) is released from the side X and tear gas (mol. mass = 176) from side Y at the same moment and at the same pressure. The person who will have a tendency to laugh and weep simultaneously is

(a) 34th from side X (b) 67th from side X
(c) 76th from side X (d) 67th from side Y

64. Under identical conditions of pressure and temperature, 2L of gaseous mixture (H_2 and CH_4) effuses through a hole in 5 minutes whereas 2 L of a gas X of molecular mass 36 takes 10 minutes to effuse through the same hole. The mole ratio of $H_2 : CH_4$ in the mixture is

(a) 1 : 2 (b) 2 : 1
(c) 2 : 3 (d) 1 : 1

65. It V is the volume of one molecule of gas under given conditions, the van der Waal's constant b is

(a) $4V$ (b) $\frac{4V}{N_0}$

(c) $\frac{N_0}{4V}$ (d) $4VN_0$

66. At critical state, the compressibility factor (Z) for a real gas is equal to

(a) $\frac{3}{8}$ (b) $\frac{8}{3}$

(c) $\frac{4}{3}$ (d) $\frac{3}{4}$

67. If P_c, V_c and T_c are critical constants, then the value of R will be

(a) $R = \frac{P_cV_c}{T_c}$ (b) $R = \frac{5}{3}.\frac{P_cV_c}{T_c}$

(c) $R = \frac{3}{2}.\frac{P_cV_c}{T_c}$ (d) $R = \frac{8}{3}\frac{P_cV_c}{T_c}$

68. The limiting density of hydrogen bromide is 3.6108 at 0°C. The exact atomic weight of bromine is (At. wt. of H = 1.008)

(a) 80.92 (b) 79.92
(c) 89.29 (d) 79.29

69. 4.5 g of PCl_5 on vapourisation occupied a volume of 1700 ml at 1 atmosphere pressure and 227°C temperature. Its degree of dissociation is

(a) 9.21% (b) 0.921%
(c) 92.1% (d) None of these

70. Virial equation of state can be written as follows to express the compressibility factor (Z).

$$Z = 1 + \frac{B}{V} + \frac{C}{V^2} + \frac{D}{V^3} + ...$$

The correct relationship for van der Waals' constant 'b' is

(a) $B = b$ (b) $B = b - \frac{a}{RT}$

(c) $b = D^3$ (d) $b = C^2$

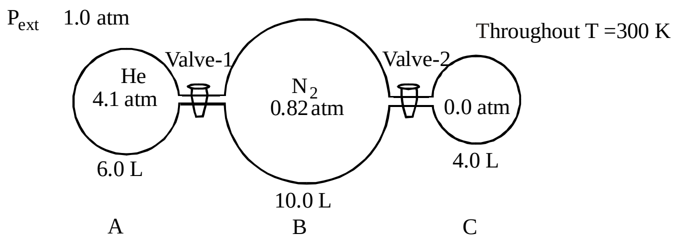
MARK YOUR RESPONSE					
	59. ⓐⓑⓒⓓ	60. ⓐⓑⓒⓓ	61. ⓐⓑⓒⓓ	62. ⓐⓑⓒⓓ	63. ⓐⓑⓒⓓ
	64. ⓐⓑⓒⓓ	65. ⓐⓑⓒⓓ	66. ⓐⓑⓒⓓ	67. ⓐⓑⓒⓓ	68. ⓐⓑⓒⓓ
	69. ⓐⓑⓒⓓ	70. ⓐⓑⓒⓓ			

B COMPREHENSION TYPE

This section contains groups of questions. Each group is followed by some multiple choice questions based on a paragraph. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

PASSAGE-1

The figure given below shows three glass chambers that are connected by valves of negligible volume. At the outset of an experiment, the valves are closed and the chambers contain the gases as detailed in the diagram. All the chambers are at the temperature of 300K and external pressure of 1.0 atm



1. Which of the following describes the relation between the average velocity of gas molecules in chambers *A* and *B* before valve-1 is opened.

(a) $\upsilon_A \neq \upsilon_B$ (b) $\upsilon_A \quad \upsilon_B$

(c) $\upsilon_A \quad \upsilon_B$ (d) Insufficient information

2. What is the total pressure in chamber *B* after valve-1 is opened?

(a) 0.31 atm (b) 2.05 atm

(c) 2.46 atm (d) 3.10 atm

3. What will be the work done by N_2 gas when the valve-2 is opened and valve-1 remaining closed?

(a) 8.2 Latm (b) – 8.2 Latm

(c) 0 (d) – 3.28 Latm

4. Which of the following represents the total kinetic energy of all the gas molecules after both valves are opened? (R = 0.082 atm $LK^{-1}mol^{-1}$ = 8.314 $JK^{-1}mol^{-1}$)

(a) 2836 J (b) 3280 J

(c) 4520 J (d) 4988 J

5. Suppose that the volume of chamber *C* is doubled with other initial conditions kept the same. Which of the following would *not* be affected by this change?

(a) The final pressure in the apparatus after both valves are opened

(b) The initial rate of effusion of gas from chamber *B* into chamber *C* as valve-2 is opened, with valve-1 keeping closed

(c) The final moles of gas in chamber *A* after both valves are opened

(d) The entropy change (ΔS) of N_2 molecules, after valve-2 is opened, with valve-1 left closed.

6. Suppose that after both valves are opened, the entire apparatus is cooled to lower the final internal pressure to 1.0 atm. What is the contribution of N_2 gas to this final pressure?

(a) 0.40 atm (b) 0.35 atm

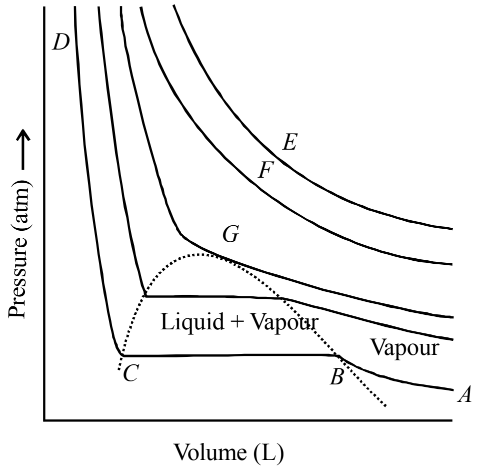
(c) 0.30 atm (d) 0.25 atm

PASSAGE-2

In the Figure-1 below, isotherms of CO_2 at several temperatures near the critical point are shown. At the critical point (critical state), the distinction between the liquid and gaseous states disappears and the density of the gaseous substance is equal to that in the liquid state. For every gas this occurs at specific values of temperature and pressure, called critical temperature and critical pressure respectively. At temperatures and pressures above the critical point value, a gas is said be in a supercritical state. The supercritical fluid has the density and ability to dissolve other substances similar to values expected for liquids.

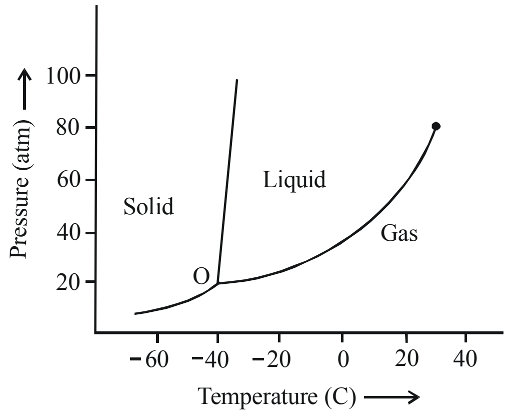
Figure-2 depicts the phase diagram of CO_2. Various curves in the diagram show the equilibrium between two phases and the areas represent different phases. The point, called triple point, describing the equilibrium between three phases has specific values of temperature and pressure.

MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ				



Isotherms of CO_2

Figure 1



Phase diagram of CO_2

Figure 2

7. In Figure-1 which of the points ($A - G$) represents the critical state of CO_2?

(a) B (b) C

(c) F (d) G

8. According to Figure-2 what is the critical temperature and pressure of CO_2?

(a) $-42°$ C and 10atm (b) $-38°$C and 80 atm

(c) 31.1° C and 75.3 atm (d) 31.1°C and 1 atm

9. Which of the following compounds is most soluble in super critical CO_2?

(a) KCl (b) NaOH

(c) $(NH_4)_2SO_4$ (d) $C_2H_5OC_2H_5$

10. According to Fig.-2, when pressure is increased the melting point of CO_2

(a) decreases

(b) increases

(c) remains unchanged

(d) information is not sufficient to predict the effect

11. According to Fig.-2, if the system of CO_2 represented by the point O is subjected to increase in pressure while keeping the temperature constant, then

(a) Liquid and solid phases would disappear

(b) Solid and gas phases would disappear

(c) Liquid and gas phases would disappear

(d) Only liquid phase would disappear

12. According to Fig.-1, which of the following is correct when CO_2 is compressed at a temperature corresponding to the isotherm ABCD?

(a) Liquefaction of CO_2 is complete at the point B

(b) Liquefaction of CO_2 is complete at the point C

(c) Volume of CO_2 system remains constant along BC

(d) Proportions of liquid and gaseous CO_2 do not change along BC.

PASSAGE-3

The extent of deviation of real gases from ideal behavior, can be expressed in terms of compressibility factor (Z). Corrected ideal gas equation is written as :

$$PV = nZRT$$

Where symbols have their usual meaning. The reasons why real gases deviate from ideal behavior can be explained by kinetic theory of gases. For a real gas, compressibility factor (Z) have different values in different pressure zones, but its value is fixed at critical state.

13. Compressibility factor of a real gas at very high temperature and very low pressure, is :

(a) <1 (b) $=1$

(c) >1 (d) Slightly more than one

14. Compressibility factor (Z) for a real gas at moderately low pressure is given as :

(a) $\frac{PV}{RT}$ (b) $\left[1+\frac{bP}{RT}\right]$

(c) $\left[1-\frac{a}{RTV}\right]$ (d) None of these

MARK YOUR RESPONSE	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ
	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ		

15. At critical state, compressibility factor (Z) is equal to

(a) $\frac{3}{8}$ (b) $\frac{8}{3}$

(c) $\frac{4}{3}$ (d) $\frac{3}{4}$

16. Identify the conditions of pressure and temperature at which a real gas shows maximum deviation from ideality :

(a) 10 atm, 273 K (b) 5 atm, 273 K

(c) 10 atm, 373 K (d) 5 atm, 373 K

17. A real gas can be liquefied by

(a) first cooling it upto its critical temperature and then applying a certain minimum pressure over it

(b) first applying pressure and then cooling it upto its inversion temperature

(c) decreasing the temperature only

(d) increasing the pressure only

PASSAGE-3

The ideal gas equation, $PV = nRT$ is not obeyed by real gases under certain conditions. The deviation from ideal behaviour was attributed to the fact that P_{ideal} is related to P_{real} by the equation

$$P_{ideal} = P_{real} + \frac{an^2}{V^2}$$

In this 'a' is a measure of intermolecular interaction between gaseous molecules that gives rise to non-ideal behaviour.

Again the volume correction was introduced by taking into account the volume occupied by gaseous molecules and the effective volume is ($V - nb$), where nb represents the volume occupied by n moles of molecules of real gas.

van der Waals equation of real gases is written as

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

18. The van der Waals equation for real gases will reduce to which one of the following forms under conditions of relatively high pressure?

(a) $PV = RT - Pb$ (b) $PV = RT + Pb$

(c) $PV = RT - \frac{a}{V^2}$ (d) $PV = RT - \frac{a}{V^2}$

19. If the value of 'a' van der Waals constant for a gas X is greater than that of another gas Y, then

(a) strength of van der Waals forces for 'X' is less than that of 'Y'

(b) strength of van der Waals forces for both 'X' and 'Y' is same.

(c) Gas 'X' can be liquified easily in comparison to 'Y'

(d) Gas 'Y' can be liquified easily than the gas 'X'

20. The van der Waals equation for a gas that has non-zero value of force of attraction between molecules but has the molecules to be point masses, will become

(a) $PV = nRT + nbP$ (b) $P(V - nb) = nRT$

(c) $PV = nRT$ (d) $PV = nRT - \frac{an^2}{V}$

PASSAGE-5

The extent of deviation of real gases from ideal behaviour can be expressed in terms of compressibility factor (Z). The gas equation can thus be modified as

$$PV = Z.\, nRT$$

The value of Z (compressibility factor) for real gases is different in different pressure zones but its value is fixed at critical state.

21. The compressibility factor (Z) of a real gas is given by

(a) $Z = \frac{PV}{R}$ (b) $Z = \frac{PV}{R^2}$

(c) $Z = \frac{R}{PV}$ (d) $Z = \frac{PV}{nRT}$

22. Under conditions of very low pressure and very high temperature the value of 'Z' for a real gas is

(a) 1 (b) more than 1

(c) less than 1 (d) can't be predicted

23. van der Waal's constant 'b' has units of volume (litre $mole^{-1}$). The constant 'a' is expressed in

(a) atom-$litre^2$ mol^{-2} (b) litre-atm mol^{-1}

(c) litre-atom $mole^{-2}$ (d) $litre^2$ –atom $mole^{-1}$

MARK YOUR RESPONSE					
	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ
	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ	

C REASONING TYPE

In the following questions two Statement-1 (Assertion) and Statement-2 (Reason) are provided. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct. Mark your responses from the following options:

(a) Both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.
(b) Both Statement-1 and Statement-2 are true and Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is true but Statement-2 is false.
(d) Statement-1 is false but Statement-2 is true.

1. Statement-1 : Volume to temperature ratio is constant for a fixed amount of gas at constant pressure.
Statement-2 : At constant pressure the volume of a given mass of a gas increases or decreases by $\frac{1}{273}$ of its volume at 0°C.

2. Statement-1 : Absolute zero is a theoretically possible temperature at which the volume of a real gas becomes zero.
Statement-2 : The total kinetic energy of the gas molecules is zero at this temperature.

3. Statement-1 : Ideal gas equation is valid at low pressure and high temperature.
Statement-2 : Molecular interactions are negligible under this condition.

4. Statement-1 : The process of diffusion is always followed by effusion.
Statement-2 : Both diffusion and effusion deal with spreading of gas.

5. Statement-1 : Greater the value of vander Waal's constant 'a' easier is the liquefaction of a gas.
Statement-2 : 'a' indirectly measures the magnitude of attractive forces between the molecules.

6. Statement-1 : Excluded volume or co-volume equals to (V-nb) for n moles.
Statement-2 : Co-volume depends on the effective size of gas molecules.

7. Statement-1 : Critical temperature is the temperature at which a real gas exhibits ideal behaviour for considerable range of pressure.
Statement-2 : At critical point the densities of a substance in gaseous and liquid states are same.

8. Statement-1 : According to kinetic theory of gases the molecular collisions are non-elastic collision.
Statement-2 : In non-elastic collisions energy and momenta of the molecules are not conserved.

9. Statement-1 : Different gases at the same conditions of temperature and pressure have same root mean square speed.
Statement-2 : Average K.E. of a gas is directly proportional to temperature in kelvin.

10. Statement-1 : At constant temperature, if pressure on a gas is doubled, density is also doubled.
Statement-2 : At constant temperature, molecular mass of a gas is directly proportional to the density and inversely proportional to pressure.

11. Statement-1 : Compressibility factor (Z) for non-ideal gases can be greater than 1.
Statement-2 : Non-ideal gases always exert higher pressure than expected.

12. Statement-1 : The value of van der Waals' constant 'a' is larger for ammonia than for nitrogen.
Statement-2 : Hydrogen bonding is present in ammonia.

13. Statement-1 : The pressure of a fixed amount of an ideal gas is proportional to its temperature.
Statement-2 : Frequency of collisions and their impact both increase in proportion to the square root of temperature.

14. Statement-1 : During isothermal expansion of an ideal gas in vacuum, no heat is absorbed.
Statement-2 : The molecules of an ideal gas occupy negligible volume.

MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ
	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	

15. Statement-1 : The value of compressibility factor for both CO_2 and CH_4 is more than 1 at 273 K.

Statement-2 : $Z < 1$ when attracive forces > repulsive forces.

16. Statement-1 : When the temperature of an ideal gas is increased from 37°C to 137°C keeping pressure constant, there will be an increasee of 100 L in volume of the gas

Statement-2 : At any constant pressure volume of gas α temperature on absolute scale.

17. Statement-1 : For an ideal gas the value of C_P and C_V are related as $C_P = C_V + R$, where R is the molar gas constant.

Statement-2 : For an ideal gas $\left(\frac{\partial E}{\partial V}\right)_T = 0$

18. Statement-1 : At critical point, both H_2 and He have nearly same compressibility factors.

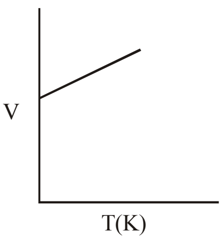
Statement-2 : The values of critical constants, for both H_2 and He are nearly same.

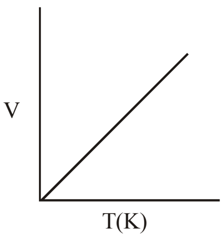
MARK YOUR RESPONSE	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	

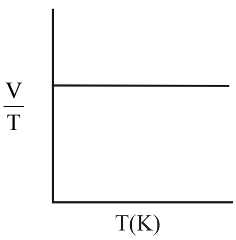
D MULTIPLE CORRECT CHOICE TYPE

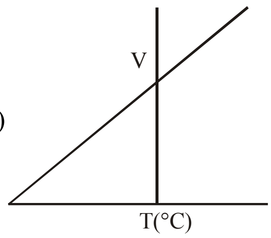
Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE OR MORE is/are correct.

1. For a fixed mass of a gas and constant pressure, which of the following graphs represent the Charle's law?

(a)


(b)


(c)


(d)


2. Which of the following statement (s) is/ are correct?
   (a) Gas molecules never come to rest except at 0K
   (b) At T > 0, some gas molecules are unfortunate not to possess translational kinetic energy
   (c) On raising temperature, fraction of molecules possessing most probable velocity increases
   (d) At a given temperature the most probable velocity varies inversely with the square root of vapour density of the gas

3. Which of the following statements is/ are correct?
   (a) All real gases are less compressible than ideal gas at high pressures
   (b) Hydrogen and helium are more compressible than ideal gas for all values of pressure
   (c) Except H_2 and He, the compressibility factor $Z = \left(\frac{PV}{nRT}\right) < 1$ for all gases at low pressures
   (d) The compressibility factor of real gases is independent of temperature

4. Which of the following is correct under the same conditions of pressure and temperature?
   (a) Hydrogen diffuses 4 times faster than oxygen
   (b) Hydrogen diffuses 2.83 times faster than methane
   (c) Helium escapes at a rate 2 times as fast as methane does
   (d) Helium escapes at a rate 4 times as much as sulphur dioxide.

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	

5. Which of the following statements is/ are true?

(a) A real gas always exerts lower pressure on the enclosure than an ideal gas under equivalent conditions

(b) The temperature of a real gas changes when it expands adiabatically in vacuum

(c) An ideal gas undergoes cooling effect when it suffers an adiabatic expansion in vacuum

(d) The Joule-Thomson coefficient $\left(\frac{dT}{dP}\right)_H$ of a real gas is negative below its critical temperature

6. If the molecules of a gas are spherical of radius 1.0 Å ,the van der waals's constant *b* of the gas is

(a) 0.0025 L Mol^{-1} (b) 0.0101 L Mol^{-1}
(c) 0.0371 L Mol^{-1} (d) 0.0224 L Mol^{-1}

7. Which of the following statements is/ are *not* correct?

(a) A real gas can be liquefied by cooling it to its inversion temperature and applying a suitable pressure.

(b) A real gas can not be liquefied by applying any pressure above its critical temperature.

(c) At ordinary temperatures H_2 and He suffer a fall in temperature when allowed to expand adiabatically in vacuum.

(d) At critical temperature the surface tension of the liquid vanishes.

8. Precisely 1 mol of helium and 1 mol of neon are placed in a container. Indicate the correct statements about the system:

(a) Molecules of the two gases strike the wall of the container with same frequency.

(b) Molecules of helium strike the wall more frequently.

(c) Molecules of helium have greater average molecular speed.

(d) Helium exerts larger pressure.

9. Actual volume of one mol of CO_2 molecules is 0.0107 L. If 220 g of CO_2 is placed in a 10.0 L container, the free space available for the molecules to move about is

(a) 10.0L (b) 9.9465L
(c) 9.9572 L (d) 9.7860 L

10. The mutual attraction of molecules in a real gas is an important aspect of

(a) Avogadro's law (b) Graham's law
(c) van der Waal's theory (d) Joule - Thomson effect

11. Pressure of a gas is the result of :

(a) Molecular speed only
(b) Molecular speed and mass
(c) Molecular mass only
(d) Intermolecular forces

12. Which of the following is correct for the inversion temperature in a real gas?

(a) The gas can be liquefied by compression at this temperature

(b) Joule-Thomson coefficient ($(\mu_{JT}) = 0$ at this temperature

(c) Below inversion temperature, a compressed gas undergoing unrestricted expansion shows the negative temperature change.

(d) Above this temperature μ_{JT} has positive value

13. Select the correct statements of the following :

(a) Ideal gas can be liquefied by cooling it to a very low temperature and applying a very high pressure

(b) Helium can be liquefied by cooling it to a characteristic temperature and compressing

(c) At ordinary temperatures compressed helium gas get heated up when passed through an orifice into vacuum under adiabatic conditions

(d) At ordinary temperatures hydrogen is less compressible than an ideal gas

14. An ideal gas undergoes adiabatic expansion against external pressure. Which of the following are correct?

(a) Internal energy of the gas remains unchanged
(b) Internal energy of the gas decreases
(c) Temperature of the system decreases
(d) $\Delta E + P\Delta V = 0$

15. If temperature of a gas is raised, which of the following would be true?

(a) Fraction of the molecules possessing most probable velocity will increase
(b) Fraction of the molecules possessing most probable velocity will decrease
(c) Fraction possessing very low velocity will decrease
(d) Fraction possessing very high velocity will increase

MARK YOUR RESPONSE					
	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ
	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ
	15. ⓐⓑⓒⓓ				

16. Heat energy is supplied to argon at constant pressure. Select the correct statements of the following :

(a) A part of heat is used up in increasing the translational K.E. of gas molecules

(b) A part of heat is used up in increasing rotational K.E.of gas molecules

(c) A part is used up in increasing vibrational K.E. of gas molecules

(d) A part is used up in doing work during expansion of the gas against external pressure

17. ΔV_{iso} and ΔV_{adia} are the volume changes of an ideal gas during reversible isothermal and adiabatic expansions between the same initial and final pressures. Pick out the correct statements of the following :

(a) $\Delta V_{iso} < \Delta V_{adia}$

(b) $\Delta V_{iso} > \Delta V_{adia}$

(c) V_{iso} versus P is steeper than V_{adia} versus P

(d) V_{adia} versus P is steeper than V_{iso} versus P

18. Equal masses of an ideal gas and a real gas having same molecular mass are placed in separate containers of equal volumes and at the same temperature. Which of the following will be the true statements?

(a) Molecules in ideal gas strike the walls with greater momentum than that in real gas

(b) The real gas exerts greater pressure than the ideal gas

(c) The real gas exerts lesser pressure than the ideal gas

(d) Free space available for the molecules to move about in real gas is smaller than that in ideal gas

19. During expansion of a gas at a fixed temperature

(a) there occurs a decrease in pressure

(b) there is no change in K.E. of the molecules of gas

(c) there occurs a decrease in K.E. of the gaseous molcules

(d) there occurs an increase in number of gas molecules

20. At Boyle temperature

(a) the intermolecular forces of attraction and repulsion are just balanced

(b) forces of repulsion > forces of attraction

(c) forces of repulsion < forces of attraction

(d) $b - \dfrac{a}{RT} > 0$

21. The critical temperature

(a) is the same as Boyle temperature

(b) is the temperature at which the gas and the liquid phase have different critical densities.

(c) is the temperature beyond which a gas cannot be liquified by application of pressure alone.

(d) is the highest temperature at which the liquid and vapour can co-exist.

22. Critical temperature and critical pressure values of four gases are given :

Gas	Critical temperature (K)	Critical pressure (atm)
P	40	3.3
Q	80	8.8
R	120	35
S	160	40

Which of the above gases can not be liquified at a temperature 90 K and pressure 45 atmosphere?

(a) S only (b) P only

(c) R and S (d) P and Q

23. Choose the correct statement (s).

(a) The ratio of mean speed to the r.m.s. speed does not depend on temperature

(b) The square of the mean speed of molecules is equal to the mean squared speed at a certain temperature

(c) Mean translational K.E. of gas molecules at any given temperature does not depend on the molar mass of the gas.

(d) The difference between r.m.s. and mean speed at any temperature for different gases diminishes when we consider larger and still larger molar masses of the gases.

MARK YOUR RESPONSE					
	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ
	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ		

E MATRIX-MATCH TYPE

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labeled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column -I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example:
If the correct matches are A–p, s and t; B–q and r; C–p and q; and D–s then the correct darkening of bubbles will look like the given.

	p	q	r	s	t
A	(p)	(q)	(r)	(s)	(t)
B	(p)	(q)	(r)	(s)	(t)
C	(p)	(q)	(r)	(s)	(t)
D	(p)	(q)	(r)	(s)	(t)

1. Match the following :

	Column I		**Column II**
(A)	Distribution of molecular velocities of a gas is	p.	Time dependent
(B)	Velocity of a gas molecule is	q.	Time independent
(C)	Fraction of molecules of a gas possessing most probable velocity is	r.	Temperature independent
(D)	Vapour density of a gas is	s.	Temperature dependent

2. T_b and T_i are the Boyle's and inversion temperatures respectively for a real gas. Match the following characteristics with appropriate temperatures.

	Column I (Gas Characteristics)		**Column II (Temperature)**
(A)	Attractive intermolecular forces become dominant over repulsive forces when	p.	$>T_i$
(B)	Repulsive forces become dominant	q.	$<T_i$
(C)	Gas becomes more or less ideal gas when	r.	Any value of temperature
(D)	$\mu_{J.T.}$ for ideal gas is zero at	s.	$=T_b$

3. The van der waal's constants a and b of a real gas are 3.6 L^2 atm mol^{-2} and 0.05 L mol^{-1} respectively. If 200 g of gas (molecular mass 40) is placed in 10 L vessel at 300 K, then match the following:

	Column I		**Column II**
(A)	Pressure correction (atm)	p.	0.25
(B)	Free space for the molecules to move about (L)	q.	0.06
(C)	Actual volume occupied by gas molecules (L)	r.	0.9
(D)	Effective volume occupied by gas molecules (L)	s.	9.75

4. Assume the gases to be ideal and match the following :

	Column I		**Column II**
(A)	K.E. of 4 g of helium molecules	p.	$\frac{5}{2}R$
(B)	Increase in energy of 32 g of oxygen molecules on raising temperature by 1°C at constant volume	q.	$3R$
(C)	Increase in energy of 1 mole of NO_2 on raising temperature by 1°C at constant volume	r.	$4R$
(D)	Increase in energy of 1 mole of NO_2 on raising temperature by 1°C at constant pressure.	s.	$1.5RT$

MARK YOUR RESPONSE

1.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

2.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

3.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

4.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

5. Match the following :

Column I		Column II
(A) Molar volume of a gas	p.	Temperature dependent
(B) Translational K.E. of gas molecules	q.	Temperature independent
(C) Vapour density of a gas	r.	Pressure dependent
(D) Density of a gas	s.	Pressure independent

6. Column *A* lists some gases and the conditions under which they are kept. Column *B* lists the properties of gases/gas laws.

Column I		Column II
(A) Hydrogen gas ($P = 250$ atm, $T = 273\ K$)	p.	Compressibility factor (Z) $\neq 1$
(B) Hydrogen gas ($P = 0.01$ mm of Hg, $T = 273\ K$)	q.	Forces of attraction > forces of repulsion
(C) Carbon dioxide ($P = 1$ atm, $T = 273K$)	r.	$PV = nRT$
(D) Real gas having a large molar volume	s.	$P(V - nb) = nRT$

MARK YOUR RESPONSE

5.	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

6.	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

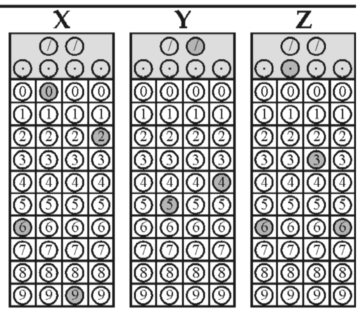
F NUMERIC/INTEGER ANSWER TYPE

The answer to each of the questions is either numeric (eg. 304, 40, 3010, 3 etc.) or a fraction (2/3, 23/7) or a decimal (2.35, 0.546).

The appropriate bubbles below the respective question numbers in the response grid have to be darkened.

For example, if the correct answers to question X, Y & Z are 6092, 5/4 & 6.36 respectively then the correct darkening of bubbles will look like the following.

For single digit integer answer darken the extreme right bubble only.

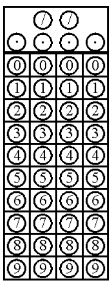


1. A helium filled balloon rises to an altitude of 40 km at which point it is fully inflated and has a volume of 8.2×10^4 L. At that altitude the temperature is 2°C and atmospheric pressure is 3.04 torr. What mass (gram) will be needed to fully inflate the balloon?

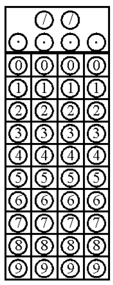
2. A balloon weighing 1.00 kg and having radius of 2.1 m is filled with helium and is fully inflated at a pressure of 1 atm and temperature of 27°C at sea level. What would be the payload on balloon (in kg) at sea level where the density of air is 1.22 kg m^{-3}?

MARK YOUR RESPONSE

1.



2.



3. At 1200°C the following equilibrium is attained in a closed vessel:

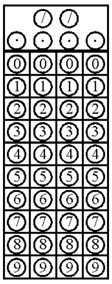
$$Cl_{2(g)} \rightleftharpoons 2Cl_{(g)}$$

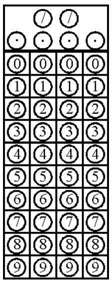
It is found that at 1.80 mm Hg pressure the equilibrium mixture effuses 1.16 times as fast as Krypton (mol mass = 84) effuses under the same conditions. Calculate degree of dissociation of chlorine molecules into atoms at the given temperature.

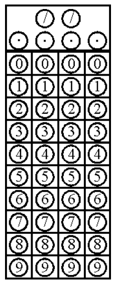
4. A mixture of ethane and ethene occupies 50.0 L at 1.00 atm and at 400 K. The mixture is just completely oxidised by 156.1 g of oxygen. Assuming ideal gas behaviour calculate mole fraction of ethene in the mixture.

5. 92.0 g of N_2O_4 (g) at 27°C is placed in a closed vessel under one atmosphere. When heated to 327°C, N_2O_4 dissociates into NO_2 (g) to the extent of 30% by mass. What will be the resultant pressure (atm) of the gaseous system?

MARK YOUR RESPONSE

3. 

4. 

5. 

Answerkey

A SINGLE CORRECT CHOICE TYPE

1.	c	**2.**	c	**3.**	d	**4.**	d	**5.**	a	**6.**	d	**7.**	d	**8.**	c	**9.**	d	**10.**	b
11.	b	**12.**	b	**13.**	c	**14.**	b	**15.**	c	**16.**	d	**17.**	c	**18.**	c	**19.**	c	**20.**	c
21.	b	**22.**	d	**23.**	d	**24.**	c	**25.**	c	**26.**	b	**27.**	d	**28.**	b	**29.**	d	**30.**	d
31.	c	**32.**	c	**33.**	b	**34.**	d	**35.**	a	**36.**	b	**37.**	c	**38.**	d	**39.**	b	**40.**	c
41.	d	**42.**	b	**43.**	a	**44.**	d	**45.**	c	**46.**	d	**47.**	c	**48.**	b	**49.**	b	**50.**	b
51	c	**52**	c	**53**	c	**54**	c	**55**	b	**56**	a	**57**	b	**58**	b	**59**	b	**60**	c
61	b	**62**	c	**63**	b	**64**	d	**65**	d	**66**	a	**67**	d	**68**	b	**69**	c	**70**	b

B COMPREHENSION TYPE

1	(c)	**5**	(b)	**9**	(d)	**13**	(b)	**17**	(a)	**21**	(d)
2	(b)	**6**	(d)	**10**	(b)	**14**	(c)	**18**	(b)	**22**	(a)
3	(c)	**7**	(d)	**11**	(c)	**15**	(b)	**19**	(c)	**23**	(a)
4	(d)	**8**	(c)	**12**	(b)	**16**	(a)	**20**	(d)		

C REASONING TYPE

1	(a)	**4**	(d)	**7**	(d)	**10**	(c)	**13**	(d)	**16**	(d)
2	(d)	**5**	(a)	**8**	(d)	**11**	(c)	**14**	(b)	**17**	(a)
3	(a)	**6**	(d)	**9**	(d)	**12**	(a)	**15**	(d)	**18**	(d)

D MULTIPLE CORRECT CHOICE TYPE

1.	b,c,d	**2.**	a,d	**3.**	a,c	**4.**	a,b,c,d	**5.**	a,b	**6.**	b	**7.**	c	**8.**	b,c	**9.**	d	**10.**	c,d
11.	b	**12.**	b,c	**13.**	b,c,d	**14.**	b,c,d	**15.**	b,c,d	**16.**	a,d	**17.**	b,d	**18.**	c,d	**19.**	a,b	**20.**	a
21.	c,d	**22.**	d	**23.**	a,c,d														

E MATRIX-MATCH TYPE

1. **A-q, s; B-p, s; C-q, s; D-r**

2. **A-q; B-p, C-s; D-r**

3. A-r; B-s; C-q; D-p

4. A-s; B-p; C-q; D-r

5. A-p, r; B-p; C-q, s; D-p, r

6. **A-p, s; B-r; C-p, q; D-r**

F NUMERIC/INTEGER ANSWER TYPE

1	**2.91 g**	**2**	40.05 kg	**3**	**0.137**	**4**	**0.4**	**5**	**2.60 atm**

Solutions

A SINGLE CORRECT CHOICE TYPE

5. (a) Pressure at the surface of lake, $P_1 = 1 \text{ atm} \cong 10 \text{ m}$ column; $V_1 = 10\text{L}$

Pressure at the bottom, $P_2 \equiv (10 + x)$ m column, $V_2 = 1.25\text{L}$

Applying $P_1V_1 = P_2V_2$, x = depth = 70m

6. (d) Volume of gas at STP $= nV_m = n \times 22.4\text{L}$

(a) $n = \frac{14}{28} + \frac{16}{32} = 1$, volume $= 1 \times 22.4\text{L} = 22.4\text{L}$

(b) $n = \frac{4}{4} + \frac{44}{44} = 2$, volume $= 2 \times 22.4\text{L} = 44.8\text{L}$

(c) $n = \frac{7}{28} + \frac{36}{48} = 1$, volume $= 1 \times 22.4\text{L} = 22.4\text{L}$

(d) $NH_3(g) + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$, volume << 44.8L

8. (c) V_m at 0°C and 1 atm (at STP) = 22.4 L

V_m at 0°C and 2 atm $= \frac{22.4}{2} = 11.2\text{L}$

10. (b) P_1 (dry gas) $= P_{\text{wet gas}}$ – aqueous tension $= 740 - 20 = 720$ mm, $V_1 = 190.0$ml

$P_2 = 1$ atm = 760 mm, $V_2 = ?$;

Apply $P_1V_1 = P_2V_2$

11. (b) During heating volume of container and pressure of the gas (= 1 atm) remain constant.
Hence, $n_1T_1 = n_2T_2$

or, $n_2 = \frac{n_1T_1}{T_2} = n_1 \times \frac{300}{500} = \frac{3}{5}n_1$ (moles remaining);

moles expelled $= n_1 - \frac{3}{5}n_1 = \frac{2}{5}n_1$

% expelled $= \frac{2}{5}n_1 \times \frac{100}{n_1} = 40$

12. (b) At the same conditions of T and P, $V \alpha n$

$n_{N_2} = \frac{14}{28} = \frac{1}{2}$; $V_{N_2} \alpha \frac{1}{2}$ $\quad n_{O_3} = \frac{36}{48} = \frac{3}{4}$; $V_{O_3} \alpha \frac{3}{4}$

Hence, $V_{N_2}/V_{O_3} = \frac{2}{3}$, $3V_{N_2} = 2V_{O_3}$

13. (c) $P_{H_2} = X_{H_2}P_{\text{total}}$

$$= \frac{\frac{w}{2}}{\frac{w}{2} + \frac{w}{32}} \times 3.4 = \frac{16}{17} \times 3.4 = 3.2 \text{ atm}$$

14. (b) $\frac{r_{He}}{r_{SO_2}} = \frac{100/t}{x/t} = \frac{P_{He}}{P_{SO_2}}\sqrt{\frac{M_{SO_2}}{M_{He}}} = \frac{1}{2} \times \sqrt{\frac{64}{4}} = 2$

or $x = 50$ cm

15. (c) $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$; HCl is limiting reagent. Mol of NH_3 left = 2–1 = 1 ;

$P = \frac{nRT}{V} = \frac{1 \times 0.0821 \times 300}{10}$ atm

16. (d) $H_{2(g)} + Cl_{2(g)} \xrightarrow{h\nu} 2HCl_{(g)}$; HCl gas is highly soluble in water and dissolves almost completely. No gas is left. The pressure is almost due to water vapour at 27°C.

17. (c) K.E. $= \frac{3}{2}nRT$; K.E.$(H_2) = \frac{3}{2} \times \frac{w}{2} \times R \times 300$;

K.E.$(CH_4) = \frac{3}{2} \times \frac{w}{16} \times R \times 600$;

Hence $\frac{\text{K.E.}(H_2)}{\text{K.E.}(CH_4)} = 4$

18. (c) Moles of $O_2 = \frac{160}{32} = 5$; $C_P - C_V = R$ for 1 mol

Hence, difference of two heat capacities for 5 moles = 5 × R

19. (c) KE $= \frac{3}{2}nRT$; $n_{N_2} = \frac{14}{28} = 0.5$ mol; $T_{N_2} = ?$

$n_{O_2} = \frac{32}{32} = 1$ mol; $T_{O_2} = 300$K

Given, K.E.(N_2) = K.E.(O_2), so $n_{N_2}T_{N_2} = n_{O_2}T_{O_2}$

or $0.5 \times T_{N_2} = 1 \times 300$, or $T_{N_2} = 600$K

20. (c) Apply $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

21. **(b)** As P and V remain constant, $n_1 T_1 = n_2 T_2$

$$n_1 = \frac{0.4}{4} = 0.1;\ T_1 = TK;\ n_2 = \frac{0.40 - 0.08}{4} = 0.08$$

$T_2 = (T + 50)K$

22. **(d)** For finite size of molecules, van der Waals eqn becomes : $P(V - nb) = nRT$ or $\frac{PV}{nRT} = 1 + \frac{Pb}{RT}$

Thus , compressibility $\frac{PV}{nRT} > 1$

28. **(b)** The gas is less compressible than ideal gas. Hence , $V_m > 22.4L$

29. **(d)** (i) Greater is the van der Waals's constant *a,* higher would be T_c (easier liquefaction of the gas).
(ii) Smaller the constants *a* and *b,* lesser departure from ideal behaviour.
(iii) Greater the constant *b,* larger is the molecular volume.

30. **(d)** For molecules to be point masses, $b = 0$
Hence,

$$\left(P + \frac{an^2}{V^2}\right)V = nRT \text{ or } PV = nRT - \frac{an^2}{V}$$

31. **(c)** The temperature $T = a / R_b$ is the Boyle temperature at which a real gas behaves as an ideal gas.

33. **(b)** Under same conditions of *P* and *T*, helium gas (smaller molecular mass) will effuse into the balloon more rapidly than the air (higher molecular mass) effusing out .

34. **(d)** % Relative humidity

$$= \frac{\text{Partial pressure of water vapour in air}}{\text{Aqueous tension}} \times 100$$

Hence, p_{H_2O} in air $= 27 \times \frac{80}{100} = 21.60$ mm Hg

35. **(a)** For equal average speeds of two of gases,

$$\sqrt{\frac{T_1}{M_1}} = \sqrt{\frac{T_2}{M_2}}$$

$T_1 = ?; M_1 = 4; T_2 = 273 + 527 = 800K; M_2 = 32$

36. **(b)** $P_1(\text{dry}) \times V_1 = P_2(\text{dry}) \times V_2; P_1 = P_{wet}$ - aqueous tension $= 760 - 55 = 705$ *torr*

$V_2 = 0.5L$. Hence, P_2 (dry gas) $= \frac{705 \times 1}{0.5} = 1410$ torr

P_2 (wet gas) $= 1410 + 55 = 1465$ torr

37. **(c)** $\frac{r_{O_2}}{r_{H_2}} = \frac{n_{O_2}}{n_{H_2}} = \frac{w/32}{4/2} = \frac{w}{64} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}} = \frac{1}{4}$

$w = 64/4 = 16$ g

38. **(d)** $\frac{r_{CH_4}}{r_X} = 2 = \sqrt{\frac{M_x}{M_{CH_4}}} = \sqrt{\frac{M_x}{16}},\ M_x = 64$

39. **(b)** $\frac{r_{H_2}}{r_{O_2}} = \frac{x/5}{x/t} = \frac{t}{5} = \sqrt{\frac{32}{2}} = 4 \Rightarrow t = 20\text{s}$

40. **(c)** For $N_2, P_1V_1 = P_2P_2,\ V_2 = 250 + 300 = 550$ml

$$P_2 = \frac{P_1V_1}{V_2} = \frac{660 \times 250}{550} = 300 \text{ torr}$$

For neon, $P_2 = \frac{P_1V_1}{V_2} = \frac{825 \times 300}{550} = 450$ torr

Total pressure $= 300 + 450 = 750$ torr

41. **(d)** $1 = \frac{r_{SO_2}}{r_{He}} = \frac{P_1}{P_2}\sqrt{\frac{M_{He}}{M_{SO_2}}} = \frac{P_1}{P_2}\sqrt{\frac{4}{64}} = \frac{P_1}{4P_2}$

or, $P_1 / P_2 = 4$

42. **(b)** Average speed of a gas molecule varies inversely with the square root of molecular mass.

43. **(a)** Number of moles of $CH_4 = \frac{80}{16} = 5$

$$KE = \frac{3}{2}nRT = \frac{3}{2} \times 5 \times 2 \times 400 = 6000 \text{ cal} = 6 \text{ k cal}$$

44. **(d)** $M_{mix} = M_1X_1 + M_2X_2$

$$= 17 \times \frac{20}{100} + 34 \times \frac{80}{100} = 30.6$$

(V.D.) mix $= 30.6/2 = 15.3$

45. **(c)** Let *N* be the number of atoms of He and oxygen. Molecules of He $= N$; molecules of $O_3 = N/3$

Total number of molecules $= N + \frac{N}{3} = 4\frac{N}{3}$;

total pressure $= P$

Hence, $P_{O_3} = X_{O_3}P = \frac{N/3}{4N/3}P = 0.25P$

47. **(c)** Critical compressibility factor $Z = \frac{P_cV_c}{RT_c}$

$$P_c = \frac{a}{27}b^2;\ Vc = 3b, Tc = \frac{8a}{Rb}$$

Hence, $Z = \frac{3}{8}$ or $\frac{1}{Z} = \frac{8}{3}$

51. **(c)** Mol atom of Sodium $= \frac{230}{23} = 10$

Mol atom of Oxygen $= \frac{80}{32} \times 2 = 5$

Mol atom of Hydrogen $= \frac{20}{2} \times 2 = 20$

52. **(c)** van der Waal's equation : $\left(P+\frac{a}{V^2}\right)(V-b)=RT$

$$PV+\frac{a}{V}-bP-\frac{ab}{V^2}=RT$$

The term $\frac{ab}{V^2}$ is very very small and for H_2 and He

$$bP>>\frac{a}{V^2}$$

Hence, $PV=RT+bP$, $\frac{PV}{RT}=1+\frac{bR}{RT}$

53. **(c)** $\frac{PV}{RT}=n=\frac{W}{M}$ Hence $\frac{PV}{RT}$ is proportional to the mass of the gas.

54. **(c)** $a=\frac{PV^2}{n^2}$ (atm L^2 mol^{-2}) ; b = L mol^{-1} ;

Hence, $\frac{a}{b}=\left(\frac{\text{atm L}^2\text{ mol}^{-2}}{\text{L mol}^{-1}}\right)=\text{atm L mol}^{-1}$

55. **(b)** The graph is a straight line parallel to the axis of pressure with intercept

$=PV_m=RT=0.082\ (\text{atm L K}^{-1}\text{mol}^{-1})\times 300(\text{K})$

$=24.6\ \text{atm L mol}^{-1}$.

56. **(a)** The intercept = Volume of 0.5 mol of gas at 0°C and 0.5 atm = 22.4 L

57. **(b)** Gas pressure = barometric pressure + pressure due to Hg column

= 743 mm Hg + (36.2 – 15.5) × 10 mm Hg = 950 mm Hg

$=\frac{950}{760}=1.25$ atm

58. **(b)** Moles of excess reactant X left = 3 – 2 = 1

Volume of the flask available for the gas X = 15 – 5 = 10 L

Hence, the pressure in the flask

$=\frac{nRT}{V}=\frac{1\times 0.082\times 300}{10}=2.46$ atm

59. **(b)** Mole atoms of X = 0.75 × 4 = 3; Mole atoms of O = 2 × 2 = 4

Hence, the product is $X_3O_{4(g)}$

Initial moles of gaseous reactants, n_1 = 2 (oxygen only)

Final moles of gaseous products, n_2 = 1 (X_3O_4)

Hence, $\frac{P_2}{P_1}=\frac{n_2T_2}{n_1T_1}=\frac{1\times 600}{2\times 300}=1$

or $P_2:P_1=1:1$

60. **(c)** Total moles of gas mixture in the vessel

$=\frac{PV}{RT}=\frac{4.1\times 3}{0.082\times 300}=0.5$

Moles of He = 0.4, Moles of X = 0.5 – 0.4 = 0.1

Hence $\frac{r_{He}}{r_X}=\frac{0.4}{0.1}=\sqrt{\frac{M_x}{M_{He}}}=\sqrt{\frac{M_x}{4}}$

$\Rightarrow M_x=64\text{g mol}^{-1}$

61. **(b)** $CH_{4(g)}+2O_{2(g)}\longrightarrow CO_{2(g)}+2H_2O_{(\ell)}$

$CH_4\left(\frac{16}{16}=1\text{mol}\right)$ and $O_2\left(\frac{64}{32}=2\text{mol}\right)$

react completely to produce 1 mole of CO_2 gas and 2 moles of liquid water at 27°C.

Hence, $P=\frac{nRT}{V}=\frac{1\times 0.082\times 300}{3}=8.2$ atm

62. **(c)** Pressure of the gas at temperature T = 1030 – 30 = 1000 mm

Since $P\propto T$, $\Delta P=\frac{1}{100}\times 1000=10$ mm

Hence final pressure = P_{gas} at lower temperature T + Aqueous tension = (1000 – 10) + 25 = 1015 mm Hg

63. **(b)** Amongst 100 persons, number of equidistant spaces = 99

Let nth be the person from side X. Then,

$\frac{r_{NO_2}}{r_{tear}}=\sqrt{\frac{M_{tear}}{M_{NO_2}}}=\sqrt{\frac{176}{44}}=2$

or $\frac{n-1}{99-(n-1)}=\frac{n-1}{100-n}=2\ \Rightarrow n=67$

64. **(d)** $\frac{r_{mix}}{r_x}=\frac{2/5}{2/10}=2=\sqrt{\frac{M_x}{M_{mix}}}\Rightarrow M_{mix}=9$

$M_{mix}=M_{H_2}X_{H_2}+M_{CH_4}X_{CH_4}$

$=2X_{H_2}+16(1-X_{H_2})=9$ (calculated)

$\Rightarrow X_{H_2}=0.5$

65. **(d)** van der Waals's constant b = 4 times the actual volume of 1 mole molecules = $4\,VN_0$

66. **(a)** We know $V_c=3b; P_c\ \frac{a}{27b^2}$; $T_c=\frac{8a}{27Rb}$

Substituting these values in $Z=\frac{P_cV_c}{RT_c}$, we get

$$Z=\frac{a}{27b^2}\times\frac{3b}{R}\times\frac{27Rb}{8a}=\frac{3}{8}$$

67. **(d)** $R = \frac{PV}{T}$

At critical point $V = V_c$

and $(V - V_c)^3 = 0$

Expanding this equation, we have

$$V^3 - 3V_c.V^2 + 3V_c^2.V - V_c^3 = 0 \quad ..(i)$$

The vander waals equation in critical point is

$$V^3 - \left(b + \frac{RT_c}{P_c}\right)V^2 + \left(\frac{a}{P_c}\right)V - \frac{ab}{P_c} = 0 \quad ...(ii)$$

Comparing (i) and (ii), we get

$$V_c = 3b, P_c = \frac{a}{27b^2}, T_c = \frac{8a}{27Rb}$$

Eliminating constants a and b from the values of critical constants, we obtain

$$R = \frac{8P_cV_c}{3T_c}$$

68. **(b)** This can be calculated by limiting density method which is based on the fact that at limit of zero pressure the ideal gas equation becomes exact for all gases i.e.,

$$PV = nRT$$

Molecular weight of HBr on this basis is

$$M = RT\left(\frac{\rho}{P}\right)_{P \to 0}$$

$M = 0.0821 \times 273.15 \times 3.6108$ [0°C = 273.15K] = 80.93

$\therefore$ 80.93 = atomic weight of hydrogen + atomic weight of bromine

= 1.008 + atomic weight of bromine

or atomic weight of bromine = 80.93 – 1.008 = 79.92

69. **(c)** Let the degree of dissociation be α, then

$PCl_5 \longrightarrow PCl_3 + Cl_2$

$(1 - \alpha) \quad \alpha \quad \alpha$

(M) Molecular weight of PCl_5 = 31 + 5 × 35.5 = 208.5

Total number of molecules before dissociation = 1

Total number of molecules after dissociation

$= 1 - \alpha + \alpha + \alpha = 1 + \alpha$

Thus each gram mole changes to $(1 + a)$ gram-mole.

Thus $PV = \frac{W}{M}(1 + \alpha)RT$

(V = volume after dissociation)

or $1 \times \frac{1700}{1000} = \frac{4.5}{208.5}(1 + \alpha)RT$ $\left[1700\text{ml} = \frac{1700}{1000}\text{L}\right]$

or $\alpha = 0.921$

$\therefore$ % age dissociation = 92.1%

70. **(b)** This is the correct relationship.

The van der Waals equation is

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT \quad \text{(For one mole)}$$

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

$$\text{or } P = \frac{RT}{V - b} - \frac{a}{V^2}$$

Multiplying throughout by molar volume (V) and dividing by RT, we have

$$\frac{PV}{RT} = \frac{V}{V - b} - \frac{a}{RTV} \quad \text{or} \quad \frac{PV}{RT} = \left(\frac{V - b}{V}\right)^{-1} - \frac{a}{RTV}$$

$$\text{or } \frac{PV}{RT} = \left(1 - \frac{b}{V}\right)^{-1} - \frac{a}{RTV}$$

$$\text{or } \frac{PV}{RT} = 1 + \frac{b}{V} + \frac{b^2}{V^2} + \frac{b^2}{V^3} - \frac{a}{RTV}$$

$$\text{or } \frac{PV}{RT} = 1 + \left(b - \frac{a}{RT}\right) \times \frac{1}{V} + \frac{b^2}{V^2} + \frac{b^3}{V^3}$$

Comparing this with virial equation we get

$$B = b - \frac{a}{RT}$$

B COMPREHENSION TYPE

1. **(c)** Since the temperature of both the gases is the same (300K), average K.E. per molecule of either gas will be the same. But since He molecules are lighter, they will have greater average velocity.

2. **(b)** $P_{\text{final}} = \frac{P_{He} \times V_{\text{inital}} + P_{N_2} \times V_{\text{inital}}}{V_{\text{final}}}$

$$= \frac{4.1 \times 6.0 + 0.82 \times 10}{6 + 10} = 2.05\text{atm}$$

3. **(c)** Work of expansion $W = -P_{ext} \times \Delta V$

[P_{ext} = Pressure against which gas expands]

Since pressure in chamber C is zero , $P_{ext} = 0$;

Hence $W = 0$

4. **(d)** Moles of He, $n = \frac{PV}{RT} = \frac{4.1 \times 6}{0.082 \times 300} = 1$; Moles of N_2

$$n = \frac{PV}{RT} = \frac{0.82 \times 10}{0.082 \times 300} = \frac{1}{3}$$

The average K.E. of 1 mole of a gas is given by $\frac{3}{2}RT$.

So, the total K.E. of n moles $= \frac{3}{2}nRT$

$$= \frac{3}{2}\left(1+\frac{1}{3}\right)\times 8.314\times 300 = 4988.4\text{ J}$$

5. **(b)** The effusion rate of a gas depends on the average speed of molecules, not the volume into which the gas is expanding. Average molecular speed remains constant, temperature remaining fixed; hence the rate of effusion remains unchanged.

On increasing the volume of chamber C, the final pressure and the number of moles of gas in chamber A will be lowered. Also, ΔS will increase due to larger expansion of N_2 gas.

6. **(d)** Partial pressure of N_2 gas = Mole fraction × total pressure $= \frac{1/3}{1+1/3}\times P_{\text{total}} = \frac{1}{4}\times 1.0 = 0.25$ atm

7. **(d)** At the point G, the liquid and gaseous phases of CO_2 can not be distinguished; the two phases have the same densities.

8. **(c)** The curve representing the gas-liquid equilibrium ends at the *dark* point, the critical point. Above the temperature corresponding to this point, CO_2 can not be liquefied for any value of pressure. Temperature and pressure corresponding to the *dark* point are T_c and P_c.

9. **(d)** Super critical CO_2 acts as a nonpolar solvent and dissolves nonpolar or less polar compounds like $C_2H_5OC_2H_5$.

10. **(b)** The curve representing the solid-liquid equilibrium is inclined away from the axis of pressure, showing thereby the increase of m.pt. of CO_2 with pressure.

11. **(c)** On increasing pressure at point 'O', while keeping temperature constant, we enter into the area representing solid phase. Hence liquid and gas phases would disappear.

12. **(b)** At point B, liquefaction of CO_2 commences and is complete at the point C. Along the line BC the proportion of gas phase of CO_2 decreases and that of liquid phase increases, and hence the volume of the system decreases along the line BC.

13. **(b)** At very high temperature and very low pressure, a real gas behaves in ideal manner.

14. **(c)** van der Waal's equation for 1 mole of gas :

$$\left(P+\frac{a}{V^2}\right)(V-b) = RT \quad\text{or}\quad PV+\frac{a}{V}-bP = RT\ ;$$

At very low pressure $\frac{a}{V} >> bP$

Hence, $PV = RT - \frac{a}{V}$; $Z = \frac{PV}{RT} = 1-\frac{a}{RTV}$

16. **(a)** Higher is the pressure and lower the temperature, greater will be the deviation from ideal behavior.

18. **(b)** For one mole of real gas, we have

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

Under conditions of high pressure

$$P+\frac{a}{V^2}\approx P$$

$\therefore$ The above equation becomes

$P(V-b) = RT$

or $PV - Pb = RT$

or $PV = RT + Pb$

19. **(c)** Higher the value of 'a' stronger are the inter molecular forces and easier to liquify a gas.

20. **(d)** Since the value of $b = 0$ in case of molecules to be point masses

$\therefore$ The van der Waals' equation will become

$$\left(P+\frac{an^2}{V^2}\right)(V-0) = nRT \quad (\because b=0,\text{ so } nb=0)$$

or $\left(P+\frac{an^2}{V^2}\right)V = nRT$

or $PV+\frac{an^2}{V} = nRT$ or $PV = nRT - \frac{an^2}{V}$

21. **(d)** Since $PV = Z.nRT$ $\therefore$ $Z = \frac{PV}{nRT}$

22. **(a)** Under given conditions the real gas behaves as an ideal gas and thus $Z = 1$

23. **(a)** The correction in pressure is

$$P' = an^2/V^2 \quad\text{or}\quad a = \frac{[P'\text{atm}]\,[V\,L]^2}{[n\text{ mol}]^2}$$

C REASONING TYPE

1. **(a)** $V_t = V_0 + \frac{V_0}{273}\times t$ (at constant P and n)

$$= V_0\left(1+\frac{t}{273}\right) = V_0\left(\frac{273+t}{273}\right)$$

$$V_t = \frac{V_0}{273}T \quad (\text{where } 273+t = T)$$

or $\frac{V_t}{T} = \frac{V_0}{273} = \frac{V_0}{T_0}$

2. **(d)** Absolute zero –273.14°C, indicates that no substances can be cooled below it. It does not mean that volume of a real gas becomes zero, all gases liquefy and solidify before this temperature is reached.

3. **(a)** According to kinetic theory of gases,
   (i) The volume occupied by the gas molecules is negligible as compared to the total volume of the gas.
   (ii) The forces of attraction or repulsion between the gas molecules are negligible.
   These two assumptions are correct only if the temperature is high and pressure is low.

4. **(d)** The process of effusion is always followed by the process of diffusion.
   Diffusion is the spreading of gas in the whole available volume irrespective of the other gases present. Effusion is escaping of gas from one chamber of a vessel through a small opening.

5. **(a)** Considering the attractive force pressure in ideal gas equation ($PV = nRT$) is corrected by introducing a factor of $\frac{an^2}{V^2}$ where a is van der waals constant.

6. **(d)** Excluded volume for n moles of molecules of gas is 4 times the actual volume occupied by them while ($V - nb$) is the corrected volume or the free volume available to the gas molecules for movement.

7. **(d)** Temperature at which the real gas exhibit ideal behaviour for considerable range of presure is known as Boyle's temperature, $T_b = \frac{a}{bR}$; a, and b are van der Waal's constants.
   Critical temperature is the temperature above which the gas cannot be liquefied, how so ever high pressure may be applied.
   $$T_c = \frac{8a}{27Rb}$$

8. **(d)** Molecular collisions, according to kinetic theory of gases, are elastic. In this case energy and momenta are conserved.

9. **(d)** $v_{rms} = \sqrt{\frac{3RT}{M}}$, therefore it is also related to molar mass.

10. **(c)** Molecular mass has a fixed value for a particular gas and does not depend upon density. From $M = \frac{\rho RT}{P}$, if P is doubled, ρ is is also doubled at constant temperature to keep M constant.

11. **(c)** Z can be greater than 1 or less than 1. Non - ideal gases exert less pressure than expected due to backward pull by other molecules.

12. **(a)** 'a' indicates the magnitude of the attractive forces among the gas molecules, which has greater value in NH_3 due to intermolecular H-bonding.

13. **(d)** Here assertion is incorrect because condition of constancy of volume is not given.

14. **(b)** Both assertion and reason are correct and reason is not the correct explanation of assertion
   Since the gas is expanding in vaccum so no energy is required to tear apart the molecules in ideal gas and no heat is absorbed.

15. **(d)** Assertion is wrong, reason is correct.
   The compressibility factor for both CO_2 and CH_4 is less than one at 273 K.

16. **(d)** Assertion in false. The increase in volume can be found by use of Charle's law.
   Reason is true.

17. **(a)** Both assertion and reason are correct and reason is the correct explanation of assertion.

18. **(d)** Assertion is true, reason is false. The critical constants of H_2 and He are not nearly same.

D MULTIPLE CORRECT CHOICE TYPE

6. **(b)** van der waal's constant $b = 4\ \upsilon$ No

$$= 4 \times \frac{4}{3}\pi\, r^3 \times 6.023 \times 10^{23}$$

$$= 4 \times \frac{4 \times 22}{3 \times 7} \times (1.0 \times 10^{-8})^3 \times 6.023 \times 10^{23}\,\text{cm}^3$$

$= 10.09\ \text{cm}^3 = 0.0101\ \text{L mol}^{-1}$

9. **(d)** b for $CO_2 = 4\,\upsilon = 4 \times 0.01007 = 0.0428\ \text{L mol}^{-1}$

Moles of $CO_2 = \frac{220}{44} = 5$

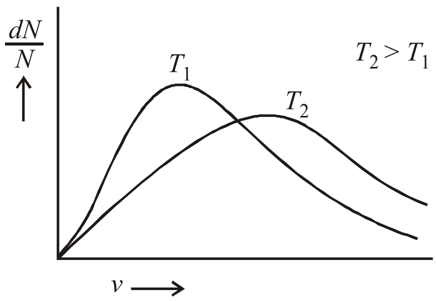
Volume correction $= nb = 5 \times 0.0428 = 0.214$ L

Hence , free or empty space = 10 - 0.214 = 9.786 L

13. **(b,c,d)** (a) An ideal gas cannot be liquefied at any temperature for any pressure. It is due to the absence of intermolecular forces.
   (b) Helium, a real gas, can be liquefied by cooling it to critical temperature or below and applying high pressure.
   (c) The inversion temperature of helium is much below the room temperature. Hence, it shows heating effect during Joule-Thompson porous plug streaming of the gas at ordinary temperatures.
   (d) Compressibility factor $\left(Z = \frac{PV}{RT}\right)$ of hydrogen is greater than unity

14. (b,c,d) For adiabatic process, q = 0.
Hence $\Delta E = W = -P\Delta V$
Also, $\Delta E = C_v \Delta T = -P\Delta V$
Since ΔV is positive for expansion, ΔE will be negative and so also ΔT.

15. (b,c,d) On increasing temperature, the Maxwell's curve of distribution of molecular velocities is flattened and maximum is shifted to higher velocity.



16. (a,d) Argon is a monoatomic gas and molecules have only the three translational degree of freedom. So heat supplied is used up in increasing translational K.E. and in doing the work of expansion of the gas against external pressure.

17. (b,d) In adiabatic expansion work done by the gas is at the expanse of its internal energy resulting fall in temperature. So ΔV in adiabatic process between the same two pressures P_1 and P_2 will be smaller than in isothermal process.

18. (a,c,d) In a real gas the molecules going to strike the walls of the container are attracted towards interior owing to the intermolecular forces. As a result the molecules strike the walls with lesser momentum and exert lesser pressure than ideal gas.
Molecules in a real gas have finite size and occupy some volume. Thus the vacant (free) space available for the molecules to move about is somewhat decreased in comparison to ideal gas.

19. (a, b) Since temperature is kept constant so pressure decrease causes the volume to increase.
K.E. remains unchanged (K.E. $\propto T$)
Number of gas molecules remains constant during expansion.

20. (a) At Boyle temperature the attraction forces are equal to repulsive forces.

21. (c, d) Critical temperature is not same as Boyle temperature.

22. (d) The critical temperature of P and Q is less than 90 K and no gas can be liquified above its critical temperature for any value of pressure.

23. (a, c, d) The statement (b) is incorrect.

E MATRIX-MATCH TYPE

1. A-q, s; B-p, s; C-q, s; D-r

(A) Although velocities of molecules of a gas go on changing with time but their distribution is independent of time. It changes with temperature.

(B) Velocity of a paricular molecule changes from time to time due to random collision. It also changes with temperature.

(C) The fraction of molecules having a particular velocity does not change with time but it changes with temperature.

(D) Vapour density (= molecular mass/2) is temperature independent.

2. A-q; B-p, C-s; D-r

(A) At temperature < T_i, $\mu_{JT} = \left[\left(\frac{dT}{dP}\right)_H\right]$ becomes positive, i.e. cooling effect takes place in streaming process. It suggests that the forces between the gas molecules are attractive in nature.

(B) At temperature > Ti, μ_{JT} is negative which suggests the existance of repulsive forces between the gas molecules.

(C) At Boyle's temperature and above, a real gas obeys gas laws over a wide range of pressure.

(D) In ideal gas the intermolecular forces do not exist. Hence Joule-Thompson effect is zero.

3. A-r; B-s; C-q; D-p

(A) Pressure correction = $\frac{an^2}{V^2}$

$$= \frac{3.6(L^2 atm\, mol^{-2})}{10^2(L^2)} \times \left(\frac{200}{40}\right)^2 (mol^2) = 0.9\text{L atm}$$

(B) Free space = $V - nb = 10 - 5 \times 0.05 = 9.75L$

(C) Actual volume of gas molecules

$$= \frac{nb}{4} = \frac{5 \times 0.05}{4} = 0.06L$$

(D) Effective volume of gas molecules

$$= nb = 5 \times 0.05 = 0.25L$$

4. A-s; B-p; C-q; D-r

(A) 4g of $H_e = \frac{4}{4} = 1$ mole;

$$\text{K.E.} = \frac{3}{2}nRT = \frac{3}{2} \times 1 \times RT = 1.5RT$$

(B) 32 g of O_2 $\frac{32}{32}$ 1 mole ; K.E. = (K.E.) translational + (K.E.) rotational

$= \frac{3}{2}RT + 2\times\frac{RT}{2}$ (Two rotational degrees of freedom)

(C) NO_2 is triatomic non-linear molecule and thus possesses three translational and three rotational degree of freedom (vibrational degrees of freedom do not contribute at ordinary temperatures).

(D) At constant pressure increase in energy

$= \Delta E + P\Delta V \quad 3R \quad R \quad 4R$

6. **A-p, s; B-r; C-p, q; D-r**

Under 250 atmosphere pressure and 273 K hydrogen gas will not show ideal gas behaviour, so $Z \neq 1$. Under these conditions it obeys van der Waals equation but pressure correction can be neglected, so it obeys the equation $P(V - nb) = nRT$

B $\rightarrow$ Under these conditions hydrogen gas behaves as ideal gas and obeys ideal gas equation, $PV = nRT$

C$\rightarrow$ Under these conditions CO_2 does not behave as ideal gas so $Z \neq 1$. Also the forces of attraction dominate the forces of repulsion.

D$\rightarrow$ Such a gas obeys ideal gas equation.

F NUMERIC/INTEGER ANSWER TYPE

1. **Ans : W = 2.91 g**

$PV = nRT = \frac{W}{M}RT = \frac{W}{4}\times 0.082\times 275$

$\frac{3.04}{760}\times 8.2\times 10^4 = \frac{W}{4}\times 0.082\times 275 \Rightarrow W \quad$ **2.91 g**

2. **Ans : 40.05 kg**

Payload = Mass of air displaced by the balloon – mass of balloon alongwith helium gas

$P = 1\text{atm} = 1.0132\times 10^5\ \text{Nm}^{-2}, V = \frac{4}{3}\times\pi\times(2.1)^3, T = 300\ \text{K}$

$\therefore n_{He} \quad \frac{PV}{RT} \quad \frac{1.0132\times 10^5\times\frac{4}{3}\times\frac{22}{7}\times(2.1)^3}{8.314\times 300} \quad 1.576\times 10^3$

Mass of He filled = $1.576\times 10^3\times 4\times 10^{-3}$ = 6.30 kg

Mass of air displaced = Volume of balloon × density of air

$= \frac{4}{3}\times\frac{22}{7}\times(2.1)^3\times 1.22 \quad 47.35$ kg

Hence, payload on balloon = 47.35 – (6.30 + 1.00)

= **40.05 kg**.

3. **Ans : 0.137**

$\frac{\text{Rate of effusion of mixture}}{\text{Rate of effusion of Krypton}} \quad 1.16 \quad \sqrt{\frac{D_{Kr}}{D_{mix}}} \quad \sqrt{\frac{42}{D_{mix}}}$

(V.D. of Kr = $\frac{84}{2}$ 42) $\Rightarrow D_{mix} \quad 31.212$

V.D. of chlorine before dissociation = $\frac{71}{2}$ 35.5

Degree of dissociation,

$\alpha \quad \frac{D_{Cl_2} - D_{mix}}{D_{mix}(n-1)} \quad \frac{35.5 - 31.212}{31.212\times(2-1)} \quad$ **0.137.**

4. **Ans : 0.40**

Ethane and Ethene undergo combustion as :

(i) $C_2H_6 \quad \frac{7}{2}O_2 \longrightarrow 2CO_2 \quad 3H_2O;$

(ii) $C_2H_4 \quad 3O_2 \longrightarrow 2CO_2 \quad 2H_2O$

x L = volume of C_2H_6;

$(50 - x)$ L = volume of C_2H_4

Then, $n_{C_2H_6} \quad \frac{PV}{RT} \quad \frac{1\times x}{0.082\times 400} \quad \frac{x}{32.8}$

$n_{C_2H_4} \quad \frac{PV}{RT} \quad \frac{1\times(50-x)}{0.082\times 400} \quad \frac{(50-x)}{32.8}$

Mass of O_2 required for complete combustion of the mixlture

$= \frac{x}{32.8}\times\frac{7}{2}\times 32 + \frac{(50-x)}{32.8}\times 3\times 32$ g $\quad$ 156.1g (given)

$\Rightarrow x = 20.0$ L; Mole fraction of $C_2H_6 = \frac{20.0}{50.0} \quad$ **0.40**

5. **Ans : 2.60 atm.**

$N_2O_{4\,(g)} \rightleftharpoons 2NO_{2\,(g)}$

$1 - x \qquad 2x$

Moles of the mixture = $1 - x + 2x = 1 + x = 1.30$

(Since $x = \frac{30}{100} \quad 0.30$)

Since the volume of the system remains constant, so

$\frac{P_1}{n_1T_1} \quad \frac{P_2}{n_2T_2}$

$\therefore P_2 = \frac{n_2T_2}{n_1T_1}\times P_1 = \frac{1.30\times 600}{1\times 300}\times 1 \quad$ **2.60** atm.

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