3. Kinetic Theory of Gases and Radiation

Important Formulae and Shortcut Methods

1. $p_1V_1 = p_2V_2$ (for a given n moles of a gas at constant T)
   $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (for a given n moles of a gas at constant p)
   $\frac{V_1}{n_1} = \frac{V_2}{n_2}$ (for a given gas at constant p and T)

2. $pV = nRT = Nk_BT$ $\quad N_A = N/n,\ k_B = R/N_A$

3. $p = p_1 + p_2 + \ldots + p_N = (n_1 + n_2 + \ldots + n_i + \ldots + n_N)\frac{RT}{V}$

4. $\bar{c} = \frac{c_1 + c_2 + \ldots + c_N}{N}$, $\quad \overline{c^2} = \frac{c_1^2 + c_2^2 + \ldots + c_N^2}{N}$, $c_{rms} = \sqrt{\overline{c^2}}$

5. $p = \frac{1}{3}\frac{Nm_o}{V}c_{rms}^2 = \frac{1}{3}\frac{m}{V}c_{rms}^2 = \frac{1}{3}\rho c_{rms}^2$

6. $c_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_BT}{m_o}}$

7. For an ideal gas :
   KE of a gas $= \frac{3}{2}pV$, $\quad$ KE per unit volume $= \frac{3}{2}p$
   KE_{av} per mole $= \frac{3}{2}RT$, $\quad$ KE per unit mass $= \frac{3}{2}\frac{RT}{M}$
   KE per molecule $= \frac{3}{2}k_BT$

8. $C_p - C_V = R$

9. Monatomic gas : $C_V = \frac{3}{2}R,\ C_P = \frac{5}{2}R,\ \gamma = \frac{5}{3}$

10. Diatomic gas :
    Rigid molecule : KE per mole $= \frac{5}{2}RT$, $C_V = \frac{5}{2}R$, $C_P = \frac{7}{2}R$, $\gamma = \frac{7}{5}$
    Non–rigid molecule : KE per mole $= \frac{7}{2}RT$, $C_V = \frac{7}{2}R$, $C_P = \frac{9}{2}R$, $\gamma = \frac{9}{5}$

11. $dQ = dE + dW = dE + pdV$
    Isothermal process : $dE = 0,\ dQ = dW$
    Adiabatic process : $dQ = 0,\ dE = -dW$

12. $Q = Q_a + Q_r + Q_t$, $\quad a = \frac{Q_a}{Q}$, $\ r = \frac{Q_r}{Q}$, $\ t = \frac{Q_t}{Q}$, $\ a + r + t = 1$

13. Emissive power, $E = \frac{1}{A}\frac{dQ_{(radiated)}}{dt}$

14. $e = \frac{E}{E_b}$, Kirchhoff's law : $a = e$

15. Wien's law : $\lambda_m T = b$ $(b = 2.898 \times 10^{-3}$ m.K)

16. Stefan's law : $E_b = \sigma T^4$ $(\sigma = 5.67 \times 10^{-8}$ W/m^2.K^4)

17. Rate of heat radiation or radiant power, $P = \frac{dQ}{dt} = E_b A = \sigma A T^4$ (blackbody)

$= EA = eE_bA = \sigma e A T^4$ (any body)

For a given body, $\frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4$

18. Rate of loss of heat by radiation by a blackbody, $\frac{dQ}{dt} = \sigma A(T^4 - T_0^4)$

19. Rate of loss of heat by radiation by a body, $R = \frac{dQ}{dt} = \sigma A e\,(T^4 - T_0^4)$

For a given body, $\frac{R_1}{R_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4}$

Multiple Choice Questions

MHT-CET 2005

1. A black body is heated from 27° C to 927° C. The ratio of radiation emitted will be
(A) 1:4 (B) 1:8 (C) 1:16 (D) 1:256

2. In terms of mechanical unit, C_p - C_v = ... where, C_p and C_v are principal specific heats.
(A) R (B) $\frac{R}{M}$ (C) $\frac{R}{J}$ (D) $\frac{R}{MJ}$

3. At constant pressure, which of the following is true?
(A) $c \propto \sqrt{\rho}$ (B) $c \propto \frac{1}{\rho}$ (C) $c \propto \rho$ (D) $c \propto \frac{1}{\sqrt{\rho}}$

4. The temperature, at which the rms velocity of hydrogen is four times of its value at NTP is
(A) 819°C (B) 1092°C (C) 4368°C (D) 4095°C

MHT-CET 2007

5. The gases carbon-monoxide (CO) and nitrogen at the same temperature have kinetic energies E_1 and E_2 respectively. Then,
(A) $E_1 = E_2$ (B) $E_1 > E_2$
(C) $E_1 < E_2$ (D) E_1 and E_2 cannot be compared

MHT-CET 2008

6. What is an ideal gas?
(A) One that consists of molecules
(B) A gas satisfying the assumptions of kinetic theory
(C) A gas having Maxwellian distribution of speed
(D) A gas consisting of massless particles

MHT-CET 2009

7. The unit of Wien's constant b is
(A) $Wm^{-2}K^{-4}$ (B) $m^{-1}K^{-1}$ (C) Wm^2 (D) m-k

8. If 150 J of energy is incident on area $2m^2$. If $Q_r = 15$ J, coefficient of absorption is 0.6, then amount of energy transmitted is
(A) 50 J (B) 45 J (C) 40 J (D) 30 J

9. To what temperature should the hydrogen at 327°C be cooled at constant pressure, so that the root mean square velocity of its molecules becomes half of its previous value?
(A) -123°C (B) 123°C (C) -100°C (D) 0°C

MHT-CET 2014

10. Gases exert pressure on the walls of the container because the gas molecules
(A) have finite volume (B) obey Boyle's law
(C) possess momentum (D) collide with one another

11. A gas is compressed isothermally. The r.m.s. velocity of its molecules
(A) increases (B) decreases
(C) first increases and then decreases (D) remains the same

MHT-CET 2015

12. In the expression for Boyle's law, the product 'PV' has dimensions of
(A) force (B) impulse (C) energy (D) momentum

13. The dimensions of Stefan's constant are
(A) $M^0 L^1 T^{-3} K^{-4}$ (B) $M^1 L^1 T^{-3} K^{-3}$ (C) $M^1 L^2 T^{-3} K^{-4}$ (D) $M^1 L^0 T^{-3} K^{-4}$

14. A black body radiates heat at temperatures 'T_1' and 'T_2' ($T_2 > T_1$). The frequency corresponding to maximum energy is
(A) more at T_1 (B) more at T_2
(C) equal for T_1 and T_2 (D) independent of T_1 and T_2

MHT-CET 2016

15. For a gas $\frac{R}{C_V} = 0.4$, where 'R' is the universal gas constant and 'C_V' is molar specific heat at constant volume. The gas is made up of molecules which are
(A) rigid diatomic (B) monoatomic (C) non-rigid diatomic (D) polyatomic

16. Assuming the expression for the pressure exerted by the gas on the walls of the container, it can be shown that pressure is

(A) $\left[\frac{1}{3}\right]^{rd}$ kinetic energy per unit volume of a gas

(B) $\left[\frac{2}{3}\right]^{rd}$ kinetic energy per unit volume of a gas

(C) $\left[\frac{3}{4}\right]^{th}$ kinetic energy per unit volume of a gas

(D) $\frac{3}{2}\times$kinetic energy per unit volume of a gas

17. A black rectangular surface of area 'A' emits energy 'E' per second at 27°C. If length and breadth are reduced to $\frac{1}{3}^{rd}$ of initial value and temperature is raised to 327°C then energy emitted per second becomes

(A) $\frac{4E}{9}$ (B) $\frac{7E}{9}$ (C) $\frac{10E}{9}$ (D) $\frac{16E}{9}$

MHT-CET 2017

18. Two spherical black bodies have radii 'r_1' and 'r_2'. Their surface temperatures are 'T_1' and 'T_2'. If they radiate same power then $\frac{r_2}{r_1}$ is

(A) $\frac{T_1}{T_2}$ (B) $\frac{T_2}{T_1}$ (C) $\left(\frac{T_1}{T_2}\right)^2$ (D) $\left(\frac{T_2}{T_1}\right)^2$

19. For a rigid diatomic molecule, universal gas constant R = nCp where 'Cp' is the molar specific heat at constant pressure and 'n' is a number. Hence n is equal to

(A) 0.2257 (B) 0.4 (C) 0.2857 (D) 0.3557

20. An ideal gas has pressure 'P', volume 'V' and absolute temperature 'T'. If 'm' is the mass of each molecule and 'K' is the Boltzmann constant then density of the gas is

(A) $\frac{Pm}{KT}$ (B) $\frac{KT}{Pm}$ (C) $\frac{Km}{PT}$ (D) $\frac{PK}{Tm}$

MHT-CET 2018

21. The molar specific heat of an ideal gas at constant pressure and constant volume is 'C_p' and 'C_v' respectively. If 'R' is the universal gas constant and the ratio of 'C_p' to 'C_v' is 'γ' then C_v =

(A) $\frac{1-\gamma}{1+\gamma}$ (B) $\frac{1+\gamma}{1-\gamma}$ (C) $\frac{\gamma-1}{R}$ (D) $\frac{R}{\gamma-1}$

22. Heat energy is incident on the surface at the rate of 1000 J/min. If coefficient of absorption is 0.8 and coefficient of reflection is 0.1 then heat energy transmitted by the surface in 5 minutes is

(A) 100 J (B) 500 J (C) 700 J (D) 900 J

MHT-CET 2019

23. If 'C_p' and C_v are molar specific heats of an ideal gas at constant pressure and volume respectively. If 'λ' is ratio of two specific heats and 'R' is universal gas constant then 'C_p' is equal to

(A) $\frac{R\gamma}{\gamma-1}$ (B) $\frac{1+\gamma}{1-\gamma}$ (C) γR (D) $\frac{R}{\gamma-1}$

24. The maximum wavelength of radiation emitted by a star is 289.8nm. Then intensity of radiation for the star is
(Given : Stefan's constant = 5.67×10^{-8} $Wm^{-2}K^{-4}$, Wien's constant, b = 2898 μ mK)

(A) 5.67×10^{-12} Wm^{-2} (B) 5.67×10^{8} Wm^{-2}
(C) 10.67×10^{14} Wm^{-2} (D) 10.67×10^{7} Wm^{-2}

25. The S. I unit and dimensions of Stefan's constant 'σ' in case of Stefan's law of radiation is

(A) J/m^2s^4K, $M^1L^0T^{-3}K^3$ (B) J/m^3sK^4, $M^1L^0T^{-3}K^4$
(C) J/m^3s^4, $M^1L^0T^{-3}K^{-4}$ (D) J/m^2sK^4, $M^1L^0T^{-3}K^{-4}$

26. The r.m.s. speed of oxygen molecule in a gas is 'u'. If the temperature is doubled and the molecules dissociate into two atoms, the r.m.s. speed will be

(A) 4u (B) $u\sqrt{2}$ (C) 2u (D) u

27. If the kinetic energy per unit volume of an ideal gas is 'E', then the pressure exerted by the gas is

(A) $\frac{3E}{2}$ (B) $\frac{E}{2}$ (C) $\frac{E}{3}$ (D) $\frac{2E}{3}$

28. The ratio of R.M.S. velocities of hydrogen molecules to oxygen molecules at 273°C is (molecular wt. of hydrogen and oxygen is 2 and 32 respectively

(A) 1 : 8 (B) 16 : 1 (C) 1 : 4 (D) 4 : 1

29. A perfect gas of 'N' molecules, each of mass 'm', moving with velocities 'C_1', 'C_2', ...'C_N' is enclosed in a cubical vessel of volume 'V'. The pressure exerted by the gas on the walls of the vessel is ('ρ' = density of gas)

(A) $\frac{1}{3}\frac{mN}{V}C_{RMS}$ (B) $\frac{1}{3}\frac{m}{V}C_{RMS}^2$ (C) $\frac{1}{3}\rho\bar{C}^2$ (D) $\frac{1}{3}\rho\bar{C}^2$

30. An iron nail changes its colour from red to orange red and then to bluish white, when heated strongly in flames. This change of colour can be explained on the basis of

(A) Newton's law of cooling (B) Kirchoff's law
(C) Wein's displacement law (D) Stefan's law of radiation

31. The original temperature of a black body is 727°C. The temperature to which the black body must be raised so as to double the total radiant energy is

(A) 2000°C (B) 1454°C (C) 1190°C (D) 917°C

MHT-CET 2020

32. According to the assumptions made in the kinetic theory of gases, when two molecules of a gas collide with each other, then

(A) neither kinetic energy nor momentum is conserved.
(B) kinetic energy is conserved but momentum is not conserved.
(C) both kinetic energy and momentum are conserved.
(D) momentum is conserved but kinetic energy is not conserved.

33. The r.m.s. velocity of hydrogen molecules at temperature T is seven times the r.m.s. velocity of nitrogen molecules at 300 K. This temperature T is (Molecular weights of hydrogen and nitrogen are 2 and 28 respectively)
(A) 1350 K (B) 1700 K (C) 1050 K (D) 2100 K

34. Two vessels separately contain two ideal gases A and B at the same temperature. The pressure of A is twice that of B. Under such conditions, the density of A is found to be 1.5 times the density of B. The ratio of molecular weights of A and B is
(A) 2 (B) $\frac{3}{4}$ (C) $\frac{1}{2}$ (D) $\frac{2}{3}$

35. The translational kinetic energy of the molecules of a gas at absolute temperature (T) can be doubled by
(A) increasing T to $\sqrt{2}$ T (B) increasing T to 2 T
(C) decreasing T to T/2 (D) increasing T to 4 T

36. Temperatures of two stars are in the ratio 3 : 2. If wavelength of maximum intensity of first star is 4500 Å, the corresponding wavelength for second star is
(A) 2250 Å (B) 3000 Å (C) 9000 Å (D) 6750 Å

37. S.I. Unit of emissive power of a body at a given temperature is
(A) $\frac{J}{m^2 s}$ (B) $\frac{J}{m^2}$ (C) $\frac{J}{s}$ (D) $\frac{W}{m}$

38. Rate of radiation by a black body is 'R' at temperature 'T'. Another body has same area but emissivity is 0.2 and temperature '3T' Its rate of radiation is
(A) (24.3) R (B) (8.1) R (C) (16.2) R (D) (32.4) R

39. The average translational kinetic energy of a molecule in a gas is 'E_1'. The kinetic energy of the electron (e) accelerated from rest through p.d. 'V' volt is 'E_2'. The temperature at which $E_1 = E_2$ is possible, is
(A) $\frac{2VNe}{3R}$ (B) $\frac{3VNe}{2R}$ (C) $\frac{VNe}{R}$ (D) $\frac{VNe}{2R}$

40. An athermanous metal plate has the coefficient of absorption 0.65. Its coefficient of reflection is
(A) 0.35 (B) zero (C) 0.45 (D) 0.55

41. The energy spectrum of a black body exhibits a maximum around a wavelength 'λ'. The temperature of a black body is now changed such that the energy is maximum around a wavelength 3λ/4. The power radiated by a black body will now increase by a factor of
(A) $\frac{128}{27}$ (B) $\frac{128}{81}$ (C) $\frac{256}{27}$ (D) $\frac{256}{81}$

42. The molar specific heats of an ideal gas at constant pressure and constant volume are denoted by C_p and C_v respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_p is equal to
(A) $\frac{\gamma - 1}{R}$ (B) $\frac{(\gamma - 1)^2}{R}$ (C) $\frac{\gamma - 1}{\gamma R}$ (D) $\frac{\gamma R}{\gamma - 1}$

43. The ratio of specific heat at constant pressure to specific heat at constant volume (γ) for a gas is $\left(1+\frac{2}{f}\right)$ where f is the number of degrees of freedom of a molecule of a gas. The ratio of 'γ_d' for rigid diatomic to 'γ_m' for monoatomic is

(A) $\frac{14}{23}$ (B) $\frac{23}{14}$ (C) $\frac{25}{21}$ (D) $\frac{21}{25}$

44. A molecule consists of two atoms each of mass 'm' and separated by a distance 'd'. At room temperature the average rotational kinetic energy is 'E', then its angular frequency is

(A) $\frac{2}{d}\sqrt{\frac{E}{m}}$ (B) $\sqrt{\frac{m}{Ed}}$ (C) $\frac{d}{2}\sqrt{\frac{m}{E}}$ (D) $\sqrt{\frac{Ed}{m}}$

45. Two spherical black bodies of radius 'r_1' and 'r_2' with surface temperature 'T_1' and 'T_2' respectively, radiate same power, then $r_1 : r_2$ is

(A) $\left(\frac{T_2}{T_1}\right)^2$ (B) $\left(\frac{T_1}{T_2}\right)^2$ (C) $\left(\frac{T_1}{T_2}\right)^4$ (D) $\left(\frac{T_2}{T_1}\right)^4$

46. A diatomic gas undergoes adiabatic change. Its pressure 'P' and temperature 'T' are related as $P \propto T^x$, where x is

(A) 1.5 (B) 3.0 (C) 2.5 (D) 3.5

47. A monoatomic gas of pressure 'P' having volume 'V' expands isothermally to a volume '2V' and then adiabatically to a volume '16V'. The final pressure of the gas is

(ratio of specific heats $=\frac{5}{3}$)

(A) $\frac{P}{16}$ (B) $\frac{P}{8}$ (C) $\frac{P}{32}$ (D) $\frac{P}{64}$

48. For a gas, $\frac{R}{C_V} = 0.4$ where 'R' is universal gas constant and C_v is the molar specific heat at constant volume. The gas is made up of molecules which are

(A) monoatomic (B) rigid diatomic
(C) non-rigid diatomic (D) polyatomic

49. We have a sample of gas characterised by P, V and T and another sample of gas characterized by 2P, V/4, and 2T. What is the ratio of the number of molecules in the first and second samples?

(A) 2 : 1 (B) 16 : 1 (C) 8 : 1 (D) 4 : 1

50. A black body radiates maximum energy at wavelength 'λ' and its emissive power is 'E'. Now, due to change in temperature of that body, it radiates maximum energy at wavelength $\frac{2\lambda}{3}$. At that temperature, emissive power is

(A) $\frac{81E}{16}$ (B) $\frac{91E}{16}$ (C) $\frac{54E}{16}$ (D) $\frac{27E}{16}$

51. Three black discs 'x', 'y', 'z' have radii 1m, 2m and 3m respectively. The wavelengths corresponding to maximum intensity are 200, 300 and 400 nm respectively. The relation between emissive powers 'E_x', 'E_y' and 'E_z' is
(A) $E_x > E_y > E_z$ (B) $E_x < E_y < E_z$ (C) $E_x = E_y = E_z$ (D) $E_x > E_y > E_z$

52. Two ideal gases A and B having the same temperature T, same pressure P and same volume V, are mixed together. If the temperature of mixture is kept constant and the volume occupied by the mixture is reduced to $\frac{V}{2}$, then the pressure of the mixture will become
(A) 4P (B) 2P (C) P (D) $\frac{P}{2}$

53. A ideal gas has pressure 'p', volume 'V' and absolute temperature 'T'. If 'm' is the mass of each molecule and 'K' is the Boltzmann constant then density of the gas is
(A) $\frac{KT}{Pm}$ (B) $\frac{Pm}{KT}$ (C) $\frac{P}{mKT}$ (D) $\frac{T}{KPm}$

54. Kirchhoff's law of radiation proves that a good emitter is a
(A) bad absorber of heat (B) good absorber of heat
(C) good reflector of heat (D) good transmitter of heat

55. A black sphere has radius 'R' whose rate of radiation is 'E' at temperature 'T'. If radius is made '$\frac{R}{3}$' and temperature '3T', the rate of radiation will be
(A) 9E (B) 6E (C) 3E (D) E

56. According to the assumptions made in the kinetic theory of gases, when two molecules of a gas collide with each other then
(A) neither K.E. nor momentum is conserved.
(B) both K.E. and momentum are conserved.
(C) momentum is conserved but K.E. is not conserved.
(D) K.E. is conserved but momentum is not conserved.

57. If temperature of black body increases from 17°C to 307°C, then the rate of radiation increases by
(A) 16 (B) 2 (C) 4 (D) $\left(\frac{307}{17}\right)^4$

58. For an ideal gas, if the ratio of Molar specific heats $\gamma = 1.4$, then the specific heat at constant pressure C_p, specific heat at constant volume C_v and corresponding molecule are respectively
(A) $\frac{9}{2}R, \frac{7}{2}R$, polyatomic (B) $\frac{7}{2}R, \frac{5}{2}R$, non - rigid diatomic
(C) $\frac{7}{2}R, \frac{5}{2}R$, rigid diatomic (D) $\frac{5}{2}R, \frac{3}{2}R$, monoatomic

59. An ideal gas occupies a volume 'V' at a pressure 'P' and absolute temperature T. The mass of each molecule is 'm'. If 'K_B' is the boltzmann's constant, then the density of gas is given by expression
(A) $\frac{P.m}{2K_B.T}$ (B) $\frac{K_B.T}{P.m}$ (C) $\frac{P.m}{K_B.T}$ (D) $\frac{3K_B.T}{2P.m}$

60. According to Boyle's law, the product PV remains constant. The dimensions of PV are same as
(A) force (B) impulse (C) momentum. (D) energy

61. The average force applied on the walls of a closed container depends as 'T^x', where 'T' is the temperature of an ideal gas. The value of 'x' is
(A) 1 (B) zero (C) 2 (D) 3

62. Average kinetic energy of H_2 molecule at 300K is 'E'. At the same temperature, average kinetic energy of O_2 molecule will be
(A) $\frac{E}{4}$ (B) $\frac{E}{2}$ (C) $\frac{E}{8}$ (D) E

63. About black body radiation, which one of the following is 'WRONG' statement?
(A) For shorter wavelengths, intensity is more.
(B) All wavelengths are emitted by a black body.
(C) For longer wavelengths, intensity is less.
(D) For all wavelengths, intensity is same.

64. Two black spheres 'P' and 'Q' have radii in the ratio 3 : 2. The wavelengths of maximum intensity radiation are in the ratio 3 : 4 respectively. The ratio of radiated power by 'P' to 'Q' is
(A) $\frac{25}{9}$ (B) $\frac{74}{9}$ (C) $\frac{16}{9}$ (D) $\frac{64}{9}$

65. Two spheres 'S_1' and 'S_2' have same radii but temperatures T_1 and T_2 respectively. Their emissive power is same and emissivity is in the ratio 1 : 4. Then the ratio of T_1 to T_2 is
(A) $\sqrt{2}:1$ (B) $1:\sqrt{2}$ (B) 1 : 2 (D) 2 : 1

66. Ordinary bodies 'A' and 'B' radiate maximum energy with wavelength difference 4µm. The absolute temperature of body 'A' is 3 times that of 'B'. The wavelength at which body 'B' radiates maximum energy is
(A) 4 µm (B) 8 µm (C) 12 µm (D) 6 µm

67. Two spheres 'S_1' and 'S_2' have radii 'R' and '3R', temperature 'T' K and $\frac{T}{3}$ K respectively. If they are coated with a material of same emissivity, rate of radiation of 'S_1' is E then rate of radiation of 'S_2' is (spheres are of the same material)
(A) $\frac{E}{9}$ (B) $\frac{E}{3}$ (C) $\frac{E}{12}$ (D) $\frac{E}{6}$

68. One mole of a diatomic gas does a work $\frac{Q}{3}$, when the amount of heat supplied is 'Q'. In this process, the molar heat capacity of the gas is
(A) $\frac{3R}{4}$ (B) $\frac{7R}{4}$ (C) $\frac{9R}{4}$ (D) $\frac{15R}{4}$

69. The value of 'γ' for a gas is given as $\gamma = 1 + \frac{2}{f}$, where 'f' is the number of degrees of freedom of freedom of a molecule of a gas. What is the ratio of '$\gamma_{monoatonic} / \gamma_{diatomic}$' ? Diatomic gas consists of rigid gas molecules
(A) $\frac{25}{21}$ (B) $\frac{3}{10}$ (C) $\frac{21}{25}$ (D) $\frac{10}{3}$

70. At what temperature is the R.M.S. Velocity of Hydrogen molecule equal to that of an oxygen molecule at 47°C?
(Molecular weight of hydrogen = 2, Molecular weight of oxygen = 32)
(A) 20 K (B) 80 K (C) 60 K (D) 40 K

71. A black body has maximum wavelength λ_m at temperature 2200 K. Its corresponding wavelength at temperature 3300 K will be
(A) $\frac{2}{3}\lambda_m$ (B) $\frac{3}{2}\lambda_m$ (C) $\frac{9}{4}\lambda_m$ (D) $\frac{4}{9}\lambda_m$

72. The ratio of the specific heats $\frac{c_p}{c_v} = \gamma$ in terms of degrees of freedom 'n' is given by
(A) $\left(1+\frac{1}{n}\right)$ (B) $\left(1+\frac{2}{n}\right)$ (C) $\left(1+\frac{n}{2}\right)$ (D) $\left(1+\frac{n}{3}\right)$

73. A black rectangular surface of area A emits energy E per second at 27°C. If length and breadth is reduced to $\left(\frac{1}{3}\right)^{rd}$ of initial value and temperature is raised to 327°C then energy emitted per second becomes
(A) $\frac{4E}{9}$ (B) $\frac{E}{9}$ (C) $\frac{16E}{9}$ (D) $\frac{2E}{9}$

74. Let the r.m.s. velocity of molecule of a given mass of gas be C_1 at temperature 27°C. When the temperature is increased to 327°C, the r.m.s. velocity of C_2. Then the ratio $\frac{c_2}{c_1}$ is
(A) $\sqrt{2}$ (B) 4 (C) 2 (D) $2\sqrt{2}$

75. Heat is applied to a rigid diatomic gas at constant pressure. The ratio $\Delta Q : \Delta U : \Delta W$ is
(A) 7 : 5 : 2 (B) 5 : 2 : 7 (C) 5 : 7 : 2 (D) 2 : 5 : 7

76. The root mean square velocity of molecules of a gas is 200 m/s. What will be the root mean square velocity of the molecules, if the molecular weight is doubled and the absolute temeprature is halved?
(A) $\frac{100}{\sqrt{2}}$ m/s (B) 100 m/s (C) 200 m/s (D) 50 m/s

77. Let 'σ' and 'b' be Stefan's cosntant and Wien's constant respectively, then dimensions of 'σb' are
(A) $L^1M^1T^3K^{-3}$ (B) $L^{-1}M^1T^{-3}K^{-3}$ (C) $L^1M^{-1}T^{-3}K^{-3}$ (D) $L^1M^1T^{-3}K^{-3}$

78. For athermanous substances, coefficient of transmission is
(A) equal to one (B) zero
(C) less than one but greater than zero (D) greater than one

79. For a gas $\frac{R}{c_v} = 0.67$. This gas is made up of molecule which are
(A) polyatomic
(B) mixture of diatomic and polyatomic
(C) monoatomic
(D) diatomic

80. If 'f' is the number of degrees of freedom of a molecule of a gas and ratio of molar specific heats of a gas, $\gamma = 1 + \frac{2}{f}$ where $\gamma = Cp/Cv$. The ratio of 'γ' for monoatomic gas to 'γ' for (rigid) diatomic gas is

(A) $\frac{15}{35}$ (B) $\frac{35}{15}$ (C) $\frac{21}{25}$ (D) $\frac{25}{21}$

SOLUTIONS

1. (D)

According to Stefan's law

$$E \propto T^4 \quad \text{or} \quad E = \sigma T^4$$

where, σ is Stefan's constant. It's value is 5.67×10^{-8} Wm^{-2} K^{-4}

Here, $T_1 = 27 + 273 = 300$ K $\qquad T_2 = 927 + 273 = 1200$ K

$$\frac{E_1}{E_2} = \left(\frac{300}{1200}\right)^4 = 1.256$$

2. (C)

The relation between the specific heat of a gas at constant volume and at a constant pressure was obtained by Robert Mayer in 1842.

$$(C_p - C_v)dT = \frac{RdT}{J} \quad \text{or} \quad C_p - C_v = \frac{R}{J}$$

3. (D)

Pressure due to an ideal gas is given by,

$$p = \frac{M}{3V}c^2$$

Putting $\frac{M}{V} = \rho$, the density of gas.

$$p = \frac{1}{3}\rho c^2 \quad \Rightarrow \quad c = \sqrt{\left(\frac{3p}{\rho}\right)}$$

$$\therefore \quad c \propto \frac{1}{\sqrt{\rho}}$$

4. (D)

Maxwellian speed distribution law states that

$$c_{rms} = \sqrt{\left(\frac{3KT}{M}\right)} \quad \Rightarrow \quad c_{rms} \propto \sqrt{T}$$

$$\therefore \quad \frac{c_{(rms)_1}}{c_{(rms)_2}} = \sqrt{\frac{T_1}{T_2}} \quad \Rightarrow \quad \frac{4}{1} = \sqrt{\frac{T'}{273}}$$

or $\quad T' = 4368 \text{ K} = 4095°\text{C}$

5. (B)

CO will have vibrational energy along with translational and rotational energy.

6. (B)

An ideal gas is a gas which satisfying the assumptions of the kinetic energy.

7. (D)

According to Wien's law, the product of wavelength corresponding to maximum intensity of radiation and temperature of body (in Kelvin) is constant i.e.

$\lambda_m T = b = \text{constant}$ Where, b is Wien's constant and has value 2.89×10^{-3} m-K.

8. (B)

When thermal radiations (Q) fall on a body, they are partly reflected, partly absorbed and partly transmitted.

$$Q = Q_a + Q_r + Q_t$$

and $$\frac{Q_a}{Q} + \frac{Q_r}{Q} + \frac{Q_t}{Q} = a + r + t = 1$$

or $$\frac{15}{150} + 0.6 + x = 1 \Rightarrow 0.1 + 0.6 + x = 1$$

or $$x = 0.3$$

Transmitting power, $t = \dfrac{Q_t}{Q}$

or $$0.3 = \frac{Q_t}{150} \Rightarrow Q_t = 45\text{ J}$$

9. (A)

$$v_{rms} \propto \sqrt{\frac{3RT}{M}} \Rightarrow T \propto v_{rms}^2$$

$$\Rightarrow \frac{T_2}{T_1} = \left[\frac{v_2}{v_1}\right]^2 = \frac{1}{4}$$

$$\Rightarrow T_2 = \frac{T_1}{4} = \frac{(273+327)}{4} = 150\text{K} = -123°\text{C}$$

10. (C)

Gases exert pressure on the walls of the container, because the gas molecules posses momentum.

11. (D)

The root mean square velocity of a gas molecule is given by, $C_{rms} = \sqrt{\dfrac{3RT}{M}}$

Gas is compressed isothermally, so T remains constant and hence, root mean square velocity will remain same.

12. (C)

$PV = ML^{-1}T^{-2}L^3 = ML^2T^{-2}$

13. (D)

14. (B)

According to Wien's displacement law $\lambda T = \text{Constant}$

$\therefore \quad \lambda \propto \dfrac{1}{T}$

$\therefore \quad \lambda_2 < \lambda_1 \quad (\because T_2 > T_1)$

But frequency $n \propto \dfrac{1}{\lambda}$

$\therefore \quad n_2 > n_1$

15. (A)

$\frac{R}{C_V} = 0.4 \quad \Rightarrow \frac{C_P - C_V}{C_V} = 0.4$

$\frac{C_P}{C_V} - 1 = 0.4 \quad \therefore \frac{C_P}{C_V} = 1.4 \Rightarrow r = 1.4$

As $r = 1.4$ the gas is diatomic in nature. For example air molecules.

16. (B)

The pressure exerted by the gas on the walls of container is

i.e. $P = \frac{1}{3}\rho C^2 = \frac{1}{3}\frac{M}{V}\cdot C^2$

$= \frac{2}{3}\left[\frac{1}{2}\frac{M}{V}C^2\right] = \frac{2}{3}$ K.E. per unit volume

17. (D)

$E = e\sigma \cdot A(T^4 - T_0^4)$ and $A = \ell b$

When ℓ and b change to $\frac{\ell}{3}$ and $\frac{b}{3}$

$A' = \frac{A}{9}$

$\frac{E'}{E} = \frac{A'}{A}\frac{(327+273)^4}{(27+273)^4}; \quad \frac{E'}{E} = \frac{1}{9}\left(\frac{600}{300}\right)^4$

$\therefore E' = \frac{1}{9}\times(2)^4 \times E \quad \Rightarrow E' = \frac{16E}{9}$

18. (C)

$\frac{Q}{t} = \sigma AT^4$

i.e. power $= \sigma AT^4$

$\therefore$ for same power

$\therefore A \propto \frac{1}{T^4}$

$\therefore \frac{A_2}{A_1} = \frac{T_1^4}{T_2^4}$

$\therefore \frac{4\pi r_2^2}{4\pi r_1^2} = \frac{T_1^4}{T_2^4}$

$\therefore \frac{r_2}{r_1} = \left(\frac{T_1}{T_2}\right)^2$

19. (C)

For rigid diatomic molecule

$\frac{C_P}{C_V} = \frac{7}{5}$

$\therefore C_V = \frac{5}{7}C_P$

Also $C_P - C_V = R$

$$C_P - \frac{5}{7}C_P = R$$

$$\frac{2}{7}C_P = R$$

$$\therefore n = \frac{2}{7} = 0.2857$$

20. (A)

For ideal gas PV = nRT

$$PV = \frac{m'}{M}RT = \frac{m'}{V}\cdot\frac{RT}{M}$$ (where m′ is the mass of the gas and M molecular weight)

$$\therefore P = \frac{\rho RT}{M}$$ (where ρ is the density of the gas)

$$\therefore \rho = \frac{PM}{RT} = \frac{PM}{NKT}$$ (where N is Avogadro number)

$$\therefore \rho = \frac{Pm}{KT}$$ (where $m = \frac{M}{N}$ = mass of each molecule)

21. (D)

$$\frac{C_P}{C_V} = \gamma$$

$$\frac{C_P - C_V}{C_V} = \frac{\gamma - 1}{1}$$

$$\frac{R}{C_V} = \gamma - 1 \qquad \therefore C_V = \frac{R}{\gamma - 1}$$

22. (B)

r + a + t = 1

t = 1 − r − a = 1 − 0.8 − 0.1 = 1 − 0.9 = 0.1

Q = 1000 J/min

∴ heat energy transmitted per minute Q.t = 1000 × 0.1 J = 100 J

∴ heat energy transmitted in 5 minutes = 500 J

23. (A)

$$\frac{C_p}{C_v} = \lambda \qquad C_p - C_v = R$$

$$\frac{C_v - C_p}{C_p} = \frac{1-\lambda}{\lambda} \Rightarrow \frac{C_p}{C_p - C_v} = \frac{\lambda}{\lambda - 1}$$

$$\frac{C_p}{R} = \frac{\lambda}{\lambda - 1}$$

$$C_p = \frac{\lambda R}{\lambda - 1}$$

24. (B)

25. (D)

$$E_b = \sigma T^4$$

$$\sigma = \frac{E_b}{T^4}$$

26. (C)

$$C_{RMS_1} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(kN)T}{M}} = U$$

$$C_{RMS_2} = \sqrt{\frac{3K}{M} \cdot 2N \cdot 2T} = 2U$$

27. (D)

$$KE = \frac{3}{2}PV$$

$$\frac{KE}{Volume} = \frac{3}{2}P = E$$

$$\therefore \quad P = \frac{2E}{3}$$

28. (D)

$$\frac{C_{RMS_{H_2}}}{C_{RMS_{O_2}}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}} = 4$$

29. (C)

$$P = \frac{1}{3}\rho C_{RMS}^2$$

Now, $C_{RMS} = \sqrt{\bar{c}^2}$

$\therefore$ Correct option is C.

30. (C)

Wien's law $\quad \lambda_{max} T = b$

It states wavelength changes with temperature.

31. (D)

$$\frac{Q_1}{Q_2} = \frac{(1000)^4}{T_2^4} \qquad \frac{1}{2} = \frac{(1000)^4}{T_2^4}$$

$$T_2 = 2^{1/4} \times 1000 = 1.189 \times 1000 = 1189\ K = 917°C$$

32. (C)

33. (C)

$$C_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{C_H}{C_N} = \sqrt{\frac{T}{2} \times \frac{28}{300}} = \sqrt{\frac{14T}{300}}$$

$$\therefore \quad \frac{14T}{300} = 49$$

$$T = \frac{49 \times 300}{14} = 1050\ K$$

34. (B)

For ideal gas, PV = RT $M = \rho V$

A	B
2p	p
1.5d	d

$\therefore \frac{PM}{\rho} = RT$

$\therefore \frac{P_A M_A}{\rho_A} = \frac{P_B M_B}{\rho_B}$

$\frac{M_A}{M_B} = \frac{\rho_A}{\rho_B} \times \frac{P_B}{P_A} = \frac{3}{2} \times \frac{1}{2} = \frac{3}{4}$

35. (B)

$C_{RMS} = \sqrt{\frac{3RT}{M}}$ $\therefore C_{RMS} \propto \sqrt{T}$

$\therefore$ KE $\propto T$

36. (D)

$\frac{T_1}{T_2} = \frac{3}{2}$

According to Wien's law,

$\lambda T = b$

$\therefore \frac{\lambda_2}{\lambda_1} = \frac{3}{2}$

$\therefore \lambda_2 = \frac{3}{2} \times 4500 = 6750$ Å

37. (A)

Emissive power $= \frac{\text{Energy}}{\text{time} \times \text{area}} = \frac{J}{m^2 s}$

38. (C)

We know

$\frac{R'}{R} = \frac{eT'^4}{T^4}$

$\Rightarrow R' = R(0.2) \times 3^4 = \frac{81R}{5} = 16.2\ R$

39. (A)

$E_1 = \frac{3}{2}kT$ for a molecule

$E_2 = eV$ for an electron accelerated through potential difference V

As per condition $E_1 = E_2$

$\therefore \frac{3}{2}kT = eV$

$T = \frac{2}{3}\frac{eV}{k}$

Now, $R = Nk$

where k = Boltzmann constant

R = Universal constant

N = Avogadro's number

$\therefore T = \frac{2}{3}\frac{N}{R}eV$

40. (A)

For athermanous metal plate there is no transmission

So, $1 = r + a$

$\therefore\ r = 1 - 0.65 = 0.35$

41. (D)

$$\frac{E_1}{E_2} = \frac{\lambda^4}{\left(\frac{3\lambda}{4}\right)^4} = \frac{256}{81}$$

42. (D)

$$\gamma = \frac{C_p}{C_v} \qquad C_p - C_v = R$$

$$\frac{C_v}{C_p} = \frac{1}{\gamma}$$

$$\frac{C_v - C_p}{C_p} = \frac{1-\gamma}{\gamma}$$

$$\frac{R}{C_p} = \frac{\gamma - 1}{\gamma}$$

$$\therefore\ C_p = \frac{\gamma R}{\gamma - 1}$$

43. (D)

$$\gamma = 1 + \frac{2}{f}$$

For diatomic $f = 5$

For monoatomic $f = 3$

$$\therefore\ \gamma_d = 1 + \frac{2}{5} = \frac{7}{5}$$

$$\gamma_m = 1 + \frac{2}{3} = \frac{5}{3}$$

$$\therefore\ \frac{\gamma_d}{\gamma_m} = \frac{7}{5} \times \frac{3}{5} = \frac{21}{25}$$

44. (A)

$$\text{MI of molecule} = m\left(\frac{d}{2}\right)^2 + m\left(\frac{d}{2}\right)^2$$

$$= \frac{md^2}{2}$$

Now, $\frac{1}{2} I\omega^2 = E$

$$\omega = \sqrt{\frac{2E}{I}} = \sqrt{\frac{2 \times E \times 2}{md^2}}$$

$$= \frac{2}{d}\sqrt{\frac{E}{m}}$$

45. (A)

$$4\pi r_1^2 T_1^4 = 4\pi r_2^2 T_2^4$$

$$\frac{r_1^2}{r_2^2} = \frac{T_2^4}{T_1^4}$$

$$\frac{r_1}{r_2} = \frac{T_2^2}{T_1^2}$$

46. (D)

Adiabatic change $\rightarrow PV^{\gamma} = k$ $\qquad PV = RT$

$$P\frac{R^{\gamma}T^{\gamma}}{P^{\gamma}} = k \qquad V^{\gamma} = \left(\frac{RT}{P}\right)^{\gamma}$$

$$P^{1-\gamma}T^{\gamma} = k'$$

$$P^{1-\gamma} = \frac{k'}{T^{\gamma}}$$

$$P = \frac{k''}{T^{\gamma/1-\gamma}} = k''T^{-\left(\frac{\gamma}{1-\gamma}\right)}$$

$$\therefore \quad x = \frac{\gamma}{\gamma-1}$$

For diatomic gas $\gamma = 1.4$

$$\therefore \quad x = \frac{1.4}{0.4} = 3.5$$

47. (D)

$$\gamma = \frac{5}{3}$$

Case I : $P_1 V_1 = P_2 V_2$

$$P\,V = P_2 \times 2\,V$$

$$\therefore \quad P_2 = \frac{P}{2}$$

Case II : $P_2 V_2^{\gamma} = P_3 V_3^{\gamma}$

$$\left(\frac{P}{2}\right)(2V)^{\gamma} = P_3(16V)^{\gamma}$$

$$P_3 = \frac{P}{2}\frac{(2V)^{\gamma}}{(16V)^{\gamma}} = \frac{P}{2}\left(\frac{1}{8}\right)^{\gamma}$$

$$= \frac{P}{2}\left(\frac{1}{2^3}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{2}\right)^{5}$$

$$= \frac{P}{2\times 32} = \frac{P}{64}$$

48. (B)

$$\frac{R}{C_v} = 0.4$$

$$R = 0.4\, C_v$$

$$C_p - C_v = R$$

$$C_p = R + C_v = (0.4 + 1)\, C_v = 1.4\, C_v$$

$$\therefore \quad \frac{C_p}{C_v} = 1.4 = \gamma$$

$\therefore$ gas is made up of rigid diatomic molecules.

49. (D)

PVT $\qquad$ 2P, V/4, 2T

$$P_1V_1 = n_1RT_1 \; ; \quad P_2V_2 = n_2RT_2$$

$$\frac{n_1}{n_2} = \frac{P_1V_1 / RT_1}{P_2V_2 / RT_2} = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2V_2}$$

$$= \frac{PV}{T} \times \frac{2T \times 2}{2P \times \frac{V}{4}} = 4:1$$

50. (A)

$$\lambda_{max} T_1 = \lambda_{2max} T_2 \qquad E = \sigma A T_1^4$$

$$T_2 = \frac{\lambda_1 T_1}{\lambda_2}$$

$$\frac{E_2}{E_1} = \frac{T_2^4}{T_1^4}$$

$$\therefore \quad E_2 = E_1 \times \frac{\lambda_1^4 T_1^4}{\lambda_2^4} \times \frac{1}{T_1^4} = E \times \frac{\lambda_1^4}{\frac{16}{81}\lambda_1^4} = \frac{81}{16} E$$

51. (A)

$$\lambda_m T = k$$

$$E = \frac{\sigma A T^4}{A} \;\Rightarrow\; E \propto T^4 \qquad \therefore\; E \propto \frac{A}{\lambda^4}$$

$$E_x : E_y : E_z = \frac{1}{\lambda_x^4} : \frac{1}{\lambda_y^4} : \frac{1}{\lambda_z^4} = \frac{1}{(200)^4} : \frac{1}{(300)^4} : \frac{1}{(400)^4}$$

$$E_x > E_y > E_z$$

52. (A)

Initially $\quad P_1 = P$

$\qquad\qquad V_1 = V + V = 2V$

Finally $\quad P_2 = P_1 V_2 = \frac{V}{2}$

$$P_1V_1 = P_2V_2$$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{P \times 2V}{\frac{V}{2}} = 4P$$

53. (B)

If M is the mass of the gas then its density is given by

$$\rho = \frac{M}{V}$$

For one mole of the gas we have

$$pV = RT = NkT$$

where N is Avogadro's number

$$\therefore \ V = \frac{NkT}{p}$$

$$\therefore \ \rho = \frac{Mp}{nKT}$$

$$\frac{M}{N} = m = \text{mass of each molecule}$$

$$\therefore \ \rho = \frac{mP}{kT}$$

54. (B)

Theory question

55. (A)

$$E_1 = \sigma \times \pi R_1^2 \times T_1^4$$

$$E_2 = \sigma \times \pi R_2^2 \times T_2^4$$

$$\therefore \frac{E_2}{E_1} = \left(\frac{R_2}{R_1}\right)^2 \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{1}{3}\right)^2 (3)^4 = 9$$

$$\therefore E_2 = 9E_1 = 9E$$

56. (B)

57. (A)

Rate of radiation $\frac{dQ}{dt} \propto T^4$

$$T_1 = 17°C = 273 + 17 = 290\,K$$

$$T_2 = 307°C = 273 + 307 = 580\,K$$

$$\therefore \frac{\left(\frac{dQ}{dt}\right)_2}{\left(\frac{dQ}{dt}\right)_1} = \left(\frac{580}{290}\right)^4 = 2^2 = 16$$

58. (C)

59. (C)

For one mole of an ideal gas

$$PV = N k_B T$$

where N is Avogadro number

If M is the mass of the gas then the density is given by

$$\rho = \frac{M}{V} \quad \text{or} \quad V = \frac{M}{\rho}$$

$$\therefore \ P.\frac{M}{\rho} = Nk_BT$$

$\therefore \quad \rho = \dfrac{PM}{Nk_BT}$

But $\dfrac{M}{N} = m =$ mass of each molecule

$\therefore \quad \rho = \dfrac{Pm}{k_BT}$

60. (D)

$PV = \left[M L^{-1} T^{-2}\right]\left[L^3\right] = \left[M L^2 T^{-2}\right]$

$=$ Dimensions of energy

61. (A)

Force F is proportional to pressure P

$P = \dfrac{nRT}{V}$

If V is constant then $P \propto T$

$\therefore \quad F \propto T^x$ where $x = 1$

62. (D)

Kinetic energy depends only on temperature since the temperature is same, the kinetic energy will remain same.

63. (D)

Theory question

64. (D)

Power $\quad P = \sigma A T^4$

$= \sigma \times 4\pi R^2 \times T^4$

$$\therefore \quad \frac{P_1}{P_2} = \frac{R_1^2}{R_2^2}\frac{T_1^4}{T_2^4} = \frac{R_1^2}{R_2^2}\left(\frac{\lambda_2}{\lambda_1}\right)^4 \qquad \left[\because \lambda \propto \frac{1}{T}\right]$$

$$= \left(\frac{3}{2}\right)^2 \cdot \left(\frac{4}{3}\right)^4 = \frac{9}{4} \times \frac{4 \times 64}{9 \times 9} = \frac{64}{9}$$

65. (A)

Emissive power $\quad P = \sigma e T^4$

$\therefore \quad \sigma e_1 T_1^4 = \sigma e_2 T_2^4$

$$\frac{T_1^4}{T_2^4} = \frac{e_2}{e_1} = 4$$

$$\therefore \quad \frac{T_1}{T_2} = \sqrt{2}$$

66. (D)

$\lambda_2 - \lambda_1 = 4\mu m \qquad T_1 = 3T_2$

$\lambda_1 T_1 = \lambda_2 T_2 \qquad \therefore \lambda_1 3T_2 = \lambda_2 T_2$

$\lambda_2 = 3\lambda_1$

$3\lambda_1 - \lambda_1 = 4\ \mu m$

$2\lambda_1 = 4\ \mu m$

$\lambda_1 = 2\mu m \qquad \therefore \lambda_2 = 6\ \mu m$

67. (A)

$$E = \sigma \times 4\pi R^2 \times T^4$$

$$E' = \sigma \times 4\pi(3R)^2 \times \left(\frac{T}{3}\right)^4$$

$$\therefore \frac{E'}{E} = \frac{(3)^2}{(3)^4} = 9$$

$$\therefore E' = 9E$$

68. (D)

The amount of heat required to increase the internal energy is

$$\left(Q - \frac{Q}{3}\right) = \frac{2}{3}Q$$

For a diatomic gas, the amount of heat required to increase the internal energy is $C_v = \frac{5}{2}R$

$$\therefore \frac{2}{3}Q = \frac{5}{2}R$$

$$\therefore Q = \frac{15}{4}R$$

69. (A)

$$\nu_{monoatomic} = 1 + \frac{2}{3} = \frac{5}{3}$$

$$\nu_{diatomic} = 1 + \frac{2}{5} = \frac{7}{5}$$

$$\therefore \frac{\nu_{monoatomic}}{\nu_{diatomic}} = \frac{5/3}{7/5} = \frac{25}{21}$$

70. (A)

The r.m.s. velocity of a molecule is given by

$$C = \sqrt{\frac{3RT}{M}}$$

$$\therefore \frac{C_H}{C_o} = \sqrt{\frac{T_H}{T_o} \cdot \frac{M_o}{M_H}}$$

$$\therefore C_H = C_o$$

$$\frac{T_H}{T_o} \cdot \frac{M_0}{M_H} = 1, \qquad T_H = 47 + 273 = 320$$

$$\therefore T_H = \frac{M_H}{M_o} \cdot T_o = \frac{2}{32} \cdot 320 = 20\text{ K}$$

71. (A)

$$\lambda_m T = \text{constant}$$

$$\therefore \frac{\lambda_m}{\lambda_m} = \frac{T}{T'} = \frac{2200}{3300} = \frac{2}{3}$$

$$\therefore \lambda'_m = \frac{2}{3}\lambda_m$$

72. (B)

$$C_v = n \times \frac{R}{2};$$

$$C_p = C_v + R = \frac{nR}{2} + R = \left(\frac{n}{2}+1\right)R$$

$$\therefore \frac{C_p}{C_v} = \frac{\left(\frac{n}{2}+1\right)R}{\frac{nR}{2}} = \left(1+\frac{2}{n}\right)R$$

73. (C)

$$E = \sigma A T^4$$

$$\therefore \frac{E_2}{E_1} = \frac{A_2}{A_1} \cdot \left(\frac{T_2}{T_1}\right)^4$$

$$A_2 = \frac{A_1}{9} \quad \therefore \frac{A_2}{A_1} = \frac{1}{9}$$

$$T_1 = 27 + 273 = 300 \text{ k}$$

$$T_2 = 327 + 273 = 600 \text{ k}$$

$$\therefore \frac{T_2}{T_1} = \frac{600}{300} = 2$$

$$\therefore \frac{E_2}{E_1} = \frac{1}{9} \times (2)^4 = \frac{16}{9}$$

$$\therefore E_2 = \frac{16}{9} E_1 = \frac{16}{9} E$$

74. (A)

$$T_1 = 27°C = 27° + 273 = 300 \text{ k}$$

$$T_2 = 327°C = 327° + 273 = 600 \text{ k}$$

$$\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{600}{300}} = \sqrt{2}$$

75. (A)

$$dQ = dU + dW$$

$$C_p dT = C_v dT + R\, dT$$

$$C_p = C_v + R$$

For a diatomic gas $C_v = \frac{5}{2}R$, $C_p = \frac{7}{2}R$

$$\therefore \Delta Q : \Delta U : \Delta W :: \frac{7}{2}R : \frac{5}{2}R : R :: 7 : 5 : 2$$

76. (B)

R.M.S. velocity $C = \sqrt{\frac{3RT}{M}}$

$\therefore \; C \propto \sqrt{\frac{T}{M}}$

$$\frac{C'}{C} = \sqrt{\frac{T'}{T}\frac{M}{M'}} = \sqrt{\frac{1}{2}\times\frac{1}{2}} = \frac{1}{\sqrt{4}} = \frac{1}{2}$$

$\therefore \; C' = \frac{C}{2} = \frac{200}{2} = 100 \text{ m/s}$

77. (D)

Stefan;s law : $\frac{Q}{t} = \sigma A T^4$

$\therefore \; \sigma = \frac{Q}{tAT^4}$

Wien's law : $\lambda T = b$

$\therefore \; \sigma b = \frac{Q\lambda T}{tAT^4} = \frac{Q\lambda}{tAT^3} = \frac{ML^2T^{-2}\cdot L}{T\cdot L^2\cdot K^3}$

$= L^1M^1T^{-3}K^{-3}$

78. (B)

Athermanous substances do not conduct heat.

79. (C)

$\frac{R}{C_v} = 0.67$

$\therefore \; R = 0.67\, C_v$

$\therefore \; C_p - C_v = 0.67\, C_v$

$\therefore \; C_p = 1.67\, C_v$

$\therefore \; \gamma = \frac{C_p}{C_v} = 1.67$

For a monoatomic gas $\gamma = \frac{5}{3}$ or 1.67

80. (D)

$$\frac{v_{mono}}{v_{diatomic}} = \frac{1+\frac{2}{3}}{1+\frac{2}{5}} \qquad f_{mono} = 3,\ f_{dia} = 5$$

$$= \frac{5/3}{7/5} = \frac{25}{21}$$