09. Kinetic Theory of Gases and Radiation

9.0 Introduction

In gases, the intermolecular forces are very weak and their molecule may fly apart in all directions. So the gas is characterized by the following properties.

i) Gas has no shape and size and can be obtained in a vessel of any shape or size.

ii) It expands indefinitely and uniformly to fill the available space.

iii) It exerts pressure on its surroundings.

iv) Intermolecular forces in a gas are minimum.

v) They can easily compressed and expand.

1. **Boyle's law:** For a given mass of an ideal gas at constant temperature, the volume of a gas is inversely proportional to its pressure.

$$V \propto \frac{1}{P} \text{ or } PV = \text{constat}$$

$$\therefore \quad P_1V_1 = P_2V_2$$

i) $PV = P\left(\frac{m}{\rho}\right) = \text{constant}$

$$\therefore \quad \frac{P}{\rho} = \text{const.}$$

$$\because \quad \frac{P_1}{\rho_1} = \frac{P_2}{\rho_2}$$

(As volume $V = m/\rho$ and m = constant)

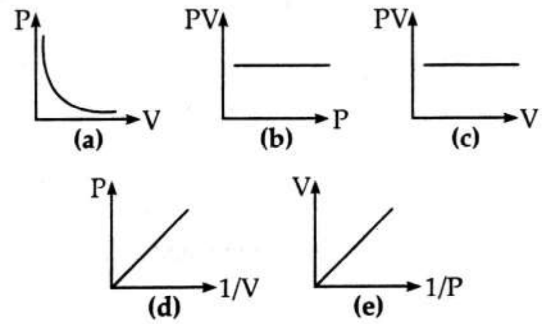
ii) $PV = P\left(\frac{N}{n}\right) = \text{constant}$

$$\therefore \quad P = \text{constant or } \frac{P_1}{n_1} = \frac{P_2}{n_2}$$

iii) As number of molecules per unit volume $n = \frac{N}{V}$

$$\therefore \quad V = \frac{N}{n} \text{ also } N = \text{Constant}$$

iv) Graphical representation: If m and T are constant



2. **Charle's law:** If the pressure remaining constant, the volume of the given mass of a gas is directly proportional to its absolute temperature.

i.e. $V \propto T \quad \therefore \quad \frac{V}{T} = \text{constant}$

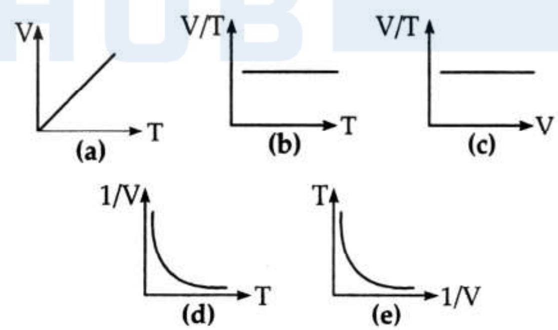
$$\therefore \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

i) $\frac{V}{T} = \frac{m}{\rho T} = \text{constant (As volume } V = \frac{m}{\rho}\text{)}$

or $\rho T = \text{constant}$

$$\therefore \quad \rho_1 T_1 = \rho_2 T_2.$$

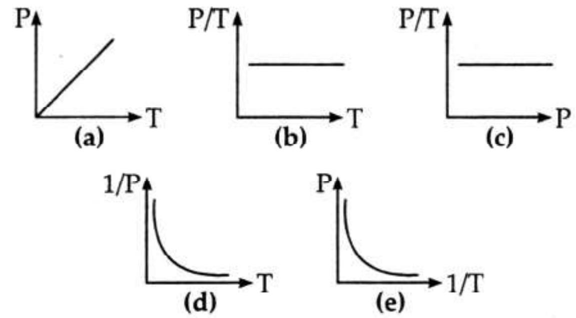
ii) Graphical representation if m and P are constant.



3. **Gay – Lussac's law or pressure law:** The remaining constant, the pressure of a given mass of a gas is proportional to its absolute temperature.

$$P \propto T \text{ or } \frac{P}{T} = \text{constant} = \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Graphical representation: If m and V are constant.



4. **Avogadro's law:** Equal volume of all the gases under similar conditions of temperature and pressure contain equal number of molecules i.e. $N_1 = N_2$.
5. **Grahm's law of diffusion:** When two gases at the same pressure and temperature are allowed to diffuse into each other, the rate of diffusion of each gas is inversely proportional to the square root of the density of the gas i.e.

$$r \propto \frac{1}{\sqrt{\rho}} \propto \frac{1}{\sqrt{M}}$$

(M is the molecular weight of the gas)

$$\therefore \quad \frac{r_1}{r_2} = \sqrt{\frac{\rho_2}{\rho_1}}$$

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

If V is the volume of gas diffused in t second, then

$$r = \frac{V}{t} \qquad \therefore \quad \frac{r_1}{r_2} = \frac{V_1}{V_2} \times \frac{t_2}{t_1}.$$

Equation of state or ideal gas equation:

The equation which relates the pressure (P) volume (V) and temperature (T) of the given state of an ideal gas is known as ideal gas equation or equation of state.

For 1 mole of gas $\frac{PV}{T} = R$ (constant)

$\therefore$ $PV = RT$

where R = universal gas constant.

Table: Different forms of gas equation

Quantity of gas	Equation	Constant
1 mole gas	$PV = RT$	R = universal gas constant
n mole gas	$PV = nRT$	
1molecule of gas	$PV = (R/N)\,T = kT$	k = Boltzmann's constant
N molecules of gas	$PV = NkT$	
1 gm of gas	$PV = (R/M)\,T = rT$	r = Specific gas constant
m gm of gas	$PV = mrT$	

1 **Universal gas constant (R) :** Universal gas constant signifies the work done by (or on) a gas per mole per kelvin.

$$R = \frac{PV}{nT} = \frac{\text{Pressure} \times \text{Volume}}{n \times \text{Temperature}}$$

$$= \frac{\text{Work done}}{n \times \text{Temperature}}$$

i) At STP the value of universal gas constant is same for all gases R = 8.31 J/mol K = 1.98 C/ mol K = 2 C/mol K.

ii) Dimensions of R = $[L^2M^1T^{-2}K^{-1}]$

2. **Boltzmann's constant (k) :** It is represented by per mole gas constant

$$k = \frac{R}{N} = \frac{8.31}{6.023 \times 10^{23}} = 1.38 \times 10^{-23} \text{J/K}$$

It's dimension are $[L^2M^1\ T^{-2}\ K^{-1}]$

3. **Specific gas constant (r) :** It is represented by per gram gas constant i.e., r = R/M. It's unit J/gm K and dimensions are $[L^2T^{-2}\ K^{-1}]$.

Since the value of M is different for different gases. Hence the value of r is different for different gases. It is maximum for hydrogen $r_H = R/2$.

Real Gases:

1. The gases actually found in nature are called real gases.
2. They do not obeys gas laws.
3. The quantity PV/RT is called the compressibility factor and should unit for an ideal gas.
4. A real gas behaves as ideal gas most closely at low pressure and high temperature also can actual gas can be liquefied most easily which deviates most from an ideal gas behaviour at low temperature and high pressure.

Characteristics of heat:

1. Heat is a form of energy that flows between two bodies due to difference in their temperatures.

2. Heat flows from a body at higher temperature to a body at lower temperature until they attain same temperature.
3. A body at low temperature may possess more heat energy than body at high temperature.
4. Heat is a scalar quantity with dimensions $[L^2M^1\ T^{-2}]$.
   Units: calorie common or practical unit Joule (SI).
5. Calorie is the quantity of heat required to raise the temperature of 1 gm of water through 1°C.
6. Mean calorie or standard calorie is the amount of heat required to raise the temperature of 1 gm of water from 14.5 °C to 15.5 °C.
7. When heat is given to a substance usually its temperature increases. During change of state temperature does not change.
8. Temperature of a body may change without heating (Adiabatic compression or expansion of a gas).

9.1 Assumption of ideal gases (or kinetic theory of gases)

Kinetic theory of gases relates the macroscopic properties of gases (such as pressure, temperature etc.) to the microscopic properties of the gas molecules (such as speed, momentum, kinetic energy of molecule etc.). Actually it attempts to develop a model of the molecular behaviour which should result in the observed behaviour of an ideal gas. It is based on following assumptions:

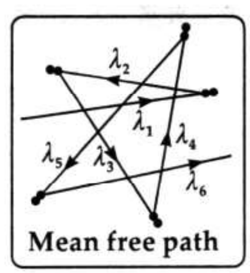
1. Every gas consists of extremely small particles known as molecules. The molecules of a given gas are all identical but are different than those of another gas.
2. The molecules of a gas are identical, spherical rigid and perfectly elastic point masses.
3. Their size is negligible in comparison to intermolecular distance (10^{-9} m).
4. The volume of a gas molecules is negligible in comparison to the volume of gas. (The volume of molecules is only 0.01% of the volume of the gas).
5. Molecules of a gas keep on moving randomly in all possible direction with all possible velocities.
6. The speed of gas molecules lies between zero to infinity.
7. The gas molecules keep on colliding among themselves as well as with the walls of containing vessel. These collisions are perfectly elastic.
8. The time spent in a collision between two molecules is negligible in comparison to time between two successive collisions.
9. The number of collisions pre unit volume in a gas remains constant.
10. No attractive or repulsive force acts between gas molecules.
11. Gravitational attraction among the molecules is ineffective due to extremely small masses and very high speed of molecules.
12. Molecules constantly colloid with the walls of container due to which their momentum changes. The changes in momentum is transferred to the walls of the container. Consequently pressure is exerted by gas molecules on the walls of container.
13. The density of gas is constant at all points of the container.

9.2 Mean free path

1. The distance travelled by a gas molecule between two successive collisions is known as free path.

$$\bar{\lambda} = \frac{\text{Total distance travelled by a gas molecule between successive collisions}}{\text{Total number of collisions}}$$

During two successive collisions, Iimolecule of a gas moves in a straight line with constant velocity and let $\lambda_1, \lambda_2, \lambda_3$ .... be the distance travelled by a gas molecule during n collisions respectively, then the means free path of a gas molecule is given by



$$\bar{\lambda} = \frac{\lambda_1 + \lambda_2 + \lambda_3 + ... + \lambda_n}{n}$$

2. $\bar{\lambda} = \dfrac{1}{\sqrt{2}\pi n d^2}$

where d = Molecular diameter of the gas molecules.

n = Number of molecules per unit volume.

3. As PV = n RT = n NkT

$$\therefore \quad \frac{N}{V} = \frac{P}{kT}$$

= n

= No. of molecule per unit volume

$$\bar{\lambda} = \frac{1}{\sqrt{2}} \times \frac{kT}{\pi d^2 P}$$

4. $$\bar{\lambda} = \frac{1}{\sqrt{2}\pi n d^2} = \frac{m}{\sqrt{2}\pi (mn) d^2} = \frac{m}{\sqrt{2}\pi d^2 \rho}$$

As m is mass each molecule, m n is mass per unit volume of the gas and ρ is the density of the gas.

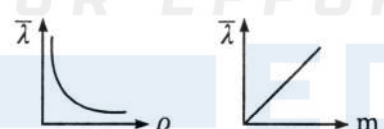
5. If average speed of molecule is c, then

$$\bar{\lambda} = c \times \frac{t}{N} = c \times T$$

where N = Number of collision in time t, T = time interval between two collisions.

6. As $\bar{\lambda} \propto \frac{1}{\rho}$ and $\bar{\lambda} \propto m$

The mean free path is inversely proportional to the density of a gas and directly proportional to the mass of molecule.

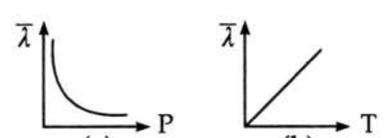


(a) (b)

7. As $\bar{\lambda} = \frac{1}{\sqrt{2}} \times \frac{kT}{\pi d^2 P}$.

For constant volume and hence constant number density n of gas molecules, P/T is constant so that $\bar{\lambda}$ will not depend on P and T.

But if volume of given mass of a gas is allowed to change with P or T, then $\bar{\lambda} \propto T$, at constant pressure and $\bar{\lambda} \propto 1/P$ at constant temperature.



(a) (b)

9.3 Pressure exerted by the gas molecules

1. The change in momentum of a gas molecule depends upon mass of the gas (nature of the gas), speed of gas molecule and temperature of the gas i.e. $-2mC_1$.
2. The change in momentum for n collision of the gas on the wall of container is – 2 mnC.
3. The number of collision per second of the gas depends upon the temperature of the gas, speed of the gas molecule and size of the container i.e. $C/2l$.
4. The force exerted by the gas molecule on the wall, of container depends upon mass, velocity of gas and dimension of the container.
5. The time between two successive collision on the same wall by the same molecule is,

$$\Delta t = \frac{2l}{C_1}$$

6. The frequency of collision of a molecule is,

$$n = \frac{C_1}{2l}$$

7. The force exerted on the wall by successive collisions of a molecule on the wall is,

$$\frac{\Delta P}{\Delta t} = \frac{mC_1^2}{l}$$

8. The pressure of a gas depends upon speed of a molecule.
9. The total pressure exerted by the gas molecule in a container is directly affected by the number of molecules. ($P \propto N$)
10. The graph between pressure and reciprocal of volume for a perfect gas at constant temperature is straight line passing through origin.
11. Pressure exerted by the gas molecule is directly proportional to the density provided that other factors remain constant i.e. $P \propto \rho$.

RMS speed:

1. At constant temperature, if pressure is changed, then C_{rms} does not change.
2. At constant temperature, C_{rms} of the gas does not depends upon pressure and density.
3. C_{rms} velocity is maximum for hydrogen gas i.e.

$$C_{rms} \propto \frac{1}{\sqrt{M}}.$$

4. The mean speed of the gas molecule is less than root mean square speed of the molecules i.e.
   $C < C_{rms}$
5. The rms speed of the gas molecule is directly proportional to the square root of absolute temperature. $C_{rms} \propto \sqrt{T}$
6. A container contains equal number of molecules of hydrogen and carbondioxide. If a fine bore is made in the container. The hydrogen gas leaks out faster since Crms of hydrogen is greater than Crms of carbondioxide.
7. The two gases have the same temperature. The rms velocities of the gas molecules are different.
   $$\text{Since } C_{rms} = \sqrt{\frac{3RT}{M}}$$
8. The rms speed of the gas molecule is independent of the number of molecules in a container.

Kinetic energy:

1. Kinetic energy per kg of a gas depends upon temperature as well as nature of the gas.
2. The kinetic energy of the gas is directly affected by the number of the gas molecules in a container. (KE $\propto$ N)
3. A vessel is filled with a mixture of the two different gases. The mean kinetic energies per molecule of both the gases will be equal.
   Since K.E. per molecule = 3/2 KT. It depends upon temperature only.
4. The translational kinetic energy of the gas molecule is directly proportional to the absolute temperature of the gas.
5. The value of Boltzmann constant
   $$k = \frac{R}{N_0} = 1.38 \times 10^{-23} \text{ J/K}$$
6. Kinetic energy per unit volume of a gas is directly proportional to the pressure of the gas.
7. A container contains a mixture of the two different gases. The mean velocities will be different. Since root mean square velocity not only depends upon the temperature but also the mass of the gas.
8. The escape velocity for the surface of moon is nearly 2.5 km/s.
9. At absolute zero of temperature, the molecules may possess only potential energy. So, the absolute zero of temperature may appropriately be called zero kinetic energy temperature. The molecular motions ceases.
10. The diatomic gas has translational, rotational and vibrational degrees of freedom.
11. When the volume of gas is increased the pressure is decreased.
12. If the radius of a bubble is doubled as it rises from the bottom of a lake to its surface. Its volume will become 8 times original volume i.e. $V \propto r^3$
13. In an ideal gas intermolecular forces are absent.
14. The number of collisions suffered by a molecule in one second is called collision frequency.
15. At absolute zero of temperature is the temperature at which all the molecular motion ceases (stops).
16. The change in the gravitational potential energy is negligible as compared to the mean kinetic energy of the molecule.
17. The air pressure in the tyres of an automobile increases slightly when the automobile moves for a long time since pressure ex: temperature. Work done against friction is converted into heat due to which there is a slightly increase in the temperature.
18. The gas is in a steady state, a state of perfect molecular chaos in which there is uniformity of temperature pressure density etc.
19. **Relation between pressure and kinetic energy :** We know that,

$$P = \frac{1}{3}\frac{mN}{V}c^2_{rms} = \frac{1}{3}\frac{M}{V}c^2_{rms}$$

$$\therefore \quad P = \frac{1}{3}\rho\, c^2_{rms} \qquad \text{..... (i)}$$

[As M = mN = Total mass of the gas and ρ = M/V]

$$\therefore \quad \text{K.E./volume } E = \frac{1}{2}\left(\frac{M}{V}\right)c^2_{rms}$$

$$= \frac{1}{2}\rho\, c^2_{rms} \qquad \text{..... (ii)}$$

From equation (i) and (ii), we get,

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

The pressure exerted by an ideal gas is

numerically equal to the two third of the mean kinetic energy of translation per unit volume of the gas.

20. **Effect of mass, volume and temperature on pressure:**

$$P = \frac{1}{3}\frac{mN}{V}c^2_{rms} \text{ or } P \propto \frac{(mN)T}{V} \quad [\text{As } c^2_{rms} \propto T]$$

21. If volume and temperature of a gas are constant $P \propto mN$ i.e. Pressure $\propto$ (Mass of gas).
    If mass of a gas is increased, number of molecules and hence number of collision per second increases i.e. pressure will increase.
22. If mass and temperature of a gas are constant. $P \propto (1/V)$. If volume decreases, number of collisions per second will increase due to lesser effective distance between the walls resulting in greater pressure.
23. If mass and volume of gas are constant,
    $P \propto (c_{rms})^2 \propto T$.
    If temperature increases, the mean square speed of gas molecules will increase and as gas molecules are moving faster, they will collide with the walls more often with greater momentum resulting in greater pressure.

Kinetic energy of ideal gas:

1. Kinetic energy per molecule of gas does not depends upon the mass of the molecule but only depends upon the temperature of the gas. As $E = 3/2\, kT$ or $E \propto T$ i.e. molecules of different gases say He, H_2 and O_2 etc., at same temperature will have same translational kinetic energy though their r.m.s. speed are different.
2. For two gases at the same temperature,
    $m_1\,(crms)_1^2 = m_2\,(crms)_2^2$.
3. Kinetic energy per mole of gas depends only upon the temperature of gas.
4. Kinetic energy per gram of gas depend upon the temperature as well as molecular weight (or mass of one molecule) of the gas.

$$E_{gram} = \frac{3}{2}\frac{k}{m}T \qquad \therefore \quad Egram \propto \frac{T}{m}$$

5. From the above expressions it is clear that higher the temperature of the gas, more will be the average kinetic energy possessed by the gas molecules at T = 0. E = 0 i.e. at absolute zero the molecular motion stops.

9.4 Various speed of gas molecules

1. **Root mean square speed:** It is defined as the square root of mean of squares of the speed of different molecules.

$$\text{i.e.} \quad c_{rms} = \sqrt{\frac{c_1^2 + c_2^2 + c_3^2 + c_4^2 + ...}{N}} = \sqrt{c^2}$$

2. From the expression of pressure $P = \frac{1}{3}\rho\, c^2_{rms}$

$$\therefore \quad c_{rms} = \left(\frac{3P}{\rho}\right) = \left(\frac{3PV}{\text{Mass of gas}}\right)$$

$$= \left(\frac{3RT}{M}\right) = \left(\frac{3kT}{m}\right)$$

Where $\rho = \dfrac{\text{Mass of gas}}{\text{Volume}}$

= Volume Density of the gas

$M = n \times m$

$\therefore$ PV = nRT where R = kN

where k is Boltzmann's constant

$m = \dfrac{M}{N_A}$ = mass of each molecule.

3. With rise in temperature rms speed of gas molecules increase as $c_{rms} \propto \sqrt{T}$.
4. With increase in molecular weight rms speed of gas molecule decreases as $c_{rms} \propto \dfrac{1}{\sqrt{M}}$. Rms speed of hydrogen molecules is four times that of oxygen molecules at the same temperature.
5. Rms speed of gas molecules is of the order of km/s e.g. at NTP for hydrogen gas

$$(c_{rms}) = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\times 8.31\times 273}{2\times 10^3}} = 1840 \text{ m/s.}$$

6. Rms speed of gas $= \sqrt{\dfrac{3}{\gamma}}$ speed of sound in gas

$$\text{As } c_{rms} = \sqrt{\frac{3RT}{M}} \text{ and } v_s = \sqrt{\frac{\gamma RT}{M}}$$

$$\therefore \quad c_{rms} = \sqrt{\frac{3}{\gamma}}\, v_s.$$

7. Rms speed of gas molecules does not depends on the pressure of gas (if temperature remains constant) because $P \propto \rho$ (Boyle's law) if pressure is increased n times then density will also increases by n times but c_{rms} remains constant.
8. Moon has no atmosphere because c_{rms} of gas molecules is more than escape velocity (v_e).
   A planet or satellite will have atmosphere only if $c_{rms} < v_e$
9. At T = 0, $c_{rms} = 0$ i.e. the rms speed of molecules of a gas is zero at 0 °K, This temperature is called absolute zero.

9.5 Specific heat

1. The quantity of heat required by one gram of a substance to raise its temperature by 1°C is called its specific heat (s).

   Units: Cal/gm °C (CGS)
   J/kgK (SI)

   Dimensions : $[L^2M^0T^{-2}\ K^{-1}]$
2. Of all solids and liquids water has the highest specific heat.
   Its value is 1 cal/gm °C or 4180 J/kg K (J = 4.18 J/Cal).
3. Specific heat of ice is 0.5 cal/gm °C or 2090 J/kg K.
   Specific heat of steam is 0.45 cal/gm = C or 1881 J/kg K.
   Specific heat of copper is 0.1 cal/gm °C or 418 J/kg K.
   Specific heat of lead is 0.03 cal/gm = C or 125.4 J/kg K.
4. Of all gases hydrogen has the highest specific heat (3.5 cal/gm °C)
5. Specific heat of a substance during its change of state is infinity.
6. Specific heat of a substance depends on temperature and nature of material.
   (In general for heavier materials it is less)
7. Specific heat of saturated water vapour is negative i.e. in order to raise the temperature, it loses a certain quantity of heat.
8. As the temperature of water increases from 0°C to 100°C, its specific heat decreases upto 35°C (minimum) and after that increases.
9. As specific heat of water is more, it is used in radiators and hot water bags.
10. In liquids, specific heat is minimum for mercury.
11. The specific heat of the substance is independent of the mass of the substance.
12. It depends upon the temperature of the substance.
13. The specific heat of the substance depends 'upon the conditions of pressure and volume.
14. Heat lost or gained by a substance is $Q = mc\,\theta$ where m is mass, c is specific heat and θ is change in temperature.

$$\text{Specific heat } c = \frac{Q}{m\theta} \quad \text{or} \quad c = \frac{1}{m}\left(\frac{dQ}{d\theta}\right)$$

15. If two substances of masses m_1, m_2 specific heats c_1, c_2 at initial temperatures θ_1 and θ_2 are mixed then final temperature of the mixture is,

$$\theta_{mix} = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_2 + m_2c_2}$$

16. If two liquids of specific heats c_1, c_2 having masses m_1, m_2 are mixed at the same temperature, effective specific heat of the mixture is,

$$c_{mix} = \frac{m_1c_2 + m_2c_2}{m_1 + m_2}$$

If $m_1 = m_2$ then $c = \dfrac{c_1 + c_2}{2}$

If V_1, V_2 are volumes and ρ_1, ρ_2 are their densities, then

$$c = \frac{\rho_1V_1c_1 + \rho_2V_2c_2}{\rho_1V_1 + \rho_2V_2}$$

If $V_1 = V_2$ then $c = \dfrac{\rho_1c_1 + \rho_2c_2}{\rho_1 + \rho_2}$

17. If same quantity of heat is given to two different substances and θ_1 and θ_2 are the changes in their temperatures, $m_1c_1\theta_1 = m_2c_2\theta_2$.
18. Specific heat is also known as specific heat capacity. At the boiling point specific heat of water is infinity.
19. Heat lost or gained by a system depends not only on the initial and final states but also on the path taken by that process.
20. When heat is supplied to a body, if greater the

specific heat of a substance, less will be the change in temperature.

21. Molar specific heat capacity C = cM, where c is principal specific heat and M is molecular weight of the 'substance.
22. The specific heat of water at 15°C is 1 cal/g °C.
23. The specific heat of any substance in an adiabatic process is zero. For adiabatic process dq = 0

$$c = \frac{dq}{m \times \Delta\theta}$$

$$= \frac{0}{md\theta} = 0$$

24. The specific heat of any substance in isothermal process is infinity. For isothermal process $d\theta = 0$

$$\therefore \quad c = \frac{dq}{m \times 0} = \infty$$

25. The gases have any values of specific heat rising from zero to infinity.
26. Adiabatic constant γ : It is the ratio of C_p to C_v i.e.

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

27. It's value is different for different types of the gases i.e. for diatomic gas it is 1.4 monatomic gas is 1.67, triatomic gas is 1.33 (nonlinear) for linear it is 1.2857.
28. For poly atomic gas it is (1 + 2/n), where n is the number of degrees of freedom.
29. The C_p is greater than C_V. But in anomalous behaviour of water i.e. a to 4°C of water $C_P < C_V$.
30. The difference between C_P and C_V is equal to the thermal equivalent of the work done by the gas in expanding against external pressure.
31. If C_P and C_V are measured in units of heat, then,

$$C_P - C_V = \frac{R}{J}$$

where J is called mechanical equivalent a heat.

32. For 1 gm of gas,

$c_p - c_v = r$

Both c_p and c_v are measured in units of work.

$$c_p - c_v = \frac{r}{J}$$

Both c_p and c_v are measured in units of heat.

Heat capacity:

1. The quantity of heat required to raise the temperature of a given substance by 1°C is called its thermal capacity.
2. It is the product of mass and specific heat.

   Units: cal/°C, J/K

   Dimensions: $[L^2MT^{-2}K^{-1}]$

3. Thermal capacity = mc = $\frac{Q}{\theta}$ (or) $\left(\frac{dQ}{d\theta}\right)$

9.6 Degrees of freedom and law of equipartition of energy

The total number of independent variables that must be known to describe configuration of a mechanical system may change is called the degrees of freedom of that system.

1. The total number of independent ways in which the particles of a system can take up energy is called the degrees of freedom of that system.
2. Relation between degrees of freedom and adiabatic constant (γ).
3. For monoatomic gas such as argon, helium, neon etc. of a single gas molecule. All the energy associated is only translation K.E.

$$\therefore \quad \text{Total energy } E = \frac{3}{2} RT$$

Differentiating with respect to 'T'

$$\frac{dE}{dT} = \frac{3}{2} R$$

$$\text{But} \quad \frac{dE}{dT} = C_v$$

$$\therefore \quad C_v = \frac{3}{2} R$$

We know that,

$$C_p - C_v = R$$

$$C_p = \frac{3}{2} R + R$$

$$C_p = \frac{5}{2} R$$

By definition of γ

$$\gamma = \frac{C_p}{C_v} = \frac{5/2R}{3/2R} = \frac{5}{3} = 1.66$$

4. For diatomic gas such as hydrogen, oxygen, nitrogen etc., consists at two atoms bound together. Total energy is,

$$E = \frac{5}{3}\ RT$$

Three degrees of freedom due to translational motion and two degrees of freedom due to rotational motion.

Differentiating with respect to 'T'

$$\frac{dE}{dT} = \frac{5}{2}\ R$$

$$C_v = \frac{5}{2}\ R$$

$$C_p - C_v = R$$

$$C_p = C_v + R = \frac{5}{2}\ R + R$$

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

By definition of gama i.e. adiabatic constant

$$\gamma = \frac{C_p}{C_v} = \frac{7/2R}{5/2R} = \frac{7}{5}$$

$$\gamma = 1.4$$

5. It should be noted that at high temperature nearly 5000 K, the diatomic molecules possesses additional two degrees of freedom due to vibrational motion.
6. For nonlinear triatomic gas molecules like O_3 in which three atoms are present at the vertices of triangle.

Total energy is,

$$E = \frac{6RT}{2} = 3RT$$

Differentiating above equation with respect to 'T'

$$C_v = \frac{dE}{dT} = 3\ R$$

$$C_p = 4\ R$$

$$\frac{C_p}{C_v} = \frac{4R}{3R} = 1.33$$

7. For linear arrangement total degrees of freedom are (7).
8. In general for n degrees of freedom total energy of the gas is,

$$E = \frac{nRT}{2}$$

$$C_v = \frac{dE}{dT} = \frac{nR}{2}$$

$$C_p = C_v + R$$

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

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

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

9.7 Maxwell distribution

At a given temperature, the root–mean–square speed of the molecules of a gas is constant. However, the speeds of individual molecules vary over a wide range. James Clerk Maxwell was the first to solve the problem of the distribution of speeds in a gas containing a large number of molecules. Maxwell derived mathematical relation for the most probable distribution of speeds among the molecules of a gas (in the steady state). This relation can be called mathematical statement of a law known as Maxwell's law of distribution of molecular speeds. This law is based on statistical mechanics because the number of molecules present even in a small volume of the gas is very large.

1. **Most probable speed:** The particles of a gas have a range of speeds. This is defined as the speed which is possessed by maximum times of total number of molecules of the gas. e.g. if speeds of 10 molecules of a gas are 1, 2, 2, 3, 3, 3, 4, 5, 6, 6 km/s, then the most probable speed is 3 km/s, as maximum times of total molecules possess this speed.

Most probable speed $c_{mp} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2RT}{M}}$

$$= \sqrt{\frac{2kT}{m}}$$

1. **Average speed :** It is the arithmetic mean of the speeds of molecules in a gas at given temperature.

$$c_{av} = \frac{c_1 + c_2 + c_3 + c_4 + ...}{N}$$

According to kinetic theory of gases,

Average speed $c_{av} = \sqrt{\frac{8P}{\pi\rho}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8kT}{\pi m}}$.

Relation between c_{av}, c_{rms} and c_{mp} :

1. $c_{av} = \sqrt{\frac{8kT}{\pi m}} = \sqrt{\frac{8}{3\pi}} \times \sqrt{\frac{3kT}{M}}$

$$= \sqrt{\frac{8}{3\pi}}\, c_{rms} = 0.92\, c_{rms}$$

2. $c_{mp} = \sqrt{\frac{2kT}{m}} = \sqrt{\frac{2}{3}} \times \sqrt{\frac{3kT}{M}}$

$$= \sqrt{\frac{2}{3}}\, c_{rms} = 0.816\, c_{rms}$$

3. $c_{rms} : c_{av} : c_{mp} = \sqrt{3} : 1.60 : 1.41 = \sqrt{3} : 1.6 : \sqrt{2}$
4. $c_{rms} > c_{av} > c_{mp}$

9.8 Thermodynamics

1. The first law of thermodynamics is essentially a restatement of the law of conservation of energy, i.e. energy can neither be created nor be destroyed but may be converted from one form to another.
2. In applying the first law of thermodynamics, all the three quantities, i.e., dQ, dU and dW must be expressed in the same units. i.e. either in units of work or in units of heat.
3. This law is applicable to every process in nature.
4. This law is applicable to all the three phases of matter i.e., solid, liquid and gas.
5. dU may be any type of internal energytr anslational kinetic energy, rotational kinetic energy, binding energy etc. It is a characteristic of the state of a system.
6. dW may be any type of work done by the system. It depends upon the manner in which the system has been changed from one state to another. So, it is not a characteristic of the state of the system. The same is true for dQ.
7. The first law of thermodynamics introduces the concept of internal energy.
8. For a given value of Q_1, the smaller the value of Q_2, the higher is the efficiency of the heat engine.
9. The value of η will be one, i.e. efficiency of the heat engine will be 100% if the value of Q_2 is zero. In such a case, the whole of the heat extracted from the source will be converted into mechanical work. No heat will be rejected to the sink. But his is impossible. Thus, we conclude that efficiency cannot be 100%.
10. For the sake of discussion, let us discuss the purely hypothetical 55%, i.e. at the most only 55% of the total heat energy extracted from the source is converted into mechanical work. Total efficiency of a stearn engine varies from 12% to 17%. The maximum efficiency of a diesel engine is 40% while that of a petrol engine is only up to 26%.
11. The low efficiency of a heat engine is not due to the bad designing of a heat engine but it is consequence of a certain law of nature. It was shown by a French engineer Sadi Carnot that there is something in nature which forbide the complete conversion of heat into work.

Internal Energy (U) :

1. The energy possessed by a system due to molecular motion and molecular configuration is called internal energy (denoted by U).
2. Internal energy $U = U_k + U_P$
   U_k is internal K.E. due to molecular motion and U_P is internal P.E. due to molecular configuration.
3. Internal energy of a gas is independent of pressure and volume. It depends only on temperature.
4. For a perfect or ideal gas $U = U_k$ i.e. internal energy is only due to K.E. of molecules. As there is no intermolecular forces, among the molecules, $U_P = 0$.
5. For an ideal gas internal energy or K.E. of all molecules depends only on temperature.
6. If temperature is constant internal energy is constant ($dU = 0$). The internal energy increases or decreases as temperature of gas increases or decreases respectively.
7. Internal energy of a system can be increased by

giving heat to the system from out side or by doing work on the system.

8. The change in internal energy of a gas depends only on the initial and final states of the gas and it is independent of the path.
9. The change in internal energy of an ideal gas is $dU = mC_v\,dT$ in terms of molar specific heat $dQ = n\,C_v dT$.
10. Internal energy is that energy of the system which is capable of doing work without any external source.
11. Internal energy is the unique function of the state of the system because its value depends on P, V and T.
12. The total energy of compressed real gas is less than that of expanded gas at the same temperature.
13. The internal energy of water molecules at 0°C is greater than that of ice molecules at 0 °C.
14. In the process of change of state, the internal energy of the system increases because additional work is done against intermolecular forces.
15. Change in internal energy in a cyclic process is always zero.
16. For an ideal gas change in internal energy $dU = \frac{3}{2}$ KT (for each molecule).

Work done during friction:

1. The work done by the frictional, force is,
$$W = f \times s$$
where s is the distance travelled by the body and $s = vt$ and $f = \mu mg$
$$\therefore \quad W = \mu\, mg\, vt$$
2. If a body travelling with a velocity u is stopped by frictional force in a distance s on a rough horizontal surface, the work done by the frictional force is equal to the K.E. of the body is,
$$f \times s = \frac{1}{2} mv^2$$
$$\mu\, mg \times s = \frac{1}{2} mv^2$$
$$\mu\, g\, s = \frac{v^2}{2}$$
3. If 'x' grams of steam (at 100°C) is mixed with y grams of ice (at 0°C) and allowed for thermal equilibrium then the final temperature of the mixture will be,
$$t = \frac{80(80x - y)}{(x + y)}$$

Heat Engine:

1. Lesser the difference in the temperatures of the cooling chamber and the atmosphere, higher is the coefficient of performance of the refrigerator.
2. In a heat engine, the efficiency can never exceed 100%. But in the case of a refrigerator, the coefficient of performance may be much higher than 100%.
3. As the refrigerator works, T_2 goes on decreasing due to formation of too much ice. There is practically no change in T_1. This decreases the value of β. However, if the refrigerator is defrosted, T_2 shall increase and consequently the value of β. So, it is necessary to defrost the refrigerator.

9.9 Absorption, reflection and transmission of heat radiation

Transmission of Heat:

Heat is a form of energy. It transfers from a point of higher temperature to a point of lower temperature. The transfer of heat from one place to another place by one of the following modes. There are three different modes of transfer of heat.

1. **Conduction:** The process of transmission of heat energy in which the heat is transferred from one particle to other particle without migration of the particle from their equilibrium position is called conduction.
   i) Heat flows from hot end to cold end. Particles of the medium simply oscillate but do not leave their place.
   ii) Medium is necessary for conduction.
   iii) It is a slow process.
   iv) The temperature of the medium increases through which heat flows.
   v) Conduction is a process which is possible in all states of matter.
   vi) When liquid and gases are heated from the top, they conduct heat from top to bottom.

vii) In solids, only conduction takes place.

viii) In nonmetallic solids and fluids, the conduction takes place only due to vibrations of molecules, therefore they are poor conductor.

ix) In metallic solids, free electrons carry the heat energy, therefore they are good conductor of heat.

2. **Convection:** Mode of transfer of heat by means of migration of material particles of medium is called convection.

Natural convection: This arise due to difference of densities at two places and is a consequence of gravity because on account of gravity the hot light particles rise up and cold heavy particles try setting down. It mostly occurs on heating a liquid/ fluid.

i) Convection coefficient (h) depends on properties of fluid such as density, viscosity, specific heat and thermal conductivity.

ii) In case of natural convection, convection currents move warm air upwards and cool air downwards. That is why heating is done from base, while cooling from the top.

iii) Natural convection plays an important role in ventilation, in changing climate and weather and in forming land and sea breezes and trade winds.

iv) Natural convection is not possible in a gravity free region such as a free falling lift or an orbiting satellite.

v) The force of blood in our body by heart helps in keeping the temperature of body constant.

vi) If liquids and gases are heated from the top (so that convection is not possible) they transfer heat (f.rom top to bottom) by conduction.

vii) Mercury through a liquid is heated by conduction and not by convection.

3. **Radiation:**

i) The process of the transfer of heat from one place to another place without heating the intervening medium is called radiation.

ii) It is the fastest mode of transfer of heat.

iii) Rough and dark surfaces are good absorbers and shining.

iv) Smooth surfaces are good reflectors of heat radiation.

v) Glass and water vapours have the property of transmitting shorter wavelength of heat radiations through them. It reflect longer wavelengths.

vi) Heat radiation are invisible and travel in a straight line. It has rectilinear propagation property.

vii) It affects photographic plate.

viii) The energy emitted by a body in the form of radiation by virtue of its temperature is called thermal radiation.

ix) The energy emitted by all body at all temperature except absolute zero temperature in the form of radiation.

x) Thermal radiation belongs in the form of electromagnetic waves.

xi) Radiations are the X–rays, y–rays, ultraviolet radiations, visible light and radio waves.

xii) Radiation never be stopped but it can be minimized by silver polishing the surface.

xiii) It can travel through vacuum and other transparent media.

xiv) It's speed is same as that of light.

xv) It shows the phenomenon of reflection, refraction, interference, diffraction and polarization.

xvi) The wavelength of thermal radiation is longer than that of visible light.

xvii) It's wavelength range is 8×10^{-7} m to 3×10^{-4} m.

xviii) Any types of ideal bodies have the coefficients (a or r or t) is unity. All bodies have the coefficients always less than unity.

xix) The energy in the form of radiation is called radiant energy.

1. **Coefficient of absorption:** It is the ratio of quantity of heat absorbed to the total radiant energy incident on it.

i) For a perfectly black body coefficient of absorption is unity.

ii) Coefficient of absorption depends upon wavelength of incident radiation. (Maximum A for black colour)

iii) It is independent of temperature of the body and surface of the body.

2. **Coefficient of reflection:** It is the ratio of quantity of heat reflected to the total radiant

energy incident on it.

i) For good reflecting surface coefficient of reflection is unity.

ii) Coefficient of reflection depends upon wavelength of incident radiation.

iii) It is independent of temperature of the body and surface of the body.

3. **Coefficient of transmission:** It is the ratio of quantity of heat transmitted to the total radiant energy incident on it.

i) For good transmission of the body surface coefficient of transmission is unity.

ii) Coefficient of transmission depends upon wavelength of incident radiation.

iii) It is independent of temperature of the body and surface of the body.

4. Sum of the coefficient of absorption reflection and transmission is unity.
5. Good absorber is bad reflector or transmitter i.e. when a = 1, r = t = 0
6. Good transmitters are bad reflector or absorber i.e. when t = 1, a = r = 0
7. Good reflector is bad transmitter or absorber i.e. when r = 1, a = t = 0
8. A diathermanous body is neither a good absorber nor a good reflector.
9. A substance may be diathermanous for some wavelengths while good absorbers for other wavelengths.
10. White body is one for which r = l.
11. A athermanous body is a good absorber, poor reflector and no part of heat energy is transmitted through it.
12. Athermanous body is called opaque body.

9.10 Perfectly Black Body

1. A black body is one which absorbs completely the radiations of all wavelengths falling on it.
2. The conical projection will protect direct reflection of any radiation in the opening from the surface opposite to it i.e. it avoid the direct reflection.
3. In a ferries perfectly black body, radiation falling on the hole is completely absorbed. Therefore hole is considered as the perfectly black body.
4. Indian ink is 85% of the absorber, lamp black is 98%, dull copper is 13% of absorber.
5. Polished surfaces possesses large reflectance.
6. Black body emits radiations of all possible wavelengths.
7. Artificially 96% to 98% of the perfectly black body is manufactured.
8. As a perfectly black body neither reflects nor transmits any radiation, therefore the absorptance of a perfectly black body is unity t = 0 and r = 0 $\therefore$ a = l.
9. We know that the colour of an opaque body is the colour (wavelength) of radiation reflected by it. As a black body reflects no wavelength so, it appears black, whatever be the colour of radiations incident on it.
10. When perfectly black body is heated to a suitable high temperature of the sun is very high (6000K) it emits all possible radiation so it is an example of black body.

9.11 Spectrum of a Black Body Radiations in Terms of Wavelength

1. The radiant energy emitted by a black body at a given temperature consists of electromagnetic waves of wide range wavelengths.
2. In 1899, Lummer and Pringsheim performed experiments to study the distribution of energy with wavelength in the spectrum of black body radiations.
3. The intensity of the black body radiation corresponding to the wavelengths ranging from zero to infinity.
4. The graph is plotted between intensity of radiation verses wavelength λ, is called the spectrum.
5. Each curve in the graph, represents the variation of monochromatic emittance E_λ .of the black body with the wavelength (λ) of the radiation emitted.
6. Different curves are plotted for different values of temperatures of the black body.
7. At a given temperature of black body:

i) The energy emitted is not distributed uniformly among all wavelengths.

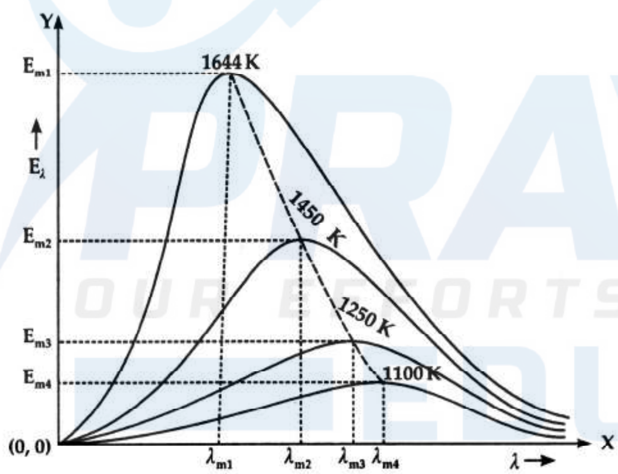
ii) The energy emitted is maximum for a certain wavelength (λ_m) and it falls on either side of maximum wavelength.

iii) The wavelength (λ_m) corresponding to which there is maximum energy emission at a given temperature is called wavelength of maximum emission.

8. **With the rise in temperature of black body:**
   i) The total energy emitted increases rapidly for any given wavelength.
   ii) The wavelength (λ_m) for which energy emitted is maximum. It is shifted towards shorted wavelength side. As Am decreases with rise in temperature.
9. The area enclosed by each curve with wavelength axis increases with rise in temperature of the black body.
10. It is found that area enclosed by a curve is directly proportional to the fourth power of the absolute temperature.
11. The area under the curve represents the total energy E emitted per second per unit area corresponding to all wavelengths at a given temperature, hence

$$E \propto T^4$$

This is Stefan's Boltzmann law.



Wien's displacement law:

1. The wavelength λ_m of maximum intensity of emission of black body radiation is inversely proportional to absolute temperature T of the black body.

$$\lambda_m \propto \frac{1}{T}$$

$$\lambda_m = \text{constant } \frac{1}{T}$$

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

where b is a constant, called Wien's constant.

$b = 2.9 \times 10^{-3}$ m K = 0.29 cm K

where b is constant of proportionality known as Wien's constant for a black body

$b = 2.892 \times 10^{-3}$ mK.

2. It is clear from the above equation as T increases, λ_m decreases i.e. with the rise in temperature of the black body, the wavelength of maximum intensity of emission shifts towards lower wavelength side.
3. The stars which have low surface temperature appears red while those with higher surface temperature appear yellow.
4. Blue stars have extremely high surface ternpera ture.
5. The Wien's displacement law accounted for the change in colour of a body from red to yellow and then to white as its temperature is increased.
6. This law is used to find the temperature of the sun and stars.

9.12 Kirchhoff's Law of Radiation and its Theoretical Proof

1. At any temperature above absolute temperature, the rate of emission of heat is equal to rate of absorption of heat.
2. Good absorber are the good emitters and bad absorber are the bad emitters.
3. If a body emits strongly the radiation of a particular wavelength it must absorb the same radiation strongly.
4. Sand is rough and black, so it is a good absorber. Hence in desert days are very hot and nights are very cold.
5. When a shining metal ball having some black spots on its surface is heated to a high temperature and is seen in dark, the black spot shine bright and the shining ball becomes dull.
6. The silvered surface of a thermos flask does not absorb much heat from outside. This stops ice from melting quickly. Also the silvered surface does not radiate much heat from inside to outside. This prevents hot liquids from becoming cold quickly.
7. A red glass appears red at room temperature. This is because it absorbs green light strongly.
8. The coefficient of emissivity depends upon the nature of the surface.
9. In winter nights, feel warmer when clouds cover the sky than when the sky is clear. Since clouds

are bad conductors. Heat of the earths atmosphere is not conducted out.

10. A person with black skin experiences more heat and more cold as compared to a person of white skin because when the outside temperature is greater, the person with black skin absorbs more heat and when the outside temperature is less the person with black skin radiates more energy.

9.13 Stefan's law and Newton's law of cooling

Stefan's law:

1. Stefan gives the relation between rate of loss of heat and absolute temperature of the body.
2. Energy radiated per unit time per unit area is directly proportional to fourth power of its absolute temperature.
3. Let 'Q' be the quantity of heat radiated by perfectly black body of temperature T in time t second.

   Therefore, according to the statement,

$$\frac{dQ}{Adt} \propto T^4$$

$$\frac{dQ}{Adt} \sigma T^4 \qquad \therefore \quad \frac{dQ}{dt} = \sigma A T^4$$

   Where σ is stefan's constant its value in SI unit is experimentally found to be 5.67×10^{-8} J/m^2 s K^4.

4. Its SI unit is J/m^2 s K^4 or watt 1m^2 k^4 and CGS unit is erg /cm^{2}s C^4.
5. The dimensions of σ are $[L^0 M^1 T^{-3} K^{-4}]$
6. Consider a perfectly black body of temperature T is kept in a perfectly black encloser of temperature T_0 lower than temperature of the body.

   According to Stefan Boltzmann's law, rate of loss of heat by body is equal to

$$\frac{dQ}{dt} = \sigma A T^4$$

   The rate of loss of heat by a perfectly black encloser

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

7. The net rate of loss of heat by perfectly black body is,

$$\frac{dQ}{dt} = \sigma A [T^4 - T_0^4]$$

8. The emissive power of a perfectly black body

$$E_b = \sigma T^4$$
$$E = e E_b$$

9. The emissive power of an ordinary body is,

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

10. For any ordinary body, the net rate of loss of heat is,

$$\frac{dQ}{dt} = \sigma A a [T^4 - T_0^4]$$

11. The energy radiated by a perfectly black body is,

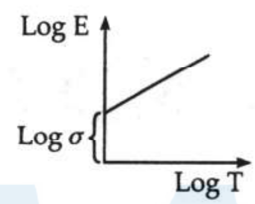
$$Q = \sigma A [T^4 - T_0^4] t$$

12. $E = \sigma T^4$

    Taking log on both side,

    we have,

    $\log E = \log \sigma + 4 \log T$



The graph of log E and log T is a straight line, with slope 4 intersecting log E axis.

Newton's law of cooling:

1. The rate of cooling depends on following factor,

i) **Nature of radiating surface:** Greater the emissivity, faster will be the cooling.

ii) **Area of radiating surface :** Greater the area of radiating surface faster will be the cooling.

iii) **Mass of radiating bodies :** Greater the mass of radiating body slower will be the cooling.

iv) **Specific heat of radiating body:** Greater the specific heat of radiating body slower will be the cooling.

v) **Temperature of radiating body:** Greater the temperature of radiating body faster will be the cooling.

vi) **Temperature of the surrounding:** Greater the temperature of surrounding slower will be the cooling.

2. Rate of loss of heat is the ratio of the surface area of the body,

$$\frac{R_1}{R_2} = \frac{A_1}{A_2} \qquad \text{For cube and sphere}$$

$$= \frac{6l^2}{4\pi r^2} = \frac{3l^2}{2\pi r^2}$$

The rate of fall of temperature is,

$$\frac{(d\theta/dt)_1}{(d\theta/dt)_2} = \frac{A_1}{A_2} \times \frac{m_2}{m_1}$$

For a cube and sphere of same material

$$\frac{(d\theta/dt)_1}{(d\theta/dt)_2} = \frac{A_1}{A_2} \times \frac{v_2}{v_1}$$

For a cube and sphere

$$= \frac{6l^2}{4\pi r^2} \times \frac{(4\pi/3)r^3}{l^3} = \frac{2r}{l}$$

If l = r then, the rate of heat loss = 3 : 2 π = 1 : 2

3. The ratio of rate of fall of temperature is 2 : 1. Thus, although the heat loss by sphere is twice that of the cube, but its fall of temperature is only half that of the cube.
4. The fall of temperature of cube is faster than that of sphere.
5. The temperature of the sun is 5800 K.
6. The relation between rate of loss of heat or rate of fall of temperature over the surrounding.
7. A body never be cooled below its surrounding temperature by radiation.
8. Greater the temperature difference between the body and its surrounding greater will be the rate of cooling.
9. If a body cools by radiation from 91 to 92 "C in time t then,

$$\frac{d\theta}{dt} = K A (\theta - \theta_0)$$

Where, $\frac{d\theta}{dt} = \left[\frac{\theta_1 - \theta_2}{t_2 - t_1}\right]$ and $\theta - \theta_{AV} = \frac{\theta_1 + \theta_2}{2}$

$$\therefore \left[\frac{\theta_1 - \theta_2}{t_2 - t_1}\right] = K A \left[\left(\frac{\theta_1 + \theta_2}{2}\right) - \theta_0\right]$$

Greater the surface area of the body, fast will be the cooling of the body.

10. The energy radiation depends upon the specific heat the material.
11. According to Newton's law of cooling, the graph of temperature against time is exponential curve.
12. The graph of ($d\theta/dt$) against θ is straight line intersecting temperature axis gives a room temperature.
13. The graph of ($d\theta/dt$) against ($\theta - \theta_0$) excess temperature is a straight line passing through origin.

$$\frac{d\theta}{dt} = K(\theta - \theta_0)$$

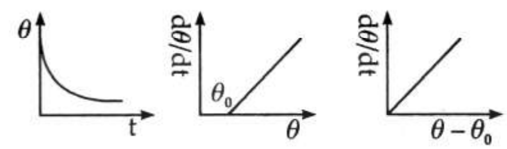
Integrating on both the sides,

$\log(\theta - \theta_0) \propto -Kt$

$\theta - \theta_0 \propto e^{-Kt}$

The curve is exponential.

14. The rate of cooling depends on the thermal capacity of the body. The maximum value of thermal capacity have minimum rate of fall of temperature.



Greenhouse effect :

1. Earth surface absorbs thermal energy from sun and becomes a source of thermal radiation.
2. The wavelength of thermal radiation lies in infrared region.
3. A large portion of thermal radiation is absorbed by greenhouse gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O). Chlorofluorocarbons and tropospheric ozone (03), which heats up the atmosphere and gives more energy to earth, resulting in warmer surface.
4. Due to thermal radiation the intensity of radiation increases, near the earth's surface. The above process is repeated until no radiation is available for absorption. This heating up of earth's surface and atmosphere is known as Greenhouse effect
5. Without the Greenhouse effect, the temperature of the earth would have been –18° C.
6. This global warming may cause many problems for human life, plants and animals. Due to global warming ice caps are melting faster, sea level is rising and weather pattern is changing, common coastal cities are at the risk of getting submerged. The increase in Greenhouse effect may result in expansion of deserts. Efforts are being made to minimise the effect of global warming.

❍❍❍

MULTIPLE CHOICE QUESTIONS

9.1 Concept of an ideal gas and gas equation

1. In an ideal gas, the molecules possess
   a) only kinetic energy
   b) kinetic energy and potential energy
   c) only potential energy
   d) only gravitational energy
2. The internal energy of a gas molecule of an ideal gas depends upon
   a) pressure alone
   b) temperature alone
   c) volume alone
   d) both on pressure and temperature
3. Water can be made to boil at 0°C. If the pressure of the surroundings is
   a) 760 mm of mercury
   b) 40 mm of mercury
   c) 76 mm of mercury
   d) 4 mm of mercury
4. Heat is not closely related to
   a) momentum b) energy
   c) temperature d) friction
5. The gas equation PV/2 = RT, V stands for
   a) volume of 2 grams of a gas
   b) volume of 2 moles of a gas
   c) volume of 1 mole of a gas
   d) volume of 1/2 mole of a gas
6. The gas equation PV = RT, V stands for volume of
   a) any amount of a gas
   b) one gram mole of a gas
   c) one gram of a gas
   d) one litre of a gas
7. The dimensions of heat are
   a) $[L^2 M^1 T^{-2}]$ b) $[L^1 M^1 T^{-2}]$
   c) $[L^1 M^0 T^{-2}]$ d) $[L^2 M^1 T^{-1}]$
8. For Boyle's law to be hold good, the gas should be
   a) perfect with constant mass and temperature
   b) perfect and at constant temperature but of variable mass
   c) real and of constant mass and temperature
   d) real and at constant temperature but of variable mass
9. Temperature of a gas remains constant, the pressure of a given mass of a gas is inversely proportional to its volume. Then the law is
   a) Charle's b) Galussac's
   c) Boyle's d) Pressure
10. Temperature determines the direction of net change of
    a) gross kinetic energy
    b) intermolecular kinetic energy
    c) gross potential energy
    d) intermolecular potential energy
11. The thermal motion means
    a) motion due to heat engine
    b) motion of the body that generates heat
    c) disorderly motion of the body as a whole
    d) random motion of the molecules
12. SI unit of heat is
    a) calorie b) kilo calorie
    c) joule d) ergs
13. The direction of flow of heat between two bodies is determined by
    a) kinetic energy
    b) total energy
    c) internal energy
    d) the difference in the average kinetic energy of the molecules in random motion.
14. Heat is absorbed by a body but its temperature does not rise. The following statement explain the phenomena of
    a) only kinetic energy of vibration increase
    b) only potential energy of inter molecular force fields increases
    c) the internal energy is not increases
    d) increase in kinetic energy is balanced by decrease in its potential energy
15. Thermal equilibrium implies equality of
    a) energy b) internal energy
    c) kinetic energy d) can not be predicted
16. Average density of a gas at constant temperature
    a) increases due to collision

b) decreases due to collision

c) does not change with collision

d) increases or decreases depending upon nature of a gas

17. In a sample of 1 cm^3 of hydrogen and 1 cm^3 of oxygen, both at N.T.P. Then

a) hydrogen sample has more molecules

b) oxygen samples has more molecules

c) both samples have equal number of molecules

d) hydrogen samples has more or less number of moles than oxygen sample

18. In the volume temperature graph for a certain amount of perfect gas at two pressures P_1 and P_2 are shown. We conclude from the graph, that

a) P_1 may be greater or less than P_2

b) $P_1 = P_2 > P_1$

c) $P_2 > P_1$

d) $P_1 > P_2$

19. For a gram molecule of a gas, the value of the constant R in the equation PV = RT will be

a) 2 cal/mol K b) 0.4 cal/mol K

c) 8 cal/mol K d) 8.3 cal/mol K

20. According to kinetic theory of gases at absolute zero temperature

a) water freezes

b) liquid helium freezes

c) molecular motion stops

d) liquid hydrogen freezes

21. The internal energy of a gram–molecules of an ideal gas depends upon

a) pressure alone

b) volume alone

c) temperature alone

d) both pressure and temperature

22. Calorie per degree kelvin is the unit of

a) temperature

b) specific heat

c) thermal capacity

d) mechanical equivalent of heat

23. Heat is

a) kinetic energy of molecule

b) potential and kinetic energy of molecules

c) energy in transit

d) work done on the system

24. The internal energy of an ideal gas is independent of

a) pressure only

b) volume only

c) both on pressure and volume

d) temperature only

25. A star which appears bluish should be

a) hotter than the sun

b) colder than the sun

c) having nearly the same temperature as that of the sun

d) nothing can be predicted

26. The volume of gas at 27°C and 1 atm pressure is 1 lit. If the pressure is doubled and absolute temperature is made half, then the volume of the gas will be

a) 0.05 lit b) 0.25 lit

c) 0.75 lit d) 1.6 lit

27. A vessel contains 2 mole of gas and the pressure is 40 cm of Hg. Under the same conditions, if 1gm of gas is introduced into the vessel, the pressure will be

a) 40 cm of Hg b) 20 cm of Hg

c) 76 cm of Hg d) 60 cm of Hg

28. The pressure of gas at 100°C is 2 atm. When the gas is heated at constant volume. At what temperature the pressure raises to 3 atm ?

a) 286.5°C b) 380.7°C

c) 420.2°C d) 227.4°C

29. It is required to double the pressure of Helium gas contained in a steel cylinder, by heating it the initial temperature of Helium be 27°C, the temperature upto which it brought to be heated is

a) 327°C b) 273°C

c) 108°C d) 54°C

30. An open mouthed bottle contains a gas at 60°C. The temperature to which the bottle should be heated so that 1/4 of the mass of the gas may leave is,

a) 171°C b) 250°C

c) 300°C d) 342°C

31. To what temperature in °C a gas has to be heated to produce 10% change in volume at constant pressure, if the initial temperature of the gas is at

O°C?

a) 17.3 b) 27.3

c) 33.3 d) 13.15

32. A cylinder contains oxygen at pressure of 28 atm and at a temperature of 300 K. The mass of oxygen enclosed is 1000 gm. After using a quantity of the gas, the pressure is found to be 7 atm and the temperature is 200 K. What mass of the gas has been used ?

a) 100 gm b) 250 gm

c) 625 gm d) 1000 gm

33. A litre of air at 27°C is heated until both the volume and pressure are doubled. What is the temperature?

a) 1200°C b) 327°C

c) 200°C d) 927°C

34. If the volume of an ideal gas decreased by 5% at constant temperature, the increase of pressure is

a) 5% b) 5.18%

c) 5.26% d) 5.41%

35. The volume of a given mass of air at temperature 27°C is 100 c.c. If its temperature is raised to 57°C maintaining the pressure constant, then the increase in its volume is

a) 100 c.c. b) 130 c.c.

c) 10 c.c. d) 30 c.c.

36. The volume of gas at 27°C and 2 atmospheric pressure is 2 litres. If the pressure is doubled and absolute temperature is reduced to half, what will be volume of the gas?

a) 2 litres b) 1 litre

c) 0.5 litre d) 0.25 litre

37. The volume of a gas at 27°C and 760 mm atmospheric pressure is 500 c.c. What will be the volume of the gas at 27°C and 380 mm of mercury pressure ?

a) 500 C.c. b) 600 C.c.

c) 750 C.c. d) 1000 C.c.

38. A given amount of gas is heated till the volume and pressure are each increased by 1%. Then the temperature increases by

a) 0.5 % b) 1%

c) 2 % d) 4 %

39. If the pressure at half of the depth of lake is 2/3 of the pressure at its bottom. Then depth of the lake is

a) 10 m b) 20 m

c) 30 m d) 40 m

40. 8 gm of oxygen and × gm of hydrogen posses same pressure, volume and temperature. Then × =

a) 1/2 b) 16

c) 32 d) 2

41. The pressure of a gas in a closed vessel is increased by 0.4%, if the temperature of the gas is increased by 1°C, the initial temperature of the gas is

a) 23°C b) 250°C

c) – 23°C d) 300 K

42. A gas 27°C and pressure 30 atm is allowed to expand to atmospheric pressure. If the volume 51. becomes 10 times its initial volume, then the final temperature becomes

a) 100°C b) 373 K

c) 373°C d) – 173°C

43. One litre of He gas at a pressure of 76 cm Hg and temperature 27°C is heated till its pressure and 52. volume are doubled. Then the final temperature attained by the gas is

a) 900°C b) 927°C

c) 627°C d) 327°C

44. An air bubble doubles its radius on raising from the bottom of water reservoir to the surface of water in it. If the atmospheric pressure is equal to 10 m of water, the height of water in the reservoir will be

a) 10 m b) 20 m

c) 70 m d) 80 m

45. A gas is heated through 2°C in a closed vessel. Its pressure is increased by 0.4%. The initial temperature of the gas is

a) 250°C b) 100°C

c) 500°C d) 227°C

46. If a given mass of a gas occupies a volume 100 cm^3 at one atmospheric pressure and a temperature of 100°C. What will be its volume at 4 atmospheric pressure, the temperature being the same?

a) 100 cm^3 b) 400 cm^3

c) 25 cm^3 d) 200 cm^3

47. It is decided to verify Boyle's law over a wide range of temperature and pressures. The most suitable gas to be selected for this purpose is

a) carbon dioxide b) helium
c) oxygen d) hydrogen

48. When a large bubble rises from the bottom of a lake to the surface, its radius doubles. The atmospheric pressure is equal to that of a column of water of height H. The depth of the lake is

a) H b) 2 H
c) 7 H d) 8 H

49. When a gas enclosed in a closed vessel was heated so as to increase its temperature by 5°C, its pressure was seen to have increased by 1%. The initial temperature of the gas was nearly

a) 500°C b) 227°C
c) 273°C d) 150°C

50. The molecular weight of a gas is 44. The volume occupied by 2.2 g of this gas at ooe and 2 atm pressure will be

a) 0.56 It b) 1.2 It
c) 2.4 It d) 5.6 It

51. Avogadro's number is the number of molecules present in

a) One litre of a gas at NTP
b) 22.4 moles of a gas at NTP
c) 22.4 liters of a gas at NTP
d) 44.8 liters of a gas at NTP

52. A gas at temperature 2500K is contained in a closed vessel. If the gas is heated through 1°C, the percentage increase in its pressure will be

a) 0.4 % b) 0.8 %
c) 0.6 % d) 1.0 %

53. At what percentage should the pressure of a given mass of a gas be increased so as to decrease its volume by 10% at a constant temperature?

a) 8.1 % b) 10.1 %
c) 9.1 % d) 11.1 %

54. Oxygen and Hydrogen in two enclosures have same mass, volume and pressure. Then the ratio of the temperature of the oxygen and hydrogen gases is

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

55. Two identical cylinders contain helium at 2.5 atmosphere and Argon at 1 atmosphere respectively. If both the gases are filled in one of the cylinders then the pressure would be

a) 3.5 atmospheres b) 1.5 atmospheres
c) 1.75 atmospheres d) 1 atmospheres

56. The volume of 2.8 g of carbon monoxide (CO) at 27°C and 0.821 atmospheric pressure is (R = 0.0821 litre atmosphere/mol K)

a) 0.3 litre b) 1.5 litre
c) 3 litre d) 60 liters

9.2 Assumption of kinetic theory of gases

57. Kinetic theory of gases is based upon the assumptions

a) matter consists of minute particles
b) the molecules are constantly in a state of random motion
c) there exist no intermolecular force between the molecules
d) all of these

58. The intermolecular force between the molecules increases

a) when the distance between the molecules increases
b) when the distance between the molecules decreases
c) when the distance remains constant
d) none of the above

59. The inter molecular distances are much greater in

a) solids b) gases
c) liquids d) 'a' and 'b'

60. The first evidence in favour of the molecular structure of gas come from the experimental observation of

a) Brownian movement of colloidal particle
b) tracks of particles in cloud chamber
c) motion of molecule in a conduction
d) gas equation

61. The molecules of a gas behaves as

a) elastic and rigid spheres
b) in elastic and nonrigid spheres
c) inelastic and rigid spheres
d) perfectly elastic and nonrigid spheres

62. Average kinetic energy of a gas molecule is

a) inversely proportional to the square of its absolute temperature.

b) directly proportional to square root of its absolute temperature.

c) directly proportional to its absolute temperature.

d) directly proportional to square of absolute temperature.

63. According to kinetic theory of gases, the average kinetic energy of a gas molecule can be determined by knowing

a) the number of molecules in the gas only

b) the pressure of the gas only

c) the temperature of the gas only

d) none of the above is enough by itself

64. The volume occupied by the gas molecules v in a container of volume V, according to kinetic theory of gases

a) $v = V$ b) $v < V$

c) $v > V$ d) $v \geq V$

65. The molecules of a gas move in

a) different direction with same velocities

b) different direction with different velocities

c) same direction with same velocity

d) same direction with different velocity

66. A perfect gas is one whose molecules

a) attracts one another weakly

b) repeal one another weakly

c) strongly attract or repeal one another

d) neither attract nor repel one another

67. A gas which obeys all the assumptions of kinetic theory of gases at all conditions of temperatures and pressures is called

a) ideal or perfect gas b) real gas

c) diatomic gas d) polyatomic gas

68. Which of the following is not the assumption of kinetic theory of gases?

a) the molecules of a gas are spherical it).shape

b) the molecules of a gas are rigid

c) the molecules of a gas are perfectly inelastic

d) the gas molecules are in a state of random motion

9.3 Mean free path

69. When the pressure of a gas decreases the mean free path of its molecules

a) decreases

b) remains the same

c) increases

d) increases or decreases depending on the nature of the gas

70. The mean free path is inversely proportional to

a) molecular diameter

b) square of the molecular diameter

c) square root of the molecular diameter

d) fourth power of the molecular diameter

71. The expression for mean free path (A) of molecules is given by

[where n is no of molecules per unit volume and d molecular diameter of the gas]

a) $\dfrac{\sqrt{2}}{\pi n d^2}$ b) $\dfrac{1}{\pi n d^2}$

c) $\dfrac{1}{\sqrt{2}\pi n d^2}$ d) $\dfrac{1}{\sqrt{2}\pi n d}$

72. SI unit of mean free path is

a) per metre b) metre

c) per centimetre d) centimetre

73. Mean free path of a gas molecule in a container depends upon

a) temperature of the gas molecule only

b) diameter of the gas molecule only

c) density of the gas molecule only

d) temperature diameter and density of the gas molecule

74. Mean free path of a gas molecule increases with increase in

a) temperature of the gas molecule

b) diameter of the gas molecule

c) density of the gas molecule

d) temperature diameter and density of the gas molecule

75. Mean free path of a gas molecule increases with decrease in

a) temperature of the gas molecule

b) diameter of the gas molecule

c) density of the gas molecule

d) diameter and density of the gas molecule

76. Mean free path of a gas molecule increases with decrease in

a) temperature and molecular diameter of the gas molecule

b) molecular diameter and pressure of the gas of the gas molecule

c) density and temperature of the gas molecule

d) volume of the gas

9.4 Pressure exerted by the gas molecules and kinetic energy

77. The average velocity of the gas molecules in a gas in equilibrium is

a) proportional tc square root of temperature

b) proportional to temperature

c) proportional to square of temperature

d) equal to zero

78. The mean square speed of a gas molecules in equilibrium is

a) proportional to square root of temperature

b) proportional to temperature

c) proportional to square of temperature

d) equal to zero

79. The pressure exerted by the gas on the walls of a container is measured by

a) rate of change of momentum imparted to walls per unit area of the wall

b) momentum imparted to walls per unit area

c) change of momentum imparted to walls per unit area

d) change of momentum per unit volume

80. The motion of a gas molecule which determines the temperature in

a) translatory b) rotatory

c) vibratory d) all types of motion

81. A surface is hit elastically and normally by n balls per unit time, all the balls having the same mass m, and moving with the same velocity v. Then the force acting on surface is

a) mnu^2 b) $\frac{1}{2}$ mnv^2

c) 2 mnv d) 2 mnv^2

82. The absolute temperature of the gas is determined by the

a) average momentum of the molecules

b) velocity of sound in a gas

c) number of molecule in the gas

d) mean square velocity of the gas molecules

83. A gas is enclosed in a closed pot. On keeping this pot in a train moving with high speed, the temperature of the gas

a) will increase

b) will decrease

c) will change according to the nature of the gas

d) will remain the same

84. The collisions between the molecules among themselves and with the walls of a container are

a) perfectly elastic in which only momentum is conserved

b) perfectly elastic in which momentum and energy both are conserved

c) in elastic in which only momentum is conserved

d) in elastic in which only energy is conserved

85. A molecule of a perfect gas travels, between two successive collisions along a

a) parabolic both b) straight–line

c) curved path d) zigzag path

86. The molecules of an ideal gas possesses

a) kinetic and potential energy

b) only kinetic energy

c) only potential energy

d) only gravitational potential energy

87. According to the kinetic theory of gasses pressure exerted by perfect gas molecules on the wall of a container is equal to momentum transferred to the wall per unit area

a) by only one molecule

b) per second by only molecules

c) per second by one–third molecules

d) by one–third molecules

88. The pressure exerted by the gas molecule is

a) $P = \frac{1}{3}\frac{mnc^2}{v}$ b) $P = \frac{1}{3}\frac{M}{v}c^2$

c) $P = \frac{1}{3}\rho c^2$ d) all of these

89. A molecule of mass 'm' collide with a wall of container in normal direction with a velocity c. If

the collision is perfectly elastic, then the change in momentum of the molecules is

a) zero b) mc
c) + 2mc d) – 2mc

90. If N number of molecules in a container are enclosed then average number of molecules moving between a pair of wall is

a) N/2 b) N/3
c) N/6 d) N/4

91. The pressure exerted by the molecules of a gas at any point on a wall in any direction in equilibrium state is

a) equal
b) greater in horizontal direction
c) lesser in vertically upward direction due to opposing gravitational force.
d) greater in vertically downward direction due to the gravitational force.

92. In an equilibrium state, pressure exerted by the gas molecules of a perfect gas on walls of a container is proportional to,

a) C_{rms} b) C^2_{rms}
c) $\sqrt{C_{rms}}$ d) $1/C_{rms}$

93. The root mean square velocity of a gas molecules of mass m at a given temperature is proportional to the

a) m^o b) m
c) $\sqrt{m}$ d) $1/\sqrt{m}$

94. Select the correct statement

a) the pressure exerted by an enclosed gas depends on the shape of the container
b) the R.M.S. speeds of molecules of different ideal gases are the same at the same temperature.
c) the average kinetic energy of the molecules in one mole of all ideal gases at the same temperature is the same
d) the average kinetic energy of 1 gm of all ideal gases at the same temperature is the same

95. One mole of an ideal gas is heated at constant pressure of 1 atmosphere form 0°C to 100°C the change in the internal energy is (R = 8 J / mol K)

a) 120 J b) 1200 J
c) 12 J d) 8 J

96. Two containers are filled, each with a different gas. Two containers are at the same temperature. Suppose that the molecular weights of the two gases are MAand MB. Then the average momenta (in magnitude) of the molecules are related as

a) $P_A = P_B$ b) $P_A = \left(\frac{M_B}{M_A}\right)P_B$
c) $P_A = \left(\frac{M_B}{M_A}\right)^{1/2} P_B$ d) $P_A = \left(\frac{M_A}{M_B}\right)^{1/2} P_B$

97. The volume of a gas at pressure 21×10^4 N/m^2 and temperature 27°C is 83 L. If R = 8.3 J/mol/K, then the quantity of gas in g-mol will be

a) 15 b) 7
c) 42 d) 14

98. When a gas is in thermal equilibrium, its molecules have

a) a certain constant energy
b) the same energy
c) both 'a' and 'b'
d) different energies whose average remain constant

99. The root mean square velocity of a gas molecule at any temperature T K of a gas molecule of molecular weight M is

a) $\sqrt{8RT/M}$ b) $\sqrt{2RT/M}$
c) $\sqrt{3RT/M}$ d) zero

100. The temperature of a gas is measure of the average

a) kinetic energy of the gaseous molecules
b) potential energy of the gaseous molecules
c) distance between the molecules of the gas
d) kinetic energy and potential energy

101. Oxygen and Helium gases are in same container. Which one has greater K.E. per molecules?

a) Oxygen b) Both have equal K.E.
c) Helium d) None of the above

102. The mean kinetic energy of a perfect gas molecule at temperature T K is

a) 1/2 KT b) 3/2 KT
c) KT d) 2 KT

103. Mean kinetic energy of a perfect gas is proportional to

a) temperature

b) reciprocal of temperature

c) square of temperature

d) square of reciprocal of temperature

104. The mean kinetic energy per molecule per degree of freedom of a gas is

a) 1/2 KT b) 3/2 RT

c) 1/2 RT d) 3/2 KT

105. Mean kinetic energy per mole per degree of freedom is given by

a) 3/2 RT b) 1/2 KT

c) 1/2 RT d) 3/2 KT

106. Mean kinetic energy of a perfect gas per gram at the temperature T K is

a) 1/2 KT b) KT

c) $\frac{3}{2}\frac{RT}{M}$ d) $\frac{1}{2}\frac{RT}{M}$

107. The mean kinetic energy of one gram molecule of a perfect gas at absolute temperature T is

a) 1/2 KT b) 1/2 RT

c) 3/2 KT d) 3/2 RT

108. The density of the gas is 6×10^{-2} kg/m^3 and r.m.s. velocity 500 m/s. Then the pressure exerted by the gas on the walls of the vessel is

a) 5×10^3 N/m^2 b) 1.2×10^4 N/m^2

c) 30 N/m^2 d) 0.8×10^4 N/m^2

109. The temperature of an ideal gas is increased from 27°C to 927°C. Then the rms speed of its molecules becomes

a) twice b) four times

c) half d) $\sqrt{2}$ times

110. The rms velocity of a gas molecule is 300 m/s. If the r.m.s. velocity of molecules of a gas with twice the molecular weight and half the absolute temperature is

a) 30 $\sqrt{2}$ m/s b) 75 m/s

c) 600 m/s d) 150 m/s

111. If the density of air at N.T.P. is 1.25 kg/m^3, then the r.m.s. velocity of air molecules at N.T.P. will be

a) 0.50 km/s b) 0.48 km/s

c) 0.96 km/s d) 0.64 km/s

112. At what temperature the r.m.s. velocity is equal to the escape velocity of the hydrogen gas from the surface of earth ?

(V_e = 11.2 km/s, R = 8.314 J/mole K, M_H = 2)

a) 1000 K b) 10,000 K

c) 100 K d) 10,0000 K

113. What will be the rms speed of Argon at 40°C? If the rms speed of oxygen molecule at 1092 K is 920 m/s. (Molecular weight of oxygen is 32 and that of Argon is 40).

a) 460 m/s b) 404.5 m/s

c) 44 m/s d) 4405.0 m/s

114. If the RM.S. velocity of oxygen molecules at NTP is 460 m/s, then the RM.S. velocity at 127°C will be (T_0 = 273 K)

a) 556.6 m/s b) 55.66 m/s

c) 380 m/s d) 382 m/s

115. Four molecules of a gas have speeds 1 km/s, 2 km/s, 3 km/s and 4 km/s, then the root mean square speed of the gas molecule will be

a) $\sqrt{\frac{30}{2}}$ km/s b) 2.7386 km/s

c) $\sqrt{\frac{15}{4}}$ km/s d) $\frac{1}{2}\sqrt{10}$ km/s

116. If the density of the gas at NTP is 0.178 kg /m^3, then the RM.S. velocity of the molecules of a gas at N.T.P. will be (P_0 = 10^5 N/m^2)

a) 1306 m/s b) 13.06 km/s

c) 130.6 km/s d) 1340 m/s

117. If the velocities of three molecules are 2 m/s, 3 m/s, 4m/s respectively. Then the mean velocity will be

a) 4.5 m/s b) 3 m/s

c) 2 m/s d) 5 m/s

118. In the above problem the root mean square velocity is

a) 4 m/s b) 3.01 m/s

c) 3 m/s d) 5 m/s

119. The mean square velocity of the five molecules of velocities are 2 m/s, 3 m/s, 4 m/s, 5 m/s and 6 m/s respectively is

a) 4.242 (m/s)^2 b) 4 (m/s)^2

c) 18 (m/s)^2 d) 16 (m/s)^2

120. If at same temperature and pressure, the densities

for two diatomic gases are respectively P_1 and P_2, then the ratio of velocities of sound in these gases will be

a) $\sqrt{\frac{\rho_2}{\rho_1}}$ b) $\sqrt{\frac{\rho_1}{\rho_2}}$

c) $\rho_1\rho_2$ d) $\sqrt{\rho_1\rho_2}$

121. The R.M.S. velocity of a gas molecule is v at pressure P. If the pressure increases by two times, at constant temperature then the R.M.S. velocity will become at same temperature

a) 0.5 v b) v

c) 2 v d) 4 v

122. The temperature at which rms velocity of nitrogen gas molecules will be doubled that at 0 °C is

a) 273 K b) 546 K

c) 136 K d) 1092 K

123. Equal volumes of hydrogen and oxygen gasses of atomic weights 1 and 16 respectively are found to exert equal pressure on the walls of two separate containers the ratio of rms speed of hydrogen and oxygen gas is

a) 1 : 4 b) 4 : 1

c) 1 : 32 d) 32 : 1

124. If the density of hydrogen gas at N.T.P. is 8.93×10^{-5} gm/cm^3 then the rms speed of the molecules of the hydrogen gas at NTP will be

a) 1840 cm/s b) 184 m/s

c) 1840 m/s d) 18.4 km/s

125. What will be r.m.s. speed of a gas at 800 K ?

a) four times the values at 200 K

b) half the value at 200 K

c) twice the value at 200 K

d) same as at 200 K ?

126. Two vessels having equal volume contain molecular hydrogen at one atmosphere and helium at two atmospheres respectively. If both samples are at the same temperature the mean velocity of hydrogen molecules is

a) equal to that of helium

b) twice that of helium

c) half that of helium

d) $\sqrt{2}$ times that of helium

127. The root mean square velocity of the molecules in a sample of helium is (5/7)th that of the molecules in a sample of hydrogen. If the temperature of the hydrogen sample is at 0°C then the temperature of helium sample will be

a) 278.46 K b) 5.46°C

c) 273 K d) 'a' and 'b'

128. The temperature at which r.m.s. velocity of oxygen molecules equal to that of the nitrogen molecules at 100°C will be

a) 42.63 K b) 426.3 K

c) 4263 K d) 4.263 K

129. When the temperature of a gas in a metal is increased from 27°C to 87°C the initial pressure of 2 atmospheres changes to

a) 1.0 atm b) 1.6 atm

c) 2.4 atm d) 3 atm

130. If the density of oxygen is 1.44 kg/m^3 at a pressure of 10^5 N/m^2, then the root–mean–square velocity of oxygen molecules in m/s will be

a) 469 b) 456

c) 120 d) 270

131. If velocities of 3 molecules are 5 m/s, –6 m/s and 7 m/s respectively, then their mean square velocity in m^2/s^2

a) 11 m^2/s^2 b) 36.7 m^2/s^2

c) 6 m^2/s^2 d) 2 m^2/s^2

132. At what temperature of oxygen molecules have the same rms velocity as helium molecules at N.T.P.?

(Molecular wt. of oxygen is 32 and that of helium is 4)

a) 1900 °C b) 1911 °C

c) 1950 °C d) 1970 °C

133. At a given temperature, ratio of root mean square velocities of two different gases of molecular weights M_1 and M_2 respectively is

a) $\sqrt{\frac{M_1}{M_2}}$ b) $\sqrt{\frac{M_2}{M_1}}$

c) $\frac{M_1}{M_2}$ d) $\frac{M_2}{M_1}$

134. The r.m.s. speed of the molecules of an enclosed gas is C_{rms}. If pressure is made four times keeping the temperature constant, the r.m.s. speed will be

a) 2 C_{rms} b) 4 C_{rms}
c) C_{rms} d) C_{rms}

135. A container has a mixture of two gases, hydrogen and oxygen at room temperature. Which one of the following statements is true? (If c_H and c_O are the root mean square velocities of hydrogen and oxygen molecules respectively)
a) $c_H > c_O$ b) $c_H < c_O$
c) $c_O = 4\ c_H$ d) $c_O = 16\ c_H$

136. The r.m.s. velocity of the molecules in a gas at 27°C is 300 m/s. Then the r.m.s. velocity of the molecules in the same gas at 927°C is
a) 1200 m/s b) 600 m/s
c) 150 m/s d) 75 m/s

137. A sample of hydrogen at temperature T, volume V and pressure P have speed v and in a sample of oxygen at temperature T, volume 2 V and pressure 3 P. The root mean square velocity of the oxygen molecule is
a) $\frac{v}{4}$ b) $\sqrt{6}\ v$
c) $\sqrt{3}\ v$ d) $\sqrt{2}\ v$

138. The root mean square velocity of the gas molecules is 300 m/s. What will be the root mean square speed of the molecules if the atomic weight is doubled and absolute temperature is halved?
a) 300 m/s b) 150 m/s
c) 600 m/s d) 75 m/s

139. If the temperature at which the r.m.s. velocity of oxygen molecules equals to that of nitrogen molecules at 0°C will be ($M_N = 28$, $M_0 = 32$)
a) 312 °C b) 292.5 °C
c) 19.5 °C d) 39 °C

140. At what temperature will the r.m.s. velocity of a gas be half its value at 0 °C?
a) –68.25 °C b) –204.75 °C
c) –34.25 °C d) –238.75 °C

141. The average translational kinetic energy and the rms speed of molecules in a sample of oxygen gas at 300 K are 6.21×10^{-21} J and 484 m/s respectively. Then the corresponding values at 600 K are
a) 12.42×10^{-21} J, 968 m/s
b) 8.78×10^{-21} J, 684 m/s
c) 6.21×10^{-21} J, 968 m/s
d) 12.42×10^{-21} J, 684 m/s

142. At what temperature is the K.E. of a gas molecule is half of its value at 27°C?
a) 13.5 C b) 150 K
c) 150°C d) –123 K

143. A jar has mixture of Hydrogen and Oxygen gases in the ratio 1 : 5. Then the ratio of mean K.E. of hydrogen and oxygen molecules is.
a) 1 : 16 b) 1 : 5
c) 1 : 4 d) 1 : 1

144. The ratio of the KE. of Chlorine and Oxygen moles at the same temperature is
a) 16 : 35.5 b) (35.5)2 : $(16)^2$
c) 35.5 : 16 d) 1 : 1

145. What temperature does the average translational KE. of a molecule in a gas becomes equal to KE. of an electron accelerated from rest through potential difference of 5 volt?
(K = 1.38×10^{-23})
a) 38.65×10^3 K b) 0.3865×10^3 K
c) 3.865×10^3 K d) 38.65 K

146. The temperature at which mean kinetic energy of an ideal gas molecule will be doubled that at 27°C is
a) 54°C b) 13.5°C
c) 6000K d) 1500K

147. At what temperature will the average KE per molecule of a gas be exactly half its value at NTP?
a) 150 K b) 136.5 K
c) 273 K d) 546K

148. The kinetic energy per kg of nitrogen molecules ai 175°C is (Molecular weight of nitrogen 28 and R = 8320 J/kmole K)
a) 19.968×10^6 J b) 1.783×10^5 J
c) 1.9968×10^5 J d) 1.678×10^5 J

149. If the temperature of a gas is increased from 0°C to 273°C, then the ratio of average kinetic energy of the gas molecules is
a) 1 : 4 b) 4 : 1
c) 1 : 1 d) 2 : 1

150. A jar has a mixture of hydrogen and oxygen in the ratio 4 : 5. Then the ratio of mean kinetic energy of hydrogen and oxygen molecule is
a) 1 : 16 b) 5 : 4

c) 4 : 5 d) 1 : 1

151. If the temperature of a gas is increased from 0°C to 273°C, then the ratio of change in the average kinetic energy of the gas molecule to the original is

a) 1 : 4 b) 4 : 1

c) 1 : 1 d) 2 : 1

152. Mean kinetic energy per gram mole of an ideal gas at 0 °C is nearly (R = 8.320 J/gm mol × K)

a) 3.4 J b) 3.4 J

c) 340 J d) 3400 J

153. If one gm mole of nitrogen gas occupies 2×10^4 c.c. at a pressure of 106 dyne/cm^2, then the average kinetic energy of nitrogen gas molecule in ergs will be (Avagadro's number $N = 6 \times 10^{23}$)

a) 5×10^{-14} b) 10×10^{12}

c) 10^6 d) 2×10^6

154. If the mean kinetic energy of the molecules of a gas is $(1/3)^{rd}$ of its value at 27°C, then the temperature of the gas will be

a) 100°C b) – 173°C

c) 900°C d) 627°C

155. If the gases are at absolute temperatures 300 K and 350 K respectively, then the ratio of average K. E of their molecules will be

a) 7 : 6 b) 6 : 7

c) 36 : 49 d) 49 : 36

156. If the average kinetic energy of gas molecule at 27°C is 6.21×10^{-21} J, then the average kinetic energy at 227°C will be

a) 52.2×10^{-21} J b) 5.22×10^{-21} J

c) 10.35×10^{-21} J d) 11.35×10^{-21} J

157. The average kinetic energy of the molecules of hydrogen is E. If the mass of oxygen molecule is 16 times that of hydrogen molecule, the average KE. of an oxygen molecule at the same temperature is

a) 4E b) E/4

c) E /16 d) E

158. When two gases having volumes 1 litre and 2 liters are at the same temperature, then the ratio of the average kinetic energy of the molecules in the two gases is

a) 1 : 1 b) 1 : 2

c) 2 : 1 d) 3 : 2

159. The kinetic energy of the molecules of 1 mole of a gas at a temperature of 300K is (R = 2 cal/ mole°C)

a) 900 cal b) 450 cal

c) 2250 cal d) 600 cal

160. The temperature of a gas is measure of the

a) average K.E. of the molecules of the gas

b) average P.E. of the molecules of the gas

c) average distance between the molecules of the gas

d) size of the molecules of the gas

161. What is the K.E. of translational motion of molecules in 15 gram of ammonia gas at 37°C? (Molecular weight of ammonia is 17.03 and R = 8.31 J/mol K)

a) 3403 J b) 340.3 J

c) 401.5 J d) 4090 J

162. A lead bullet strikes a target with velocity of 480 m/s. If the bullet falls dead, then the rise in temperature of bullet is,

(Assuming that heat produced is equally shared between the bullet and target.)

($J = 4.2 \times 10^3$ J/ kcal, C = 0.03 kcal/kg K)

a) 557°C b) 457°C

c) 857°C d) 754°C

163. Water falls from a height of 500 m. What will be the rise in temperature of water at the bottom if the whole of energy remains in the water?

($J = 4.2 \times 10^3$ J/kcal)

a) 0.96 °C b) 1.02 °C

c) 1.16 °C d) 0.23 °C

164. An ice block at 0°C falls from rest at certain height. If 0.1% of ice melts on reaching the ground, then the height from which it is released

(g = 10 m/s^2, L = 80 cal/gm, J = 4.2 J/cal)

a) 33.6 m b) 336 m

c) 3360 m d) 33.6 Km

165. A bullet of mass 4.2 gm is moving at certain velocity. If all its kinetic energy is converted to heat, the amount of energy liberated is 20 cal, then the initial velocity of the bullet is

a) 100 m/s b)200 m/s

c) 10 m/s d) 20 m/s

166. The density of oxygen at N.T.P. is 16×0.089 kg/

m^3 then the R.M.S. velocity of oxygen molecules at N.T.P.would be

a) 4.6×10^2 m/s b) 46×10^2 m/s

c) 0.46×10^2 m/s d) 3.6×10^2 m/s

167. A gas at a pressure P_0 is contained in a vessel. If the masses of all the molecules are halved and their velocities are doubled, the resulting pressure P would be

a) 4 P_0 b) P_0

c) $2P_0$ d) $P_0/2$

9.5 Degrees of freedom and law of equipartition of energy & Application of specific heat capacities of gases

168. Which of the following substance have the highest value of molar specific heat?

a) Aluminium b) Hydrogen

c) copper d) water

169. Specific heat capacity is given by

a) $(dQ/d\theta)$ b) $(1/m)\ dQ/d\theta$

c) $(l/m)\ d\theta/dQ$ d) $m\ (dQ/d\theta)$

170. The specific heat capacity is

a) constant for each material

b) depends on the conditions under which it is measured

c) same for a material at all conditions

d) the statement 'a', 'b' and 'c' are correct

171. The SI unit of principal specific heat is

a) kcal/kg K b) J/mole K

c) J/kg K d) kcal/kmol K

172. The SI unit of molar specific heat is

a) kcal/kg K b) J/mole K

c) J/kg K d) kcal/kmol K

173. The CGS unit of specific heat is

a) cal/kg = C b) cal/gm °C

c) kcal/gm = C d) erg/gm = C

174. The solid and liquid have only one specific heat because of there is

a) no considerable increase in pressure and volume

b) considerable increase in volume and pressure

c) considerable increase in volume only

d) considerable increase in pressure only

175. The solid and liquid have

a) one specific heat b) three specific heats

c) two specific heats d) infinite specific heats

176. The gases have

a) one specific heat b) three specific heats

c) two specific heats d) infinite specific heats

177. Molar specific heat is

a) quantity of heat required to raise temperature of one kg through 10K

b) quantity of heat required to raise temperature of 1 mole through 1 K

c) quantity of heat required to raise temperature of 1 gram through 1 K

d) none of the above

178. The relation between molar specific heat and principal specific heats is

a) Molar specific heat = Molecular weight × principal specific heat

b) Principal specific heat = Molecular weight × molar specific heat

c) Molar specific heat = Principal specific heat

d) molar specific heat and principal specific heat product is constant

179. Generally C_p is

a) greater than C_v b) equal to C_v

c) less than C_v d) greater than or equal to

180. Heat supplied to a gas at constant volume is utilised to

a) increase the internal energy of the gas

b) to do external work done against external pressure

c) either 'a' or 'b'

d) both 'a' and 'b'

181. The MKS units of principal specific heat is,

a) kcal/kg K b) kg K/kcal

c) J/kg K d) J/gm °C

182. Which of the following substances has the lowest value of specific heat

a) glass b) copper

c) lead d) mercury

183. The dimensions of specific heat are

a) $[L^2M^0T^{-2}\ K^{-1}]$ b) $[L^2\ M^1\ T^{-2}\ K^{-1}]$

c) $[L^2M^0T^{-2}\ K^{-2}]$ d) $[L^2\ M^1\ T^2\ K^{-2}]$

184. The mechanical equivalent of heat is

a) a physical quantity

b) a dimensional quantity

c) a conversion factor

d) all of the above

185. The amount of heat required to raise the temperature of 1 kg of water by 10K at constant pressure is

a) c_p b) C_p

c) c_v d) C_v

186. Which of the following has the highest specific heat?

a) copper b) water

c) hydrogen d) silver

187. A monoatomic gas molecule has translatory motion along

a) a single axes only

b) two axes only

c) three axes only

d) three axes and rotatory motio~ zero

188. The specific heat during an adiabatic change is

a) zero b) infinity

c) 1 d) less than 1

189. A gas that has 3 degrees of freedom is

a) mono atomic b) diatomic

c) triatomic d) polyatomic

190. Which of the following in solids, liquids and gases has largest specific heat?

a) copper b) water

c) hydrogen d) mercury

191. The specific heat of ice at aoc is

a) zero

b) infinity

c) in between zero to infinity

d) negative values

192. Water is used as a coolant because of its

a) lower density b) easily availability

c) high specific heat d) low specific heat

193. If temperature scale is changed from centrigrade scale to Fahrenheit scale, numerical values of specific heat will

a) increase b) decrease

c) remains same d) can not say

194. The graph of specific heat at constant volume for a monoatomic gas is

a)

195. The molar specific heat at constant volume, for a non linear triatomic gas is

a) 3 R b) 4 R

c) 2 R d) R

196. The specific heat of water at boiling point is

a) zero b) one

c) infinity d) less than one

197. The value of heat required to raise the temperature of unit mass of gas through 1 K is

a) less when pressure is constant

b) equal when pressure is constant or volume is constant

c) greater when pressure is constant

d) greater when volume is constant

198. Heat capacity of a substance is infinite it means

a) heat is given out

b) heat is taken in

c) no change in temperature whether heat is taken in or given out

d) first heat is taken then heat is given out

199. The values of the specific heat of the gas during adiabatic change is

a) infinite

b) finite

c) zero

d) any values from zero to infinity

200. Specific heat at constant pressure C_p of a gas

a) more than the specific heat at constant volume (C_v)

b) less then the specific heat at constant volume (C_v)

c) equal to the specific heat at constant volume (C_v)

d) may be more or less than specific heat at constant volume (C_v)

201. If M is the molecular weight of a gas then the principal specific heat of a gas is given by

a) M × Molar specific heat

b) (11M) × molar specific heat

c) M_2 molar specific heat

d) $(11M_2)$ molar specific heat

202. An ideal gas has volume V_0 at 27°C. It is heated

at constant pressure, so that its volume becomes $2V_0$, then the final temperature is

a) 327 K b) 327°C

c) 54° d) 150°C

203. One mole of an ideal gas requires 207 J of heat to raise the temperature by 10 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by 10 K then heat required will be [R = 8.3 J/mol K]

a) 96.6 J b) 124 J

c) 198.8 J d) 215.4 J

204. The principal specific heat of hydrogen gas at constant pressure and at constant volume are 3400 cal/kg °K and 2400 cal/kg °K respectively. Then the value of J will be

(R = 8300 J/kmol K, mol wt of H_2 = 2)

a) 4.18 b) 4.17

c) 4.16 d) 4.15

205. If 2 kg of steam at 100 °C condenses into water at 40°C, then the energy evolved in calories will be

(L = 540 cal/gm, C = 1 cal / gm °C)

a) 600 k cal b) 60 k cal

c) 1200 k cal d) 120 k cal

206. The ratio of the densities of the two liquids is 2 : 3 and the ratio of their specific heats is 3 : 2. What will be the ratio of their thermal heat capacities, when same volume of both liquids are taken?

a) 2 : 3 b) 3 : 2

c) 9 : 4 d) 1 : 1

207. If one mole of argon is to be heated at constant volume so that its temperature rises by 2 K. How much heat in calories will be required?

(R = 2 cal/mole K)

a) 4.24 cal b) 6 cal

c) 6.94 cal d) 7.94 cal

208. One mole of an ideal gas requires 135 J of heat to raise its temperature by 15 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same, then the heat required will be

(R = 8.3 J/ mole K)

a) 198.7 J b) 105 J

c) 215.3 J d) 10.5 J

209. If one mole of a monatomic gas of (y = 5/3) is mixed with one mole of a diatomic gas, then the (y =7/5) value of y for the mixture will be

a) 1.5 b) 1.54

c) 1.4 d) 1.45

210. The quantity of heat energy supplied to 14 grams of nitrogen to raise its temperature by 40°C at constant pressure in terms of R is

(Molecular weight of nitrogen is 28)

a) 50 R b) 60 R

c) 70 R d) 80 R

211. If the specific heat of helium at constant volume is 12.6 J/mol K, then the specific heat of hydrogen at constant volume in J/mole K will be

a) 12.6 b) 16.8

c) 18.9 d) 21

212. 743 J of heat energy is needed to raise the temperature of 5 moles of an ideal gas by 2 K at constant pressure. How much heat energy is needed to raise the temperature of the same mass of the gas by 2 K at constant volume?

(R = 8.3 J/mol K)

a) 826 J b) 743 J

c) 660 J d) 74.3 J

213. If 70 cal heat is required to raise the temperature of 2 moles of an ideal gas at constant pressure from 30°C to 35°C, then the amount of heat required to raise the temperature of the same gas through same range at constant volume will be

(R = 2 cal/mol K)

a) 50 cal b) 70 cal

c) 60 cal d) 65 cal

214. The specific heat of hydrogen gas at constant pressure is 3.4×10^3 cal/kg °C and at constant volume is 2.4×10^3 cal/kg °C. If one kilogram of hydrogen gas is heated from io'c to 20°C at constant pressure, the external work done on the gas to maintain it at constant pressure will be

a) 10^3 cal b) 10^4 cal

c) 5×10^3 cal d) 10^5 cal

215. If a gas R/C_v = 0.67, then the gas is made up of molecules which are

a) diatomic b) moatomic

c) triatomic d) polyatomic

216. If 294 joules of heat energy is required to raise

the temperature of 2 moles of an ideal gas from 30°C to 35 °C at constant pressure, then the specific heat at constant pressure will be (R = 8.4 J/mol °K)

a) 27.4 J/mol K b) 28.4 J/mol K
c) 29.4 J/mol K d) 30.4 J/mol K

217. In Q. No. 216, the amount of heat required to raise the temperature of the same gas through the same range of temperature at constant volume is

a) 210 J b) 190 J
c) 200 J d) 220 J

218. One mole of mono atomic gas is mixed with 2 moles of diatomic gas. What is the value of molecular specific heat of the gas at constant pressure in cal/mol K ? (R = 2 cal/mol K)

a) 1.5 b) 6.32
c) 3.5 d) 4.16

219. If the specific heat of lead is 0.03 cal/gm, then the thermal capacity of 500 gm of lead will be

a) 5 cal/°C b) 10 cal/°C
c) 15 cal/°C d) 20 cal/°C

220. Ratio of thermal capacities of two copper spheres of radii 5 cm and 10 cm is

a) 1 : 4 b) 1 : 1
c) 1 : 8 d) 8 : 1

221. The molar specific heat of a gas at constant volume is 24 J/mol K. Then change in its internal energy if one mole of such gas is heated at constant volume from 10 °C to 30°C is

a) 240 J b) 480 J
c) 360 J d) 720 J

222. '5' moles of oxygen is heated at constant volume from 10 °C to 20°C. What will be the change in the internal energy of the gas in calories?

(For the gas C_p = 7 cal/gm mol/°C & R= 2 cal/mol °C)

a) 50 b) 100
c) 150 d) 250

223. If the difference between the principal specific – heats of nitrogen is 300 J/kg K and ratio of specific heat is 1.4 then c, will be

a) 1050 J/kg K b) 250 J/kg K
c) 750 J/kg K d) 150J/kg K

224. One mole of an ideal monatomic gas is heated at a constant pressure of one atmosphere from 0°C to 100°C. Work done by the gas is (R = 8.3 J/mol K)

a) 8.31×10^3 J b) 8.31×10^{-3} J
c) 8.31×10^{-2} J d) 8.31×10^2 J

225. The change in internal energy when 5 mole of hydrogen is heated to 20°C from 10 °C, specific heat of hydrogen at constant pressure is 8 cal/mol °C is

[R = 2 cal/mol °C]

a) 200 cal b) 350 cal
c) 300 cal d) 475 cal

226. The difference between the principal specific heats of nitrogen is 300 J/kg K and ratio of the two specific heats is 1.4. Then C_p is

a) 1050 J/kg K b) 750 J/kg K
c) 650 J/kg K d) 150 J/kg K

227. For a gas, $C_p - C_v$ = 5000 J/kg K, if the ratio of principal specific heat is 1.5, then C_p in J/kg K will be

a) 12000 b) 15000
c) 14000 c) 16000

228. If c_p and c_v are thesprincipal specific heats of an ideal gas in cal/grn °C, ρ is the density, P is the pressure and T is the temperature of the gas, then Mayer's relation is

a) $\rho(c_p - c_v) = \dfrac{P}{JT}$ b) $c_p - c_v = \dfrac{dP}{JT}$

c) $c_p - c_v = \dfrac{JP}{\rho T}$ d) $c_p - c_v = \dfrac{JP}{\rho P}$

229. For hydrogen gas $c_p - c_v$ = a and for oxygen gas $c_p - c_v$ = b where c_p and c_v refer to specific heats at constant pressure and constant volume, for unit mass, then

a) b = 16 a
b) a = b
c) 'a' and 'b' are not related
d) a = 16 b

230. The molar specific heat of oxygen at constant pressure is 7.03 cal/mol °C and R = 8.31 J/mol °C. Then the amount of heat taken by 5 moles of oxygen when heated at constant volume from 10°C to 20 °C will be

a) 25 cal b) 50 cal

c) 250.5 cal d) 500 cal

331. If R is the molar gas constant and $\gamma = C_p/C_v$, then C, is equal to

a) R/γ b) γ R

c) $\frac{2R}{\gamma - 1}$ d) $\frac{R}{\gamma - 1}$

332. If R is the molar gas constant and $\gamma = C_p/C_v$, then C_p is equal to

a) R/γ b) γ R

c) $\frac{2R}{\gamma - 1}$ d) $\frac{R}{\gamma - 1}$

233. If the amount of heat given to a system is 50 J and work done on the system is 15 J, then change in internal energy of the system will be

a) 35 J b) 50 J

c) 65 J d) 15 J

234. For a gas, the difference between two specific heats is 4150 J/kg K and the ratio of the two specific heats is 1.4. What is the specific heat of the gas at constant volume in J/kg K ?

a) 8475 b) 5186

c) 1660 d) 10375

235. The temperature of Argon, in a vessel, is raised by 1°C at constant volume. Part of total heat supplied to the gas may be taken as translational and rotational energies. Their respective shares are

a) 60 %, 40 % b) 100 %, 0 %

c) 0 %, 100 % d) 40 %, 60 %

236. The temperature of hydrogen in a vessel, is raised by 1°C at constant volume. Part of total heat supplied to the gas may be taken as translational and rotational energies. Their respective shares are

a) 60 %, 40 % b) 100 %, 0 %

c) 0 %, 100 % d) 40 %, 60 %

237. The temperature of ozone in a vessel, is raised by 1°C at constant volume. Part of total heat supplied to the gas may be taken as translational and rotational energies. Their respective shares are

a) 50 %, 50 % b) 100 %, 0 %

c) 0 %, 100 % d) 40 %, 60 %

238. Molar specific heat of a monatomic gas at constant pressure is

a) 5/2 R b) 3/2 R

c) 7/2 R d) R

239. One mole of an ideal gas requires 207 J of heat to raise the temperature by 1 K, when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same range, the heat required will be

[R = 8.3 J/mole K]

a) 215.3 J b) 198.7 J

c) 207 J d) 19.87 J

240. If the difference between the two specific heats of triatomic gas is 500 J/kg K. Then the principal specific heat of a gas constant volume c_v in J/kg K. ($\gamma = 4/3$)

a) 2000 b) 1250

c) 1000 d) 1500

241. If the difference between the two specific heats of triatomic gas is 500 J/kgK. Then the principal specific heat of a gas constant pressure c_p in J/kgK. ($\gamma = 4/3$)

a) 1250 b) 1500

c) 1000 d) 2000

242. Molar specific heat of oxygen at constant pressure is 7.2 cal/mol °C and R = 8.3 J/mol K. At constant volume, 5 moles of oxygen is heated from 10°C to 20°C, then the quantity of heat required will be

a) 25 cal b) 50 cal

c) 260 cal d) 500 cal

243. The temperature of 5 moles of a gas which is held at constant volume is changed from 100°C to 120°C. If the change in internal energy is found to be 80 J, then the total heat capacity of the gas at constant volume will be

a) 8 J/K b) 4.0 J/K

c) 0.8 J/K d) 0.4 J/K

244. 5 moles of gas were heated from 100°C to 120°C at constant volume. The internal energy was changed by 200 J. What is the specific heat capacity of the gas?

a) 5 J/mol K b) 4 J/mol K

c) 2 J/mol K d) 10 J/mol K

245. The specific heat of a gas at constant volume is 20 J/mol K. When two moles of such gas is heated through 10°C at constant pressure, what is the

increase in internal energy and work done?
(R = 8 J/mol K)

a) 200 J, 160 J b) 400 J, 260 J
c) 400 J, 160 J d) 200 J, 460 J

246. The ratio of specific heats of a gas is 1.4. If the value of C_v is 20. 8 J/mol K, then the C_p is
a) 3.93 cal/mol K b) 4.93 cal/mol K
c) 5.93 cal/mol K d) 6.93 cal/mol K

247. The relation between principal specific heats of gases at constant pressure and at volume is
a) $c_p - c_v = R/JM$ b) $c_p + c_y = R/JM$
c) $c_p - c_v = JM/R$ d) $c_p + c_v = JM/R$

248. For hydrogen gas molar specific heat $C_p - C_v = a$ and for oxygen gas $C_p - C_v = b$, the relation between a and b is
a) a = 16 b b) a = 4 b
c) 16 b = a d) none of these

249. The Mayer's relation is
a) $c_p - c_v = r$ b) $C_p - C_v = R$
c) $C_p + C_v = R/JM$ d) 'a' and 'b'

250. If temperature of 5 moles of a gas is raised through 100°C at constant pressure, then external work done by the gas will be (R = 8.32 J/mol K)
a) 832 J b) 4160 J
c) 41.6 J d) 15280 J

251. When a gas in a vessel expands, its internal energy decreases. The process involved is
a) irreversible b) reversible
c) adiabatic d) isothermal

252. There are two lead spheres at the same temperature, the ratio of radii being 1 : 2. The ratio of heat capacities are
a) 1 : 2 b) 1 : 4
c) 1 : 6 d) 1 : 8

253. The thermal capacity of 10 gram of a substance is 8 calories. Then the specific heat is
a) 0.8 b) 1.25
c) 0.4 d) 0.1

254. The number of degrees of freedom of diatomic gas are
a) 3 b) 5
c) 6 d) 2

255. The difference between the specific heat is 600 J/kg K. The ratio of their specific heats is 1.6. The value of c_p is J/kg K.
a) 600 b) 1600
c) 1000 d) 40

9.6 Thermodynamics

256. Measurement of temperature based on
a) Zeroth law of Thermodynamics
b) First law of thermodynamics 266.
c) Second law of thermodynamics
d) All the above

257. Mercury is used as thermometric liquid because
a) it has low specific heat
b) it does not wet the glass tube
c) it is opaque and bright
d) all the above

258. The temperature of sun is measured with
a) Resistance thermometer
b) Vapour pressure thermometer
c) Radiation pyrometer
d) Gas thermometer

259. The heat given to an ideal gas in isothermal change is used
a) in raising temperature
b) in doing external work
c) both 'a' and 'b'
d) increasing the internal energy

260. Heat added to a system is equal to
a) a change in internal kinetic energy
b) a change in internal potential energy
c) the work done by it
d) all the above

261. An adiabatic change takes place at constant
a) heat content of the system
b) temperature of the system
c) pressure of the system
d) pressure and temperature of the system

262. When a bullet is stopped suddenly the rise in temperature is independent of
a) velocity of the bullet
b) material of the bullet
c) mass of the bullet
d) all of these

263. Which of the following parameters does not

characterise the thermodynamic state of matter

a) Pressure b) Volume

c) Work d) Temperature

264. In a given process, on an ideal gas work done $dW = a$ and $dQ < 0$, then for the gas

a) temperature will decreases

b) volume will increase

c) temperature will increases

d) pressure remains constant

265. Heat can not by itself flow from a body at lower temperature to a body at higher temperature is a statement of

a) 1st law of thermodynamics

b) 2nd law of thermodynamics

c) zeroth law of thermodynamics

d) 4th law of thermodynamics

366. It is impossible to convert total heat into work". This is the statement of law of thermodynamics.

a) zeroth law b) first law

c) second law d) third law

267. Two bodies are said to be in thermal equilibrium when is same.

a) amount of heat b) specific heat

c) temperature d) thermal capacity

268. The concept of temperature is given by law of thermodynamics

a) zeroth b) first

c) second d) third

269. Work done on a system or by a system generally depends on

a) final state

b) initial and final states

c) path

d) path, initial and final states

270. During the change of state the heat is

a) absorbed

b) liberated

c) absorbed or liberated

d) neither absorbed nor liberated

271. Which of the changes is not isothermal change?

a) melting of ice

b) boiling of water

c) slow conversion of iodine into vapour

d) sudden conversion of iodine into vapour

272. On opening the door of a refrigerator in a room

a) cools the room to that of the inside of the refrigerator

b) room warms up slightly

c) neither the room cools nor warms

d) cools the room to a certain temperature

273. The internal energy of monoatomic gas is due to

a) rotatory motion b) translatory motion

c) vibratory motion d) all the above

274. The internal energy of diatomic gas is due to

a) rotatory motion b) translatory motion

c) vibratory motion d) both 'a' and 'b'

275. The internal energy of triatomic gas is due to

a) vibratory motion b) rotatory motion

c) translatory motion d) both 'b' and 'c'

276. For an adiabatic process, the correct statement is

a) $dU = -dW$ b) $dQ = 0$

c) $dU = dW$ d) both 'a' and 'b'

277. For an ideal gas $dW = 0$ and $dQ < 0$ then for the gas

a) volume increases

b) pressure decreases

c) temperature decreases

d) temperature increases

278. If the coffe in a thormos flask is shaked vigorously. Then,

a) Temperature increases

b) Temperature decreases

c) No change in temperature

d) Can not say

279. A refrigerator with its power on is kept in a closed room and its door is kept open, the temperature of the room

a) falls

b) rises

c) remains same

d) depends on area of the room

280. A gas receives an amount of heat equal to 110 J and performs 40 J of work. The change in the internal energy of the gas is

a) 70J b) 150J

c) 110J d) 40J

281. In a thermodynamics process, the pressure of a fixed mass of gas is changed in such a way that the gas releases 20 J of heat and 8 J of work is done on the gas. If the initial internal energy of the gas was 30 J, then the final internal energy will be

a) 58J b) 18J

c) 42 J d) 2 J

282. The change in internal energy when a system absorbs 200 calorie of heat and at the same time does 500 J of work

a) 6400 J b) 8200 J

c) 5600 J d) 7900 J

283. If the amount of heat given to a system is 40 J and the amount of work done on the system is 15 J then the change in internal energy is

a) 50 J b) –50 J

c) 30 J d) 55 J

284. The change in internal energy of a gas kept in a rigid cylinder on supplying 120 J of heat is

a) 0 J b) 60 J

c) 100 J d) 120 J

285. When heat energy of 1500 J is supplied to a gas it is compressed from 10 m3 to 5 m3 at a pressure of 100 Pa. The change in internal energy is

a) 2000 J b) 1000 J

c) 500 J d) 2500 J

286. A gas at constant pressure of 4.5×10^5 Pa changes the volume from 1.5 m3 to 3.0 m3 on giving a heat of 800 k J. The change in internal energy is

a) 5.25×10^5 J b) 6.75×10^5 J

c) 1.25×10^5 J d) 3.25×10^5 J

287. A system absorbs 100 cal of heat and does an external work of 150 J. If J = 4.2 J/cal the change in internal energy is

a) 420 J b) 270 J

c) 250 J d) 150 J

288. At a constant pressure of 20 Pa a gas is compressed from 10 m^3 to 5 m^3. Later 100 J of heat is added to the system. The change in internal energy is

a) 200 J b) 400 J

c) 300 J d) 100 J

289. 5 more of hydrogen (γ = 7/5) initially at STP is compressed adiabatically so that its temperature increases by 400°C (R = 8.3 J/mole K). The increase in internal energy in kJ is

a) 20.5 b) 41.5

c) 21.5 d) 65.5

290. The temperature of 2 moles of a gas is changed from 20°C to 30°C when heated at constant volume. If the molar heat capacity at constant volume is 8 J mol $^{o}K^{-1}$, the change in internal energy is

a) 80 J b) 20 J

c) 160 J d) 16J

291. A gas expands from 75 litres to 125 litres at constant pressure of 4 atmosphere. Work done by the gas during this change is (10 atm = 10^5 Nm^{-2})

a) 50 kJ b) 40 kJ

c) 30 kJ d) 20 kJ

292. At a constant pressure of 10^4 Nm^{-2}, a gas expands by 0.25 m^3. Work done by the gas is

a) 2500 J b) 250 J

c) 25 J d) 2.5 J

293. A gas of volume 2 litres is given 300 J of heat and the gas increases to 2.5 litres of volume (1 atm = 10^5 Nm^{-2}). The change in internal energy is

a) 50 J b) 100 J

c) 250 J d) 200 J

294. A gas is compressed at constant pressure of 20 Pa from a volume 10 m^3 to 5 m^3. Later energy of 100 J is added to the gas. What is the change in internal energy?

a) 100 J b) 200 J

c) 300 J d) 400 J

295. Heat is supplied to a monoatomic gas which expands at constant pressure. The % of heat that goes into work done by the gas is

a) 20 b) 40

c) 60 d) 80

296. Heat is supplied to a diatomic gas which expands at constant pressure. The % of change in internal energy to heat supplied is

a) 71.4 b) 60.8

c) 40.9 d) 18.6

297. An ideal heat engine works between the

temperature 327°C (source) an d 27°C (sin)k. What is its efficiency?

a) 100% b) 75%
c) 50% d) 25%

298. An ideal heat engine works between source at 127°C and sink 27°C. If 800 J heat is taken from reservoir, the amount of heat rejected to sink is

a) 300 J b) 400 J
c) 500 J d) 600 J

299. A heat engine working between 300 K and 600 K has a work output 800 J/cycle. How much heat energy is supplied from source per cycle?

a) 1400 J b) 1600 J
c) 1500 J d) 1700 J

300. A heat engine whose sink at a temperature of 300 K has an efficiency 40%. By how much the temperature of source should be increased to attain efficiency to 60% ?

a) 750 K b) 200 K
c) 300 K d) 275 K

301. An ideal heat engine working between 27°C and 127°C takes 400 cal of heat in one cycle. The work done is

a) 75 cal b) 50 cal
c) 100 cal d) 200 cal

302. A heat engine converts 1/6th of input heat into work. When temperature of sink is reduced by 62 K the efficiency of engine becomes 1/3. The temperature of source is

a) 362 K b) 372 K
c) 392 K d) 412 K

303. What is the efficiency of a heat engine whose temperature of source and sink are 800 K and 600 K respectively?

a) 100% b) 75%
c) 50% d) 25%

304. The efficiency of a heat engine operating with reservoir temperature of 100°C and sink temperature of –23°C will be

a) $\frac{100-30}{100}$ b) $\frac{100-23}{373}$

c) $\frac{100+23}{373}$ d) $\frac{100+30}{100}$

305. Two heat engines A and B have their sources at 327°CC and 227°C and sinks at 127°C and 27°C. The ratio of their efficiencies is

a) 6/5 b) 5/6
c) 2/5 d) 5/2

306. The temperature of the sink of a heat engine is 27°C. If the efficiency of the engine is 25%, the temperature of the source is

a) 27°C b) 127°C
c) 327°C d) 227°C

307. A heat engine works on a Carnot cycle with a heat sink of 27°C. The efficiency is 10%. The temperature of source is

a) 270 K b) 30 K
c) 60°C d) 30°C

308. Heat engine takes 300 cal of heat at 500 K and rejects 150 cal of heat to sink. The temperature of sink is

a) 1000 K b) 750 K
c) 250 K d) 125K

309. An ideal heat engine exhausting heat at 77°C is to have a 30% efficiency. It must take heat at

a) 127°C b) 227°C
c) 327°C d) 673°C

310. A heat engine takes in 3000 K cal of heat from a reservoir at 627°C and gives it to a sink at 27°C. The work done by the engine is

a) 4.2×10^6 J b) 16.8×10^6 J
c) 8.4×10^6 J d) 2.1×10^6 J

311. The efficiency of reversible heat engine is 111 and that of irreversible heat engine is 112. Then,

a) 111 > 112 b) 111 < 112
c) 111 = 112 d) 111 ≥ 112

9.7 Absorption, reflection and transmission of heat radiation

312. The heat can be transferred from a point of higher temperature to the point of lower temperature in the form of

a) conduction b) convection
c) radiation d) all of the above

313. In conduction mode, heat can be transferred from a point of higher temperature to the point of lower temperature

a) with the actual migration of the particles of medium

b) without actual migration of the particles of medium
c) in the form of electromagnetic radiation
d) in the form of corpuscles

314. Convection of heat takes place in
a) solids b) liquids
c) gases d) 'b' and' c'

315. In radiation mode, heat energy can be transferred
a) in presence of material medium
b) without any material medium
c) in presence of any material medium or without any material medium
d) none of these

316. It is hotter at some distance over the fire than in front of it because
a) heat is radiated upwards only
b) convection heat takes downward only
c) air conducts heat upwards only
d) convection takes more heat upwards

317. The transmission of heat by conduction is
a) a reversible process
b) an irreversible process
c) an adiabatic process
d) contain large number of free electrons

318. Metals are good conductance of heat because metals
a) are ductile
b) have a few free electrons
c) have no free electron
d) contain large number of free electrons

319. In a room, heat can go from one place to another by
a) conduction b) convection
c) radiation d) both 'b' and 'c'

320. Heat energy reaches on the earth from the sun in the form of
a) conduction b) convection
c) radiation d) scattering

321. Water placed in a pot is heated because of
a) conduction b) convection
c) radiation d) absorption

322. The false statement in the following is
a) radiations are electromagnetic waves
b) radiations can pass through vacuum
c) radiations travel with the velocity of light
d) none of the above

323. In winter, the temperature inside the wall of a room as compared to the temperature of air in the room is
a) lower
b) higher
c) same
d) may be lower or higher depending on atmospheric pressure

324. In a thermos flask, attempt is made to reduce losses of heat by
a) conduction only
b) conduction and convection
c) convection only
d) conduction, convection and radiation

325. The velocity of heat radiation in vacuum is
a) equal to that of light
b) equal to that of sound
c) greater than that light
d) less than that sound

326. Thermal radiations are electromagnetic radiation belonging to
a) visible region b) ultra violet region
c) infra red region d) x–ray region

327. The fire screen produces the sensation of cooling because it does not allow
a) infra red rays
b) electromagnetic waves
c) ultra violet rays
d) visible light

328. The fastest mode of transfer of heat is
a) conduction b) convection
c) radiation d) all the above

329. Heat radiations cannot exhibit the following phenomenon. That is
a) interference b) diffraction
c) polarisation d) beats

330. The solar cooker works on the same principle as
a) bolometer b) green house
c) pyrometer d) hygrometer

331. The thermal radiations are similar to

a) cathode–rays b) x–rays
c) y–rays d) x–rays

332. Thermos flask prevents heat loss by
a) convention b) conduction
c) radiation d) both 'a' and 'b'

333. On which of the following factors does the intensity of heat radiations from a body depend
a) temperature of the body
b) thermal capacity
c) amount of heat content
d) can not be predicted

334. Cloudy nights are warmer than clear ones because
a) clouds absorb heat in the day and supply it in the night
b) clouds reflect black heat radiations to the earth
c) heat of the earth's atmosphere increases in the presence of clouds
d) the question is irrelevant

335. Two persons ordered tea in a restaurant and waited for a friend to arrive. The first person mixed hot tea and cold milk in the cup and waited for the fried and the second mixed hot tea and hot milk in the cup after the arrival of the friend. If the temperature of the two cups of tea are T_1 and T_2 respectively, then
a)$T_1 < T_2$ b)$T_1 = T_2$
c) $T_1 > T_2$ d) $T_1 \geq T_2$

336. Heat radiation have wavelengths in the region of
a) visible light b) ultraviolet
c) radio wave d) infrared

337. The substances which are transparent to thermal radiations are
a) athermanous b) diathermanous
c) water vapour d) black body

338. Two bodies one hot and the other cold are kept in vacuum. What will happen to the temperature of the hot body after some time?
a) remain the same
b) decrease due to radiation
c) increase due to radiation
d) increase due to convection

339. On which one of the factors do the nature of the thermal radiation depends inside an encolsure ?
a) nature of walls
b) temperature
c) size of the enclosure
d) colour of the walls

340. A black body at high temperature emits thermal radiations of
a) small wavelength b) large wavelength
c) fixed wavelength d) all wavelengths

341. Under steady state, the temperature of a body
a) decrease with time
b) does not change with time and is same at all the points of the body
c) increase with time
d) does not change with time but can be different at different point of the body

342. The slowest mode of transfer of heat is
a) conduction b) convection
c) radiation d) all the above

343. The colour of a star is an indication of its
a) weight b) size
c) temperature d) distance

344. If the temperature of the sun increases by 100%, the maximum energy radiated by the sun would correspond to
a) radio wave region b) ultra violet region
c) infrared region d) visible region

345. The sea breeze and land breeze arise due to
a) convection
b) conduction
c) both convection and conduction
d) Radiations

346. A medium is not required for transfer of thermal energy from one body to another body in
a) conduction b) convection
c) radiation d) all of these

347. If thermal radiation passes through free space then the temperature of the free space
a) increases
b) decreases
c) does not change
d) either increases or decreases

348. Thermal radiations may exhibit the following phenomenon

a) interference only

b) diffraction only

c) polarisation only

d) interference, polarisation and diffraction

349. The door of refrigerator in a room is left open the room is

a) cooled

b) warmed

c) no effect

d) first heated then cooled

350. Mode of transmission of heat, in which heat is carried by the moving particles, is

a) radiation   b) conduction

c) convection   d) wave motion

351. Morning sun is not as hot as the mid–day sun because

a) sun is cooler in the morning

b) sun rays have to travel longer in the morning than at mid–day

c) earth is farther away in the morning

d) of some reason other than those given above

352. If a liquid is heated in weightlessness, the heat is transmitted through

a) conduction

b) convection

c) radiation

d) neither, because the liquid cannot be heated in weightlessness

353. In which of the following process, convection does not take place primarily

a) sea and land breeze

b) boiling of water

c) warming of glass of bulb due to filament

d) heating air around a furnace

354. A thermos flask is polished well

a) to make attractive

b) for shining

c) to absorb all radiations from outside

d) to reflect all radiations from outside

355. Heat travels through vacuum by

a) conduction   b) convection

c) radiation   d) both 'a' and 'b'

356. We consider the radiation emitted by the human body. Which of the following statements is true?

a) The radiation is emitted only during the day

b) The radiation is emitted during the summers and absorbed during the winters

c) The radiation emitted lies in the ultraviolet region and hence is not visible

d) The radiation emitted is in the infrared region

357. The earth radiates in the infrared region of the spectrum.

a) Wien's law

b) Rayleigh jeans law

c) Planck's law of radiation

d) Stefan's law of radiation

358. Infrared radiation is detected by

a) spectrometer   b) pyrometer

c) nanometer   d) photometer

359. A hot and a cold body are kept in vacuum separated from each other. Which of the following cause decrease in temperature of the hot body?

a) Radiation

b) Convection

c) Conduction

d) Temperature remains unchanged

360. The coefficient of absorption is the ratio of

a) radiant energy incident to the radiant energy absorbed

b) the radiant energy absorbed to the radiant energy incident

c) both' a' and 'b'

d) energy incident to energy emitted

361. The athermanous is

a) a medium which does not allow heat radiation

b) a medium which transmits heat radiation

c) both' a' and 'b'

d) which reflect heat radiation

362. The transmission of heat by molecular collision is called

a) conduction   b) convection

c) radiation   d) scattering

363. When thermal radiations incident on athermanous medium, the temperature of the medium

a) increases

b) decreases

c) does not change

d) nothing can be predicted

364. The coefficient of the absorption of the thermal radiation of body is

a) dependent on wavelength of incident radiation

b) dependent on temperature

c) independent to the nature of the surface

d) independent of wavelengths

365. The sum of the absorptance, reflectance and transmittance of a body is

a) 1 b) 2

c) 3 d) ∞

366. The substance which are transparent to thermal radiaion are

a) athermanous b) diathermanous

c) thermo electric d) radioactive

367. Absorptive power of a body depends upon

a) surface area

b) time of observation

c) temperature

d) neither surface area nor temperature

368. The coefficient of transmission is the ratio of

a) radiant energy incident to the radiant energy transmitted through the body

b) the radiant energy transmitted through the body to the radiant energy incident on it

c) the ratio of radiant energy transmitted to the radiant energy absorbed by the body

d) none of these

369. The coefficient of reflection is the ratio of

a) radiant energy reflected from the body to the radiant energy incident on it

b) radiant energy incident on the body to the radiant energy transmitted through the body

c) both' a' and 'b'

d) none of these

370. A good absorber is a

a) poor reflector and transmitter

b) good reflector

c) perfect reflector and transmitter

d) bad absorber

371. The diathermanous is

a) a medium which does not allow heat radiation

b) a medium which transmits heat radiation

c) both 'a' and 'b'

d) which reflect heat radiation

372. The coefficients of absorption and reflection of the surface of a thin plate are 0.74 and 0.22 respectively. If 150 J of radiant energy are incident on the plate, then the quantity of heat transmitted is

a) 6.0 J b) 3.3 J

c) 33 J d) 60 J

373. Out of 10 J of radiant energy incident on a surface, the energy absorbed by the surface is 2 J and the energy reflected is 7 J. Then coefficient of transmission of the body is

a) 0.2 b) 0.7

c) 0.1 d) zero

374. If an athermanous body absorbs 20 % of the incident radiant energy, then reflection coefficient of the body is

a) 0.2 b) zero

c) 0.8 d) 1

375. The coefficients of absorption and reflection of the surface of a body are 0.70 and 0.25 respectively. If 200 calories of radiant heat is incident on the surface of the body, the quantity of heat transmitted will be

a) 140 cal b) 50 cal

c) 10 cal d) 60 cal

376. The coefficients of absorption and transmission of the are 0.50 and 0.25 respectively. If 200 calories of radiant heat j s incident on the surface of the body, the quantity of heat reflected will be

a) 140 cal b) 150 cal

c) 50 cal d) 200 cal

9.8 Perfectly black body, emmissive power and emmissivity

377. A black hole, absorbs

a) all radiation

b) all radiations except x–rays

c) all radiations except visible radiations

d) x–rays only

378. In Ferries perfectly black body, the black body is

a) aperture b) outer sphere

c) inner sphere d) conical projection

379. The best ideal black body is
a) lamp of charcoal heated to a high temperature
b) metal coated with a black dye
c) glass surface coated with colter
d) hollow enclosure blackened inside and having a small hole

380. Which of the following will radiate heat to a large extent?
a) Rough surface
b) Black and rough surface
c) Polished surface
d) Black – polished surface

381. The phenomenon of emission of heat by a black body was satisfactory explained by
a) kinetic theory b) quantum theory
c) classical theory d) theory of relativity

382. An electric heater, kept in vacuum is heated continuously by passing electric current. Its temperature will
a) go on rising with time
b) stop rising after some time as it will lose heat to surroundings by conduction
c) will rise for some time and there after will start falling
d) will become constant after some time due to loss of heat by radiation

383. A polished metal plate with a rough black spot on it is heated to about 1400 K and quickly taken into a dark room. Which one of the following statements will be true?
a) The spot will appear brighter than the plate
b) The spot will appear darker than the plate
c) The spot and the plate will appear equally bright
d) The spot and the plate will not be visible in the dark room

384. A person with dark skin as compared to a person with white skin will experience
a) less heat and less cold
b) more heat and less cold
c) more heat and more cold
d) less heat and more cold

385. If the temperature of a perfectly black – body increases two times then the rate of radiation of the body also increases by
a) eight times b) two times
c) sixteen times d) four times

386. A perfectly black body is one which absorbs radiation of
a) all wavelengths
c) small wavelengths
b) large wavelengths
d) infrared wavelengths

387. Reflectance of a perfectly black body is
a) zero b) 0.9
c) 0.2 d) infinity

388. The good absorbers of heat are
a) bad–emitters b) poor emitters
c) good emitters d) 'a' and 'b'

389. The maximum energy emitted per unit time per unit area by a body for a particular wavelength depends directly on
a) temperature
b) cube root of temperature
c) square of temperature
d) fourth power of temperature

390. Coffee cools faster in saucer than in cup because of
a) the emissive power of saucer is less than cup
b) its surface area in the saucer is more than cup
c) its emissivity in saucer is higher than cup
d) saucer absorb more energy

391. The ratio of spectral emissive power of a body and that of a black body at a certain wavelength f and temperature T is equal to a physical quantity at that wavelength and temperature. Then the physical quantity is
a) emissive power of the body
b) absorptive power of the body
c) reflective power of the body
d) transmission coefficient of the body

392. The spectrum from a black body radiation is
a) line spectrum
b) band spectrum
c) continuous spectrum
d) line and band spectrum

393. A perfectly black body is one whose emissivity is
a) zero b) unity

c) maximum d) minimum

394. The emissive power of a surface depends upon

a) area b) temperature

c) time of observation d) none

395. A perfectly white body

a) which reflects all the wavelengths incident on it

b) absorbing power is zero

c) white chalk is an approximations of a perfectly white body as per as visible radiations are concerned

d) all of the above

396. The amount of heat energy radiated per second by a surface depends upon

a) the nature of the surface

b) the area of the surface

c) the temperature of the surface

d) all the above three factors

397. SI unit of emissive power is

a) J/s b) J/m^2

c) J/s m^2 d) Watt/m

398. Below a list of four types of surfaces

A) Rough white

B) White Polished mirror

C) Black polished mirror

D) Rough–black.

Which one of them is better, absorber of heat?

a) A b) B

c) C d) D

399. The silver polishing the walls of a thermos bottle minimizes the transfer of heat by

a) conduction b) radiation

c) convection d) absorption

400. The bulbs of two identical thermometers are coated one with lamp black and the other with silver thin film coated. When exposed in sun light for shorter time then the reading of the thermometer with lamp black coating will be

a) more than that with silver coating

b) less than that with silver coating

c) same of that with silver coating

d) nothing can be predicted

401. By which of the following methods could a cup of hot tea lose heat, if situated on metal table in a class room

a) conduction

b) convection

c) radiation and evaporation

d) all

402. A black body at high temperature emits thermal radiations of

a) large wavelength

b) small wavelength

c) one fixed wavelength

d) all wavelengths

403. If a sphere, cube and thin plate are heated and then kept in same surrounding, which one cools first?

a) sphere b) cube

c) plate d) both 'a' and 'b'

404. A body, which emits radiations of all possible wavelengths, is known as

a) godconductor

b) partial radiator

c) absorber of photons

d) perfectly black–body

405. Which of the following is the example of ideal black body

a) kajal b) black board

c) a pin hole in a box d) none of these

406. An ideal black body at room temperature is thrown into a furnace. It is observed that

a) initially it is the darkest body and at later times the brightest

b) it is the darkest body at all times

c) it cannot be distinguished at all times

d) initially it is the darkest body and at later times it cannot be distinguished

407. Which of the following statement is correct?

a) A good absorber is a bad emitter

b) Every body absorbs and emits radiations at every temperature

c) The energy of radiations emitted from a black body is same for all wavelengths

d) The law showing the relation of temperatures with the wavelength of maximum emission from an ideal black body is Wien's law

408. Which of the following law states that "good

absorbers of heat are good emitters"

a) Stefan's law b) Kirchoff's law

c) Planck's law d) Wien's law

409. The emissive power of a perfectly black body is equal to

a) absorption power b) transmative power

c) reflective power d) none of the above

410. Three cubes of sides 1, 2, 3 cm are at constant temperature of 100°C. Then the amount of heat lost per second by them are in the ratio

a) 1 : 8 : 27 b) 27 : 8 : 1

c) 1 : 4 : 9 d) 9 : 4 : 1

411. The emissive power of a sphere of area 0.07 m^2 is 0.5 k cal/m/s. The amount of heat radiated by the spherical surface in 20 second is

a) 7 kcal b) 0.7 kcal

c) 0.07 kcal d) 20 kcal

412. A sphere of radius 50 cm is maintained at a constant temperature, radiates energy at the rate of 0.5 kcal/s. Then the emissive power of sphere is ($J = 4.2 \times 10^3$ J/kcal)

a) 11.11×10^{-4} J/m²s b) 6×10^2 J/m²s

c) 11.11×10^{-2} J/m²s d) 11.11 J/m²s

413. A metal cube with each side 3 cm long emits 0.27 kcal in 100s. Then its emissive power is

a) 1 kcal/sm² b) 1.5 kcal/sm²

c) 0.5 kcal/sm² d), 3.5 kcal/sm²

414. The filament of an evacuated light bulb has a length 10 cm, diameter 0.2 mm and emissivity 0.2. Then the power it radiates at 1727°C is [$\sigma = 5.67 \times 10^{-8}$ SI units]

a) 11.4 W b) 1140 W

c) 114 W d) 1.4×10^5 W

9.9 Spectrum of a Black Body Radiations in Terms of Wavelength

415. When the temperature of black body rises, then the wavelength corresponding to the maximum intensity (λ_m)

a) decreases

b) increases

c) it may increase or decrease depending upon the nature of the black body

d) it may increase or decrease depending upon the scale of temperature

416. If the temperature of a black body is increased then the wavelength corresponding to the maximum emission will

a) shift towards smaller wavelength

b) shift towards longer wavelength

c) not shift

d) shift in proportion to increase in temperature

417. The cause of Fraunhofer lines is

a) reflection of radiation by chromosphere

b) absorption of radiation by chromosphere

c) emission of radiation by chromosomes

d) transmission of radiation by chromosomes

418. Wien's distribution law fails at

a) high temperature b) low temperature

c) short wavelength d) long wavelength

419. Which of the following can be used to estimate the temperature of a star?

a) Radiation spectrum

b) Speed of the star

c) Shape of the star

d) Distance from the earth

420. If the wavelength corresponding to maximum energy radiated from the moon is 14 micron, and Wien's constant is 2.8×10^{-3} m K, then temperature of moon is

a) 100 K b) 200 K

c) 2000 K d) 400 K

421. A spherical body of 5cm radius is maintained at a temperature of 327°C. The wavelength at which maximum energy radiated will be nearly ($b = 2.898 \times 10^{-3}$ m K)

a) 482 A° b) 4.82 A°

c) 482 J/ m d) 4.82 μm

422. Two stars A and B radiates maximum energy at 3600 A° and 4200 A°, respectively. Then the ratio of their temperature is

a) 6 : 7 b) 7 : 6

c) $\sqrt{6} : \sqrt{7}$ d) $\sqrt{7} : \sqrt{6}$

423. The maximum radiant energy emitted at 1000 K is for a wavelength of 2.9 Å, the maximum radiant energy emitted at 2000 K will be for a wavelength of

a) 29000 Å b) 14500 Å

c) 1.45 Å d) 7250 Å

424. The surface temperature of the sun is about 6000 K. The sun's radiation has maximum energy at a wavelength of 0.5 μm. A certain light bulb filament emits radiations with a maximum at 2 μm. If both the surface of the sun and the filament have the same emissive characteristics, then the temperature of the filament will be

a) 1500 K b) 2000 K
c) 2500 K d) 3000 K

425. If wavelengths of maximum intensity of radiations emitted by the sun and the moon are 0.5×10^{-6} m and 10^{-4} m respectively, the ratio of their temperature is

a) 1/100 b) 1/200
c) 100 d) 200

426. The wavelength of maximum emitted energy of a body at 700 K is 4.08 μm. If the temperature of the body is raised to 1400 K, the wavelength of maximum emitted energy will be

a) 1.02 μm b) 16.32 μm
c) 8.16 μm d) 2.04 μm

427. A black body at 200 K is found to exit maximum energy at a wavelength of 14 μm. When its temperature is raised to 1000K. The wavelength at which maximum energy is emitted is

a) 14 μm b) 70 μF
c) 2.8 μm d) 7 μm

428. Two stars emit maximum radiation at wavelength 3600 Å and 4800 Å respectively. The ratio of their temperature is

a) 1 : 2 b) 3 : 4
c) 4 : 3 d) 2 : 1

429. A black body emits radiation of maximum intensity an a wavelength of 5000 Å, when the temperature of the body is 1227°C. If the temperature of the body is increased by 1000°C, then maximum intensity of emitted radiation would be observed at

a) 2754.8 Å b) 3000 Å
c) 3500 Å d) 4000 Å

430. A black –body at a temperature of 1640 K has the wavelength corresponding to maximum emission equal to 1.75 μ. Assuming the moon to be a perfectly black body, the temperature of the moon, if the wavelength corresponding to maximum emission is 14.35 μ is

a) 100 K b) 150 K
c) 200 K d) 250 K

431. Solar radiation emitted by sun resembles that emitted by a black body at a wavelength of about 4800 Å. If the sun were to cool down from 6000 K to 3000 K then the peak intensity would occur at a wavelength

a) 4800 Å b) 9600 Å
c) 7200 Å d) 6400 Å

432. What will be the ratio of temperatures of sun and moon if the wavelengths of their maximum emission radiations rates are 140 Å and 4200 Å respectively?

a) 1 : 30 b) 30 : 1
c) 42 : 14 d) 14 : 42

433. The absolute temperature of two black bodies are 2000 K and 3000 K respectively. The ratio of wavelengths corresponding to maximum emission of radiation by them will be

a) 2 : 3 b) 3 : 2
c) 9 : 4 d) 4 : 9

434. A particular star (assuming it as a black body) has a surface temperature of about 5×10^4 K. The wavelength in nanometers at which its radiation becomes maximum is (b = 0.0029 mK)

a) 48 b) 58
c) 60 d) 70

435. The maximum energy in thermal radiation from a source occurs at the wavelength 4000 Å. The effective temperature of the source is

a) 7000 K b) 80000 K
c) 10^4 K d) 10^6 K

436. The intensity of radiation emitted by the sun has its maximum value at a wavelength of 510 nm and that emitted by the north star has the maximum value at 350 nm. If these stars behave like black bodies, then the ratio of the surface temperature of the sun and north star is

a) 1.46 b) 0.69
c) 1.21 d) 0.83

9.10 Kirchhoff's law of heat radiation

437. The essence of Kirchhoff's law is that a good absorber must be a

a) bad radiator b) bad conductor
c) good conductor d) good radiator

438. The black body have

a) good absorption of heat capacity

b) better absorption of heat capacity

c) best absorption of heat capacity

d) no absorption of heat capacity

439. A piece of charcoal and a piece of shining steel of the same area are kept for a long time in an open lawn in bright sun

a) the steel will. absorb more heat than the charcoal

b) the temperature of the steel will be lower than that of the charcoal

c) if both are picked up by bare hands, the steel will be felt hotter than the charcoal

d) if both are picked up by bare hands, the charcoal will be felt hotter than steel

440. On investigation of light from three different stars A, B and C it was found that in the spectrum of A, the intensity of red colour is maximum in B, the intensity of blue colour is maximum and in C the intensity of yellow colour is maximum in A. From the observation it can be concluded that

a) the temperature of A is maximum, B is minimum and C is intermediate

b) the temperature of A is maximum, C is minimum and B is intermediate

c) the temperature of B is maximum, A is minimum and C is intermediate

d) the temperature of C is .maximurn, B is minimum and A is intermediate

441. Three identical spheres of different materials iron, gold and silver are at the same temperature. The one that radiates more energy is

a) gold b) silver

c) iron d) all radiates equally

442. Which of the following is a good emitter

a) black and polished

b) white and rough

c) white and polished

d) black and rough

443. Green house effect is

a) black radiations from both the types of sources at high and low temperature

b) transmit radiations from both the types of source

c) transmit radiations from a source at low temperature and block radiations from a source at high temperature

d) transmit radiates from a source at high temperature and block radiations from a source at low temperature

444. A spherical earthen vessel with a hole is heated in a furnace till it becomes red hot. When it is taken out, the hole will appear

a) as bright as the rest of the vessel

b) brighter than other parts of the vessel

c) darker. than other parts of the vessel

d) any of the above depending upon the quality of the clay used

445. Who explained the Fraunhoffer line in the spectrum of solar radiations?

a) Wein b) Stefan

c) Kirchhoff d) Fraunhoffer

446. A good absorber of heat is a good radiator of heat, this statement is

a) Stefan b) Kirchhoff

c) Newton d) Maxwell Boltzmann

447. Relation between emissivity e and absorptive power a is (for black body)

a) $e = a$ b) $e = 1/a$

c) $e = a^2$ d) $a = e^2$

448. Which of the following statements is wrong?

a) Rough surfaces are better radiators than smooth surface

b) Highly polished mirror like surfaces are very good radiators

c) Black surfaces are better absorbers than white ones

d) Black surfaces are better radiators than white

449. Half part of ice block is covered with black cloth and rest half is covered with white cloth and then it is kept in sunlight. After some time clothes are removed to see the melted ice. Which of the following statements is correct?

a) Ice covered with white cloth will melt more.

b) Ice covered with black cloth will melt more.

c) Equal ice will melt under both clothes.

d) It will depend on the temperature of surrounding of ice.

450. If between wavelength Aand A+ dA, eA and aA be the emissive and absorptive powers of a body

and EA be the emissive power of a perfectly black body, then according to Kirchhoff's law, which is true

a) $e_\lambda = 0_\lambda = E_\lambda$ b) $e_\lambda \ E_\lambda = a_\lambda$

c) $e_\lambda = a_\lambda \ E_\lambda$ d) $e_\lambda \ a_\lambda \ E_\lambda$ = constant

451. When p calories of heat is given to a body, it absorbs q calories, then the absorption power of body will be

a) p/q b) q/p

c) p^2 / q^2 d) q^2 / p^2

452. Distribution of energy in the spectrum of a black body can be correctly represented by

a) Wien's law b) Stefan's law

c) Planck's law d) Kirchhoff's law

453. At a certain temperature for given wave length, the ratio of emissive power of a body to emissive power of black body in same circumstances is known as

a) relative emissivity

b) emissivity

c) of transmission coefficient

d) coefficient of reflection

454. The Kirchhoff's law leads to the conclusion that the good radiators of thermal radiations are

a) good absorbers b) bad absorbers

c) good conductors d) bad conductors

455. If E is emissive power and' a' is the coefficient of absorption of a body at any temperature, E_b is the emissive power of a perfectly black body at that temperature, then according to Kirchhoff's law

a) $E = E_b/a$ b) $E/a = E_b$

c) $E.E_b = a$ d) $E.E_b = 1/a$

9.11 Stefan's Law of Black Body Radiation

456. The radiation emitted by a perfectly black body is proportional to

a) absolute temperature

b) fourth root of absolute temperature

c) fourth power of absolute temperature

d) square of absolute temperature

457. Radiation emitted by a surface is directly proportional to

a) third power of its temperature

b) equal to its temperature

c) twice power of its temperature

d) fourth power of its temperature

458. The SI unit of Stefan's constant is

a) N/m^2 b) Jm^2

c) $W/m^2 \ K^4$ d) J/m^2 s K

459. The amount of heat energy radiated per unit time per unit area by a body depends upon

a) area of the body

b) temperature and nature of the body

c) nature of the body only

d) all of these

460. A body radiates heat at high temperature T. The rate of radiation of heat is proportional to

a) T^4 b) T^5

c) T^2 d) T^3

461. The relation between rate of loss of heat from the body and its absolute temperature is known as

a) Newton's law of cooling

b) Stefan's law of radiation

c) Kirchhoff's law of heat radiation

d) Prevost's law of heat exchanges

462. In MKS system the unit of Stefan's constant (σ') is

a) $watt/m^2/K$ b) $watt/m/K^4$

c) $watt/m^2/K^4$ d) $watt/m^2/K^2$

463. The amount of heat energy radiated per second by the surface depends on

a) the nature of surface only

b) the area of the surface only

c) the difference of temperature between the surface and the surrounding only

d) the nature of surface, area of the surface and the temperature of body.

464. The emissive power of a body at temperature T is E then the graph between $\log_e E$ and $\log_e T$ is

465. Two spheres of the same material and radii 4 m and 1 m are at temperature 1000 K and 2000 K respectively. Then the ratio of energies radiated by them per second is

a) 1 : 2 b) 2 : 1

c) 1 : 1 d) 1 : 4

466. The luminousity of a star is 10000 times that of the sun. If the surface temperature of the sun is 6000 K, then the surface temperature of the star is

a) 8446 K b) 84860 K
c) 848600 K d) 60,000 K

467. A spherical black body of 5 cm radius is maintained at a temperature of 327°C. Then the power radiated will be ($\sigma = 5.7 \times 10^{-8}$ SI unit)

a) 58 w b) 231 w
c) 75 w d) 482 w

468. A black body radiates energy at the rate of E watt/m^2 at high temperature T K. When the temperature falls to T/2 K, then the radiated energy will be

a) E/16 b) E/4
c) E/2 d) 16 E

469. A black body is at temperature of 500 K, emits energy per unit time per unit area is

($\sigma = 5.67 \times 10^{-8}$ SI unit)

a) 25×10^4 J/s b) 25×10^8 J/sm^2
c) 5×10^2 J/s d) 3543 J/sm^2

470. A black body at temperature 227°C radiates heat at the rate of 5 cal/cm^2 s, at a temperature of 27°C, the rate of heat radiated per unit area per unit time in cat/cm^2 s, is,

a) 4 b) 1.5
c) 0.64 d) 0.25

471. The temperature of the sun is doubled, the rate of energy received on the earth will be increased by a factor of

a) 2 b) 4
c) 8 d) 16

472. The temperature of a black body becomes half of its original temperature, the amount of radiation emitted by the body will reduce to

a) 1/16 b) 1/18
c) 1/12 d) 1/8

473. A body at 300°C radiates 10^5 watt/m^2. If the sun radiates 10^9 watt/m^2, then its temperature will be

(If both the bodies are considered as black)

a) 5730 K b) 5457 °C
c) 3000 °C d) both 'a' and 'b'

474. Two bodies A and B are placed in an evacuated vessel maintained at a temperature of 27°C, the temperature of A is 327°C and that of B is 227°C. Then the ratio of heat loss by body A and B is

a) 3 : 2 b) 245 : 1
c) 2 : 1 d) 3 : 1

475. A metal ball of surface area 200 cm^2, of temperature 527°C. If the emissivity of metal is 0.4, the rate of loss of heat will be

($\sigma = 5.7 \times 10^{-8}$ SI units)

a) 108 watt b) 168 watt
c) 182 watt d) 192 watt

476. A solid sphere cools at the rate of 2.8°C per minute, when its temperature is 127°C. Find the rate at which another solid copper sphere of twice the radius looses its temperature at 127°C, in both the cases, the room temperature is maintained at 27°C is

a) 9.72°C/min b) 11.2°C/min
c) 3.6°C/min d) 1.4°C/min

477. Ratio of rate of radiation of heat of body at 227°C to that of the same body at 27°C is

a) 3.25 : 9 b) 27 : 125
c) 5 : 3 d) 625 : 81

478. The ratio of the rate of radiation of heat by a perfectly black body at a temperatures 527°C and 127°C is

a) 16 : 1
b) 4 : 1
c) 2 : 1
d) cannot be found as the temperature of the surroundings is not known

479. A body radiates heat at the rate of 50 J/s at 300 K. When the same body is at 600 K then its rate of radiation of heat will be

a) 100 J/s b) 200 J/s
c) 400 J/s d) 800 J/s

480. The rate of emission of heat energy of an iron ball of radius 5 cm is 10 J/s, then rate of emission of heat energy by a copper ball of radius 1 cm at same temperature will be

(If emissivity of both the balls is same.)

a) 2 J/s b) 0.4 J/s
c) 2 calls d) 250 J

481. Ascube, which may be regarded as a perfectly black body/radiates heat at the rate of 2770.2 watt when its temperature is 27°C. The volume of the

cube is (σ = 5.7 × 10^{-8} J/m^2 s K^4)

a) 10^{-2} cm^3 b) 100 m^3
c) 1 m^3 d) 10^3 m^3

482. The amount of thermal radiations emitted from one square metre area of a black body in one second when at a temperature of 100 K is

a) 5.67 J b) 56.7 J
c) 567 J d) 5670 J

483. A black body radiates 3 J/cm^2 s when its temperature is 127°C. How much heat will be radiated/cm^2 s when its temperature is 527°C?

a) 6 b) 12
c) 3.84 d) 48

484. The rate of loss of heat by radiation from a body at 400°C is R. Then radiation from it when the temperature rises to 800°C is

a) 2R b) 4R
c) 16R d) 5R

485. A ball is coated with lamp black. Its temperature is 327°C and is placed in the atmosphere at 27°C, It's rate of loss of heat per unit area is R. If the temperature of the ball is 627°C. Then the rate of loss of heat per unit area will be

a) 2R b) 4R
c) 3/16 R d) 16/3 R

486. A black body at 227°C radiates heat at the rate of 5 cal/cm^2s. Then rate of heat radiated in cal/cm^2s at 727°C is

a) 40 b) 80
c) 160 d) 240

487. If the temperature of a hot body is increased by 50 %, then amount of radiant energy emitted by it increases approximately by

a) 22.5 % b) 250 %
c) 400 % d) 50 %

488. Two solid spheres of radii R_1 and R_2 are made of the same material and have similar surfaces. These are raised to the same temperature and then allowed to cool under identical conditions. Then ratio of their initial rates of loss of heat is

a) R_1/R_2 b) R_2/R_1
c) $\frac{R_1^2}{R_2^2}$ d) $\frac{R_2^2}{R_1^2}$

489. In Q. No. 488, the ratio of the initial rates of cooling is

a) R_1/R_2 b) R_2/R_1
c) $\frac{R_1^2}{R_2^2}$ d) $\frac{R_2^2}{R_1^2}$

490. Two spheres P and Q of the same colour having radii 8 cm and 2 cm respectively are maintained at temperatures 127°C and 527°C respectively. Then the ratio of the energy radiated by P and Q is

a) 4 : 1 b) 1 : 16
c) 1 : 1 d) 2 : 1

491. A black body at a temperature of 127°C radiates heat at the rate of 5 cal/cm^2s at a temperature of 927°C, its rate of emission in units of cal/cm^2 s will be nearly

a) 405 b) 35
c) 245 d) 350

492. The ratio of loss of heat from a metal sphere at 327°C to that of the same sphere at 527 °C. When placed in the surrounding of temperature 127°C is

a) $\frac{1}{2}$ b) $\frac{13}{48}$
c) $\frac{22}{48}$ d) $\frac{1}{16}$

493. The radiant energy from the sun incident normally at the surface of the earth is 20 kcal/mmin. The radiant energy, incident normally on the earth, if the temperature of sun is twice of the present one is

a) 160 kcal/m^2 min b) 40 kcal/m^2 min
c) 320 kcal/m^2 min d) 80 kca/m^2 min

494. A body radiates heat at the rate of 50 J/s at 300 K. When the same body is at 600 K then its rate of radiation of heat will be

a) 100 J/s b) 200 J/s
c) 400 J/s d) 800 J/s

495. If the temperature of a hot body is raised by 4%, then the heat energy radiated would increased by

a) 16% b) 12.5%
c) 4% d) 9%

496. A 60 w bulb has a filament temperature of 2000 K. What will be the wattage of another bulbs of

same filament area and material at a temperature of 4000 K ?

a) 8 w b) 32 w

c) 64 w d) 960 w

497. The surface of a house hold radiator has an emissivity of 0.5 and an area of 1.5 m^2. The rate at which the radiation is emitted by then the radiator when its temperature is 47°C will be nearly

($\sigma = 5.7 \times 10^{-8}$ SI units)

a) 598 watt b) 299 watt

c) 448 watt d) 346 watt

498. In the above question, if the temperature of the walls of the room is 27°C, then the radiation absorbed by the radiator is nearly

a) 462 watt b) 231 watt

c) 346 watt d) zero watt

499. A body emits Q cal/cm^2 of radiation at temperature 227°C. If the temperature of the body is raised to 727°C, then the amount of radiant energy emitted will be

a) 2Q b) 4Q

c) 16Q d) 32Q

500. The thermal capacities of two bodies A and B are in the ratio 1 : 4. If the rate of heat loss are equal for these two bodies then the rate of fall of the temperature will be in the ratio

a) 1 : 1 b) 1 : 4

c) 4 : 1 d) $(4)^{1/4} : 1$

501. A black body is at a temperature of 527°C, to radiate twice as much energy per second its temperature must be increased to

a) 921°C b) 960 K

c) 678 K d) 400 K

502. If the temperature of the black body is increased from 7°C to 287°C then the radiated power increases to

a) 16% b) 41%

c) 1600% d) 1177%

503. Two solid sphere of copper have radii 10 cm and 8 cm respectively. Their temperature are 227°C and 127°C respectively they are allowed to cool by radiation in a room of temperature 27°C then the initial rates of heat loss are in the ratio

a) $\frac{85}{14}$ b) $\frac{34}{7}$

c) $\frac{7}{34}$ d) $\frac{14}{85}$

504. In the above problem the ratio of the initial rate of fall of the temperatures is nearly

a) 2.49 b) 3.11

c) 1.99 d) 24.9

505. If the temperature of a body is reduced to half of in initial temperature, then radiation power decreases by

a) 84% b) 94%

c) 6% d) 16%

506. A spherical black body with radius 12 cm radiates 450w power at 500 K. If the radius were halved and temperature doubled, the power radiated in watt would be

a) 3600 b) 450

c) 900 d) 1800

507. A small hole is made in a metallic hollow enclosure whose walls are maintained at a temperature of 10^3 K. Then the amount of radiant energy emitted per metre square per second from the hole is

a) 56.7 J b) 56.7 KJ

c) 10^3 J d) data is in sufficient

508. A body of a surface area 50 cm^2, radiates 300 J of energy per minute at a temperature of 727°C. Then the emissivity of the body is

(Stefan's constant $\sigma = 5.67 \times 10^{-8}$ J/s m^2 K^4)

a) 0.09 b) 0.018

c) 0.36 d) 0.54

509. Two objects have exactly the same shape. Object A has emissivity of 0.3 and object B has emissivity of 0.6, each radiates the same power, then

a) temperature of A is twice that of B measured inK

b) temperature of B is twice that of A in "k

c) temperature of A is 21/4 times that of B in "k

d) temperature of B is 2 times that of A in °C

9.12 Newton's Law of Cooling

510. Equal volumes of two liquids A and B are heated to the same temperature and left in the atmosphere in identical vessels.

a) both will cool at the same rate

b) B will cool faster

c) A will cool faster

d) A and Bwill cool faster

511. A sphere, a cube and a thin circular plate are made of the same material and have the same mass. They are initially heated to same a temperature, which one cools faster?

a) cube

b) sphere

c) plate

d) can not be predicated

512. The temperature–time graphs obtained in Newton's cooling experiment is

a) a straight line with positive slope

b) a straight line with negative slope

c) a curve with positive slope

d) a curve with negative slope

513. A sphere, a cube, a cone and a thin disc all made up of the same material and all have the same mass. If they are heated to the same temperature θ and allowed to cool in identical surrounding then the initial rate of cooling is maximum for

a) sphere b) cube

c) disc d) cone

514. A solid cylinder, a solid cube and a solid sphere are made of the same material and have the same mass. They are heated to the same temperature and kept in a room. The one that will cool at the minimum rate is

a) cylinder

b) sphere

c) cube

d) all will cool at the same rate

515. A solid cube and a sphere are made of the same material and both have the same surface area. If both are at the temperature of 300 K then initial

a) rate of heat loss for both is same

b) rate of heat loss for sphere is more

c) rate of heat loss for cube is more

d) data is in sufficient

516. For the above question, the initial rate of fall of temperature is

a) more for cube

b) more for sphere

c) equal for both

d) nothing can be predicted

517. Two spheres of the same material have radii 1m and 4 m and temperature 4000 K and 2000 K respectively. Then the energy radiated per second by the first sphere is

a) more than that by the second

b) less than that by the second

c) equal to that by the second

d) nothing can be predicted

518. There is a circular hole in a square copper plate. If the plate is heated then the radius of the circular hole will

a) increase

b) decrease

c) remain the same

d) increase or decrease depending on size of the square plate

519. Newton's law of cooling is used in laboratory for the determination of the specific heat of

a) steam b) solids

c) gases d) liquids

520. Newton's law of cooling holds good, if the temperature difference between body and surrounding is

a) large b) small

c) the same d) very small

521. Newton's law of cooling leads to the following expression. The correct expression is

a) $(\theta - \theta_0) = Kt + C$

b) $\log(\theta - \theta_0) = -Kt + C$

c) $\log \theta = -Kt + C$

d) $\theta = K\theta_0 + C$

522. Newton's law of cooling is valid for

a) low temperature

b) high temperature

c) small temperature difference

d) large temperature difference

523. When a body of mass M loses heat, the rate of fall of temperature is proportional to

a) $M^{1/2}$ b) $M^{-1/2}$

c) M d) M^{-1}

524. A solid sphere of copper of radius R and hollow sphere of copper of inner radius r and outer radius R are heated to the same temperature and allowed to cool in the same environment. The

rate of cooling is

a) more for hollow sphere

b) more for solid sphere

c) same for both the sphere

d) can not say

525. A mechanism of equalization of temperature of a body by thermal radiations, with that of its surroundings was proposed by

a) Newton b) Stefan

c) Kirchhoff d) Prevost

526. The Newton's law of cooling is based on

a) Planck's law b) Prevost's law

c) Kirchhoff's law d) Stefan's law

527. Newton's law of cooling is also applicable to

a) forced convection losses

b) convections losses

c) natural convection losses

d) none of these

528. A solid sphere, cube and a cylinder of same material and density, are heated to the same temperature. If height of cylinder radius of cylinder and sphere and side length of the cube all are equal to R, then the body that cool faster is

a) sphere b) cube

c) cylinder d) all cool equal

529. In the above question, the body that cool slowest is

a) sphere b) cube

c) cylinder d) all

530. A solid sphere and a hollow sphere of same material of equal radii and of equal surface finish are heated to the same temperature. Which statement is incorrect?

a) both will emit equal amount of radiation per unit time in the beginning

b) both will absorb equal amount of radiation from the surrounding in the beginning

c) the initial rate of cooling will not be same for the two spheres

d) the two spheres will have equal temperature at any instant

531. Newton's law of cooling can be obtained from

a) Rayleigh's law b) Stefan's law

c) Wien's law d) Planck's law

532. In simple radiation correction, correction in the temperature is due to loss of heat by

a) convection

b) radiation

c) conduction

d) conduction and convection

533. A metal sphere cools from 72 °C to 60 °C in 10 minutes. If the surroundings temperature is 36 °C, then the time taken by it to cool from 60 °C to 52 °C is

a) 8 minutes b) 4 minutes

c) 12 minutes d) 10 minutes

534. A body cools in 7 minutes from 60 °C to 40°C. Its temperature after the next 7 minutes is (temperature of the surroundings is 10 °C)

a) 32 °C b) 28 °C

c) 20 °C d) 25 °C

535. Newton's law of cooling holds good only, if the temperature difference between the body and surroundings is

a) less than 20 °C b) more than 10 °C

c) less than 100 °C d) more than 100 °C

536. A body takes, 4 minutes to cool from 100 °C to 70°C. If the room temperature is 25 °C, then the time taken to cool from 70 °C to 40 °C will be

a) 10 minute b) 3 minute

c) 6 minute d) 8 minute

537. A body in a room cools from 85 °C to 80 °C in 5 minutes. Then the time taken to cool from 80 °C to 75 °C is

a) 5 minutes b) more than 5 minutes

c) less than 5 minutes d) 10 minutes

538. A hot water kept in a beaker placed in a room cools from 60 °C to sooe in 8 min. Then the time taken by it to cool from sooe to 40 °C is

a) 8 min

b) more than 8 min

c) less than 8 min

d) depends on quantity of water in a beaker

539. A beaker containing full of hot water is kept in a room. If cools from 80°C to 75°C in t_1 minutes, from 75°C to 70°C in t_2 and from 70°C to 65°C in time t_3 minutes then

a) $t_1 = t_2 = t_3$ b) $t_1 < t_2 = t_3$

c) $t_1 < t_2 < t_3$ d) $t_1 > t_2 > t_3$

540. A body cools from 50°C to 49.9°C in 5 s. The temperature of the surrounding is 30°C. How long will the body, take to cool from 40°Cto 39.9°C?
a) 2.5 seconds b) 5 seconds
c) 7.5 seconds d) 10 seconds

541. A body cools from 50°C to 46°C in 5 min and to 40°C in the next 10 min. Then the temperature of the surrounding is
a) 30°C b) 36°C
c) 28°C d) 32°C

542. A body cools from 60°C to 50°C in 10 minutes. Its temperature at the end of the next 10 minutes, if the room temperature is 25°C is
a) 42.85°C b) 24°C
c) 56.85°C d) 46.5°C

543. A body cools at the rate of 0.6°C/s when it is 40°C above the surrounding. Then the rate of cooling when it is at 20°C above the same surrounding is
a) 0.2°C/s b) 0.3°C/s
c) 0.15°C/s d) 0.4°C/s

544. A body cools from 60°C to 52°C in five minutes. What will be further fall in temperature in the next five minutes? If the temperature of the surrounding is 28°C
a) 4°C b) 6°C
c) 8°C d) 2°C

545. A body cools at the rate of 3°C/min when its temperature is 50°C. If the temperature of surroundings is 25°C then the rate of cooling of the body at 40°C is
a) 2 °C/min b) 2.4°C/min
c) 2.8 °C/min d) 1.8 °C/min

546. A body cools at the rate of 0.75°C/s when it is 50°C above the surrounding. Its rate of cooling when it is 30°C above the same surrounding is
a) 0.32°C/s b) 0.36°C/s
c) 0.40°C/s d) 0.45°C/s

547. A sphere and a cube of equal volumes both are made of iron and have similar surface. If both are heated to the same temperature and allowed to cool in identical surrounding, at a lower temperature, then the ratio of the initial rates of loss of heat is
a) $\left(\frac{\pi}{6}\right)^{1/3}:1$ b) $\left(\frac{3}{4\pi}\right)^{-1/3}:1$
c) $\left(\frac{3}{4\pi}\right)^{2/3}:1$ d) 1 : 1

548. In the above question, the ratio of the initial rate of fall of temperature is
a) $\left(\frac{\pi}{6}\right)^{1/3}:1$ b) 1 : 1
c) $\left(\frac{4\pi}{3}\right)^{1/3}:1$ d) $\left(\frac{3}{\pi 4}\right)^{2/3}:1$

549. A body cools from 60°C to 52°C in 5 minutes what will be the further fall in its temperature in the next five minutes? If the temperature of the surrounding is 28°C.
a) 46 °C b) 40 °C
c) 36 °C d) 48 °C

550. A body cools at the ratio of 1.2°C/min when its temperature is more than that of the surrounding by 40°C. The rate of cooling of the body when its temperature is more than that of surrounding by 25°C will be
a) 0.75 °C/min b) 0.25°C/min
c) 1.25 °C/min d) 1 °C/min

551. If the temperature of the body θ and time of cooling 't' and room temperature of the surrounding θ_0, The cooling curve is

Questions given in MHT-CET

552. The difference between the principal specific heats of Nitrogen is 300 J/kg K and ratio of the two specific heats is 1.4. Then the C_P is
a) 1050 J/kg K b) 650 J/kg K
c) 750 J/kg K d) 150 J/kg K

553. The mean kinetic energy of one gram–mole of a perfect gas at absolute temperature T is
a) $\frac{1}{2}kT$ b) $\frac{1}{2}RT$
c) $\frac{3}{2}kT$ d) $\frac{3}{2}RT$

554. The volume of 2.8 gm of carbon monoxide (CO)

at 27° C and 0.821 atm pressure is

(R = 0.0821 litre atm/mol K)

a) 0.3 litre b) 1.5 litre

c) 3 litre d) 60 litre

555. A body cools from 50°C to 46° in 5 minutes and to 40°C in the next 10 minutes. The surrounding temperature is

a) 30°C b) 28°C

c) 36°C d) 32°C

556. Two thermometers A and B exposed to sunlight. The valve of A is painted black but that of B is not painted. The correct statement regarding this case is

a) temperature of B will rise faster

b) temperature of A will remain more than B

c) both of A and B show equal rise from the beginning

d) temperature of A will rise faster than B but the final temperature will be same in both

557. If at same temperature and pressure, the densities for two diatomic gases are respectively d_1 and d_2, then the ratio of velocities of sound in these will be

a) $\sqrt{\frac{d_2}{d_1}}$ b) $\sqrt{\frac{d_1}{d_2}}$

c) d_1d_2 d) $\sqrt{d_1d_2}$

558. One mole of an ideal gas requires 207 J heat to raise the temperature by 10 K, when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by 10 K, then heat required is [R = 8.3 J/mol K]

a) 96.6 J b) 124 J

c) 198.8 J d) 215.4 J

559. The volume of a gas at 20°C is 100 cm^3 at normal pressure. If it is heated to 100 °C, its volume becomes 125 cm^3 at the same pressure, then volume coefficient of the gas is

(At normal pressure)

a) 0.0033/°C b) 0.0030/°C

c) 0.0025/°C d) 0.0021/°C

560. Radiation emitted by a surface is directly proportional to

a) third power of its temperature

b) equal to its temperature

c) twice power of its temperature

d) fourth power of tis temperature

561. A sphere, a cube and a thin circular plate all made of the same material and having the same mass are initially heated to a temperature of 3000°C. Which of these cools fastest?

a) Sphere b) Cube

c) Plate d) None of these

562. An ideal gas is that which can

a) be solidified b) liquefied

c) not be liquefied d) not be solidified

563. 5 gm of air is heated from 273 K to 275 K. The change in internal energy of air will be

[C_v = 172 cal/kg K and J = 4.2 J/cal]

a) 7.22 J b) 5.22 J

c) 8.16 J d) 3.5 J

564. Calculate the RMS velocity of molecules of a gas of which the ratio of two specific heats is 1.42 and velocity of sound in the gas is 500 m/s

a) 727 m/s b) 527 m/s

c) 927 m/s d) 750 m/s

565. A body at higher temperature T K radiates heat at a rate which is proportional to

a) T b) T2

c) T^{-4} d) T^4

566. The wavelength of maximum energy released during an atomic explosion was 2.93×10^{-10} m. The maximum temperature attained must be (Wein's constant = 2.93×10^{-3} mK)

a) 5.86×10^7 K b) 10^{-13} K

c) 10^{-7} K d) 10^7 K

567. The root mean square speed of hydrogen molecules at 300 K is 1930 m/s. Then the root mean square speed of oxygen molecules at 900 K will be

a) $1930\sqrt{3}$ m/s b) 836 m/s

c) 643 m/s d) $\frac{1930}{\sqrt{3}}$ m/s

568. What is the true for 3 moles of a gas?

a) $3(C_p - C_v) = R$ b) $\frac{(C_p - C_v)}{3} = R$

c) $C_p - C_v = R$ d) $C_p - 3\,C_v = R$

569. PV/3 = RT, V represents volume of

a) any amount of gas b) 2 moles of gas
c) 3 moles of gas d) 4 moles of gas

570. In a gas, 5 molecules have speed 150 m/s, 160 m/s, 170 m/s, 180 m/s, 190 m/s. Ratio of V_{rms} to v_{mean} is nearly
a) 1 b) 3
c) 0.5 d) 0.04

571. K.E. per unit volume is given by
a) $E = \frac{3}{2}$ P b) $E = \frac{2}{3}$ P
c) $E = \frac{1}{2}$ mv^2 d) $E = \frac{5}{2}$ P

572. If 3 kg of mass is converted into energy. Energy released is
a) 9×10^8 J b) 9×10^{16} J
c) 27×10^8 J d) 27×10^{16} J

573. Energy supplied to convert unit mass of substance from solid to liquid state at its melting point is called
a) latent heat of fusion
b) evaporation
c) solidification
d) latent heat of fission

574. A unit mass of solid converted to liquid at its melting point. Heat is required for this process is
a) specific heat
b) latent heat of vaporisation
c) latent heat of fusion
d) external latent heat

575. If 2 kcal, of heat is supplied to a system cause to change the internal energy of a gas is 5030 J, and external work done is 3350 J, then what is mechanical equivalent of heat?
a) 41.90 J/kcal b) 4190 J/cal
c) 4.19 J/kcal d) 4.19 J/cal

576. Emissivity of perfectly black body is
a) 1 b) 2
c) 5 d) 0

577. If a = 0.72, r = 0.24, then value of t is
a) 0.02 b) 0.04
c) 0.4 d) 0.2

578. Mass of gas is 300 gm and its specific heat at constant volume is 750 J/kg K. If gas is heated through 75° C at constant pressure of 10^5 N/m^2, it expands by volume 0.08×106 cm^2. Find C_p/ C_v.
a) 1.4 b) 1.374
c) 1.474 d) 1.5

579. A gas expands adiabatically at constant pressure such that its temperature $T \propto 1/\sqrt{V}$. The value of C_p/C_v of the gas is
a) 1.30 b) 1.50
c) 1.67 d) 2.00

580. Which of the following is the unit of specific heat!
a) J kg/°C b) J/kg °C
c) kg °C/J d) J kg/ °C^2

581. Average kinetic energy of molecules is
a) directly proportional to square root of temperature
b) directly proportional to absolute temperature
c) independent of absolute temperature
d) inversely proportional to absolute temperature

582. At what temperature, the rms speed of gas molecules is half the value at NTP ?
a) 68.25 K b) 273 K
c) 345 K d) 0 K

583. The pressure exerted in terms of total kinetic energy per unit volume (E) is
a) 3/2 E b) E
c) 2/3 E d) $\sqrt{3}$ E

584. Two spheres made of same material have radii in the ratio 2 : 1. If both the spheres are at same temperature, then what is the ratio of heat radiation energy emitted per second by them?
a) 1 : 4 b) 4 : 1
c) 3 : 4 d) 4 : 3

585. The coefficient of absorption of perfectly black body is
a) 1 b) 0
c) 0.75 d) none of these

586. Rate of cooling of body is 0.5° C/min, when the system is 50° C above the surroundings. When a system is 30° C above the surroundings, the rate of cooling will be
a) 0.3° C/min b) 0.6° C/min
c) 0.7° C/min d) 0.4° C/min

587. The temperature at which the rms velocity of hydrogen is four times of its value at NTP, is

a) 819°C b) 4368°C
c) 1092°C d) 4095°C

588. At constant pressure, which of the following is TRUE?

a) $c \propto \sqrt{\rho}$ b) $c \propto r$
c) $c \propto 1/p$ d) $c \propto 1/\sqrt{\rho}$

589. In terms of mechanical unit, $c_p - c_v$ is, where c_p and c_v are principal specific heats.

a) R b) R/J
c) R/M d) R/MJ

590. If a black body is heated from 27°C to 927°C. Then the ratio of radiation emitted will be

a) 1 : 4 b) 1 : 16
c) 1 : 8 d) 1 : 256

591. Coefficient of transmission and coefficient of reflection for a given body are 0.22 and 0.74 respectively. Then, at a given temperature, the coefficient of emission for the body is

a) 0.4 b) 0.04
c) 0.96 d) 0.22

592. A body cools from 100°C to 70°C in 8 minutes. If the room temperature is 15°C and assuming Newton's law of cooling holds good, then time required for the body to cool from 70°C to 40°C is

a) 14 min b) 10 min
c) 8 min d) 5 min

593. Internal latent heat of ice is

a) greater than latent heat
b) less than latent heat
c) equal to latent heat
d) equal to half that of latent heat

594. Given that $C_p - C_v = R$ and $\gamma = C_p / C_v$, where C_p = molar specific heat at constant pressure, C_v = molar specific heat at constant volume. Then C_v =

a) $\frac{\gamma R}{\gamma - 1}$ b) $\frac{R}{\gamma - 1}$
c) $\frac{\gamma - 1}{R}$ d) $\frac{\gamma - 1}{\gamma R}$

595. The speed of molecules are given by 2 m/s, 3 m/s, 4 m/s, 5 m/s and 6 m/s. The mean square speed is

a) 20 m^2/s^2 b) 25 m^2/s^2
c) 36 m^2/s^2 d) 18 m^2/s^2

596. The unit of Stefan's constant is

a) watt/m^2/ K^4 b) watt/m^3/ K
c) watt/m^2 K d) watt/m^3 K^4

597. The correct equation out of the following is

a) $E.\ E_b = a$ b) $\frac{E}{E_b} = a$
c) $\frac{E_b}{E} = a$ d) $E.\ E_b = \frac{1}{a}$

598. If the pressure of an ideal gas decreases by 10%, isothermally, then its volume will

a) decrease by 9% b) increase by 10%
c) increase by 11.6% d) increase by 9%

599. For an ideal gas, C_v/C_p is

a) < 1 b) > 1
c) = 1 d) ≥ 1

600. Internal latent heat is defined as

a) amount of heat needed to do work against external pressure
b) amount of heat needed to do to work against intermolecular force
c) amount of heat needed to increase the K.E. of the molecules
d) heat needed to change the state of a substance

601. Pressure at the triple point of water is

a) 4 N/m^2 b) 760 mm of Hg
c) 5440 Pa d) 0.544 mm of Hg

602. A body radiates heat at the rate of 5 cal/m^2 – s when its temperature is 227°C. The heat radiate.d by the same body when its temperature is T2.7°C is

a) 10 cal/m^2 s b) 20 cal/m^2 s
c) 40 cal/m^2 s d) 80 cal/m^2 s

603. According to Prevost's theory of heat exchange, the heat exchange shops at

a) 0 °C b) –5 °C
c) – 273 °C d) – 273 K

604. Kinetic energy per unit volume of a gas is E, then the pressure exerted by the gas is

a) 3/2 E b) 2/3 E
c) 1/3 E d) E

605. Two gases have densities in the ratio 2 : 3 and pressure exerted are in the ratio 3 : 2. Then the ratio of their RMS velocity is
a) 2 : 3 b) 3 : 2
c) 1 : 3 d) 6 : 8

606. At what temperature will the R.M.S. velocity of a gasbe double its value at N.T.P.?
a) 273° C b) 546° C
c) 819 ° C d) 1092 ° C

607. SI unit of Wein's constant is
a) m K b) Cal/m^2
c) J/m^2 d) K/m

608. A black body of emissive power 81 J/m^2 s when it is at 300 K and ordinary body of emissivity 0.8 when it is at 500 K. What is the emissive power of an ordinary body?
a) 500 J/m^2 s b) 600 J/m^2 s
c) 800 J/m^2 s d) 400 J/m^2 s

609. For athermanous surface
a) r = 1 b) a = 1
c) t = 0 d) t = 1

610. The average distance covered by a molecule between two successive collisions is called
a) free path
b) constant path
c) mean free path
d) free path per unit time

611. A body cools at the rate of 0.5 °C/s when it is 50°C above the surrounding temperature. The rat of cooling at excess temperature of 30°C over the surrounding temperature is
a) 3°C/s b) 0.3°C/s
c) 0.2°C/s d) 0.1 °C/s

612. If a gas expands under isothermal conduction, then what happen to rms velocity will be ?
a) increases b) decreases
c) remains constant d) can not be predicted

613. When 19 m of water at 100 °C is completely converted to steam at 100°C, occupies 1650cc. The increase in the internal energy of the molecules is (Atm. press. = 105 Pa, L = 540 cal/gm and J = 4.2 J/cal)
a) 2103 J b) 2310 J
c) 210 J d) 375 J

614. What will be r.m.s. speed of a gas at 800 K?
a) four times the values at 200 K
b) half the value at 200 K
c) twice the value at 200 K
d) same as at 200 K

615. What temperature does the average translational K.E. of a molecule in a gas becomes equal to K.E. of an electron accelerated from rest through potential difference of V volt? All symbols have their usual meaning.
a) $\frac{2eVN}{3R}$ b) $\frac{3R}{2eVN}$
c) $\frac{NeV}{R}$ d) $\frac{2NeV}{R}$

616. 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

617. 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

618. In the expression for Boyle's law, the product 'PV' has dimensions of
a) force b) impulse
c) energy d) momentum

619. The dimensions of Stefan's constant are
a) $[L^1M^0T^{-3}K^{-4}]$ b) $[L^1M^1T^{-3}K^{-3}]$
c) $[L^2M^1T^{-3}K^{-4}]$ d) $[L^0M^1T^{-3}K^{-4}]$

620. A black body radiates heat at temperature '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

❍❍❍

Answers

1. (a)	2. (b)	3. (d)	4. (a)	5. (b)	6. (b)	7. (a)	8. (a)	9. (c)	10. (a)
11. (d)	12. (c)	13. (d)	14. (b)	15. (c)	16. (c)	17. (c)	18. (d)	19. (a)	20. (c)
21. (c)	22. (c)	23. (c)	24. (c)	25. (a)	26. (b)	27. (d)	28. (a)	29. (a)	30. (a)
31. (b)	32. (c)	33. (d)	34. (c)	35. (c)	36. (c)	37. (d)	38. (c)	39. (b)	40. (a)
41. (c)	42. (d)	43. (b)	44. (c)	45. (d)	46. (c)	47. (d)	48. (c)	49. (b)	50. (a)
51. (c)	52. (a)	53. (d)	54. (b)	55. (a)	56. (c)	57. (d)	58. (b)	59. (b)	60. (a)
61. (a)	62. (c)	63. (c)	64. (b)	65. (b)	66. (d)	67. (a)	68. (c)	69. (c)	70. (b)
71. (c)	72. (b)	73. (d)	74. (a)	75. (d)	76. (b)	77. (a)	78. (b)	79. (a)	80. (a)
81. (c)	82. (d)	83. (b)	84. (b)	85. (b)	86. (a)	87. (c)	88. (d)	89. (d)	90. (b)
91. (a)	92. (b)	93. (d)	94. (c)	95. (b)	96. (d)	97. (b)	98. (c)	99. (c)	100. (a)
101. (b)	102. (b)	103. (a)	104. (a)	105. (c)	106. (c)	107. (d)	108. (a)	109. (a)	110. (d)
111. (b)	112. (b)	113. (a)	114. (a)	115. (b)	116. (a)	117. (b)	118. (b)	119. (c)	120. (a)
121. (b)	122. (d)	123. (b)	124. (c)	125. (c)	126. (d)	127. (d)	128. (b)	129. (c)	130. (b)
131. (b)	132. (b)	133. (b)	134. (c)	135. (a)	136. (b)	137. (a)	138. (b)	139. (d)	140. (b)
141. (d)	142. (b)	143. (d)	144. (d)	145. (a)	146. (c)	147. (b)	148. (c)	149. (d)	150. (d)
151. (c)	152. (d)	153. (a)	154. (b)	155. (b)	156. (c)	157. (d)	158. (a)	159. (a)	160. (a)
161. (a)	162. (b)	163. (c)	164. (a)	165. (b)	166. (a)	167. (c)	168. (b)	169. (b)	170. (b)
171. (c)	172. (b)	173. (b)	174. (a)	175. (a)	176. (c)	177. (b)	178. (a)	179. (a)	180. (a)
181. (a)	182. (d)	183. (a)	184. (c)	185. (a)	186. (c)	187. (c)	188. (a)	189. (a)	190. (c)
191. (b)	192. (c)	193. (b)	194. (b)	195. (a)	196. (c)	197. (c)	198. (c)	199. (c)	200. (a)
201. (b)	202. (b)	203. (b)	204. (d)	205. (c)	206. (d)	207. (b)	208. (d)	209. (a)	210. (c)
211. (d)	212. (c)	213. (a)	214. (b)	215. (b)	216. (c)	217. (a)	218. (b)	219. (c)	220. (c)
221. (b)	222. (d)	223. (c)	224. (d)	225. (c)	226. (a)	227. (b)	228. (a)	229. (d)	230. (c)
231. (d)	232. (d)	233. (c)	234. (d)	235. (b)	236. (a)	237. (a)	238. (a)	239. (b)	240. (d)
241. (d)	242. (c)	243. (b)	244. (d)	245. (c)	246. (d)	247. (a)	248. (d)	249. (d)	250. (b)
251. (c)	252. (d)	253. (a)	254. (b)	255. (b)	256. (a)	257. (c)	258. (c)	259. (b)	260. (d)
261. (a)	262. (c)	263. (c)	264. (a)	265. (b)	266. (c)	267. (c)	268. (a)	269. (d)	270. (c)
271. (d)	272. (b)	273. (a)	274. (d)	275. (d)	276. (d)	277. (c)	278. (a)	279. (b)	280. (a)
281. (b)	282. (d)	283. (d)	284. (d)	285. (a)	286. (c)	287. (b)	288. (a)	289. (b)	290. (c)
291. (d)	292. (a)	293. (c)	294. (b)	295. (b)	296. (a)	297. (c)	298. (d)	299. (b)	300. (a)
301. (c)	302. (b)	303. (d)	304. (c)	305. (b)	306. (b)	307. (c)	308. (c)	309. (b)	310. (c)
311. (a)	312. (d)	313. (b)	314. (d)	315. (c)	316. (d)	317. (b)	318. (d)	319. (d)	320. (c)
321. (b)	322. (d)	323. (b)	324. (d)	325. (a)	326. (c)	327. (a)	328. (c)	329. (d)	330. (b)
331. (b)	332. (d)	333. (a)	334. (b)	335. (c)	336. (d)	337. (b)	338. (b)	339. (b)	340. (d)
341. (d)	342. (a)	343. (c)	344. (b)	345. (a)	346. (c)	347. (c)	348. (d)	349. (b)	350. (c)
351. (b)	352. (a)	353. (c)	354. (d)	355. (c)	356. (d)	357. (c)	358. (b)	359. (a)	360. (b)
361. (a)	362. (a)	363. (a)	364. (a)	365. (a)	366. (b)	367. (d)	368. (b)	369. (a)	370. (a)
371. (b)	372. (a)	373. (c)	374. (c)	375. (c)	376. (c)	377. (c)	378. (a)	379. (d)	380. (b)
381. (b)	382. (d)	383. (a)	384. (c)	385. (c)	386. (a)	387. (a)	388. (c)	389. (a)	390. (b)
391. (b)	392. (c)	393. (b)	394. (b)	395. (d)	396. (d)	397. (c)	398. (d)	399. (b)	400. (a)
401. (d)	402. (d)	403. (c)	404. (d)	405. (d)	406. (a)	407. (d)	408. (b)	409. (d)	410. (c)

411.	(b)	412.	(d)	413.	(c)	414.	(a)	415.	(a)	416.	(a)	417.	(b)	418.	(a)	419.	(b)	420.	(b)
421.	(d)	422.	(b)	423.	(c)	424.	(a)	425.	(d)	426.	(d)	427.	(c)	428.	(c)	429.	(b)	430.	(c)
431.	(b)	432.	(b)	433.	(b)	434.	(b)	435.	(a)	436.	(b)	437.	(d)	438.	(c)	439.	(c)	440.	(c)
441.	(d)	442.	(d)	443.	(d)	444.	(c)	445.	(c)	446.	(b)	447.	(a)	448.	(b)	449.	(b)	450.	(c)
451.	(b)	452.	(c)	453.	(b)	454.	(a)	455.	(b)	456.	(c)	457.	(d)	458.	(c)	459.	(b)	460.	(a)
461.	(b)	462.	(c)	463.	(d)	464.	(c)	465.	(c)	466.	(d)	467.	(b)	468.	(a)	469.	(d)	470.	(c)
471.	(d)	472.	(a)	473.	(d)	474.	(c)	475.	(c)	476.	(b)	477.	(d)	478.	(a)	479.	(d)	480.	(b)
481.	(c)	482.	(a)	483.	(d)	484.	(d)	485.	(d)	486.	(b)	487.	(c)	488.	(c)	489.	(b)	490.	(c)
491.	(a)	492.	(b)	493.	(c)	494.	(d)	495.	(a)	496.	(d)	497.	(c)	498.	(c)	499.	(c)	500.	(c)
501.	(b)	502.	(c)	503.	(b)	504.	(a)	505.	(b)	506.	(d)	507.	(b)	508.	(b)	509.	(c)	510.	(a)
511.	(c)	512.	(d)	513.	(c)	514.	(b)	515.	(a)	516.	(a)	517.	(c)	518.	(a)	519.	(d)	520.	(b)
521.	(b)	522.	(c)	523.	(d)	524.	(a)	525.	(d)	526.	(d)	527.	(a)	528.	(b)	529.	(a)	530.	(d)
531.	(b)	532.	(b)	533.	(d)	534.	(b)	535.	(a)	536.	(d)	537.	(b)	538.	(b)	539.	(c)	540.	(d)
541.	(c)	542.	(a)	543.	(b)	544.	(b)	545.	(d)	546.	(d)	547.	(a)	548.	(a)	549.	(a)	550.	(a)
551.	(b)	552.	(a)	553.	(d)	554.	(c)	555.	(a)	556.	(d)	557.	(a)	558.	(b)	559.	(a)	560.	(d)
561.	(c)	562.	(c)	563.	(a)	564.	(a)	565.	(d)	566.	(d)	567.	(b)	568.	(c)	569.	(c)	570.	(a)
571.	(a)	572.	(d)	573.	(a)	574.	(c)	575.	(d)	576.	(a)	577.	(b)	578.	(c)	579.	(b)	580.	(b)
581.	(b)	582.	(a)	583.	(c)	584.	(b)	585.	(a)	586.	(a)	587.	(b)	588.	(d)	589.	(d)	590.	(d)
591.	(b)	592.	(a)	593.	(a)	594.	(b)	595.	(d)	596.	(a)	597.	(b)	598.	(c)	599.	(a)	600.	(b)
601.	(c)	602.	(d)	603.	(c)	604.	(b)	605.	(b)	606.	(c)	607.	(a)	608.	(a)	609.	(b)	610.	(c)
611.	(b)	612.	(c)	613.	(a)	614.	(c)	615.	(a)	616.	(c)	617.	(d)	618.	(c)	619.	(d)	620.	(b)

Hint / Solutions

10. Temperature is proportional to the average molecular kinetic energy.

15. Thermal equilibrium implies equality of temperature which depends upon the average molecular kinetic energy.

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

27. $P_1 \propto n_1$ and $P_2 \propto n_2$ $\frac{P_2}{P_1} = \frac{n_2}{n_1} = \frac{n_1+1}{n_1}$

28. $\frac{T_2}{T_1} = \frac{P_2}{P_1}$

29. $\frac{T_2}{T_1} = \frac{P_2}{P_1}$

30. $\frac{T_2}{T_1} = \frac{n_1}{n_2}$

$\therefore$ $PV = n_1RT_1$ and $PV = n_2RT_2$

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

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

$\frac{10}{100} = \frac{T_2 - T_1}{T_1}$

On solving $T_2 = 27.3\ °C$

32. $P_2V = m_2 RT_2$ and $P_1V = m_1RT_1$

$\therefore$ $m_2 = \frac{P_2}{P_1} \times \frac{T_1}{T_2} \times m_1$ $m_2 = 375\ m = m_1 - m_2$

$= 1000 - 375 = 625$ g

33. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $T_2 = 1200 - 273 = 927\ °C$

34. $\frac{P_2}{P_1} = \frac{V_1}{V_2}$

$\frac{P_2 - P_1}{P_1} = \frac{V_1 - V_2}{V_2}$

$\frac{\Delta P}{P_1} = \frac{V_1 - 0.95\ V_1}{0.95\ V_1} = \frac{0.5\ V_1}{0.95\ V_1}$

$\frac{\Delta P}{P_1} = 5.2\ \%$

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

$\frac{V_2 - V_1}{V_1} = \frac{T_2 - T_1}{T_1} = \frac{330 - 300}{300}$

$V_2 - V_1 = \frac{30V_1}{300} = 10$ c.c.

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

37. $P_1V_1 = P_2V_2$

38. $\frac{\Delta T}{T} = \left(\frac{\Delta V}{V} + \frac{\Delta P}{P}\right) = \left(\frac{1}{100} + \frac{1}{100}\right) = \frac{2}{100} = 2\%$

40. $\frac{n_1P_1V_1}{T_1} = \frac{P_2V_2}{T_2} n_2\ n_1 = n_2\ \frac{8}{32} = \frac{x}{2}\ x = \frac{1}{2}$

52. $\frac{\Delta p}{p} = \frac{\Delta T}{T}$

56. $PV = nRT$

81. $\frac{\Delta p}{sec} = \frac{\Delta p}{collsion} \times$ frequency

93. $C_{rms} \propto \frac{1}{\sqrt{m}}$

111. $C = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 1.013 \times 10^5}{1.25}} = 0.4847$ km/s

112. $\sqrt{\frac{3RT}{M}} = V_e = 10000$ K

117. $\overline{C} = \frac{c_1 + c_2 + c_3}{3}$

118. $C = \sqrt{\frac{c_1^2 + c_2^2 + c_3^2}{3}}$

119. $C^{-2} = \frac{c_1^2 + c_2^2 + c_3^2 + c_4^2 + c_5^2}{5}$

$= \frac{4 + 9 + 16 + 25 + 36}{5} = 18\ (m/s)^2$

122. $C_1 \propto \sqrt{T_1}$ and $C_2 \propto \sqrt{T_2}$ $\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}}$

$\therefore$ $T_2 = \frac{C_2^2}{C_1^2} T_1$

$= 4 \times 273 = 1092$ K

123. $C_1 \propto \frac{1}{\sqrt{M_1}}$ and $C_2 = \frac{1}{\sqrt{M_2}}$ $\frac{C_2}{C_1} = \sqrt{\frac{M_1}{M_2}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

$\therefore \quad \frac{C_1}{C_2} = \frac{4}{1}$

124. $C = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}}$

$= \sqrt{\frac{3.039 \times 10^6}{8.93 \times 10^{-5}}} = \sqrt{\frac{3.039}{8.93}} \times 10^5$

$= 1840$ m/s

125. $C_1 = K\sqrt{800}$ and $C_2 = K\sqrt{200}$

$\frac{C_2}{C_1} = \sqrt{\frac{200}{800}} = \frac{1}{2}$ $C_1 = 2\,C_2$

126. $\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{4}{2}} = \sqrt{2}$ $V_1 = \sqrt{2}V_2$

127. $V_{he} = \frac{5}{7} v_h$

$V_2 = \frac{5}{7} V_1$

$\sqrt{\frac{3RT_2}{M_2}} = \frac{5}{2} \times \sqrt{\frac{3RT_1}{M_1}}$

$\frac{T_2}{T_1} = \frac{25}{4} \times \frac{4}{2} = \frac{100}{98}$ T_2

$= 1.02 \times 273 = 278.5$ K

128. $V_n = V_o$

$\sqrt{\frac{3RT_n}{M_n}} = \sqrt{\frac{3RT_o}{M_o}}$

$\frac{T_o}{T_n} = \frac{M_o}{M_n}$

$T_o = 373 \times \frac{32}{28} = 426.3$ K

137. $\frac{c_2}{c_1} = \sqrt{\frac{T_2}{T_1} \times \frac{M_1}{M_2}}$

143. K.E. per molecule is independent of nature of the gas.

145. K.E. = ev

$\frac{3}{2}KT = 1.6 \times 10^{-19} \times 5$

$\therefore \quad T = \frac{3.2 \times 5 \times 10^{-19}}{3 \times 8.314 \times 10^3}$

$= 38.65 \times 10^3$ K

146. $K.E_1 \propto T_1$ and $KE_2 \propto T_2$

$\frac{KE_2}{KE_1} = \frac{T_2}{T_1}$

$\therefore \quad \frac{2KE_1}{KE_1} \times T_1 = T_2$

$2 \times 300 = T_2$

$\therefore \quad T_2 = 600$ K

147. $E_2 = \frac{E_1}{2}$ and $T_1 = 273$

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

$\therefore \quad T_2 = \frac{E_2}{E_1}$

$T_1 = \frac{273}{2}$

$\therefore \quad T_2 = 136.5$ K

148. $K.E_2 / kg = \frac{3}{2}\frac{RT}{M} = \frac{3}{2} \times \frac{8320 \times 448}{28}$

$= \frac{3 \times 8320 \times 224}{28}$

$= 3 \times 8320 \times 8 = 24 \times 8320 = 199680$

149. $KE_1 \propto T_1$ and $KE_2 \propto T_2$

$\frac{KE_2}{KE_1} = \frac{T_2}{T_1} = \frac{273+273}{273} = \frac{2 \times 273}{273} = \frac{2}{1}$

150. $KE_1 \propto T$ and $KE_2 \propto T$

$\frac{KE_1}{KE_2} = \frac{T}{T} = 1$

151. $KE_1 \propto T_1$ and $KE_2 \propto T_2$

$\frac{KE_2}{KE_1} = \frac{T_2}{T_1} = \frac{273+273}{273} = \frac{2 \times 273}{273} = \frac{2}{1}$

$\frac{KE_2 - KE_1}{KE_1} = 1$

152. $\frac{KE_2}{gm} = \frac{3}{2}RT = 1.5 \times 8.320 \times 273 = 3400$ J

153. K. E. / molecule $= \frac{3}{2}KT = \frac{3}{2}\frac{RT}{N_0} = \frac{3}{2}\frac{PV}{N_0}$

154. $KE_2 = \frac{1}{3} KE_1$

$\frac{KE_2}{KE_1} = \frac{T_2}{T_1}$ $\quad \therefore \frac{1}{3} = \frac{T_2}{T_1}$

$\therefore \quad T_2 = \frac{T_1}{3} = \frac{300}{3} = 100$ K

$T_2 = 100 - 273 = -173°C$

161. K.E. $= \frac{3}{2}\frac{RT}{M}$ m $= \frac{1.5 \times 8.31 \times 310 \times 15 \times 10^{-3}}{17.03 \times 10^{-3}} = 3403$ J

162. $$mc\,\Delta T = \frac{\left(\frac{1}{2}mv^2\right)}{2J}$$

$$\therefore \quad \Delta T = \frac{1}{4}\frac{v^2}{Jc} = \frac{1}{4}\frac{480 \times 480}{4.2 \times 0.03 \times 10^3} = 457°C$$

163. By the law of conservation of energy.

$$J\,mC\,dT = mgh$$

$$dT = \frac{gh}{Jc} = \frac{9.8 \times 500}{4.2 \times 10^3} = 1.17°C$$

167. $\frac{C_2}{C_1} = \sqrt{\frac{3p_2v}{M_2} \times \frac{M_1}{3p_1v}}$

191. $C = \frac{dQ}{mDT} = \frac{dQ}{mxo} = \infty$

192. For a particular change in temperature it would draw maximum heat.

193. As magnitude of 1°F $= \frac{5}{9}$ °C.

The numerical values of specific heat will decrease.

208. $Q_p = nC_v\,dT$ and $Q_v = nC_p\,dT$

209. For monatomic gas $C_v = 3/2$ R and for diatomic gas $C_v = 5/2$ R. Since one mole of each gas is mixed together, the C'_v of the mixture will be

$$C'_v = \frac{1}{2}\left[\frac{3}{2}R + \frac{5}{2}R\right] = 2R$$

$$C'_p = C'_v + R = 2R + R = 3R$$

$$\gamma_{mix} = \frac{C'_p}{C'_v} = \frac{3R}{2R} = 1.5$$

210. Number of molecules in 14 grams of nitrogen

$$n = \frac{\text{mass of nitrogen}}{\text{molecular wt}} = \frac{14}{28} = \frac{1}{2}$$

Since nitrogen is diatomic

$$\therefore \quad C_p = \frac{7}{2}R$$

Therefore the amount of heat energy supplied

$$= n \times C_p \times dT$$

211. Helium is a monatomic gas

$$\therefore \quad C_v = \frac{3}{2}R$$

Hydrogen is diatomic gas

$$C_v = \frac{5}{2}R$$

$$\therefore \quad \frac{C_{vd}}{C_{vm}} = \frac{5}{2}$$

212. $$dQp = nC_p\,dt$$

$$C_p = \frac{dQ_p}{nd_T}$$

$$C_p - C_v = R$$

$$C_v = C_p - R$$

$$dQ_v = nC_v dT = \frac{1}{2} \times \frac{7}{2} R \times 40 = 70\,R$$

213. $$dQ_p = n\,C_p\,dT$$

$$\therefore \quad C_p = \frac{70}{10} = 7 \text{ cal/mol K}$$

$$C_v = C_p - R = 7 - 2 = 5$$

$$dQ_v = n\,C_v\,dT = 2 \times 5 \times 5 = 50 \text{ cal}$$

215. $\frac{R}{C_v} = 0.67 = \frac{2}{3} \quad \therefore C_v = \frac{3}{2}R$

The gas must be monatomic.

218. $C_{p\,mix} = \frac{n_1C_{p_1} + n_2C_{p_2}}{n_1 + n_2}$

224. $dw = n\,Pdv = n\,R\,dT = nR\,(T_2 - T_1)$

225. $$C_v = C_p - R = 8 - 2 = 6 \text{ cal/mol °C}$$

$$du = n\,C_v\,(T_2 - T_1) = 5 \times 6 \times 10 = 300$$

233. $$dQ = 50\text{ J} \qquad dw = -15\text{ J}$$

$$du = dQ - dw$$

$$= 50 - (-15) = 50 + 15 = 65\text{ J}$$

234. $C_p - C_v = R$ and $C_p/C_v = 1.4$

$$\therefore \quad C_p = 1.4\,C_v \qquad \therefore 1.4\,C_v - C_v = R$$

$$\therefore \quad 0.4\,C_v = R$$

$$C_v = \frac{4150}{0.4} = \frac{41500}{4}$$

$$= 10375$$

235. As argon is monatomic gas its atoms have no rotational motion. Therefore the entire energy is translational.

238. For a monatomic gas number of degree of freedom n = 3

$$\gamma = 1 + \frac{2}{n} = 1 + \frac{2}{3} = \frac{5}{3}$$

$$C_v = \frac{R}{\gamma - 1} = \frac{R}{\frac{5}{3} - 1} = \frac{3}{2}R$$

$$C_p = C_v + R = \frac{3}{2}R + R = \frac{5}{2}R$$

239. $C_v = C_p - R = 207 - 8.31 = 198.7$ J

250. $$Pdv = nRdT$$

$$dw = 5 \times 8.32 \times 100 = 4160\text{ J}$$

251. $du + dw = dQ = 0 \qquad \therefore du = -\,dw.$

Hence change must be adiabatic.

255. $c_p - c_v = 600$ $c_p = 1.6\, c_v$

$1.6\, c_v - c_v = 600,\ 0.6\, c_v = 600$

$c_v = 1000$ J/kg K

$\therefore\ c_p = 1.6\, c_v = 1600$ J/kg K.

278. $\Delta Q = 0$

$\therefore\ \Delta U = -dW$

Work done on the coffee. The temperature increases.

279. AB is isothermal change,

$\therefore\ P_1V_1 = P_2V_2$ OR $P_2 = \dfrac{P_1V_1}{V_2}$

BC is adiabatic change $P_2V^{\gamma}_2 = P_3V^{\gamma}_1$

$P_1V^{\gamma}{}_2^{-1} = P_3V^{\gamma}{}_1^{-1}$

as $V_2 > V_1$ then $P_3 > P_1$

Area under the adiabatic curve is more than that under isothermal curve. During adiabatic curve gas is compressed by doing work on it. So it is negative and during isothermal curve gas undergoes expansion. Gas does work. So it is positive. As negative work is more than positive work, the net work W < O.

280.
$$\begin{aligned} dQ &= dU + dW \\ dU &= dQ - dW \\ &= 110 - 40 \\ &= 70\text{ J.} \end{aligned}$$

281.
$$\begin{aligned} dQ &= -20\text{ J} \\ dW &= -8\text{ J (on the gas)} \\ dU &= dQ - dW \\ &= -20 + 8 \\ &= -12 \\ U_r &= U_i + (dQ - dW) \\ &= 30 - 12 \\ &= 18\text{ J} \end{aligned}$$

282.
$$\begin{aligned} dQ &= 2000 \times 4.2\text{ J} \\ &= 8400\text{ J} \\ dW &= 500\text{ J} \\ dU &= 8400 - 500 \\ &= 7900\text{ J} \end{aligned}$$

284.
$$\begin{aligned} \Delta U &= \Delta Q \\ &= 120\text{ J} \quad (\because \Delta w = 0) \end{aligned}$$

285.
$$\begin{aligned} P\Delta V &= P(V_2 - V_1) \\ &= 100\ (5 - 10) \\ &= -500\text{ J} \\ \Delta U &= \Delta Q - \Delta W \\ &= 1500 - (-500) \\ &= 2000\text{ J.} \end{aligned}$$

286.
$$\begin{aligned} \Delta W &= +P\Delta V \\ &= 4.5 \times 10^5 \times 1.5 \\ &= 6.75 \times 10^5 \\ \Delta Q &= 800\text{ kJ} \\ &= 8 \times 10^5\text{ J} \\ \Delta U &= 8.0 \times 10^5 - 6.75 \times 10^5 \\ \Delta U &= 1.25 \times 10^5\text{ J.} \end{aligned}$$

287.
$$\begin{aligned} \Delta Q &= 100 \times 4.2 \\ &= 420\text{ J} \\ \Delta W &= 150\text{ J} \\ \Delta U &= \Delta Q - \Delta W \\ &= 420 - 150 = 270\text{ J.} \end{aligned}$$

288.
$$\begin{aligned} \Delta W &= P(V_2 - V_1) \\ &= 20\ (5 - 10) \\ &= -100\text{ J} \\ \Delta Q &= 100\text{ J} \\ \Delta Q &= \Delta U + \Delta W \\ 100 &= \Delta U - 100 \Rightarrow \Delta U = 200\text{ J} \end{aligned}$$

289.
$$\begin{aligned} \Delta U &= mc_v\Delta T \\ &= 5 \times \frac{5}{2} \times 8.3 \times 400 \\ &= 5 \times 8.3 \times 10^3 = 41.5\text{ kJ.} \end{aligned}$$

290.
$$\begin{aligned} dU &= nc_v dT \\ &= 2 \times 8 \times 10 \\ &= 160\text{ J} \end{aligned}$$

291.
$$\begin{aligned} P &= 4 \times 10^5\text{ Pa};\ V_2 - V_1 \\ &= 50\text{ litres} \\ &= 50 \times 10^{-3}\text{ m}^3 \\ W &= PdV \\ &= 4 \times 10^5 \times 50 \times 10^{-3} \\ &= 20 \times 10^3\text{ J} \\ &= 20\text{ K J} \end{aligned}$$

292.
$$\begin{aligned} W &= PdV \\ &= 10^4 \times 0.25 \\ &= 2500\text{ J.} \end{aligned}$$

293.
$$\begin{aligned} 1\text{ litre} &= 1000\text{ cc} \\ &= 10^3 \times 10^{-6} \\ &= 10^{-3}\text{ m}^3 \\ W &= PdV \\ &= 10^5 \times 4 \times 10^{-3} \\ &= 400\text{ J} \\ dU &= dQ - PdV \\ &= 300 - 50 \\ &= 250\text{ J} \end{aligned}$$

296. Heat supplied, $dQ = nc_p dT$

increase in internal energy $= nc_v dT$

$$\frac{\Delta U}{dQ} = \frac{1}{\gamma} = \frac{5}{7} = 71.4\%$$

298. $\eta = 1 - \frac{T_2}{T_1}$

$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} = \frac{300}{600} = \frac{1}{2}$

$\therefore \frac{Q_2}{Q_1} = \frac{T_2}{T_1}$

$Q_2 = \frac{T_2}{T_1} \times Q_1$

$= \frac{300}{400} \times 800$

$= 600$ J

299. $\eta = \frac{dW}{dQ} = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{600} = \frac{1}{2}$

$\frac{800}{dQ} = \frac{1}{2}$

$dQ = 1600$ J

300. Efficiency, $\eta = 1 - \frac{T_2}{T_1}$

$\eta = 1 - \frac{T_2}{T_1} = \frac{40}{100} = 1 - \frac{300}{T_1}$

$= 0.6 \Rightarrow$

$T_1 = 500$ K

Final : $\frac{60}{100} = 1 - \frac{300}{T'_1} = 0.4$

$\frac{T'_1}{T_1} = \frac{3}{2}$

$T'_1 = \frac{3}{2} \times 500 = 750$ K

301. $\eta = \frac{dW}{dQ}$

$\frac{1}{4} = \frac{dW}{400}$

$dW = 100$ cal $\left(\eta = 1 - \frac{300}{400} = \frac{1}{4}\right)$

302. $\eta = \frac{dW}{dQ} = 1 - \frac{T_2}{T_1}$

$\frac{1}{6} = 1 - \frac{T_2}{T_1}; \frac{T_2}{T_1} = \frac{5}{6}; T_2 = \frac{5T_1}{6}$

$3T_2 - 186 = 2T_1$

$3 \times \frac{5T_1}{6} - 186 = 2T_1 \ \frac{5T_1}{6} - 186 = 2T_1$

$5T_1 - 372 = 4T$

$\therefore T_1 = 372$ K.

303. $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{600}{800}$

$= 1 - \frac{3}{4} = \frac{1}{4} \times 100$

$= 25\%$

304. $\eta = \frac{T_1 - T_2}{T_1} = \frac{(273+100)-(273-23)}{273+100} = \frac{100+23}{373}$

305. $\frac{\eta_A}{\eta_B} = \frac{T_1 - T_2}{T_1} \times \frac{T_1}{T'_1 - T'_2}$

$= \frac{600-400}{600} \times \frac{500}{500-300}$

$= \frac{2}{6} \times \frac{5}{2} = \frac{5}{6}$.

306. $\eta = 1 - \frac{T_2}{T_1} = \frac{1}{4} = 1 - \frac{300}{T_1}; \frac{300}{T_1} = \frac{3}{4};$

$T_1 = 400$ K

$t_1 = 400 - 273$

$= 127°C$.

307. $0.1 = 1 - \frac{300}{T_1}$

$\frac{300}{T_1} = 0.9$

$T_1 = \frac{3000}{9} = 333$ K

$t_1 = 333 - 273$

$= 60°C$.

308. $\eta = \frac{W}{Q} = 1 - \frac{T_2}{T_1}$

$\therefore \frac{T_2}{T_1} = \frac{Q-W}{Q}$

$T_2 = 500 \ \frac{150}{300} = 250$ K.

309. $0.3 = 1 - \frac{350}{T_1}$

$\frac{350}{T_1} = 0.7$

$\therefore T_1 = \frac{350}{0.7} = 500$ K or 227°C.

310. $Q = 3000 \times 10^3$ cal

$= 3 \times 10^6 \times 4.2$ J $= 12.6 \times 10^6$ J

$W = Q\left(1 - \frac{T_2}{T_1}\right)$

$= 12.6 \times 10^6 \left(1 - \frac{300}{900}\right) = 12.6 \times 10^6 \times \frac{2}{3}$

$= 8.4 \times 10^6$ J.

311. In a irreversible heat engine a part of energy is lost due to friction.

350. In convection hot particles moves up ward (due to low density) and light particle moves downward (done to high density).

352. Convection is not possible in weightlessness. So the liquid will be heated through conduction.

354. The polished surface reflects all the radiation.

355. Heat radiations are electromagnetic waves of wavelength.

356. Every body at all time, at all temperatures emits radiation (except at T = 0). The radiation emitted by the human body is in the infrared region.

358. Infrared radiations are detected by pyrometer.

372.
$$a + r + t = 1$$
$$t = 1 - (a + r) = 1 - 0.96 = 0.04$$
$$Q_t = t\,Q = 0.04 \times 150 = 63$$

373.
$$Q = Q_a + Q_r + Q_t$$
$$Q_t = 10 - (7 + 2) = 1$$
$$t = \frac{Q_t}{Q} = \frac{1}{10} = 0.1$$

375.
$$a + r + t = 1$$
$$t = 1 - (a + r) = 1 - 0.95 = 0.05$$
$$Q_t = t + Q = 0.05 \times 200 = 10 \text{ cal}$$

376.
$$a + r + t = 1$$
$$r = 1 - (a + t) = 1 - 0.75 = 0.25$$
$$Q_r = r\,Q = 0.25 \times 200 = 50 \text{ cal}$$

405. When light incident on pin hole, enters into the box and suffers successive reflection at the inner wall. At each reflection some energy is absorbed. Hence the ray once it enters the box can never come out and pin hole acts like a perfect black body.

406. Initially black body absorbs all the radiant energy incident on it. So it is the darkest one. Black body radiates maximum energy if all other condition are same. So when the temperature of the black body becomes equal to the temperature of furnace it will be brightest of all.

407. A good absorber is a good emitter hence option (a) is wrong. Every body stops absorbing and emitting radiation at 0 K hence option (b) is wrong.

The energy of radiation emitted from a black body is not same for all wavelength hence option (c) is wrong.

Plank's law relates the wavelength (λ) and temperature (T) according to the relation

$$E_\lambda d_\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{[e^{hc/kT} - 1]}d_\lambda$$

Hence option (d) is correct.

410.
$$R_1 = \sigma A_1 T^4$$
$$R_2 = \sigma A_2 T^4$$
$$R_3 = \sigma A_3 T^4$$
$$R_1 : R_2 : R_3 = A_1 : A_2 : A_3$$
$$= l_1^2 : l_2^2 : l_3^2$$
$$= 1 : 4 : 9$$

411.
$$E = \frac{Q}{At}$$
$$\therefore \quad Q = EAt = 0.5 \times 0.07 \times 20 = 0.7 \text{ kcal}$$

412.
$$E = \frac{Q}{At} = \frac{0.5 \times 4.2 \times 10^{-3}}{4\pi \times 0.5 \times 0.5 \times 60} = 11.11$$

413.
$$E = \left(\frac{\theta}{At}\right)$$
$$= \frac{0.27}{6 \times 1^2 \times 100} = \frac{0.27}{6 \times 9 \times 10^{-4} \times 100}$$
$$= 0.5$$

414.
$$P = s\,A\,r\,T^4$$

420.
$$\lambda T = b$$
$$T = \frac{2.8 \times 10^{-3}}{14 \times 10^{-6}} = 0.2 \times 10^3 = 200 \text{ K}$$

421.
$$\lambda T = b$$
$$\lambda = \frac{b}{T} = \frac{2.898 \times 10^{-3}}{600} = 4.82\ \mu\text{m}$$

422.
$$\lambda_1 T_1 = \lambda_2 T_2 \quad \therefore \frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1}$$
$$\frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} = \frac{4200}{3600} = \frac{7}{6}$$

423.
$$\lambda_1 T_1 = \lambda_2 T_2$$
$$\therefore \quad \lambda_2 = \frac{\lambda_1 T_1}{T_2} = \frac{2.9 \times 10^3}{2 \times 10^3} = 1.45 \text{ A}^\circ$$

424.
$$\lambda_1 T_1 = \lambda_2 T_2$$

425.
$$\lambda_m T = \text{constant}$$
$$\therefore \quad \frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} \quad \therefore \frac{10^{-4}}{0.5 \times 10^{-5}} = 200.$$

426.
$$\lambda_{m_1} T_1 = \lambda_{m_2} T_2$$
$$\therefore \quad \lambda_{m_2} = \frac{\lambda_{m_1} T_1}{T_2} = 4.08 \times \frac{700}{1400} = 2.04 \text{ m.}$$

427.
$$\lambda_{m_1} T_1 = \lambda_{m_2} T_2$$
$$\therefore \quad \lambda_{m_2} = \frac{\lambda_{m_1} T_1}{T_2} = \frac{14 \times 200}{1000}$$
$$= 2.8\ \mu\text{m.}$$

428. $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{4800}{3600} = \frac{48}{36} = \frac{4}{3}$

429. $\lambda_{m_2} = \frac{T_1}{T_2} \times \lambda_{m_1} = \frac{1500}{2500} \times 5000 = 3000\ A°$

430. $\frac{T_2}{T_1} = \frac{\lambda_{m_1}}{\lambda_{m_2}} = \frac{1.75}{14.35}$

$\therefore\ T_2 = \frac{1.75}{14.35} \times 1640 = 200\ K$

431. $\lambda_{m_2} = \frac{\lambda_{m_1} T_2}{T_1} = \frac{4800 \times 6000}{3000} = 9600\ A°$.

432. $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{4200}{140} = \frac{30}{1}$

433. $\lambda_m T = \lambda'_m T'$

$\therefore\ \frac{\lambda_m}{\lambda'_m} = \frac{T'}{T} = \frac{3000}{2000} = \frac{3}{2}$

434. According to Wien's displacement law,

$\lambda_m T = b$

or $\lambda_m = \frac{b}{T} = \frac{0.0029}{5 \times 10^4} = 58 \times 10^{-9}\ m = 58\ nm.$

435. $\lambda_m = \frac{b}{T}\quad \therefore\ T = \frac{b}{\lambda_m} = \frac{2.93 \times 10^{-3}}{4000 \times 10^{-10}} = 7325\ K.$

436. $\frac{T_S}{T_N} = \frac{(\lambda_N)_{max}}{(\lambda_S)_{max}} = \frac{350}{510} = 0.69.$

447. For a black body emissivity = absorptive power.

448. Highly polished mirror like surfaces are good reflectors, but not good radiators.

449. Black cloth is a good absorber of heat, therefore ice covered by black cloth melts more as compared to that covered by white cloth.

450. According to Kirchoff's law, the ratio of emissive power to absorptive power is same for all bodies is equal to the emissive power of a perfectly black body i.e.,

$\left(\frac{e}{a}\right)_{body} = E_{Black\ body}$ for a particular wave length

$\left(\frac{e_\lambda}{a_\lambda}\right)_{body} = (E_l)_{Black\ body}\qquad \therefore\ e_\lambda = a_\lambda E_\lambda$

452. Because Planck's law explains the distribution of energy correctly at low temperature as well as at high temperature.

465. $\frac{E_1}{E_2} = \frac{A_1 T_1^4}{A_2 T_2^4} = \frac{r_1^2}{r_2^2}\frac{T_1^4}{T_2^4} = \frac{16}{1} \times \frac{1}{16} = 1$

466. $P_1 = I_1 A_1$ and $P_2 = I_2 A_2$

But $P_1 = \sigma A_1 T_1^4$ and $P_2 = \sigma A_1 T_1^4$

$\therefore\ \sigma T_1^4 A_1 = I_1 A_1$

$\sigma T_2^4 A_2 = I_2 A_2$

$\left(\frac{T_2}{T_1}\right)^4 = \frac{I_2}{I_1}$

$\frac{T_2}{T_1} = \left(\frac{I_2}{I_1}\right)^{1/4} = (10^4)^{1/4} = 10$

$T_2 = T_1 \times 10 = 6000\ K$

467. $\frac{dQ}{dt} = \sigma A T^4$

$= 5.76 \times 4\pi \times 25 \times 10^{-4} \times 36 \times 36$

$= 5.76 \times \frac{22}{7} \times 10^{-2} \times 36 \times 36$

469. $\left(\frac{dQ}{dt\,A}\right) = s\,T^4$

470. $\frac{R_2}{R_1} = \frac{T_2^4}{T_1^4}$

$R_2 = \frac{81 \times 5}{125} = 0.64$

471. $\frac{R_2}{R_1} = \frac{T_2^4}{T_1^4} = \left(\frac{2T_1}{T_1}\right)^4 = 16$

472. $\frac{R_2}{R_1} = \frac{T_2^4}{T_1^4} = \frac{1}{16}$

473. $\frac{R_2}{R_1} = \frac{T_2^4}{T_1^4} = \left(\frac{573}{T}\right)^4$

$\therefore\ T^4 = \frac{R_1}{R_2}(573)^4$

$T = 5730\ K$ or $5457\ °C$

474. $\frac{R_2}{R_1} = \frac{T_1^4}{T_2^4}\quad \frac{2}{1}$

475. $\frac{dQ}{dt} = \sigma A T^4 \rho$

476. $\frac{R_2}{R_1} = \frac{A_2}{A_1}\frac{(T_2^4 - T_0^4)}{(T_1^4 - T_0^4)} = \frac{4r_1^2}{r_1^2} = 4$

$R_2 = 4\,R_1$

$= 4 \times 2.8$

$= 11.2\ c/min.$

477. $\frac{R_2}{R_1} = \frac{T_2^4}{T_1^4} = \frac{625}{81}$

478. $\frac{R_2}{R_1} = \frac{T_2^4}{T_1^4} = \left(\frac{800}{400}\right)^4 = \frac{16}{1}$

479. $\frac{R_2}{R_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{600}{300}\right)^4 = 16$

$R_2 = 16 \times 50 = 800$ J/s

480. $\frac{R_2}{R_1} = \frac{A_2}{A_1}\left(\frac{T_2}{T_1}\right)^4$ as $T_1 = T_2$

$\frac{R_2}{R_1} = \frac{1}{25}$

$\therefore \quad R_2 = \frac{10}{25} = 0.4$ J/s

481. $\frac{dQ}{dt} = \sigma AT^4$

$\therefore \quad A = \frac{dQ}{dt}/rT^4$

$6l^2 = 6$

$l^2 = 1$

$V = l^3 = 1\ m^3$

482. $\frac{dQ}{dtA} = \sigma T^4$

483. $E_1 = \sigma T_1^4$ and $E_2 = \sigma T_2^4$

$E_2 = \left(\frac{T_2}{T_1}\right)^4 E_1 = \left(\frac{800}{400}\right)^4 E_1 = 16 E_1$

$E_2 = 48$ J/s cm^2

485. $\frac{R_2}{R_1} = \frac{T_2^4 - T_0^4}{T_1^4 - T_0^4} = \frac{(900^4 - 300^4)}{(600^4 - 300^4)}$

$= \frac{(81+9)(81-9)}{(36+9)(36-9)} = \frac{90 \times 72}{45 \times 27} = \frac{16}{3}$

486. $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{10000}{500}\right)^4 = 24 = 16$

$E_2 = 16 \times 5 = 80$

487. $T_2 = T_1(1.5)$

$\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 = (1.5)^4 = \frac{81}{16}$

$\frac{E_2}{E_1} - 1 = \frac{81-16}{16} = 4$

$\frac{E_2 - E_1}{E_1}\% = 400\%$

488. $\frac{R_1}{R_2} = \frac{A_1}{A_2} = \frac{4\pi r_1^2}{4\pi r^2} = \left(\frac{r_2}{r_1}\right)^2$

489. $\frac{R_1}{R_2} = \frac{A_1}{A_2} \times \frac{m_2}{m_1} = \left(\frac{r_1}{r_2}\right)$

490. $\frac{R_1}{R_2} = \frac{A_1}{A_2} \times \frac{T_1^4}{T_2^4}$

492. $\frac{R_1}{R_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4} = \frac{500^4 - 400^4}{800^4 - 400^4} = \frac{13}{48}$

495. $\frac{R_1}{R_2} = \left(\frac{T_2}{T_1}\right)^4 = (1.04)^4 = 1 + 4 \times 0.04$

$\frac{R_2 - R_1}{R_1} = 0.16 = 16\%$

496. $\frac{P_2}{P_1} = \frac{T_2^4}{T_1^4} = \left(\frac{4000}{2000}\right)^4 = 16$

$P_2 = 16 \times P_1 = 16 \times 60 = 960$ w

$P = \sigma A \rho T^4$

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

$\therefore \quad \left(\frac{T_2}{T_1}\right)^4 = 2$

$T_2 = 2^{1/4} T_1 = 1.19 \times 800$ K

502. $\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4$

506. $\frac{P_2}{P_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4$

$P_2 = \frac{1}{4} \times (2)^4$

$P_1 = \frac{14}{4} P_1 = 4 \times 450 = 1800$

508. $\frac{dQ}{dt} = \sigma A \rho T^4$

509. $P_1 = \sigma A \rho_1 T_1^4$ and $P_2 = \sigma A \rho_2 T_2^4$

$P_1 = P_2$

$\rho_1 T_1^4 = \rho_2 T_2^4$

$\left(\frac{T_1}{T_2}\right)^4 = \frac{\rho_1}{\rho_2} = \frac{0.6}{0.3} = 2$

$T_1 = 2^{1/4} T_2$

515. $\frac{d\theta}{dt} = AK(\theta - \theta_0)$

524. $\frac{d\theta}{dt} = \frac{kA}{mc}(\theta - \theta_0)$ and $M_h < M_s$

533.
$$\frac{d\theta}{dt} = k(\theta_{AV} - \theta_0)$$
$$\frac{12}{10} = k(66 - 36) = k\,30$$
$$k = \frac{12}{300} = \frac{1}{25}$$
$$\left(\frac{d\theta}{dt}\right) = k(\theta_{AV} - \theta_0)$$
$$\frac{8}{dt} = \frac{1}{25}(56 - 36)$$
$$dt = 10 \text{ mint.}$$

534.
$$\frac{d\theta}{dt} = k(\theta_{AV} - \theta_0)$$
$$\frac{20}{7} = k(50 - 10) \quad \text{..... (i)}$$
$$\frac{40-\theta}{7} = k\left(\frac{40+\theta}{2} - 10\right) \quad \text{..... (ii)}$$

Dividing equation (ii) by (i)
$$\frac{40-\theta}{20} = \frac{40+\theta-20}{2\times 40}$$
$$4(40-\theta) = \theta + 20$$
$$5\theta = 160 - 20$$
$$\theta = \frac{140}{5} = 28°C$$

536.
$$\frac{d\theta}{dt} = k(\theta_{AV} - \theta_0)$$
$$\frac{30}{4} = k(85 - 25)$$
$$\frac{30}{dt} = k(55 - 25)$$
$$dt = 8$$

540.
$$\left(\frac{d\theta}{dt}\right)_1 = k(\theta_{AV} - \theta_0)$$
$$\left(\frac{d\theta}{dt}\right)_2 = k(\theta_{AV} - \theta_0)$$

541.
$$\left(\frac{d\theta}{dt}\right)_1 = k(\theta_{AV} - \theta_0)$$
$$\frac{4}{5} = k(48 - \theta_0) \quad \text{... (i)}$$
$$\frac{6}{10} = k(43 - \theta_0) \quad \text{... (ii)}$$

Solving equation (i) and (ii),
$$\theta_0 = 28\,°C$$

542.
$$\left(\frac{d\theta}{dt}\right) = k(\theta_{AV} - \theta_0)$$
$$\frac{60-50}{10} = k(55 - 25)$$
$$k = \frac{1}{30}$$
$$\frac{50-\theta}{10} = \frac{1}{30}\left(\frac{50+\theta}{2} - 25\right)$$
$$\theta = 42.85\,°C$$

543.
$$R_1 = k(\theta_1 - \theta_2)$$
$$R_2 = k(\theta_2 - \theta_0)$$
$$\frac{R_2}{R_1} = \left(\frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}\right)$$
$$R_2 = 0.3\,°C/\text{min.}$$

544.
$$\left(\frac{d\theta}{dt}\right) = k(\theta_{AV} - \theta_0)$$
$$\frac{8}{5} = k(56 - 28) \quad \text{... (i)}$$
$$\frac{52-\theta}{5} = k\left(\frac{52+\theta}{2} - 28\right) \quad \text{... (ii)}$$
$$\frac{52-\theta}{8} = \frac{(52+\theta-56)}{2\times 28}$$
$$\theta = 46$$
$$d\theta = 52 - 46 = 6\,°C$$

545.
$$R_1 = k(\theta_1 - \theta_0)$$
$$R_2 = k(\theta_2 - \theta_0)$$
$$\frac{R_2}{R_1} = \frac{40-25}{50-25} = \frac{15}{25} = \frac{3}{5}$$
$$R_2 = \frac{3}{5}\times 3 = 1.8\,°C/\text{min.}$$

547. Volume of sphere = Volume of cube
$$\frac{4\pi}{3}r^3 = l^3$$
$$\frac{r}{l} = \left(\frac{3}{4\pi}\right)^{1/3} \quad \text{... (i)}$$
$$\left(\frac{dQ}{dt}\right)_s = 4\pi r^2(T^4 - T_o^4)$$
$$\left(\frac{dQ}{dt}\right)_c = 6\,l^2(T^4 - T_o^4)$$

$$\frac{(dQ/dt)_s}{(dQ/dt)_c} = \frac{4\pi r^2}{6l^2}$$

Substitute r/l from equation (i), we have,

$$= \frac{4\pi}{6} \times \left(\frac{3}{4\pi}\right)^{2/3} = \left(\frac{\pi}{6}\right)^{1/3}$$

550. $R_1 = K(\theta_1 - \theta_0)$ and $R_2 = k(\theta_2 - \theta_0)$

$$\frac{R_2}{R_1} = \frac{(\theta_2 - \theta_0)}{(\theta_1 - \theta_0)} = \frac{25}{40} = \frac{5}{8}$$

$$R_2 = 0.75$$

552. $C_P - C_V = 300,\ \frac{C_p}{C_v} = 1.4,\ C_p = 1.4\,C_v$

$$1.4\,C_v - C_v = 300$$

$$0.4\,C_v = 300$$

$$C_v = \frac{300}{0.4}$$

$$C_p = \frac{300}{0.4} \times 1.4 = 1050 \text{ J/kg K}$$

553. $KE = \frac{3}{2}RT.$

554. $PV = nRT$

$$V = \frac{nRT}{P} = \frac{m}{M}\frac{RT}{P}$$

$$= \frac{2.8}{28} \times \frac{0.0821 \times 300 \times 10^3}{0.821} = 3 \text{ lit.}$$

555. $$\frac{d\theta}{dt} = K(\theta_{av} - \theta_0)$$

$$\frac{4}{5} = K(48 - \theta_0) \qquad \text{..... (i)}$$

$$\frac{6}{10} = K(43 - \theta_0) \qquad \text{..... (ii)}$$

$$\frac{4}{5} \times \frac{10}{6} = \frac{(48 - \theta_0)}{(43 - \theta_0)}$$

$$\frac{4}{3} = \frac{(48 - \theta_0)}{(43 - \theta_0)}$$

After solving,

$$\theta_0 = 30°C.$$

557. $C_1 \propto \frac{1}{\sqrt{d_1}}$ and $C_2 \propto \frac{1}{\sqrt{d_2}}$

$$\frac{C_1}{C_2} = \sqrt{\frac{d_2}{d_1}}$$

558. $n = 1,\ dQ_P = 207$ J; $\Delta T = 10$ K

$$dQ_P = dQ_V + dw$$

$$dQ_V = dQ_P - dw$$

$$= 207 - nRdT$$

$$= 207 - 1 \times 8.3 \times 10$$

$$= 207 - 83$$

$$= 124 \text{ J.}$$

559. $v = \frac{\Delta V}{V\,\Delta t} = \frac{25}{100 \times 80} = 0.0033\ /\ °C.$

561. The rate of colling is directly proportional to surface area.

563. $du = m\,C_v\,dT$

$$= 5 \times 10^{-3} \times 172 \times 2 \times 4.2$$

$$= 7.22 \text{ J.}$$

564. $$V_s = \sqrt{\frac{\gamma}{3}}\ C_{rms}$$

$$= \sqrt{\frac{1.42}{3}} \times C_{rms}$$

$$500 = \sqrt{0.47}\ C_{rms}$$

$$C_{rms} = \frac{500}{\sqrt{0.47}} = 727 \text{ m/s.}$$

566. $T = \frac{b}{\lambda} = \frac{2.93 \times 10^{-3}}{2.93 \times 10^{-10}} = 10^7$ K.

567. $$\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}\frac{M_1}{M_2}}$$

$$= \sqrt{\frac{900}{300} \times \frac{2}{32}} = \sqrt{\frac{3}{16}}$$

$$C_2 = \frac{\sqrt{3}}{4} \times C_1$$

$$= \frac{\sqrt{3}}{4} \times 1930$$

$$= 836 \text{ m/s.}$$

568. $C_P - C_V = R$

569. $$\frac{PV}{3} = RT$$

$$PV = 3\,RT$$

$$n = 3 \text{ moles.}$$

570. $$C_{mean} = \frac{C_1 + C_2 + C_3 + C_4 + C_5}{5}$$

$$= \frac{150 + 160 + 170 + 180 + 190}{5}$$

$$C_{mean} = 17 \text{ m/s}$$

$$C_{rms} = \sqrt{\frac{225 + 256 + 289 + 324 + 361}{5}}$$

$$C_{rms} = 17.05$$

$$\frac{C_{rms}}{C_{mean}} = \frac{17.05}{17} = \frac{1}{1} = 1.$$

571. $$\frac{KE}{mole} = \frac{3}{2} RT$$

$$PV = RT$$

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

$$\frac{KE}{volume} = \frac{3}{2} P.$$

575. dQ = 2 kcal, du = 5030 J, dw = 3350 J, J = ?

$$dQ = du + dw$$

$$J\,dQ = 5030 + 3350$$

$$J = \frac{8380}{2}$$

$$J = 4190 \text{ J/kcal}$$

$$J = 4.190 \text{ J/cal.}$$

577. $$a + r + t = 1$$

$$t = 1 - (a + r)$$

$$= 1 - (0.72 + 0.24)$$

$$= (1 - 0.96)$$

$$= 0.04.$$

578. $$C_p = C_v + r$$

$$= 750 + \frac{pv}{mT}$$

$$= 750 + \frac{10^5 \times 8 \times 10^{-2}}{0.3 \times 75}$$

$$\frac{C_p}{C_v} = \frac{750}{C_v} + \frac{800}{22.5 \times C_v}$$

$$\gamma = \frac{C_p}{C_v} = 1 + \frac{800}{22.5 \times 750} = 1 + 0.474$$

$$\gamma = 1.474.$$

582. $$\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}}$$

$$\frac{1}{2} = \sqrt{\frac{T_2}{T_1}}$$

$$\frac{1}{4} = \frac{T_2}{T_1}$$

$$T_2 = \frac{T_1}{4}$$

$$= \frac{273}{4} = 68.25 \text{ K.}$$

583. $$P = \frac{1}{3} \rho C^2$$

$$= \frac{1}{3} \frac{m}{v} C^2$$

$$P = \frac{2}{3} \times \frac{1}{2} \frac{mc^2}{v}$$

$$P = \frac{2}{3} E.$$

584. $$\frac{E_1}{E_2} = \frac{A_1}{A_2} = \frac{4\pi r_1^2}{4\pi r_2^2}$$

$$= \left(\frac{r_1}{r_2}\right)^2 = \frac{4}{1}.$$

586. $$\frac{R_2}{R_1} = \frac{K(\theta_2 - \theta_1)}{K(\theta_1 - \theta_0)} = \frac{30}{50}$$

$$R_2 = \frac{3}{5} R_1$$

$$= \frac{3}{5} \times 0.5 = 0.3\ ^\circ\text{C/min.}$$

587. $$\frac{V_2}{V_1} = \sqrt{\frac{T_2}{T_1}}$$

$$\frac{4 V_1}{V_1} = \sqrt{\frac{T_2}{T_1}}$$

$$16 = \frac{T_2}{T_1}$$

$$T_2 = 16 \times 273 = 4368\ ^\circ\text{C.}$$

590. $$\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{300}{1200}\right)^4 = \left(\frac{1}{4}\right)^4 = \frac{1}{256}.$$

591. $$a + r + t = 1$$

$$a = 1 - (r + t)$$

$$= 1 - (0.22 + 0.74)$$

$$= 1 - 0.96$$

$$a = 0.04.$$

592. $$\frac{d\theta}{dt} = k(\theta_{av} - \theta_0)$$

$$\frac{30}{8} = k(85 - 15) \qquad \text{..... (i)}$$

$$\frac{30}{dt} = k(55 - 15) \qquad \text{..... (ii)}$$

$$\frac{30}{8} \times \frac{dt}{30} = \frac{70}{40}$$

$$dt = \frac{8 \times 70}{40} = 14 \text{ min.}$$

594. $C_P - C_V = R$

$$\frac{C_V}{C_V} = \frac{C_P}{C_V} - \frac{R}{C_V}$$

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

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

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

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

595. $C^2 = \dfrac{C_1^2 + C_2^2 + C_3^2 + C_4^2 + C_5^2}{5}$

$$= \frac{4+9+16+25+36}{5}$$

$$= \frac{90}{5} = 18\ m^2/s^2.$$

598. $\dfrac{dV}{V} = \dfrac{dP}{P_2}$

$$= \frac{10}{0.9}\% = \frac{100}{9} = 11.6\%.$$

602. $\dfrac{E_2}{E_1} = \left(\dfrac{T_2}{T_1}\right)^4 = \left(\dfrac{1000}{500}\right)^4$

$$E_2 = 16\ E_1$$

$$= 16 \times 5 = 80\ cal/m^2\ s$$

605. $\dfrac{C_1}{C_2} = \sqrt{\dfrac{\rho_2}{\rho_1} \times \dfrac{P_1}{P_2}}$

$$= \sqrt{\frac{3}{2} \times \frac{3}{2}} = \frac{3}{2}$$

$$\frac{C_1}{C_2} = \frac{3}{2}.$$

606. $C_2 = 2\ C_1$

$$\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}}$$

$$\frac{2C_1}{C_1} = \sqrt{\frac{T_2}{T_1}}$$

$$4 = \frac{T_2}{T_1}$$

$$T_2 = 4 \times 273 = 1092\ K$$

$$T_2 = 1092 - 273$$

$$= 819\ C.$$

608. $\dfrac{E_2}{E_1} = \left(\dfrac{T_2}{T_1}\right)^4 = \left(\dfrac{500}{300}\right)^4$

$$E_2 = \frac{625}{81} \times E_1$$

$$E_2 = \frac{625}{81} \times 81$$

$$E_2 = 625$$

$$E = 0.8 \times 625$$

$$= 500$$

$$E = 500\ J/m^2\ s.$$

618. $[P\ V] = [L^{-1}M^1T^{-2}]\ [L^3]$

$$= [L^2M^1T^{-2}]$$

$$= [E]$$

619. $\sigma = \dfrac{d\theta}{dtAT^4}$

$$[\sigma] = \frac{[d\theta]}{[dt][A][T^4]}$$

$$= \frac{[L^2M^1T^{-2}]}{[L^2M^0T^1K^4]} = [L^0M^1T^{-3}K^{-4}]$$

620. $E \propto T^4$

E_2 greater for T_2 (As $T_2 > T_1$).