$$T_2 = 0{\cdot}99\ T_1$$

and hence,

$$p_2 = 0{\cdot}99\ p_1$$

$= 0{\cdot}99 \times 800$ mm of mercury = 792 mm of mercury.

The vapour is still saturated and hence, its pressure is 25 mm of mercury. The total pressure at the reduced temperature is

$$p = (792 + 25) \text{ mm of mercury}$$
$$= 817 \text{ mm of mercury.}$$

22. *Calculate the mass of* 1 litre *of moist air at* 27°C *when the barometer reads* 753·6 mm of mercury *and the dew point is* 16·1°C. *Saturation vapour pressure of water at* 16·1°C = 13·6 mm of mercury, *density of air at STP* = 0·001293 g/cc, *density of saturated water vapour at STP* = 0·000808 g/cc.

Solution : We have $pV = \frac{m}{M}RT$

or,
$$\rho = \frac{m}{V} = \frac{Mp}{RT}. \quad \text{... (i)}$$

The dew point is 16·1°C and the saturation vapour pressure is 13·6 mm of mercury at the dew point. This means that the present vapour pressure is 13·6 mm of mercury.

At this pressure and temperature, the density of vapour will be

$$\rho = \frac{Mp}{RT}$$
$$= \frac{(18 \text{ g/mol})(13{\cdot}6 \times 10^{-3} \text{ m})(13600 \text{ kg/m}^3)(9{\cdot}8 \text{ m/s}^2)}{(8{\cdot}3 \text{ J/mol-K})(300 \text{ K})}$$
$$= 13{\cdot}1 \text{ g/m}^3.$$

Thus, 1 litre of moist air at 27°C contains 0·0131 g of vapour.

The pressure of dry air at 27°C is 753·6 mm – 13·6 mm = 740 mm of mercury. The density of air at STP is 0·001293 g/cc. The density at 27°C is given by equation (i),

$$\frac{\rho_1}{\rho_2} = \frac{p_1/T_1}{p_2/T_2}$$

or,
$$\rho_2 = \frac{p_2 T_1}{T_2 p_1}\rho_1$$
$$= \frac{740 \times 273}{300 \times 760} \times 0{\cdot}001293 \text{ g/cc.}$$
$$= {\cdot}001457 \text{ g/cc.}$$

Thus, 1 litre of moist air contains 1·145 g of dry air. The mass of 1 litre of moist air is 1·1457 g + 0·0131 g ≈ 1·159 g.

□

QUESTIONS FOR SHORT ANSWER

1. When we place a gas cylinder on a van and the van moves, does the kinetic energy of the molecules increase ? Does the temperature increase ?
2. While gas from a cooking gas cylinder is used, the pressure does not fall appreciably till the last few minutes. Why ?
3. Do you expect the gas in a cooking gas cylinder to obey the ideal gas equation ?
4. Can we define the temperature of vacuum ? The temperature of a single molecule ?
5. Comment on the following statement. The temperature of all the molecules in a sample of a gas is the same.
6. Consider a gas of neutrons. Do you expect it to behave much better as an ideal gas as compared to hydrogen gas at the same pressure and temperature ?
7. A gas is kept in a rigid cubical container. If a load of 10 kg is put on the top of the container, does the pressure increase ?
8. If it were possible for a gas in a container to reach the temperature 0 K, its pressure would be zero. Would the molecules not collide with the walls ? Would they not transfer momentum to the walls ?
9. It is said that the assumptions of kinetic theory are good for gases having low densities. Suppose a container is so evacuated that only one molecule is left in it. Which of the assumptions of kinetic theory will not be valid for such a situation ? Can we assign a temperature to this gas ?
10. A gas is kept in an enclosure. The pressure of the gas is reduced by pumping out some gas. Will the temperature of the gas decrease by Charles' law ?
11. Explain why cooking is faster in a pressure cooker.
12. If the molecules were not allowed to collide among themselves, would you expect more evaporation or less evaporation ?
13. Is it possible to boil water at room temperature, say 30°C ? If we touch a flask containing water boiling at this temperature, will it be hot ?
14. When you come out of a river after a dip, you feel cold. Explain.

OBJECTIVE I

1. Which of the following parameters is the same for molecules of all gases at a given temperature ?
(a) mass (b) speed
(c) momentum (d) kinetic energy.

2. A gas behaves more closely as an ideal gas at
(a) low pressure and low temperature
(b) low pressure and high temperature
(c) high pressure and low temperature
(d) high pressure and high temperature.

3. The pressure of an ideal gas is written as $p = \frac{2E}{3V}$. Here E refers to
(a) translational kinetic energy
(b) rotational kinetic energy
(c) vibrational kinetic energy
(d) total kinetic energy.

4. The energy of a given sample of an ideal gas depends only on its
(a) volume (b) pressure (c) density (d) temperature.

5. Which of the following gases has maximum rms speed at a given temperature ?
(a) hydrogen (b) nitrogen
(c) oxygen (d) carbon dioxide.

6. Figure 24-Q1 shows graphs of pressure vs. density for an ideal gas at two temperatures T_1 and T_2.
(a) $T_1 > T_2$ (b) $T_1 = T_2$
(c) $T_1 < T_2$ (d) any of the three is possible.

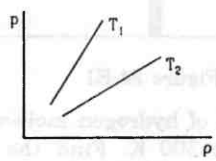


Figure 24-Q1

7. The mean square speed of the molecules of a gas at absolute temperature T is proportional to
(a) $\frac{1}{T}$ (b) $\sqrt{T}$ (c) T (d) T^2.

8. Suppose a container is evacuated to leave just one molecule of a gas in it. Let v_a and v_{rms} represent the average speed and the rms speed of the gas.
(a) $v_a > v_{rms}$. (b) $v_a < v_{rms}$.
(c) $v_a = v_{rms}$. (d) v_{rms} is undefined.

9. The rms speed of oxygen at room temperature is about 500 m/s. The rms speed of hydrogen at the same temperature is about
(a) 125 m/s (b) 2000 m/s (c) 8000 m/s (d) 31 m/s.

10. The pressure of a gas kept in an isothermal container is 200 kPa. If half the gas is removed from it, the pressure will be
(a) 100 kPa (b) 200 kPa (c) 400 kPa (d) 800 kPa.

11. The rms speed of oxygen molecules in a gas is v. If the temerature is doubled and the oxygen molecules dissociate into oxygen atoms, the rms speed will become
(a) v (b) $v\sqrt{2}$ (c) $2v$ (d) $4v$.

12. The quantity $\frac{pV}{kT}$ represents
(a) mass of the gas
(b) kinetic energy of the gas
(c) number of moles of the gas
(d) number of molecules in the gas.

13. The process on an ideal gas, shown in figure (24-Q2), is
(a) isothermal (b) isobaric (c) isochoric (d) none of these.

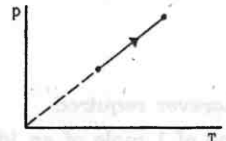


Figure 24-Q2

14. There is some liquid in a closed bottle. The amount of liquid is continuously decreasing. The vapour in the remaining part
(a) must be saturated (b) must be unsaturated
(c) may be saturated (d) there will be no vapour.

15. There is some liquid in a closed bottle. The amount of liquid remains constant as time passes. The vapour in the remaining part
(a) must be saturated (b) must be unsaturated
(c) may be unsaturated (d) there will be no vapour.

16. Vapour is injected at a uniform rate in a closed vessel which was initially evacuated. The pressure in the vessel
(a) increases continuously
(b) decreases continuously
(c) first increases and then decreases
(d) first increases and then becomes constant.

17. A vessel A has volume V and a vessel B has volume $2V$. Both contain some water which has a constant volume. The pressure in the space above water is p_a for vessel A and p_b for vessel B.
(a) $p_a = p_b$. (b) $p_a = 2p_b$.
(c) $p_b = 2p_a$. (d) $p_b = 4p_a$.

OBJECTIVE II

1. Consider a collision between an oxygen molecule and a hydrogen molecule in a mixture of oxygen and hydrogen kept at room temperature. Which of the following are possible ?
(a) The kinetic energies of both the molecules increase.
(b) The kinetic energies of both the molecules decrease.

(c) The kinetic energy of the oxygen molecule increases and that of the hydrogen molecule decreases.
(d) The kinetic energy of the hydrogen molecule increases and that of the oxygen molecule decreases.

2. Consider a mixture of oxygen and hydrogen kept at room temperature. As compared to a hydrogen molecule an oxygen molecule hits the wall
(a) with greater average speed
(b) with smaller average speed
(c) with greater average kinetic energy
(d) with smaller average kinetic energy.

3. Which of the following quantities is zero on an average for the molecules of an ideal gas in equilibrium?
(a) kinetic energy (b) momentum
(c) density (d) speed.

4. Keeping the number of moles, volume and temperature the same, which of the following are the same for all ideal gases?
(a) rms speed of a molecule (b) density
(c) pressure
(d) average magnitude of momentum.

5. The average momentum of a molecule in a sample of an ideal gas depends on
(a) temperature (b) number of moles
(c) volume (d) none of these.

6. Which of the following quantities is the same for all ideal gases at the same temperature?
(a) the kinetic energy of 1 mole
(b) the kinetic energy of 1 g
(c) the number of molecules in 1 mole
(d) the number of molecules in 1 g

7. Consider the quantity $\frac{MkT}{pV}$ of an ideal gas where M is the mass of the gas. It depends on the
(a) temperature of the gas (b) volume of the gas
(c) pressure of the gas (d) nature of the gas.

EXERCISES

Use $R = 8{\cdot}3$ J/mol–K wherever required.

1. Calculate the volume of 1 mole of an ideal gas at STP.
2. Find the number of molecules of an ideal gas in a volume of 1·000 cm^3 at STP.
3. Find the number of molecules in 1 cm^3 of an ideal gas at 0°C and at a pressure of 10^{-5} mm of mercury.
4. Calculate the mass of 1 cm^3 of oxygen kept at STP.
5. Equal masses of air are sealed in two vessels, one of volume V_0 and the other of volume $2V_0$. If the first vessel is maintained at a temperature 300 K and the other at 600 K, find the ratio of the pressures in the two vessels.
6. An electric bulb of volume 250 cc was sealed during manufacturing at a pressure of 10^{-3} mm of mercury at 27°C. Compute the number of air molecules contained in the bulb. Avogadro constant $= 6 \times 10^{23}$ per mol, density of mercury $= 13600$ kg/m^3 and $g = 10$ m/s^2.
7. A gas cylinder has walls that can bear a maximum pressure of $1{\cdot}0 \times 10^6$ Pa. It contains a gas at $8{\cdot}0 \times 10^5$ Pa and 300 K. The cylinder is steadily heated. Neglecting any change in the volume, calculate the temperature at which the cylinder will break.
8. 2 g of hydrogen is sealed in a vessel of volume 0·02 m^3 and is maintained at 300 K. Calculate the pressure in the vessel.
9. The density of an ideal gas is $1{\cdot}25 \times 10^{-3}$ g/cm^3 at STP. Calculate the molecular weight of the gas.
10. The temperature and pressure at Simla are 15·0°C and 72·0 cm of mercury and at Kalka these are 35·0°C and 76·0 cm of mercury. Find the ratio of air density at Kalka to the air density at Simla.
11. Figure (24-E1) shows a cylindrical tube with adiabatic walls and fitted with a diathermic separator. The separator can be slid in the tube by an external mechanism. An ideal gas is injected in the two sides at equal pressures and equal temperatures. The separator remains in equilibrium at the middle. It is now slid to a position where it divides the tube in the ratio of 1:3. Find the ratio of the pressures in the two parts of the vessel.

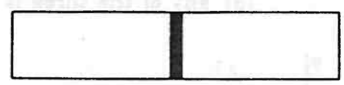


Figure 24-E1

12. Find the rms speed of hydrogen molecules in a sample of hydrogen gas at 300 K. Find the temperature at which the rms speed is double the speed calculated in the previous part.
13. A sample of 0·177 g of an ideal gas occupies 1000 cm^3 at STP. Calculate the rms speed of the gas molecules.
14. The average translational kinetic energy of air molecules is 0·040 eV (1 eV $= 1{\cdot}6 \times 10^{-19}$ J). Calculate the temperature of the air. Boltzmann constant $k = 1{\cdot}38 \times 10^{-23}$ J/K.
15. Consider a sample of oxygen at 300 K. Find the average time taken by a molecule to travel a distance equal to the diameter of the earth.
16. Find the average magnitude of linear momentum of a helium molecule in a sample of helium gas at 0°C. Mass of a helium molecule $= 6{\cdot}64 \times 10^{-27}$ kg and Boltzmann constant $= 1{\cdot}38 \times 10^{-23}$ J/K.
17. The mean speed of the molecules of a hydrogen sample equals the mean speed of the molecules of a helium sample. Calculate the ratio of the temperature of the hydrogen sample to the temperature of the helium sample.
18. At what temperature the mean speed of the molecules of hydrogen gas equals the escape speed from the earth?

19. Find the ratio of the mean speed of hydrogen molecules to the mean speed of nitrogen molecules in a sample containing a mixture of the two gases.

20. Figure (24-E2) shows a vessel partitioned by a fixed diathermic separator. Different ideal gases are filled in the two parts. The rms speed of the molecules in the left part equals the mean speed of the molecules in the right part. Calculate the ratio of the mass of a molecule in the left part to the mass of a molecule in the right part.

Figure 24-E2

21. Estimate the number of collisions per second suffered by a molecule in a sample of hydrogen at STP. The mean free path (average distance covered by a molecule between successive collisions) = $1{\cdot}38 \times 10^{-5}$ cm.

22. Hydrogen gas is contained in a closed vessel at 1 atm (100 kPa) and 300 K. (a) Calculate the mean speed of the molecules. (b) Suppose the molecules strike the wall with this speed making an average angle of 45° with it. How many molecules strike each square metre of the wall per second?

23. Air is pumped into an automobile tyre's tube upto a pressure of 200 kPa in the morning when the air temperature is 20°C. During the day the temperature rises to 40°C and the tube expands by 2%. Calculate the pressure of the air in the tube at this temperature.

24. Oxygen is filled in a closed metal jar of volume $1{\cdot}0 \times 10^{-3}\ m^3$ at a pressure of $1{\cdot}5 \times 10^5$ Pa and temperature 400 K. The jar has a small leak in it. The atomospheric pressure is $1{\cdot}0 \times 10^5$ Pa and the atmospheric temperature is 300 K. Find the mass of the gas that leaks out by the time the pressure and the temperature inside the jar equalise with the surrounding.

25. An air bubble of radius 2·0 mm is formed at the bottom of a 3·3 m deep river. Calculate the radius of the bubble as it comes to the surface. Atmospheric pressure $= 1{\cdot}0 \times 10^5$ Pa and density of water = 1000 kg/m³.

26. Air is pumped into the tubes of a cycle rickshaw at a pressure of 2 atm. The volume of each tube at this pressure is $0{\cdot}002\ m^3$. One of the tubes gets punctured and the volume of the tube reduces to $0{\cdot}0005\ m^3$. How many moles of air have leaked out? Assume that the temperature remains constant at 300 K and that the air behaves as an ideal gas.

27. 0·040 g of He is kept in a closed container initially at 100·0°C. The container is now heated. Neglecting the expansion of the container, calculate the temperature at which the internal energy is increased by 12 J.

28. During an experiment, an ideal gas is found to obey an additional law pV^2 = constant. The gas is initially at a temperature T and volume V. Find the temperature when it expands to a volume $2V$.

29. A vessel contains 1·60 g of oxygen and 2·80 g of nitrogen. The temperature is maintained at 300 K and the volume of the vessel is $0{\cdot}166\ m^3$. Find the pressure of the mixture.

30. A vertical cylinder of height 100 cm contains air at a constant temperature. The top is closed by a frictionless light piston. The atmospheric pressure is equal to 75 cm of mercury. Mercury is slowly poured over the piston. Find the maximum height of the mercury column that can be put on the piston.

31. Figure (24-E3) shows two vessels A and B with rigid walls containing ideal gases. The pressure, temperature and the volume are p_A, T_A, V in the vessel A and p_B, T_B, V in the vessel B. The vessels are now connected through a small tube. Show that the pressure p and the temperature T satisfy

$$\frac{p}{T} = \frac{1}{2}\left(\frac{p_A}{T_A} + \frac{p_B}{T_B}\right)$$

when equilibrium is achieved.

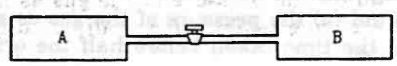


Figure 24-E3

32. A container of volume 50 cc contains air (mean molecular weight = 28·8 g) and is open to atmosphere where the pressure is 100 kPa. The container is kept in a bath containing melting ice (0°C). (a) Find the mass of the air in the container when thermal equilibrium is reached. (b) The container is now placed in another bath containing boiling water (100°C). Find the mass of air in the container. (c) The container is now closed and placed in the melting-ice bath. Find the pressure of the air when thermal equilibrium is reached.

33. A uniform tube closed at one end, contains a pallet of mercury 10 cm long. When the tube is kept vertically with the closed end upward, the length of the air column trapped is 20 cm. Find the length of the air column trapped when the tube is inverted so that the closed end goes down. Atmospheric pressure = 75 cm of mercury.

34. A glass tube, sealed at both ends, is 100 cm long. It lies horizontally with the middle 10 cm containing mercury. The two ends of the tube contain air at 27°C and at a pressure 76 cm of mercury. The air column on one side is maintained at 0°C and the other side is maintained at 127°C. Calculate the length of the air column on the cooler side. Neglect the changes in the volume of mercury and of the glass.

35. An ideal gas is trapped between a mercury column and the closed end of a narrow vertical tube of uniform base containing the column. The upper end of the tube is open to the atmosphere. The atmospheric pressure equals 76 cm of mercury. The lengths of the mercury column and the trapped air column are 20 cm and 43 cm respectively. What will be the length of the air column when the tube is tilted slowly in a vertical plane through an angle of 60°? Assume the temperature to remain constant.

36. Figure (24-E4) shows a cylindrical tube of length 30 cm which is partitioned by a tight-fitting separator. The separator is very weakly conducting and can freely slide along the tube. Ideal gases are filled in the two parts of the vessel. In the beginning, the temperatures in the parts A and B are 400 K and 100 K respectively. The separator slides to a momentary equilibrium position shown in the figure. Find the final equilibrium position of the separator, reached after a long time.

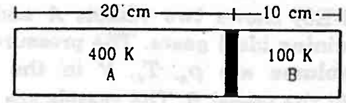


Figure 24-E4

37. A vessel of volume V_0 contains an ideal gas at pressure p_0 and temperature T. Gas is continuously pumped out of this vessel at a constant volume-rate $dV/dt = r$ keeping the temperature constant. The pressure of the gas being taken out equals the pressure inside the vessel. Find (a) the pressure of the gas as a function of time, (b) the time taken before half the original gas is pumped out.

38. One mole of an ideal gas undergoes a process

$$p = \frac{p_0}{1 + (V/V_0)^2}$$

where p_0 and V_0 are constants. Find the temperature of the gas when $V = V_0$.

39. Show that the internal energy of the air (treated as an ideal gas) contained in a room remains constant as the temperature changes between day and night. Assume that the atmospheric pressure around remains constant and the air in the room maintains this pressure by communicating with the surrounding through the windows etc.

40. Figure (24-E5) shows a cylindrical tube of radius 5 cm and length 20 cm. It is closed by a tight-fitting cork. The friction coefficient between the cork and the tube is 0·20. The tube contains an ideal gas at a pressure of 1 atm and a temperature of 300 K. The tube is slowly heated and it is found that the cork pops out when the temperature reaches 600 K. Let dN denote the magnitude of the normal contact force exerted by a small length dl of the cork along the periphery (see the figure). Assuming that the temperature of the gas is uniform at any instant, calculate $\frac{dN}{dl}$.

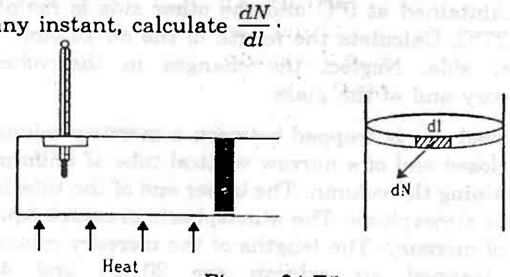


Figure 24-E5

41. Figure (24-E6) shows a cylindrical tube of cross-sectional area A fitted with two frictionless pistons. The pistons are connected to each other by a metallic wire. Initially, the temperature of the gas is T_0 and its pressure is p_0 which equals the atmospheric pressure. (a) What is the tension in the wire ? (b) What will be the tension if the temperature is increased to $2T_0$?

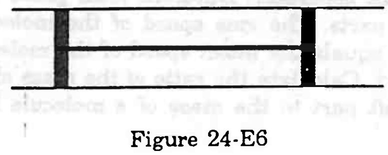


Figure 24-E6

42. Figure (24-E7) shows a large closed cylindrical tank containing water. Initially the air trapped above the water surface has a height h_0 and pressure $2p_0$ where p_0 is the atmospheric pressure. There is a hole in the wall of the tank at a depth h_1 below the top from which water comes out. A long vertical tube is connected as shown. (a) Find the height h_2 of the water in the long tube above the top initially. (b) Find the speed with which water comes out of the hole. (c) Find the height of the water in the long tube above the top when the water stops coming out of the hole.

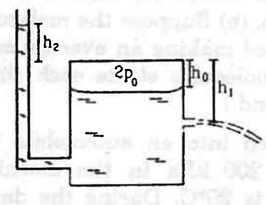


Figure 24-E7

43. An ideal gas is kept in a long cylindrical vessel fitted with a frictionless piston of cross-sectional area 10 cm² and weight 1 kg (figure 24-E8). The vessel itself is kept in a big chamber containing air at atmospheric pressure 100 kPa. The length of the gas column is 20 cm. If the chamber is now completely evacuated by an exhaust pump, what will be the length of the gas column ? Assume the temperature to remain constant throughout the process.

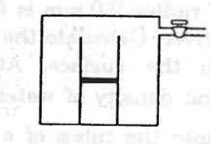


Figure 24-E8

44. An ideal gas is kept in a long cylindrical vessel fitted with a frictionless piston of cross-sectional area 10 cm² and weight 1 kg. The length of the gas column in the vessel is 20 cm. The atmospheric pressure is 100 kPa. The vessel is now taken into a spaceship revolving round the earth as a satellite. The air pressure in the spaceship is maintained at 100 kPa. Find the length of the gas column in the cylinder.

45. Two glass bulbs of equal volume are connected by a narrow tube and are filled with a gas at 0°C at a pressure of 76 cm of mercury. One of the bulbs is then placed in melting ice and the other is placed in a water bath maintained at 62°C. What is the new value of the

pressure inside the bulbs ? The volume of the connecting tube is negligible.

46. The weather report reads, "Temperature 20°C : Relative humidity 100%". What is the dew point ?

47. The condition of air in a closed room is described as follows. Temperature = 25°C, relative humidity = 60%, pressure = 104 kPa. If all the water vapour is removed from the room without changing the temperature, what will be the new pressure? The saturation vapour pressure at 25°C = 3·2 kPa.

48. The temperature and the dew point in an open room are 20°C and 10°C. If the room temperature drops to 15°C, what will be the new dew point ?

49. Pure water vapour is trapped in a vessel of volume 10 cm^3. The relative humidity is 40%. The vapour is compressed slowly and isothermally. Find the volume of the vapour at which it will start condensing.

50. A barometer tube is 80 cm long (above the mercury reservoir). It reads 76 cm on a particular day. A small amount of water is introduced in the tube and the reading drops to 75·4 cm. Find the relative humidity in the space above the mercury column if the saturation vapour pressure at the room temperature is 1·0 cm.

51. Using figure (24.6) of the text, find the boiling point of methyl alcohol at 1 atm (760 mm of mercury) and at 0·5 atm.

52. The human body has an average temperature of 98 °F. Assume that the vapour pressure of the blood in the veins behaves like that of pure water. Find the minimum atmospheric pressure which is necessary to prevent the blood from boiling. Use figure (24.6) of the text for the vapour pressures.

53. A glass contains some water at room temperature 20°C. Refrigerated water is added to it slowly. When the temperature of the glass reaches 10°C, small droplets condense on the outer surface. Calculate the relative humidity in the room. The boiling point of water at a pressure of 17·5 mm of mercury is 20°C and at 8·9 mm of mercury it is 10°C.

54. 50 m^3 of saturated vapour is cooled down from 30°C to 20°C. Find the mass of the water condensed. The absolute humidity of saturated water vapour is 30 g/m^3 at 30°C and 16 g/m^3 at 20°C.

55. A barometer correctly reads the atmospheric pressure as 76 cm of mercury. Water droplets are slowly introduced into the barometer tube by a dropper. The height of the mercury column first decreases and then becomes constant. If the saturation vapour pressure at the atmospheric temperature is 0·80 cm of mercury, find the height of the mercury column when it reaches its minimum value.

56. 50 cc of oxygen is collected in an inverted gas jar over water. The atmospheric pressure is 99·4 kPa and the room temperature is 27°C. The water level in the jar is same as the level outside. The saturation vapour pressure at 27°C is 3·4 kPa. Calculate the number of moles of oxygen collected in the jar.

57. A faulty barometer contains certain amount of air and saturated water vapour. It reads 74·0 cm when the atmospheric pressure is 76·0 cm of mercury and reads 72·10 cm when the atmospheric pressure is 74·0 cm of mercury. Saturation vapour pressure at the air temperature = 1·0 cm of mercury. Find the length of the barometer tube above the mercury level in the reservoir.

58. On a winter day, the outside temperature is 0°C and relative humidity 40%. The air from outside comes into a room and is heated to 20°C. What is the relative humidity in the room ? The saturation vapour pressure at 0°C is 4·6 mm of mercury and at 20°C it is 18 mm of mercury.

59. The temperature and humidity of air are 27°C and 50% on a particular day. Calculate the amount of vapour that should be added to 1 cubic metre of air to saturate it. The saturation vapour pressure at 27°C = 3600 Pa.

60. The temperature and relative humidity in a room are 300 K and 20% respectively. The volume of the room is 50 m^3. The saturation vapour pressure at 300 K is 3·3 kPa. Calculate the mass of the water vapour present in the room.

61. The temperature and the relative humidity are 300 K and 20% in a room of volume 50 m^3. The floor is washed with water, 500 g of water sticking on the floor. Assuming no communication with the surrounding, find the relative humidity when the floor dries. The changes in temperature and pressure may be neglected. Saturation vapour pressure at 300 K = 3·3 kPa.

62. A bucket full of water is placed in a room at 15°C with initial relative humidity 40%. The volume of the room is 50 m^3. (a) How much water will evaporate ? (b) If the room temperature is increased by 5°C how much more water will evaporate ? The saturation vapour pressure of water at 15°C and 20°C are 1·6 kPa and 2·4 kPa respectively.

□

ANSWERS

OBJECTIVE I

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

OBJECTICE II

1. (c), (d)	2. (b)	3. (b)
4. (c)	5. (d)	6. (a), (c)
7. (d)		

EXERCISES

1. $2{\cdot}24 \times 10^{-2}\ m^3$
2. $2{\cdot}685 \times 10^{19}$
3. $3{\cdot}53 \times 10^{11}$
4. 1·43 mg
5. 1 : 1
6. $8{\cdot}0 \times 10^{15}$
7. 375 K
8. $1{\cdot}24 \times 10^5$ Pa
9. 28·3 g/mol
10. 0·987
11. 3 : 1
12. 1930 m/s, 1200 K
13. 1300 m/s
14. 310 K
15. 8·0 hour
16. $8{\cdot}0 \times 10^{-24}$ kg–m/s
17. 1 : 2
18. 11800 K
19. 3·74
20. 1·18
21. $1{\cdot}23 \times 10^{10}$
22. (a) 1780 m/s (b) $1{\cdot}2 \times 10^{28}$
23. 209 kPa
24. 0·16 g
25. 2·2 mm
26. 0·14
27. 196°C
28. 7/2
29. 2250 N/m^2
30. 25 cm
32. (a) 0·058 g (b) 0·0468 g (c) 73·0 kPa
33. 15 cm
34. 36·5 cm
35. 48 cm
36. 10 cm from the left end
37. (a) $p = p_0 e^{-\gamma t/V_0}$ (b) $\frac{V_0 \ln 2}{\gamma}$
38. $\frac{p_0 V_0}{2R}$ mol^{-1}
40. $1{\cdot}25 \times 10^4$ N/m
41. (a) zero (b) $p_0 A$
42. (a) $\frac{p_0}{\rho g} - h_0$ (b) $\left[\frac{2}{\rho}\left(p_0 + \rho g\,(h_1 - h_0)\right)\right]^{1/2}$ (c) $-h_1$
43. 2·2 m
44. 22 cm
45. 84 cm of mercury
46. 20°C
47. 102 kPa
48. 10°C
49. 4·0 cm^3
50. 60%
51. 65°C, 48°C
52. 50 mm of mercury
53. 51%
54. 700 g
55. 75·2 cm
56. $1{\cdot}93 \times 10^{-3}$
57. 91·1 cm
58. 9·5%
59. 13 g
60. 238 g
61. 62%
62. (a) 361 g (b) 296 g

□

CHAPTER 24
KINETIC THEORY OF GASES

1. Volume of 1 mole of gas

   PV = nRT $\Rightarrow$ V = $\frac{RT}{P} = \frac{0.082 \times 273}{1}$ = 22.38 ≈ 22.4 L = 22.4 × 10^{-3} = 2.24 × 10^{-2} m^3

2. n = $\frac{PV}{RT} = \frac{1 \times 1 \times 10^{-3}}{0.082 \times 273} = \frac{10^{-3}}{22.4} = \frac{1}{22400}$

   No of molecules = 6.023 × 10^{23} × $\frac{1}{22400}$ = 2.688 × 10^{19}

3. V = 1 cm^3, T = 0°C, P = 10^{-5} mm of Hg

   n = $\frac{PV}{RT} = \frac{f gh \times V}{RT} = \frac{1.36 \times 980 \times 10^{-6} \times 1}{8.31 \times 273}$ = 5.874 × 10^{-13}

   No. of moluclues = No × n = 6.023 × 10^{23} × 5.874 × 10^{-13} = 3.538 × 10^{11}

4. n = $\frac{PV}{RT} = \frac{1 \times 1 \times 10^{-3}}{0.082 \times 273} = \frac{10^{-3}}{22.4}$

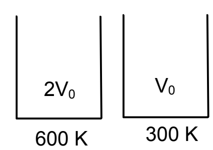
   mass = $\frac{(10^{-3} \times 32)}{22.4}$ g = 1.428 × 10^{-3} g = 1.428 mg

5. Since mass is same

   $n_1 = n_2 = n$

   $P_1 = \frac{nR \times 300}{V_0}$, $P_2 = \frac{nR \times 600}{2V_0}$

   $\frac{P_1}{P_2} = \frac{nR \times 300}{V_0} \times \frac{2V_0}{nR \times 600} = \frac{1}{1}$ = 1 : 1



6. V = 250 cc = 250 × 10^{-3}

   P = 10^{-3} mm = 10^{-3} × 10^{-3} m = 10^{-6} × 13600 × 10 pascal = 136 × 10^{-3} pascal

   T = 27°C = 300 K

   n = $\frac{PV}{RT} = \frac{136 \times 10^{-3} \times 250}{8.3 \times 300} \times 10^{-3} = \frac{136 \times 250}{8.3 \times 300} \times 10^{-6}$

   No. of molecules = $\frac{136 \times 250}{8.3 \times 300} \times 10^{-6} \times 6 \times 10^{23}$ = 81 × 10^{17} ≈ 0.8 × 10^{15}

7. P_1 = 8.0 × 10^5 P_a, P_2 = 1 × 10^6 P_a, T_1 = 300 K, T_2 = ?

   Since, $V_1 = V_2 = V$

   $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{8 \times 10^5 \times V}{300} = \frac{1 \times 10^6 \times V}{T_2} \Rightarrow T_2 = \frac{1 \times 10^6 \times 300}{8 \times 10^5}$ = 375° K

8. m = 2 g, V = 0.02 m^3 = 0.02 × 10^6 cc = 0.02 × 10^3 L, T = 300 K, P = ?

   M = 2 g,

   PV = nRT $\Rightarrow$ PV = $\frac{m}{M}RT \Rightarrow$ P × 20 = $\frac{2}{2} \times 0.082 \times 300$

   $\Rightarrow$ P = $\frac{0.082 \times 300}{20}$ = 1.23 atm = 1.23 × 10^5 pa ≈ 1.23 × 10^5 pa

9. P = $\frac{nRT}{V} = \frac{m}{M} \times \frac{RT}{V} = \frac{f RT}{M}$

   $f \rightarrow$ 1.25 × 10^{-3} g/cm^3

   R $\rightarrow$ 8.31 × 10^7 ert/deg/mole

   T $\rightarrow$ 273 K

   $\Rightarrow$ M = $\frac{f RT}{P} = \frac{1.25 \times 10^{-3} \times 8.31 \times 10^7 \times 273}{13.6 \times 980 \times 76}$ = 0.002796 × 10^4 ≈ 28 g/mol

10. T at Simla = 15°C = 15 + 273 = 288 K
P at Simla = 72 cm = $72 \times 10^{-2} \times 13600 \times 9.8$
T at Kalka = 35°C = 35 + 273 = 308 K
P at Kalka = 76 cm = $76 \times 10^{-2} \times 13600 \times 9.8$
PV = nRT

$$\Rightarrow PV = \frac{m}{M}RT \Rightarrow PM = \frac{m}{V}RT \Rightarrow f = \frac{PM}{RT}$$

$$\frac{f\text{Simla}}{f\text{Kalka}} = \frac{P_{\text{Simla}} \times M}{RT_{\text{Simla}}} \times \frac{RT_{\text{Kalka}}}{P_{\text{Kalka}} \times M}$$

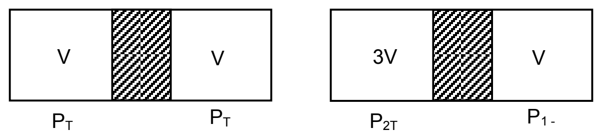
$$= \frac{72 \times 10^{-2} \times 13600 \times 9.8 \times 308}{288 \times 76 \times 10^{-2} \times 13600 \times 9.8} = \frac{72 \times 308}{76 \times 288} = 1.013$$

$$\frac{f\text{Kalka}}{f\text{Simla}} = \frac{1}{1.013} = 0.987$$

11. $n_1 = n_2 = n$

$$P_1 = \frac{nRT}{V}, \qquad P_2 = \frac{nRT}{3V}$$

$$\frac{P_1}{P_2} = \frac{nRT}{V} \times \frac{3V}{nRT} = 3:1$$



12. r.m.s velocity of hydrogen molecules = ?
T = 300 K, R = 8.3, M = 2 g = 2×10^{-3} Kg

$$C = \sqrt{\frac{3RT}{M}} \Rightarrow C = \sqrt{\frac{3 \times 8.3 \times 300}{2 \times 10^{-3}}} = 1932.\ 6 \text{ m/s} \approx 1930 \text{ m/s}$$

Let the temp. at which the C = 2 × 1932.6 is T′

$$2 \times 1932.6 = \sqrt{\frac{3 \times 8.3 \times T'}{2 \times 10^{-3}}} \Rightarrow (2 \times 1932.6)^2 = \frac{3 \times 8.3 \times T'}{2 \times 10^{-3}}$$

$$\Rightarrow \frac{(2 \times 1932.6)^2 \times 2 \times 10^{-3}}{3 \times 8.3} = T'$$

$\Rightarrow$ T′ = 1199.98 ≈ 1200 K.

13. $V_{rms} = \sqrt{\frac{3P}{f}}$ P = 10^5 Pa = 1 atm, $f = \frac{1.77 \times 10^{-4}}{10^{-3}}$

$$= \sqrt{\frac{3 \times 10^5 \times 10^{-3}}{1.77 \times 10^{-4}}} = 1301.8 \approx 1302 \text{ m/s.}$$

14. Agv. K.E. = 3/2 KT
3/2 KT = $0.04 \times 1.6 \times 10^{-19}$
$\Rightarrow (3/2) \times 1.38 \times 10^{-23} \times T = 0.04 \times 1.6 \times 10^{-19}$

$$\Rightarrow T = \frac{2 \times 0.04 \times 1.6 \times 10^{-19}}{3 \times 1.38 \times 10^{-23}} = 0.0309178 \times 10^4 = 309.178 \approx 310 \text{ K}$$

15. $V_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.3 \times 300}{3.14 \times 0.032}}$

$$T = \frac{\text{Dis tan ce}}{\text{Speed}} = \frac{6400000 \times 2}{445.25} = 445.25 \text{ m/s}$$

$$= \frac{28747.83}{3600} \text{ km} = 7.985 \approx 8 \text{ hrs.}$$

16. M = 4×10^{-3} Kg

$$V_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.3 \times 273}{3.14 \times 4 \times 10^{-3}}} = 1201.35$$

Momentum = M × V_{avg} = $6.64 \times 10^{-27} \times 1201.35 = 7.97 \times 10^{-24} \approx 8 \times 10^{-24}$ Kg-m/s.

17. $V_{avg} = \sqrt{\frac{8RT}{\pi M}} = \frac{8 \times 8.3 \times 300}{3.14 \times 0.032}$

Now, $\frac{8RT_1}{\pi \times 2} = \frac{8RT_2}{\pi \times 4}$ $\qquad \frac{T_1}{T_2} = \frac{1}{2}$

18. Mean speed of the molecule = $\sqrt{\frac{8RT}{\pi M}}$

Escape velocity = $\sqrt{2gr}$

$\sqrt{\frac{8RT}{\pi M}} = \sqrt{2gr} \qquad \Rightarrow \frac{8RT}{\pi M} = 2gr$

$\Rightarrow T = \frac{2gr\pi M}{8R} = \frac{2 \times 9.8 \times 6400000 \times 3.14 \times 2 \times 10^{-3}}{8 \times 8.3} = 11863.9 \approx 11800$ m/s.

19. $V_{avg} = \sqrt{\frac{8RT}{\pi M}}$

$\frac{V_{avg}H_2}{V_{avg}N_2} = \sqrt{\frac{8RT}{\pi \times 2}} \times \sqrt{\frac{\pi \times 28}{8RT}} = \sqrt{\frac{28}{2}} = \sqrt{14} = 3.74$

20. The left side of the container has a gas, let having molecular wt. M_1
Right part has Mol. wt = M_2
Temperature of both left and right chambers are equal as the separating wall is diathermic

$\sqrt{\frac{3RT}{M_1}} = \sqrt{\frac{8RT}{\pi M_2}} \Rightarrow \frac{3RT}{M_1} = \frac{8RT}{\pi M_2} \Rightarrow \frac{M_1}{\pi M_2} = \frac{3}{8} \Rightarrow \frac{M_1}{M_2} = \frac{3\pi}{8} = 1.1775 \approx 1.18$

21. $V_{mean} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.3 \times 273}{3.14 \times 2 \times 10^{-3}}} = 1698.96$

Total Dist = 1698.96 m

No. of Collisions = $\frac{1698.96}{1.38 \times 10^{-7}} = 1.23 \times 10^{10}$

22. P = 1 atm = 10^5 Pascal
T = 300 K, $\qquad$ M = 2 g = 2×10^{-3} Kg

(a) $V_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.3 \times 300}{3.14 \times 2 \times 10^{-3}}} = 1781.004 \approx 1780$ m/s

(b) When the molecules strike at an angle 45°,

Force exerted = mV Cos 45° – (–mV Cos 45°) = 2 mV Cos 45° = $2 \text{ m V } \frac{1}{\sqrt{2}} = \sqrt{2}$ mV

No. of molecules striking per unit area = $\frac{\text{Force}}{\sqrt{2}mv \times \text{Area}} = \frac{\text{Pressure}}{\sqrt{2}mV}$

$= \frac{10^5}{\frac{\sqrt{2} \times 2 \times 10^{-3} \times 1780}{6 \times 10^{23}}} = \frac{3}{\sqrt{2} \times 1780} \times 10^{31} = 1.19 \times 10^{-3} \times 10^{31} = 1.19 \times 10^{28} \approx 1.2 \times 10^{28}$

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

$P_1 \rightarrow$ 200 KPa = 2×10^5 pa $\qquad$ P_2 = ?
T_1 = 20°C = 293 K $\qquad$ T_2 = 40°C = 313 K

$V_2 = V_1 + 2\% \, V_1 = \frac{102 \times V_1}{100}$

$\Rightarrow \frac{2 \times 10^5 \times V_1}{293} = \frac{P_2 \times 102 \times V_1}{100 \times 313} \Rightarrow P_2 = \frac{2 \times 10^7 \times 313}{102 \times 293} = 209462$ Pa = 209.462 KPa

24. $V_1 = 1 \times 10^{-3}$ m^3, $P_1 = 1.5 \times 10^5$ Pa, $T_1 = 400$ K

$P_1V_1 = n_1R_1T_1$

$\Rightarrow n = \frac{P_1V_1}{R_1T_1} = \frac{1.5\times10^5\times1\times10^{-3}}{8.3\times400}$ $\Rightarrow n = \frac{1.5}{8.3\times4}$

$\Rightarrow m_1 = \frac{1.5}{8.3\times4}\times M = \frac{1.5}{8.3\times4}\times32 = 1.4457 \approx 1.446$

$P_2 = 1 \times 10^5$ Pa, $V_2 = 1 \times 10^{-3}$ m^3, $T_2 = 300$ K

$P_2V_2 = n_2R_2T_2$

$\Rightarrow n_2 = \frac{P_2V_2}{R_2T_2} = \frac{10^5\times10^{-3}}{8.3\times300} = \frac{1}{3\times8.3} = 0.040$

$\Rightarrow m_2 = 0.04 \times 32 = 1.285$

$\Delta m = m_1 - m_2 = 1.446 - 1.285 = 0.1608 \text{ g} \approx 0.16 \text{ g}$

25. $P_1 = 10^5 + \rho gh = 10^5 + 1000 \times 10 \times 3.3 = 1.33 \times 10^5$ pa

$P_2 = 10^5$, $T_1 = T_2 = T$, $V_1 = \frac{4}{3}\pi(2 \times 10^{-3})^3$

$V_2 = \frac{4}{3}\pi r^3$, $r = ?$

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

$\Rightarrow \frac{1.33\times10^5\times\frac{4}{3}\times\pi\times(2\times10^{-3})^3}{T_1} = \frac{10^5\times\frac{4}{3}\times\pi r^2}{T_2}$

$\Rightarrow 1.33 \times 8 \times 10^5 \times 10^{-9} = 10^5 \times r^3$ $\Rightarrow r = \sqrt[3]{10.64\times10^{-3}} = 2.19 \times 10^{-3} \approx 2.2$ mm

26. $P_1 = 2$ atm $= 2 \times 10^5$ pa

$V_1 = 0.002$ m^3, $T_1 = 300$ K

$P_1V_1 = n_1RT_1$

$\Rightarrow n = \frac{P_1V_1}{RT_1} = \frac{2\times10^5\times0.002}{8.3\times300} = \frac{4}{8.3\times3} = 0.1606$

$P_2 = 1$ atm $= 10^5$ pa

$V_2 = 0.0005$ m^3, $T_2 = 300$ K

$P_2V_2 = n_2RT_2$

$\Rightarrow n_2 = \frac{P_2V_2}{RT_2} = \frac{10^5\times0.0005}{8.3\times300} = \frac{5}{3\times8.3}\times\frac{1}{10} = 0.02$

Δn = moles leaked out $= 0.16 - 0.02 = 0.14$

27. $m = 0.040$ g, $T = 100°C$, $M_{He} = 4$ g

$U = \frac{3}{2}nRt = \frac{3}{2}\times\frac{m}{M}\times RT$ $T' = ?$

Given $\frac{3}{2}\times\frac{m}{M}\times RT + 12 = \frac{3}{2}\times\frac{m}{M}\times RT'$

$\Rightarrow 1.5 \times 0.01 \times 8.3 \times 373 + 12 = 1.5 \times 0.01 \times 8.3 \times T'$

$\Rightarrow T' = \frac{58.4385}{0.1245} = 469.3855 \text{ K} = 196.3°C \approx 196°C$

28. PV^2 = constant

$\Rightarrow P_1V_1^2 = P_2V_2^2$

$\Rightarrow \frac{nRT_1}{V_1}\times V_1^2 = \frac{nRT_2}{V_2}\times V_2^2$

$\Rightarrow T_1 V_1 = T_2 V_2 = TV = T_1 \times 2V \Rightarrow T_2 = \frac{T}{2}$

29. $P_{O_2} = \frac{n_{o_2}RT}{V}$, $P_{H_2} = \frac{n_{H_2}RT}{V}$

$n_{O_2} = \frac{m}{M_{O_2}} = \frac{1.60}{32} = 0.05$

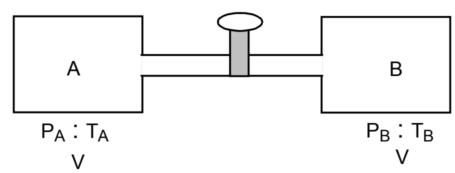
Now, $P_{mix} = \left(\frac{n_{O_2} + n_{H_2}}{V}\right)RT$

$n_{H_2} = \frac{m}{M_{H_2}} = \frac{2.80}{28} = 0.1$

$P_{mix} = \frac{(0.05 + 0.1) \times 8.3 \times 300}{0.166} = 2250\ N/m^2$

30. P_1 = Atmospheric pressure = 75 × fg
$V_1 = 100 \times A$
P_2 = Atmospheric pressure + Mercury pessue = 75fg + hg$f$g (if h = height of mercury)
$V_2 = (100 - h)\ A$
$P_1V_1 = P_2V_2$
$\Rightarrow 75fg(100A) = (75 + h)fg(100 - h)A$
$\Rightarrow 75 \times 100 = (74 + h)\ (100 - h) \Rightarrow 7500 = 7500 - 75\ h + 100\ h - h^2$
$\Rightarrow h^2 - 25\ h = 0 \Rightarrow h^2 = 25\ h \Rightarrow h = 25$ cm
Height of mercury that can be poured = 25 cm

31. Now, Let the final pressure; Volume & Temp be
After connection = $P_A' \rightarrow$ Partial pressure of A
$P_B' \rightarrow$ Partial pressure of B



Now, $\frac{P_A' \times 2V}{T} = \frac{P_A \times V}{T_A}$

Or $\frac{P_A'}{T} = \frac{P_A}{2T_A}$ …(1)

Similarly, $\frac{P_B'}{T} = \frac{P_B}{2T_B}$ …(2)

Adding (1) & (2)

$\frac{P_A'}{T} + \frac{P_B'}{T} = \frac{P_A}{2T_A} + \frac{P_B}{2T_B} = \frac{1}{2}\left(\frac{P_A}{T_A} + \frac{P_B}{T_B}\right)$

$\Rightarrow \frac{P}{T} = \frac{1}{2}\left(\frac{P_A}{T_A} + \frac{P_B}{T_B}\right)$ [$\therefore P_A' + P_B' = P$]

32. $V = 50\ cc = 50 \times 10^{-6}\ cm^3$
$P = 100\ KPa = 10^5\ Pa$ M = 28.8 g
(a) $PV = nrT_1$

$\Rightarrow PV = \frac{m}{M}RT_1 \Rightarrow m = \frac{PMV}{RT_1} = \frac{10^5 \times 28.8 \times 50 \times 10^{-6}}{8.3 \times 273} = \frac{50 \times 28.8 \times 10^{-1}}{8.3 \times 273} = 0.0635$ g.

(b) When the vessel is kept on boiling water

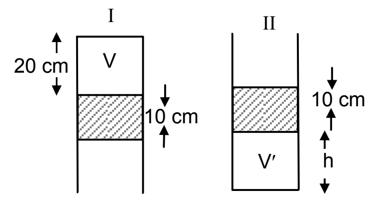
$PV = \frac{m}{M}RT_2 \Rightarrow m = \frac{PVM}{RT_2} = \frac{10^5 \times 28.8 \times 50 \times 10^{-6}}{8.3 \times 373} = \frac{50 \times 28.8 \times 10^{-1}}{8.3 \times 373} = 0.0465$

(c) When the vessel is closed

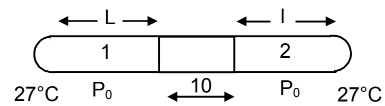
$P \times 50 \times 10^{-6} = \frac{0.0465}{28.8} \times 8.3 \times 273$

$\Rightarrow P = \frac{0.0465 \times 8.3 \times 273}{28.8 \times 50 \times 10^{-6}} = 0.07316 \times 10^6\ Pa \approx 73\ KPa$

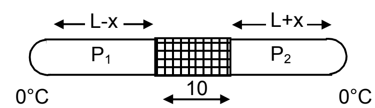
33. <u>Case I</u> → Net pressure on air in volume V
$= P_{atm} - hfg = 75 \times f_{Hg} - 10\ f_{Hg} = 65 \times f_{Hg} \times g$
<u>Case II</u> → Net pressure on air in volume 'V' $= P_{atm} + f_{Hg} \times g \times h$
$P_1V_1 = P_2V_2$
$\Rightarrow f_{Hg} \times g \times 65 \times A \times 20 = f_{Hg} \times g \times 75 + f_{Hg} \times g \times 10 \times A \times h$
$\Rightarrow 62 \times 20 = 85\ h \Rightarrow h = \dfrac{65 \times 20}{85} = 15.2 \text{ cm} \approx 15 \text{ cm}$



34. $2L + 10 = 100 \Rightarrow 2L = 90 \Rightarrow L = 45$ cm
Applying combined gas eqn to part 1 of the tube
$\dfrac{(45A)P_0}{300} = \dfrac{(45 - x)P_1}{273}$
$\Rightarrow P_1 = \dfrac{273 \times 45 \times P_0}{300(45 - x)}$

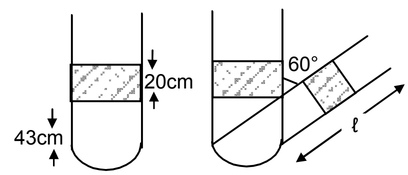


Applying combined gas eqn to part 2 of the tube
$\dfrac{45AP_0}{300} = \dfrac{(45 + x)AP_2}{400}$
$\Rightarrow P_2 = \dfrac{400 \times 45 \times P_0}{300(45 + x)}$
$P_1 = P_2$

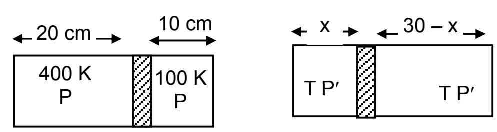


$\Rightarrow \dfrac{273 \times 45 \times P_0}{300(45 - x)} = \dfrac{400 \times 45 \times P_0}{300(45 + x)}$
$\Rightarrow (45 - x)\ 400 = (45 + x)\ 273 \qquad \Rightarrow 18000 - 400\ x = 12285 + 273\ x$
$\Rightarrow (400 + 273)x = 18000 - 12285 \qquad \Rightarrow x = 8.49$
$P_1 = \dfrac{273 \times 46 \times 76}{300 \times 36.51} = 85$ % 25 cm of Hg
Length of air column on the cooler side $= L - x = 45 - 8.49 = 36.51$

35. <u>Case I</u> Atmospheric pressure + pressure due to mercury column
<u>Case II</u> Atmospheric pressure + Component of the pressure due to mercury column
$P_1V_1 = P_2V_2$
$\Rightarrow (76 \times f_{Hg} \times g + f_{Hg} \times g \times 20) \times A \times 43$
$= (76 \times f_{Hg} \times g + f_{Hg} \times g \times 20 \times \cos 60°)\ A \times \ell$
$\Rightarrow 96 \times 43 = 86 \times \ell$
$\Rightarrow \ell = \dfrac{96 \times 43}{86} = 48$ cm



36. The middle wall is weakly conducting. Thus after a long time the temperature of both the parts will equalise.
The final position of the separating wall be at distance x from the left end. So it is at a distance 30 – x from the right end



Putting combined gas equation of one side of the separating wall,
$\dfrac{P_1 \times V_1}{T_1} = \dfrac{P_2 \times V_2}{T_2}$
$\Rightarrow \dfrac{P \times 20A}{400} = \dfrac{P' \times A}{T} \qquad \ldots(1)$
$\Rightarrow \dfrac{P \times 10A}{100} = \dfrac{-P'(30 - x)}{T} \qquad \ldots(2)$
Equating (1) and (2)
$\Rightarrow \dfrac{1}{2} = \dfrac{x}{30 - x} \qquad \Rightarrow 30 - x = 2x \Rightarrow 3x = 30 \Rightarrow x = 10$ cm
The separator will be at a distance 10 cm from left end.

37. $\frac{dV}{dt} = r \Rightarrow dV = r\ dt$

Let the pumped out gas pressure dp

Volume of container = V_0 At a pump dv amount of gas has been pumped out.

$Pdv = -V_0 df \Rightarrow P_V\ df = -V_0\ dp$

$$\Rightarrow \int_P^P \frac{dp}{p} = -\int_0^t \frac{dtr}{V_0} \Rightarrow P = P\ e^{-rt/V_0}$$

Half of the gas has been pump out, Pressure will be half = $\frac{1}{2} e^{-vt/V_0}$

$\Rightarrow \ln 2 = \frac{rt}{V_0}$ $\Rightarrow t = \ln^2 \frac{\gamma_0}{r}$

38. $P = \frac{P_0}{1+\left(\frac{V}{V_0}\right)^2}$

$\Rightarrow \frac{nRT}{V} = \frac{P_0}{1+\left(\frac{V}{V_0}\right)^2}$ [PV = nRT according to ideal gas equation]

$\Rightarrow \frac{RT}{V} = \frac{P_0}{1+\left(\frac{V}{V_0}\right)^2}$ [Since n = 1 mole]

$\Rightarrow \frac{RT}{V_0} = \frac{P_0}{1+\left(\frac{V}{V_0}\right)^2}$ [At $V = V_0$]

$\Rightarrow P_0V_0 = RT(1+1) \Rightarrow P_0V_0 = 2\ RT \Rightarrow T = \frac{P_0V_0}{2R}$

39. Internal energy = nRT

Now, PV = nRT

$nT = \frac{PV}{R}$ Here P & V constant

$\Rightarrow$ nT is constant

$\therefore$ Internal energy = R × Constant = Constant

40. Frictional force = μ N

Let the cork moves to a distance = dl

$\therefore$ Work done by frictional force = μNde

Before that the work will not start that means volume remains constant

$\Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow \frac{1}{300} = \frac{P_2}{600} \Rightarrow P_2 = 2$ atm

$\therefore$ Extra Pressure = 2 atm – 1 atm = 1 atm

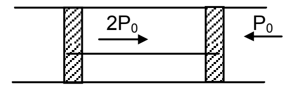
Work done by cork = 1 atm (Adl) μNdl = [1atm][Adl]

$$N = \frac{1\times10^5 \times (5\times10^{-2})^2}{2} = \frac{1\times10^5 \times \pi \times 25\times10^{-5}}{2}$$

Total circumference of work = $2\pi r$ $\frac{dN}{dl} = \frac{N}{2\pi r}$

$$= \frac{1\times10^5 \times \pi \times 25\times10^{-5}}{0.2\times2\pi r} = \frac{1\times10^5 \times 25\times10^{-5}}{0.2\times2\times5\times10^5} = 1.25 \times 10^4 \text{ N/M}$$

41. $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$



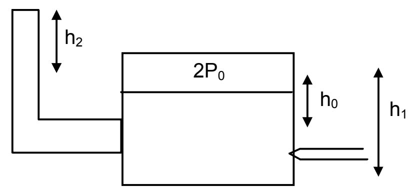
$\Rightarrow \dfrac{P_0V}{T_0} = \dfrac{P'V}{2T_0} \Rightarrow P' = 2\,P_0$

Net pressure = P_0 outwards

$\therefore$ Tension in wire = P_0 A

Where A is area of tube.

42. (a) $2P_0x = (h_2 + h_0)fg$ [$\therefore$ Since liquid at the same level have same pressure]



$\Rightarrow 2P_0 = h_2\,fg + h_0\,fg$

$\Rightarrow h_2\,fg = 2P_0 - h_0\,fg$

$h_2 = \dfrac{2P_0}{fg} - \dfrac{h_0fg}{fg} = \dfrac{2P_0}{fg} - h_0$

(b) K.E. of the water = Pressure energy of the water at that layer

$\Rightarrow \dfrac{1}{2}mV^2 = m \times \dfrac{P}{f}$

$\Rightarrow V^2 = \dfrac{2P}{f} = \left[\dfrac{2}{f(P_0 + fg(h_1 - h_0))}\right]$

$\Rightarrow V = \left[\dfrac{2}{f(P_0 + fg(h_1 - h_0))}\right]^{1/2}$

(c) $(x + P_0)fh = 2P_0$

$\therefore 2P_0 + fg\,(h - h_0) = P_0 + fgx$

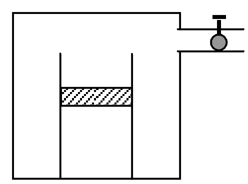
$\therefore X = \dfrac{P_0}{fg + h_1 - h_0} = h_2 + h_1$

$\therefore$ i.e. x is h_1 meter below the top $\Rightarrow$ x is $-h_1$ above the top

43. A = 100 cm^2 = 10^{-3} m

m = 1 kg, P = 100 K Pa = 10^5 Pa

ℓ = 20 cm



<u>Case I</u> = External pressure exists

<u>Case II</u> = Internal Pressure does not exist

$P_1V_1 = P_2V_2$

$\Rightarrow \left(10^5 + \dfrac{1\times 9.8}{10^{-3}}\right)V = \dfrac{1 \times 9.8}{10^{-3}} \times V'$

$\Rightarrow (10^5 + 9.8 \times 10^3)A \times \ell = 9.8 \times 10^3 \times A \times \ell'$

$\Rightarrow 10^5 \times 2 \times 10^{-1} + 2 \times 9.8 \times 10^2 = 9.8 \times 10^3 \times \ell'$

$\Rightarrow \ell' = \dfrac{2\times 10^4 + 19.6 \times 10^2}{9.8 \times 10^3} = 2.24081$ m

44. $P_1V_1 = P_2V_2$

$\Rightarrow \left(\dfrac{mg}{A} + P_0\right)A\ell\ \ P_0\,A\ell$

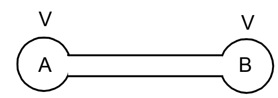
$\Rightarrow \left(\dfrac{1 \times 9.8}{10 \times 10^{-4}} + 10^5\right)0.2 = 10^5\,\ell'$

$\Rightarrow (9.8 \times 10^3 + 10^5) \times 0.2 = 10^5\,\ell'$

$\Rightarrow 109.8 \times 10^3 \times 0.2 = 10^5\,\ell'$

$\Rightarrow \ell' = \dfrac{109.8 \times 0.2}{10^2} = 0.2196 \approx 0.22$ m ≈ 22 cm

45. When the bulbs are maintained at two different temperatures.



The total heat gained by 'B' is the heat lost by 'A'

Let the final temp be x So, $m_1 S\Delta t = m_2 S\Delta t$

$\Rightarrow n_1 M \times s(x - 0) = n_2 M \times S \times (62 - x)$ $\Rightarrow n_1 x = 62n_2 - n_2 x$

$\Rightarrow x = \frac{62n_2}{n_1 + n_2} = \frac{62n_2}{2n_2} = 31°C = 304\ K$

For a single ball Initial Temp = 0°C P = 76 cm of Hg

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $V_1 = V_2$ Hence $n_1 = n_2$

$\Rightarrow \frac{76 \times V}{273} = \frac{P_2 \times V}{304}$ $\Rightarrow P_2 = \frac{403 \times 76}{273} = 84.630 \approx 84°C$

46. Temp is 20° Relative humidity = 100%

So the air is saturated at 20°C

Dew point is the temperature at which SVP is equal to present vapour pressure

So 20°C is the dew point.

47. T = 25°C P = 104 KPa

$RH = \frac{VP}{SVP}$ [SVP = 3.2 KPa, RH = 0.6]

$VP = 0.6 \times 3.2 \times 10^3 = 1.92 \times 10^3 \approx 2 \times 10^3$

When vapours are removed VP reduces to zero

Net pressure inside the room now = $104 \times 10^3 - 2 \times 10^3 = 102 \times 10^3$ = 102 KPa

48. Temp = 20°C Dew point = 10°C

The place is saturated at 10°C

Even if the temp drop dew point remains unaffected.

The air has V.P. which is the saturation VP at 10°C. It (SVP) does not change on temp.

49. $RH = \frac{VP}{SVP}$

The point where the vapour starts condensing, VP = SVP

We know $P_1V_1 = P_2V_2$

$R_H\ SVP \times 10 = SVP \times V_2$ $\Rightarrow V_2 = 10R_H \Rightarrow 10 \times 0.4 = 4\ cm^3$

50. Atm–Pressure = 76 cm of Hg

When water is introduced the water vapour exerts some pressure which counter acts the atm pressure.

The pressure drops to 75.4 cm

Pressure of Vapour = (76 – 75.4) cm = 0.6 cm

R. Humidity = $\frac{VP}{SVP} = \frac{0.6}{1} = 0.6 = 60\%$

51. From fig. 24.6, we draw ⊥r, from Y axis to meet the graphs.

Hence we find the temp. to be approximately 65°C & 45°C

52. The temp. of body is 98°F = 37°C

At 37°C from the graph SVP = Just less than 50 mm

B.P. is the temp. when atmospheric pressure equals the atmospheric pressure.

Thus min. pressure to prevent boiling is 50 mm of Hg.

53. Given

SVP at the dew point = 8.9 mm SVP at room temp = 17.5 mm

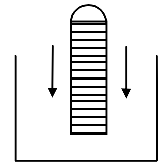
Dew point = 10°C as at this temp. the condensation starts

Room temp = 20°C

$RH = \frac{\text{SVP at dew point}}{\text{SVP at room temp}} = \frac{8.9}{17.5} = 0.508 \approx 51\%$

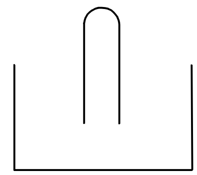
54. 50 cm^3 of saturated vapour is cooled 30° to 20°. The absolute humidity of saturated H_2O vapour 30 g/m^3
Absolute humidity is the mass of water vapour present in a given volume at 30°C, it contains 30 g/m^3
at 50 m^3 it contains 30 × 50 = 1500 g
at 20°C it contains 16 × 50 = 800 g
Water condense = 1500 – 800 = 700 g.

55. Pressure is minimum when the vapour present inside are at saturation vapour pressure
As this is the max. pressure which the vapours can exert.
Hence the normal level of mercury drops down by 0.80 cm
∴ The height of the Hg column = 76 – 0.80 cm = 75.2 cm of Hg.
[∵ Given SVP at atmospheric temp = 0.80 cm of Hg]



56. Pressure inside the tube = Atmospheric Pressure = 99.4 KPa
Pressure exerted by O_2 vapour = Atmospheric pressure – V.P.
= 99.4 KPa – 3.4 KPa = 96 KPa
No of moles of O_2 = n
$96 \times 10^3 \times 50 \times 10^{-6} = n \times 8.3 \times 300$

$\Rightarrow n = \frac{96 \times 50 \times 10^{-3}}{8.3 \times 300} = 1.9277 \times 10^{-3} \approx 1.93 \times 10^{-3}$



57. Let the barometer has a length = x
Height of air above the mercury column = (x – 74 – 1) = (x – 73)
Pressure of air = 76 – 74 – 1 = 1 cm
For 2nd case height of air above = (x – 72.1 – 1 – 1) = (x – 71.1)
Pressure of air = (74 – 72.1 – 1) = 0.99

$(x - 73)(1) = \frac{9}{10}(x - 71.1) \qquad \Rightarrow 10(x - 73) = 9(x - 71.1)$

$\Rightarrow x = 10 \times 73 - 9 \times 71.1 = 730 - 639.9 = 90.1$
Height of air = 90.1
Height of barometer tube above the mercury column = 90.1 + 1 = 91.1 mm

58. Relative humidity = 40%
SVP = 4.6 mm of Hg

$0.4 = \frac{VP}{4.6} \qquad \Rightarrow VP = 0.4 \times 4.6 = 1.84$

$\frac{P_1 V}{T_1} = \frac{P_2 V}{T_2} \qquad \Rightarrow \frac{1.84}{273} = \frac{P_2}{293} \Rightarrow P_2 = \frac{1.84}{273} \times 293$

Relative humidity at 20°C

$= \frac{VP}{SVP} = \frac{1.84 \times 293}{273 \times 10} = 0.109 = 10.9\%$

59. $RH = \frac{VP}{SVP}$

Given, $0.50 = \frac{VP}{3600}$

$\Rightarrow VP = 3600 \times 0.5$
Let the Extra pressure needed be P

So, $P = \frac{m}{M} \times \frac{RT}{V} = \frac{m}{18} \times \frac{8.3 \times 300}{1}$

Now, $\frac{m}{18} \times 8.3 \times 300 + 3600 \times 0.50 = 3600$ [air is saturated i.e. RH = 100% = 1 or VP = SVP]

$\Rightarrow m = \left(\frac{36 - 18}{8.3}\right) \times 6 = 13$ g

60. T = 300 K, Rel. humidity = 20%, V = 50 m^3

SVP at 300 K = 3.3 KPa, V.P. = Relative humidity × SVP = 0.2 × 3.3 × 10^3

$PV = \frac{m}{M}RT \Rightarrow 0.2 \times 3.3 \times 10^3 \times 50 = \frac{m}{18} \times 8.3 \times 300$

$\Rightarrow m = \frac{0.2 \times 3.3 \times 50 \times 18 \times 10^3}{8.3 \times 300}$ = 238.55 grams ≈ 238 g

Mass of water present in the room = 238 g.

61. $RH = \frac{VP}{SVP} \Rightarrow 0.20 = \frac{VP}{3.3 \times 10^3} \Rightarrow VP = 0.2 \times 3.3 \times 10^3 = 660$

$PV = nRT \Rightarrow P = \frac{nRT}{V} = \frac{m}{M} \times \frac{RT}{V} = \frac{500}{18} \times \frac{8.3 \times 300}{50} = 1383.3$

Net P = 1383.3 + 660 = 2043.3 Now, $RH = \frac{2034.3}{3300} = 0.619 \approx 62\%$

62. (a) Rel. humidity = $\frac{VP}{\text{SVP at } 15°C} \Rightarrow 0.4 = \frac{VP}{1.6 \times 10^3} \Rightarrow VP = 0.4 \times 1.6 \times 10^3$

The evaporation occurs as along as the atmosphere does not become saturated.

Net pressure change = 1.6 × 10^3 – 0.4 × 1.6 × 10^3 = (1.6 – 0.4 × 1.6)10^3 = 0.96 × 10^3

Net mass of water evaporated = m $\Rightarrow 0.96 \times 10^3 \times 50 = \frac{m}{18} \times 8.3 \times 288$

$\Rightarrow m = \frac{0.96 \times 50 \times 18 \times 10^3}{8.3 \times 288}$ = 361.45 ≈ 361 g

(b) At 20°C SVP = 2.4 KPa, At 15°C SVP = 1.6 KPa

Net pressure charge = (2.4 – 1.6) × 10^3 Pa = 0.8 × 10^3 Pa

Mass of water evaporated = m′ = 0.8 × 10^3 50 = $\frac{m'}{18} \times 8.3 \times 293$

$\Rightarrow m' = \frac{0.8 \times 50 \times 18 \times 10^3}{8.3 \times 293}$ = 296.06 ≈ 296 grams

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