IIT JEE
SOLVED PAPER 2009

Physics

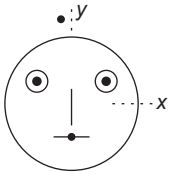
Paper I

SECTION I

Single Correct Choice Type

This section contains 8 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

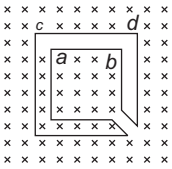
Look at the drawing given in the figure, which has been drawn with ink of uniform line-thickness.



The mass of ink used to draw each of the two inner circles, and each of the two line segments is m. The mass of the ink used to draw the outer circle is $6m$. The coordinates of the centres of the different parts are, outer circle (0, 0), left inner circle (0, 0), right inner circle (a, a), vertical line (0, 0) and horizontal line (0, $-a$). The y-coordinate of the centre of mass of the ink in this drawing is

(a) $\frac{a}{10}$ (b) $\frac{a}{8}$ (c) $\frac{a}{12}$ (d) $\frac{a}{3}$

The figure shows certain wire segments joined together to form a coplanar loop. The loop is placed in a perpendicular magnetic field in the direction going into the plane of the figure. The magnitude of the field increases with time. I_1 and I_2 are the currents in the segments ab and cd. Then,

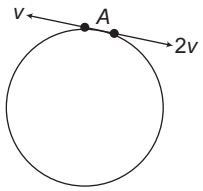


(a) $I_1 > I_2$ (b) $I_1 < I_2$

(c) I_1 is in the direction ba and I_2 is in the direction cd

(d) I_1 is in the direction ab and I_2 is in the direction dc

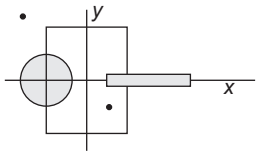
Two small particles of equal masses start moving in opposite directions from a point A in a horizontal circular orbit. Their tangential velocities are v and $2v$ respectively, as shown in the figure. Between collisions, the particles move with constant speeds. After making how many elastic collisions, other than that at A, these two particles will again reach the point A?



(a) 4 (b) 3 (c) 2 (d) 1

A disk of radius $\frac{a}{4}$ having a uniformly distributed charge 6 C is placed in the $x-y$ plane with its centre at $\left(\frac{-a}{2}, 0, 0\right)$. A rod of length a carrying a uniformly distributed charge 8 C is placed on the x-axis from $x = \frac{a}{4}$ to $x = \frac{5a}{4}$. Two point charges -7 C and 3 C are placed at $\left(\frac{a}{4}, \frac{-a}{4}, 0\right)$ and $\left(\frac{-3a}{4}, \frac{3a}{4}, 0\right)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm\frac{a}{2}$, $y = \pm\frac{a}{2}$, $z = \pm\frac{a}{2}$.

The electric flux through this cubical surface is



(a) $\frac{-2C}{\varepsilon_0}$ (b) $\frac{2C}{\varepsilon_0}$

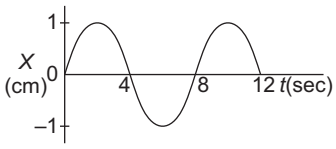
(c) $\frac{10C}{\varepsilon_0}$ (d) $\frac{12C}{\varepsilon_0}$

Three concentric metallic spherical shells of radii R, $2R$, $3R$ are given charges Q_1, Q_2, Q_3, respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells, $Q_1 : Q_2 : Q_3$, is

(a) 1 : 2 : 3 (b) 1 : 3 : 5

(c) 1 : 4 : 9 (d) 1 : 8 : 18

The $x-t$ graph of a particle undergoing simple harmonic motion is shown below. The acceleration of the particle at $t = \frac{4}{3}$ s is



(a) $\frac{\sqrt{3}}{32}\pi^2$ cms^{-2} (b) $\frac{-\pi^2}{32}$ cms^{-2}

(c) $\frac{\pi^2}{32}$ cms^{-2} (d) $-\frac{\sqrt{3}}{32}\pi^2$ cms^{-2}

A ball is dropped from a height of 20 m above the surface of water in a lake. The refractive index of water is $\frac{4}{3}$. A fish inside the lake, in the line of fall of the ball, is looking at the ball. At an instant, when the ball is 12.8 m above the water surface, the fish sees the speed of ball as

(a) 9 ms^{-1} (b) 12 ms^{-1}

(c) 16 ms^{-1} (d) 21.33 ms^{-1}

A block of base 10 cm × 10 cm and height 15 cm is kept on an inclined plane. The coefficient of friction between them is $\sqrt{3}$. The inclination θ of this inclined plane from the horizontal plane is gradually increased from 0°. Then,

(a) at $\theta = 30°$, the block will start sliding down the plane

(b) the block will remain at rest on the plane up to certain θ and then it will topple

(c) at $\theta = 60°$, the block will start sliding down the plane and continue to do so at higher angles

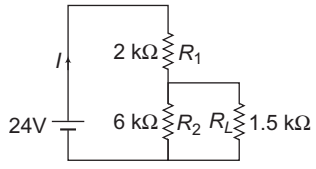
(d) at $\theta = 60°$, the block will start sliding down the plane and on further increasing θ, it will topple at certain θ

SECTION II

Multiple Correct Choice Type

This section contains 4 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ***ONE OR MORE*** *is/are correct.*

For the circuit shown in the figure



(a) the current I through the battery is 7.5 mA

(b) the potential difference across R_L is 18 V

(c) ratio of powers dissipated in R_1 and R_2 is 3

(d) if R_1 and R_2 are interchanged, magnitude of the power dissipated in R_L will decrease by a factor of 9.

C_V and C_p denote the molar specific heat capacities of a gas at constant volume and constant pressure, respectively. Then

(a) $C_p - C_V$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(b) $C_p + C_V$ is larger for a diatomic ideal gas than for a monoatomic ideal gas.

(c) $\frac{C_p}{C_V}$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(d) $C_p \cdot C_V$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

A student performed the experiment of determination of focal length of a concave mirror by $u - v$ method using an optical bench of length 1.5 m. The focal length of the mirror used is 24 cm. The maximum error in the location of the image can be 0.2 cm. The 5 sets of (u, v) values recorded by the student (in cm) are : (42, 56), (48, 48), (60, 40), (66, 33), (78, 39). The data set(s) that cannot come from experiment and is (are) incorrectly recorded, is(are)

(a) (42, 56) (b) (48, 48)
(c) (66, 33) (d) (78, 39)

If the resultant of all the external forces acting on a system of particles is zero, then from an inertial frame, one can surely say that

(a) linear momentum of the system does not change in time

(b) kinetic energy of the system does not change in time

(c) angular momentum of the system does not change in time

(d) potential energy of the system does not change in time

SECTION III

Comprehension Type

This section contains 2 groups of questions. Each group has 3 multiple choice questions based on a paragraph. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ***ONLY ONE*** *is correct.*

Paragraph for Question Nos. 13 to 15

When a particle is restricted to move along x-axis between $x = 0$ and $x = a$, where a is of nanometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the liner momentum p of the particle according to the de Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus, the energy of the particle can be denoted by a quantum number n taking values 1, 2, 3, … ($n = 1$, called the ground state) corresponding to the number of loops in the standing wave.

Use the model described above to answer the following three questions for a particle moving in the line $x = 0$ to $x = a$. [Take $h = 6.6 \times 10^{-34}$ Js and $e = 1.6 \times 10^{-19}$ C]

The allowed energy for the particle for a particular value of n is proportional to

(a) a^{-2} (b) $a^{-3/2}$
(c) a^{-1} (d) a^2

If the mass of the particle is $m = 1.0 \times 10^{-30}$ kg and $a = 6.6$ nm, the energy of the particle in its ground state is closest to

(a) 0.8 meV (b) 8 meV
(c) 80 meV (d) 800 meV

The speed of the particle that can take discrete values is proportional to

(a) $n^{-3/2}$ (b) n^{-1} (c) $n^{1/2}$ (d) n

Paragraph for Question Nos. 16 to 18

Scientists are working hard to develop nuclear fusion reactor. Nuclei of heavy hydrogen, ${}^{2}_{1}\mathrm{H}$ *known as deuteron and denoted by D can be thought of as a candidate for fusion reactor. The D-D reaction is* ${}^{2}_{1}\mathrm{H}+{}^{2}_{1}\mathrm{H}\rightarrow{}^{3}_{2}\mathrm{He}+n+$ *energy. In the core of fusion reactor. A gas of heavy hydrogen is fully ionized into deuteron nuclei and electrons. This collection of* ${}^{4}_{1}\mathrm{H}$ *nuclei and electrons is known as plasma. The nuclei move randomly in the reactor core and occasionally come close enough for nuclear fusion to take place. Usually, the temperatures in the reactor core are too high and no material wall can be used to confine the plasma. Special techniques are used which confine the plasma for a time* t_0 *before the particles fly away from the core. If n is the density (number/volume) of deutrons, the product* nt_0 *is called Lawson number. In one of the criteria, a reactor is termed successful if Lawson number is greater than* 5×10^{14} scm^{-3}.

It may be helpful to use the following : Boltzmann constant $k=8.6\times10^{-5}$ eV/K; $\frac{e^2}{4\pi\varepsilon_0}=1.44\times10^{-9}$ eVm.

In the core of nuclear fusion reactor, the gas becomes plasma because of

(a) strong nuclear force acting between the deuterons

(b) Coulomb fore acting between the deuterons

(c) Coulomb force acting between deuteron-electron pairs

(d) the high temperature maintained inside the reactor core

Assume that two deuteron nuclei in the core of fusion reactor at temperature T are moving towards each other, each with kinetic energy $1.5\,kT$, when the separation between them is large enough to neglect Coulomb potential energy. Also neglect any interaction from other particles in the core. The minimum temperature T required for them to reach a separation of 4×10^{-15} m is in the range

(a) $1.0\times10^{9}\ \mathrm{K}<T<2.0\times10^{9}\ \mathrm{K}$

(b) $2.0\times10^{9}\ \mathrm{K}<T<3.0\times10^{9}\ \mathrm{K}$

(c) $3.0\times10^{9}\ \mathrm{K}<T<4.0\times10^{9}\ \mathrm{K}$

(d) $4.0\times10^{9}\ \mathrm{K}<T<5.0\times10^{9}\ \mathrm{K}$

Results of calculations for four different designs of a fusion reactor using D-D reaction are given below. Which of these is most promising based on Lawson criterion?

(a) Deuteron density $=2.0\times10^{12}$ cm^{-3}, confinement time $=5.0\times10^{-3}$ s

(b) Deuteron density$=8.0\times10^{14}$ cm^{-3}, confinement time $=9.0\times10^{-1}$ s

(c) Deuteron density $=4.0\times10^{23}$ cm^{-3}, confinement time $=1.0\times10^{-11}$ s

(d) Deuteron density $=1.0\times10^{24}$ cm^{-3}, confinement time $=4.0\times10^{-12}$ s

SECTION IV

Matrix-Match Type

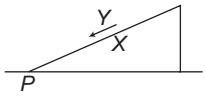
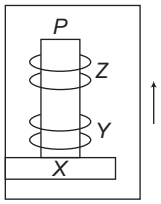
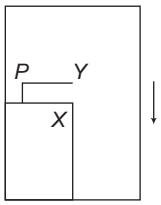
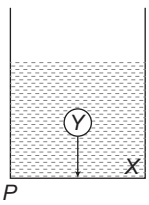
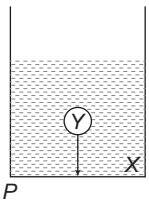
This section contains 2 questions. Each question contains Statements given in two Columns which have to be matched. The Statements in Column I *are labelled (A), (B), (C) and (D), while the Statements in Column* II *are labelled p, q, r, s and t. Any given Statement in Column* I *can have correct matching with* ***ONE OR MORE*** *statement(s) in Column* II*. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example.*

If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s and t; then the correct darkening of bubbles will look like the following.

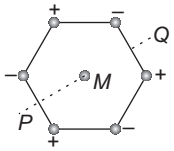
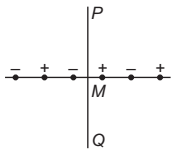
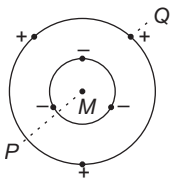
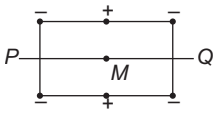
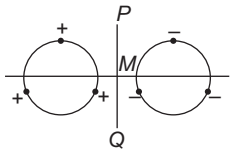
	p	q	r	s	t
A	●	●	○	●	●
B	○	●	●	○	○
C	●	●	○	○	○
D	○	○	○	●	●

Column II shows five systems in which two objects are labelled as X and Y. Also in each case a point P is shown. Column-I gives some statements about X and/or Y.

Match these statements to the appropriate system(s) from Column-II.

	Column I			Column II
A.	The force exerted by X on Y has a magnitude Mg.	(p)		Block Y of mass M left on a fixed inclined plane X, slides on it with a constant velocity.
B.	The gravitational potential energy of X is continuously increasing.	(q)		Two ring magnets Y and Z each of mass M, are kept in frictionless vertical plastic stand so that they repel each other. Y rests on the base X and Z hangs in air in equilibrium. P is the topmost point of the stand on the common axis of the two rings. The whole system is in a lift that is going up with a constant velocity.
C.	Mechanical energy of the system $X + Y$ is continuously decreasing.	(r)		A pulley Y of mass m_0 is fixed to a table through a clamp X. A block of mass M hangs from a string that goes over the pulley and is fixed at point P of the table. The whole system is kept in a lift that is going down with a constant velocity.
D.	The torque of the weight of Y about point P is zero.	(s)		A sphere Y of mass M is put in a non-viscous liquid X kept in a container at rest. The sphere is released and it moves down in the liquid.
		(t)		A sphere Y of mass M is falling with its terminal velocity in a viscous liquid X kept in a container.

Six point charges, each of the same magnitude q, are arranged in different manners as shown in Column-II. In each case, a point M and a line PQ passing through M are shown. Let E be the electric field and V be the electric potential at M (potential at infinity is zero) due to the given charge distribution when it is at rest. Now, the whole system is set into rotation with a constant angular velocity about the line PQ. Let B the magnetic field at M and μ be the magnetic moment of the system in this condition. Assume each rotating charge to be equivalent to a steady current.

Column I			Column II
A. $E = 0$	(p)		Charges are at the corners of a regular hexagon. *M* is at the centre of the hexagon. *PQ* is perpendicular to the plane of the hexagon.
B. $V \neq 0$	(q)		Charges are on a line perpendicular to *PQ* at equal intervals. *M* is the mid-point between the two innermost charges.
C. $B = 0$	(r)		Charges are placed on two coplanar insulating rings at equal intervals. *M* is the common centre of the rings. *PQ* is perpendicular to the plane of the rings.
D. $\mu \neq 0$	(s)		Charges are placed at the corners of a rectangle of sides *a* and 2*a* and at the mid points of the longer sides. *M* is at the centre of the rectangle. *PQ* is parallel to the longer sides.
	(t)		Charges are placed on two coplanar, identical insulting rings at equal intervals. *M* is the mid points between the centres of the rings. *PQ* is perpendicular to the line joining the centres and coplanar to the rings.

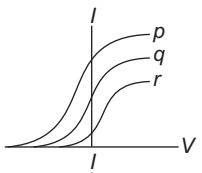
Paper II

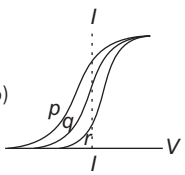
SECTION I

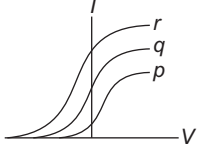
Single Correct Choice Type

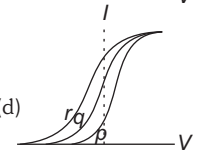
This section contains 4 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) for its answer, out which ***ONLY ONE*** *is correct.*

Photoelectric effect experiments are performed using three different metal plates *p*, *q* and *r* having work functions $\varphi_p = 2.0$ eV, $\varphi_q = 2.5$ eV and $\varphi_r = 3.0$ eV, respectively. A light beam containing wavelengths of 550 nm, 450 nm and 350 nm with equal intensities illuminates each of the plates. The correct $I - V$ graph for the experiment is

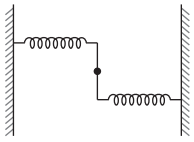
(a) 

(b) 

(c) 

(d) 

A uniform rod of length L and mass M is pivoted at the centre. Its two ends are attached to two springs of equal spring constants k. The springs are fixed to rigid supports as shown in the figure, and rod is free to oscillate in the horizontal plane. The rod is gently pushed through a small angle θ in one direction and released. The frequency of oscillation is



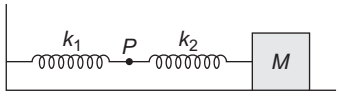
(a) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{k}{M}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{6k}{M}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{24k}{M}}$

A piece of wire is bent in the shape of a parabola $y = kx^2$ (y-axis vertical) with a bead of mass m on it. The bead can slide on the wire without friction. It stays at the lowest point of the parabola when the wire is at rest. The wire is now accelerated parallel to the x-axis with the constant acceleration a. The distance of the new equilibrium position of the bead, where the bead can stays at rest with respect to the wire, from the y-axis is

(a) $\frac{a}{gk}$ (b) $\frac{a}{2gk}$ (c) $\frac{2a}{gk}$ (d) $\frac{a}{4gk}$

The mass M shown in the figure oscillates in simple harmonic motion with amplitude A. The amplitude of the point P is



(a) $\frac{k_a A}{k_2}$ (b) $\frac{k_2 A}{k_1}$

(c) $\frac{k_1 A}{k_1 + k_2}$ (d) $\frac{k_2 A}{k_1 + k_2}$

SECTION II

Multiple Correct Choice Type

This section contains 5 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ***ONE OR MORE*** *is/are correct.*

Under the influence of the coulomb field of charge $+Q$, a charge $-q$ is moving around it in an elliptical orbit. Find out the correct statement(s).

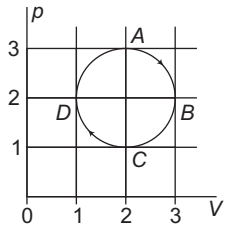
(a) The angular momentum of the charge $-q$ is constant

(b) The linear momentum of the charge $-q$ is constant

(c) The angular velocity of the charge $-q$ is constant

(d) The linear speed of the charge $-q$ is constant

The figure shows the $p - V$ plot of an ideal gas taken through a cycle $ABCDA$. The part ABC is a semi-circle and CDA is half of an ellipse. Then,



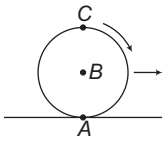
(a) the process during the path $A \to B$ is isothermal

(b) heat flows out of the gas during the path $B \to C \to D$

(c) work done during the path $A \to B \to C$ is zero

(d) positive work is done by the gas in the cycle $ABCDA$.

A sphere is rolling without slipping on a fixed horizontal plane surface. In the figure, A is the point of contact. B is the centre of the sphere and C is its topmost point. Then,



(a) $\vec{\mathbf{v}}_C - \vec{\mathbf{v}}_A = 2(\vec{\mathbf{v}}_B - \vec{\mathbf{v}}_C)$

(b) $\vec{\mathbf{v}}_C - \vec{\mathbf{v}}_B = \vec{\mathbf{v}}_B - \vec{\mathbf{v}}_A$

(c) $|\vec{\mathbf{v}}_C - \vec{\mathbf{v}}_A| = 2|\vec{\mathbf{v}}_B - \vec{\mathbf{v}}_C|$

(d) $|\vec{\mathbf{v}}_C - \vec{\mathbf{v}}_A| = 4|\vec{\mathbf{v}}_B|$

A student performed the experiment to measure the speed of sound in air using resonance air-column method. Two resonances in the air-column were obtained by lowering the water level. The resonance with the shorter air-column is the first resonance and that with the longer air column is the second resonance. Then,

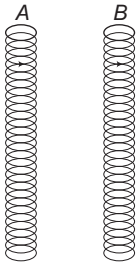
(a) the intensity of the sound heard at the first resonance was more than that at the second resonance

(b) the prongs of the tuning fork were kept in a horizontal place above the resonance tube

(c) the amplitude of vibration of the ends of the prongs is typically around 1 cm

(d) the length of the air-column at the first resonance was somewhat shorter than 1/4th of the wavelength of the sound in air

Two metallic rings A and B, identical in shape and size but having different resistivities ρ_A and ρ_B, are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights h_A and h_B, respectively, with $h_A > h_B$. The possible relation(s) between their resistivities and their masses m_A and m_B is(are)



(a) $\rho_A > \rho_B$ and $m_A = m_B$

(b) $\rho_A < \rho_B$ and $m_A = m_B$

(c) $\rho_A > \rho_B$ and $m_A > m_B$

(d) $\rho_A < \rho_B$ and $m_A < m_B$

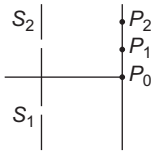
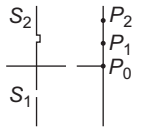
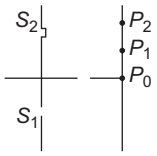
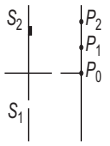
SECTION III

Matrix-Match Type

This section contains 2 questions. Each question contains statements given in two Columns, which have to be matched. The statements in Column I *are labelled (A), (B), (C) and (D), while the statements in Column* II *are labelled p, q, r, s and t. Any given statement in Column* I *can have correct matching with* ***ONE OR MORE*** *statement(s) in Column* II*. The appropriate bubbles corresponding to the answer to these questions have to be darkened as illustrated in the following example. If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s and t; then the correct darkening of bubbles will took like the following*

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

Column I shows four situations of standard Young's double slit arrangement with the screen placed far away from the slits S_1 and S_2. In each of these cases $S_1P_0 = S_2P_0$, $S_1P_1 - S_2P_1 = \frac{\lambda}{4}$ and $S_1P_2 - S_2P_2 = \frac{\lambda}{3}$, where λ is the wavelength of the light used. In the cases B, C and D, a transparent sheet of refractive index μ and thickness t is pasted on slit S_2. The thickness of the sheets are different in different cases. The phase difference between the light waves reaching a point P on the screen from the two slits is denoted by $\delta(P)$ and the intensity by $I(P)$. Match each situation given in Column-I with the statement(s) in Column-II valid for that situation.

Column I		Column II	
A.		p.	$\delta(P_0) = 0$
B. $(\mu - 1)t = \frac{\lambda}{4}$		q.	$\delta(P_1) = 0$
C. $(\mu - 1)t = \frac{\lambda}{2}$		r.	$I(P_1) = 0$
D. $(\mu - 1)t = \frac{3\lambda}{4}$		s.	$I(P_0) > I(P_1)$
		t.	$I(P_2) > I(P_1)$

Column-II gives certain systems undergoing a process. Column-I suggests changes in some of the parameters related to the system. Match the statements in Column-I to the appropriate process (es) from Column-II.

	Column I		Column II
A.	The energy of the system is increased	p.	System : A capacitor, initially uncharged Process : It is connected to a battery
B.	Mechanical energy is provided to the system, which is converted into energy of random motion of its parts	q.	System : A gas in an adiabatic container fitted with an adiabatic piston
			Process : The gas is compressed by pushing the piston
C.	Internal energy of the system is converted in to its mechanical energy	r.	System : A gas in a rigid container
			Process : The gas gets cooled due to colder atmosphere surrounding it
D.	Mass of the system is decreased	s.	System : A heavy nucleus, initially at rest
			Process : The nucleus fissions into two fragments of nearly equal masses and some neutrons are emitted
		t.	System : A resistive wire loop
			Process : The loop is placed in a time varying magnetic field perpendicular to its plane

SECTION IV

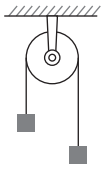
Integer Answer Type

This section contains 8 questions. The answer to each of the questions is a single-digit integer, ranging from 0 to 9. The appropriate bubbles below the respective question numbers in the ORS have to be darkened. For example, if the correct answer to question numbers X, Y, Z and W (say) are 6, 0, 9 and 2, respectively, then the correct darkening of bubbles will look like the following

X	Y	Z	W
0	**0**	0	0
1	1	1	1
2	2	2	**2**
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	**9**	9

A steady current I goes through a wire loop PQR having shape of a right angle triangle with $PQ = 3x$, $PR = 4x$ and $QR = 5x$. If the magnitude of the magnetic field at P due to this loop is $k\left(\frac{\mu_0 I}{48\pi x}\right)$, find the value of k.

A light inextensible string that goes over a smooth fixed pulley as shown in the figure connects two blocks of masses 0.36 kg and 0.72 kg. Taking $g = 10\ \text{ms}^{-2}$, find the work done (in Joule) by string on the block of mass 0.36 kg during the first second after the system is released from rest.



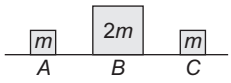
A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at $r = R$, find the value of a.

A metal rod AB of length $10x$ has its one end A in ice at 0°C and the other end B in water at 100°C. If a point P on the rod is maintained at 400°C, then it is found that equal amounts of water and ice evaporate and melt per unit time. The latent heat of evaporation of water is 540 calg^{-1} and latent heat of melting of ice is 80 calg^{-1}. If the point P is at a distance of λx from the ice end A, find the value of λ. [Neglect any heat loss to the surrounding.]

Two soap bubbles A and B are kept in a closed chamber where the air is maintained at pressure 8 Nm^{-2}. The radii of bubbles A and B are 2 cm, respectively. Surface tension of the soap-water used to make bubbles is 0.04 Nm^{-1}. Find the ratio $\frac{n_B}{n_A}$, where n_A and n_B are the number of moles of air in bubbles A and B, respectively. [Neglect the effect of gravity]

A 20 cm long string, having a mass of 1.0 g, is fixed at both the ends. The tension in the string is 0.5 N. The string is set into vibration using an external vibrator of frequency 100 Hz. Find the separation (in cm) between the successive nodes on the string.

Three objects *A*, *B* and *C* are kept in a straight line on a frictionless horizontal surface. These have masses *m*, 2*m* and *m*, respectively. The object *A* moves towards *B* with a speed 9 ms^{-1} and makes an elastic collision with it. Thereafter, *B* makes completely inelastic collision with *C*. All motions occur on the same straight line. Find the final speed (in ms^{-1}) of the object *C*.



A cylindrical vessel of height 500 mm has an orifice (small hole) at its bottom. The orifice is initially closed and water is filled in it upto height *H*. Now the top is completely sealed with a cap and the orifice at the bottom is opened. Some water comes out from the orifice and the water level in the vessel becomes steady with height of water column being 200 mm. Find the fall in height (in mm) of water level due to opening of the orifice.

[Take atmospheric pressure = 1.0×10^5 Nm^{-2}, density of water = 1000 kg m^{-3} and $g = 10$ ms^{-2}. Neglect any effect of surface tension.]

Paper 1

1. (a) **2.** (d) **3.** (c) **4.** (a) **5.** (b) **6.** (d)
7. (c) **8.** (b) **9.** (a, d) **10.** (b, d) **11.** (c, d) **12.** (a)
13. (a) **14.** (b) **15.** (d) **16.** (d) **17.** (a) **18.** (b)
19. A→p, t B→q, s, t C→p, r, t D→r, q, t **20.** A→p, r, s B→r, s C→p, q, t D→r, s

Paper 2

1. (None) **2.** (c) **3.** (b) **4.** (d) **5.** (a) **6.** (b, d)
7. (b, c) **8.**(a, d) **9.** (b, d) **10.** A→p, s B→q C→t D→r, s, t
11. A→p, q, s, t B→q C→s D→s **12.** (7) **13.** (8) **14.** (2)
15. (9) **16.** (6) **17.** (5) **18.** (4) **19.** (6)

SOLUTIONS

Paper 1

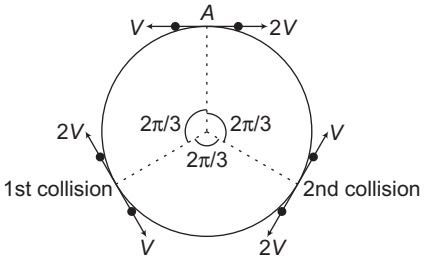
1. y_{CM}

$$= \frac{m_1y_1 + m_2y_2 + m_3y_3 + m_4y_4 + m_5y_5}{m_1 + m_2 + m_3 + m_4 + m_5}$$

$$= \frac{(6m)(0) + (m)(a) + m(a) + m(0) + m(-a)}{6m + m + m + m + m} = \frac{a}{10}$$

2. Cross $\otimes$ magnetic field passing from the closed loop is increasing. Therefore, from Lenz's law induced current will product dot $\odot$ magnetic field. Hence, induced current is anticlockwise.

3. At first collision one particle having speed $2v$ will rotate $240^\circ \left(\text{or } \frac{4\pi}{3}\right)$ while other particle having speed v will rotate $120^\circ \left(\text{or } \frac{2\pi}{3}\right)$. At first collision they will exchange their velocities. Now as shown in figure, after two collisions they will again reach at point A.



4. Total enclosed charge as already shown is

$$q_{net} = \frac{6\ C}{2} + \frac{8\ C}{4} - 7C = -2C$$

From Gauss-theorem, net flux,

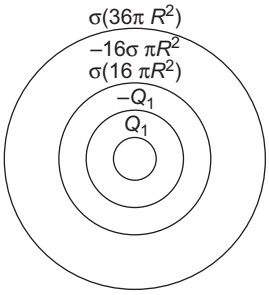
$$\varphi_{net} = \frac{q_{net}}{\varepsilon_0} = \frac{-2C}{\varepsilon_0}$$

5. $Q_1 = \sigma(4\pi R^2) = 4\pi\sigma R^2$

$$Q_2 = 16\pi\sigma R^2 - Q_1 = 12\pi\sigma R^2$$

$$Q_3 = 36\pi\sigma R^2 - 16\pi\sigma R^2 = 20\pi\sigma R^2$$

$$Q_1 : Q_2 : Q_3 = 1 : 3 : 5$$



6. $T = 8$ s, $\omega = \frac{2\pi}{T} = \left(\frac{\pi}{4}\right)$ rads^{-1}

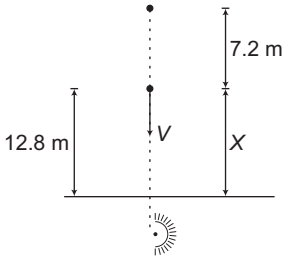
$$x = A\sin\omega t$$

$$\therefore \quad a = -\omega^2 x = -\left(\frac{\pi^2}{16}\right)\sin\left(\frac{\pi}{4}t\right)$$

Substituting $t = \frac{4}{3}$ s, we get

$$a = -\left(\frac{\sqrt{3}}{32}\pi^2\right) \text{ cms}^{-2}$$

7. $v = \sqrt{2gh} = \sqrt{2\times 10\times 7} = 12\ \text{ms}^{-1}$



In this case when eye is inside water,

$$x_{app.} = \mu x \Rightarrow \frac{dx_{app.}}{dt} = \mu\cdot\frac{dx}{dt}$$

or $\quad v_{app.} = \mu v = \frac{4}{3}\times 12 = 16\ \text{ms}^{-1}$

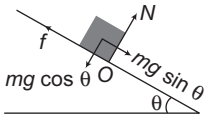
8. Condition of sliding is

$$mg\sin\theta > \mu mg\cos\theta$$

or $\quad \tan\theta > \mu$

or $\quad \tan\theta > \sqrt{3}$ …(i)

Condition of toppling is



Torque of $mg \sin\theta$ about 0 > torque of $mg \cos\theta$ about

$$\therefore \quad (mg \sin\theta)\left(\frac{15}{2}\right) > (mg \cos\theta)\left(\frac{10}{2}\right)$$

or $$\tan\theta > \frac{2}{3} \qquad \ldots(ii)$$

With increase in value of θ, condition of sliding is satisfied first.

9. $$R_{\text{total}} = 2 + \frac{6 \times 1.5}{6 + 1.5} = 3.2\ \text{k}\Omega$$

(A) $$I = \frac{24\ \text{V}}{3.2\ \text{k}\Omega} = 7.5\ \text{mA} = I_{R_1}$$

$$I_{R_2} = \left(\frac{R_L}{R_L + R_2}\right) I$$

$$I = \frac{1.5}{7.5} \times 7.5 = 1.5\ \text{mA}$$

$$I_{R_L} = 6\ \text{mA}$$

(B) $V_{R_L} = (I_{R_L})(R_L) = 9\ \text{V}$

(C) $$\frac{P_{R_1}}{P_{R_2}} = \frac{(I_{R_1}^2)R_1}{(I_{R_2}^2)R_2} = \frac{(7.5)^2(2)}{(1.5)^2(6)} = \frac{25}{3}$$

(D) When R_1 and R_2 are interchanged, then

$$\frac{R_2 R_L}{R_2 + R_L} = \frac{2 \times 1.5}{3.5} = \frac{6}{7}\ \text{k}\Omega$$

Now potential difference across R_L will be

$$V_L = 24\left[\frac{6/7}{6 + 6/7}\right]$$

Earlier it was 9 V

Since, $$P = \frac{V^2}{R} \text{ or } P \propto V^2$$

In new situation potential difference has been decreased three times. Therefore, power dissipated will decrease by a factor of 9.

10. For monoatomic gas,

$$C_p = \frac{5}{2}R \text{ and } C_V = \frac{3}{2}R$$

For diatomic gas,

$$C_p = \frac{7}{2}R \text{ and } C_V = \frac{5}{2}R$$

11. Values of options (c) and (d) don't match with the mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

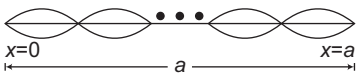
12. On a system of particles if,

$$\Sigma \vec{\mathbf{F}}_{\text{ext.}} = 0$$

then $$\vec{\mathbf{P}}_{\text{system}} = \text{constant}$$

No other conclusions can be drawn.

13.



$$a = \frac{n\lambda}{2}$$

$$\therefore \quad \lambda = \frac{2a}{n} = \frac{h}{p} = \frac{h}{\sqrt{2Em}} \qquad \ldots(i)$$

or $$\sqrt{E} \propto \frac{1}{a} \Rightarrow E \propto \frac{1}{a^2}$$

14. From Eq. (i)

$$E = \frac{n^2 h^2}{8a^2 m}$$

In ground state $n = 1$

$$\therefore \quad E_1 = \frac{h^2}{8ma^2}$$

Substituting the values, we get

$$E_1 = 8\ \text{meV}$$

15. From Eq. (i)

$$p \propto n$$

$$\therefore \quad mv \propto n \quad \text{or} \quad v \propto n$$

17. From conservation of mechanical energy, we have

$$U_i + K_i = U_f + U_f$$

$$0 + 2(1.5kT) = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(e)(e)}{d} + 0$$

Substituting the values, we get

$$T = 1.4 \times 10^9\ \text{K}$$

18. As given in the paragraph, a reactor is termed successful, if

$$nt_0 > 5 \times 10^{14}\ \text{scm}^{-3}$$

19. (A)→(p, t)→Net force on Y is ero.

(B)→(q, s, t)→In (s) and (t) gravitational potential energy of Y is decreasing and that of X is increasing.

(C) →(p, r, t)→In (t), Y is moving with constant speed.

(D) →(q)→No explanation is required

Paper 2

1. $K_p = E_p - \phi_p = \dfrac{1240}{550} - 2.0 = 0.2545\ eV$

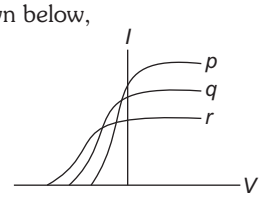
$K_q = E_q - \phi_q = \dfrac{1240}{450} - 2.5 = 0.255\ eV$

$K_r = E_r - \phi_r = \dfrac{1240}{350} - 3.0 = 0.543\ eV$

In the above equation K represents maximum kinetic energy of photoelectrons and E, the energy of incident right. From the above values we can see that stopping potential, $|V_r| > |V_q| > |V_p|$

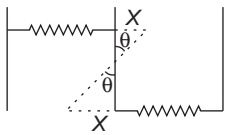
Further, their intensities are equal, but energy of individual photon of r is maximum. Hence, number of photons incident (per unit area per unit time) of r can be assumed to be least. Hence, saturation current of r should be minimum.

Keeping these points in mind no option seems to be correct. The correct graph is shown below,



∴No choice is correct.

2. $x = \dfrac{L}{2}\theta$



Restoring torque $= -(2kx)\cdot\dfrac{L}{2}$

$$\alpha = -\frac{kL(L/2\theta)}{I} = -\left[\frac{kL^2/2}{ML^2/12}\right]\cdot\theta$$

$$= -\left(\frac{6k}{M}\right)\theta$$

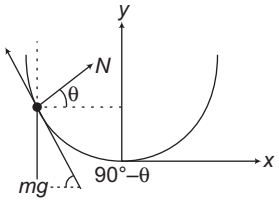
$$\therefore \quad f = \frac{1}{2\pi}\sqrt{\left|\frac{\alpha}{\theta}\right|} = \frac{1}{2\pi}\sqrt{\frac{6k}{M}}$$

3. $N\sin\theta = mg$

$N\cos\theta = ma$

$\tan\theta = \dfrac{g}{a}$

$\cot\theta = \dfrac{a}{g} = \tan(90^\circ - \theta) = \dfrac{dy}{dx} = 2kx$



$$\therefore \quad x = \frac{a}{2kg}$$

4. $x_1 + x_2 = A$ and $k_1x_1 = k_2x_2$ or $\dfrac{x_1}{x_2} = \dfrac{k_2}{k_1}$

Solving these equations, we get

$$x_1 = \left(\frac{k_2}{k_1 + k_2}\right)A$$

5. Net torque on $(-q)$ about a point (say P) lying over $+Q$ is zero. Therefore, angular momentum of $(-q)$ about point P should remain constant.

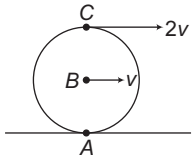
6. (A) $p-V$ graph is not rectangular hyperbola. Therefore, process $A-B$ is not isothermal.

(B) In process BCD, product of pV (therefore temperature and internal energy) is decreasing. Further, volume is decreasing. Hence, work done is also negative. Hence, Q will be negative or heat will flow out of the gas.

(C) W_{ABC} = positive

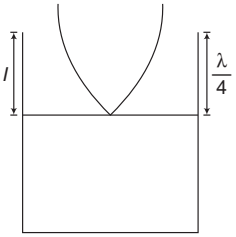
(D) For clockwise cycle on $p-V$ diagram with P on y-axis, net work done is positive.

7. $v_A = 0, v_B = v$ and $v_C = 2v$



8. $l < \frac{\lambda}{4}$

Further, larger the length of air column, feebler is the intensity.



9. Induced emf $e = -\frac{d\phi}{dt}$. For identical rings induced emf will be same. But currents will be different. Given $h_A > h_B$. Hence, $v_A > v_B$ as $\left(h = \frac{v^2}{2g}\right)$.

If $\rho_A > \rho_B$, then, $I_A < I_B$. In this case given condition can be fulfilled if $m_A < m_B$.

If $\rho_A < \rho_B$, then $I_A > I_B$. In this case given condition can be fulfilled of $m_A \le m_B$.

10. (A)→(p, s)→Intensity at P_0 is maximum. It will continuously decrease from P_0 towards P_2.

(B)→(q)→Path difference due to slap will be compensated by geometrical path difference. Hence, $\delta(P_1) = 0$.

(C)→(t)→$\delta(P_0) = \frac{\lambda}{2}$, $\delta(P_1) = \frac{\lambda}{2} - \frac{\lambda}{4} = \frac{\lambda}{4}$

and $\delta(P_2) = \frac{\lambda}{2} - \frac{\lambda}{3} = \frac{\lambda}{6}$. When path difference increases from 0 to $\frac{\lambda}{2}$, intensity will decrease from maximum to zero. Hence, in this case,

$$I(P_2) > I(P_1) > I(P_0)$$

(D)→(r, s, t)

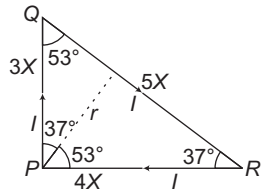
$$\delta(P_0) = \frac{3\lambda}{4}, \delta(P_1) = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

and $\delta(P_2) = \frac{3\lambda}{4} - \frac{\lambda}{3} = \frac{5\lambda}{12}$

In this case $I(P_1) = 0$

12. Magnetic field at point P due to wires RP and RQ is zero. Only wire QR will produce magnetic field at P.

$$r = 3x\cos 37° = (3x)\left(\frac{4}{5}\right) = \frac{12x}{5}$$



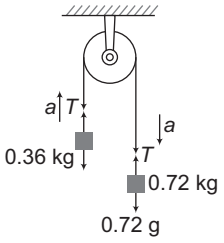
Now, $B = \frac{\mu_0}{4\pi}\frac{I}{12x/5}[\sin 37° + \sin 53°]$

$$= 7\left(\frac{\mu_0 I}{48\pi x}\right)$$

13. $a = \frac{\text{Net pulling force}}{\text{Total mass}}$

$$= \frac{0.72g - 0.36g}{0.72 + 0.36} = \frac{g}{3}$$

$$s = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{g}{3}\right)(1)^2 = \frac{g}{6}$$



$$T - 0.36g = 0.36a = 0.36\frac{g}{3}$$

$\therefore$ $T = 0.48g$

Now, $W_T = TS\cos 0°$ (on 3.6 kg mass)

$$= (0.48g)\left(\frac{g}{6}\right)(1) = 0.08(g^2)$$

$$= 0.08(10)^2 = 8\text{ J}$$

14. From Gauss theorem,

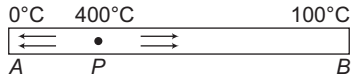
$$E \propto \frac{q}{r^2} \quad (q = \text{charge enclosed})$$

$$\therefore \quad \frac{E_2}{E_1} = \frac{q_2}{q_1} = \frac{r_1^2}{r_2^2}$$

$$\text{or} \quad 8 = \frac{\int_0^R (4\pi r^2) k r^a dr}{\int_0^{R/2} (4\pi r^2) k r^a dr} \times \frac{(R/2)^2}{(R)^2}$$

Solving this equation we get, $a = 2$

15.



Heat will flow both sides from point P.

$$L_1 \frac{dm_1}{dt} = \left(\frac{\text{Temperature difference}}{\text{Thermal resistance}}\right)_1$$

$$= \frac{400}{(\lambda x)/kA} \quad \ldots(i)$$

$$L_1 \frac{dm_2}{dt} = \frac{400 - 100}{(100 - \lambda)x/kA} \quad \ldots(ii)$$

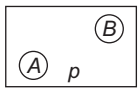
In about two equations,

$$\frac{dm_1}{dt} = \frac{dm_2}{dt} \quad \text{(given)}$$

$L_1 = 80\ \text{calg}^{-1}$ and $L_2 = 540\ \text{calg}^{-1}$

Solving these two equations we get $\lambda = 9$.

16. Although not given in the question but we will have to assume that temperatures of A and B are same.



$$\frac{n_B}{n_A} = \frac{p_B V_B / RT}{p_A V_A / RT} = \frac{p_B V_B}{p_A V_A}$$

$$= \frac{p + 4s/r_A \times 4/3\pi(r_A)^3}{(p + 4s/r_B) \times 4/3\pi(r_B)^3}$$

(s = surface tension)

Substitution the values, we get $\frac{n_B}{n_A} = 6$

17. Distance between the successive nodes,

$$d = \frac{\lambda}{2} = \frac{v}{2f}$$

$$= \frac{\sqrt{T/\mu}}{2f}$$

Substituting the values we get

$$d = 5\ \text{cm}$$

18. After elastic collision,

$$v'_A = \left(\frac{m - 2m}{m + 2m}\right)(9) + \frac{2(2m)}{m + 2m}(0)$$

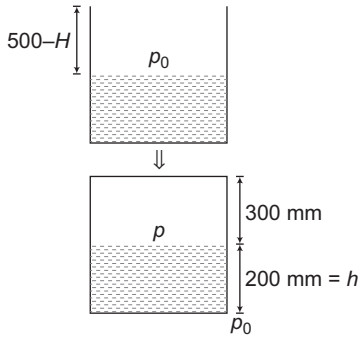
$$= -3\ \text{ms}^{-1}$$

Now from conservation of linear momentum after all collisions are complete,

$$m(+9\ \text{ms}^{-1}) = m(-3\ \text{ms}^{-1}) + 3m(v_C)$$

or $\quad v_C = 4\ \text{ms}^{-1}$

19. In this question we will have to assume that temperature of enclosed air about water is constant (or pV = constant)



$$p = p_0 - \rho g h \quad \ldots(i)$$

$$p_0[A(500 - H)] = p[A(200)] \quad \ldots(ii)$$

Solving these two equations, we get

$$H = 206\ \text{mm}$$

$\therefore$ Level fall = (206 – 200) mm

= 6 mm

IIT JEE
SOLVED PAPER 2009

Chemistry

Paper 1

SECTION I

Single Correct Choice Type

This section contains 8 multiple choice questions numbered 1 to 8. Each question has 4 choices (a), (b), (c) and (d), out of which ***ONLY ONE*** *is correct.*

1. Among the electrolytes Na_2SO_4, $CaCl_2$ $Al_2(SO_4)_3$ and NH_4Cl, the most effective coagulating agent for Sb_2S_3 sol is
(a) Na_2SO_4 (b) $CaCl_2$
(c) $Al_2(SO_4)_3$ (d) NH_4Cl

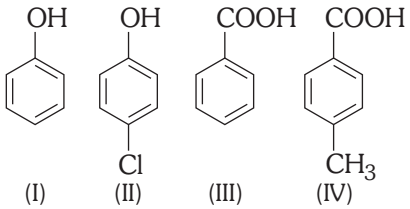
2. The term that corrects for the attractive forces present in a real gas in the van der Waals' equation is
(a) nb (b) n^2a/V^2
(c) $-(n^2a/V^2)$ (d) $-nb$

3. The Henry's law constant for the solubility of N_2 gas in water at 298 K is 1.0×105 atm. The mole fraction of N_2 in air is 0.8. The number of moles of N_2 from air dissolved in 10 moles of water of 298 K and 5 atm pressure is
(a) 4×10^{-4} (b) 4.0×10^{-5}
(c) 5.0×10^{-4} (d) 4.0×10^{-6}

4. The reaction of P_2 with X leads selectively to P_4O_6. The X is
(a) dry O_2
(b) a mixture of O_2 and N_2
(c) moist O_2
(d) O_2 in the presence of *aq*. NaOH

5. Among cellulose, polyvinyl chloride, nylon and natural rubber, the polymer in which the intermolecular force of attraction is weakest in
(a) nylon (b) polyvinyl chloride
(c) cellulose (d) natural rubber

6. The correct acidity order of the following is

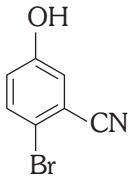


(I) (II) (III) (IV)

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

7. Given, that the abundances of isotopes, $_{54}Fe$, $_{56}F$ and $_{57}Fe$ are 5%, 90% and 5%, respectively, the atomic mass of Fe is
(a) 55.85 (b) 55.95
(c) 55.75 (d) 56.05

8. The IUPAC name of the following compound, is



(a) 4-bromo-3-cyanophenol
(b) 2-bromo-5-hydroxybenzonitrile
(c) 2-cyano-4-hydroxybromobenzene
(d) 6-bromo-3-hydroxybenzonitrile

SECTION II

Multiple Correct Choice Type

This section contains 4 *multiple correct answer(s) type questions. Each question has* 4 *choices (a), (b), (c) and (d), out of which of* ***ONE*** *or* ***MORE*** *is/are correct.*

9. The correct statement(s) about the compound,
$H_3C(HO)HC—CH = CH—CH(OH)CH_3$ (*X*) is (are)
(a) the total number of stereoisomers possible for *X* is 6
(b) the total number of diastereomers possible for *X* is 3
(c) if the stereochemistry about the double bond in *X* is *trans*, the number of enantiomers possible for *X* is 4
(d) if the stereochemistry about the double bond in *X* is *cis*, the number of enantiomers possible for *X* is 2

10. The compound(s) formed upon combustion of sodium metal in excess air is (are)
(a) Na_2O_2 (b) Na_2O
(c) NaO_2 (d) NaOH

11. The correct statement(s) regarding defects in solids is (are)
(a) Frenkel defect is usually favoured by a very small difference in the sizes of cation and anion
(b) Frenkel defect is a dislocation defect
(c) Trapping of an electron in the lattice leads to the formation of F-centre
(d) Schottky defects have no effect on the physical properties of solids

12. The compound (s) that exhibit (s) geometrical isomerism is (are)
(a) $[Pt(en)Cl_2]$ (b) $[Pt(en)_2Cl_2]$
(c) $[Pt(en)_2Cl_2]Cl_2$ (d) $[Pt(NH_3)_2Cl_2]$

SECTION III

Comprehension Type

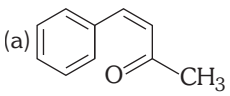
This section contains 2 *paragraphs C* 13-15 *and C* 16-18. *Based upon each paragraph,* 3 *multiple choice questions have to be answered. Each question has* 4 *choices (a), (b), (c) and (d) out of which* ***ONLY ONE*** *is correct.*

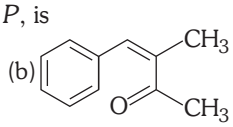
Paragraph (for Q. Nos. 13 *to* 15*)*

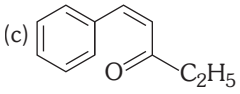
A carbonyl compound *P*, which gives positive iodoform test, undergoes reaction with MeMgBr followed by dehydration to give an olefin *Q*. Ozonolysis of *Q* leads to a dicarbonyl compound *R*, which undergoes intramolecular aldol reaction to give predominantly *S*.

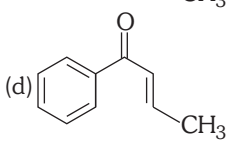
$$P \xrightarrow[\text{(ii) } H^+, H_2O \text{ (iii) } H_2SO_4/\text{Heat}]{\text{(i) MeMgBr}} Q \xrightarrow{O_3/Zn-H_2O} R \xrightarrow[\text{Heat}]{OH^-} S$$

13. The structure of the carbonyl compound *P*, is

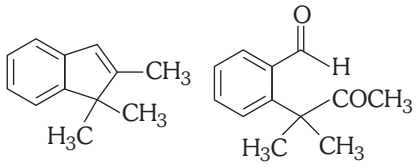
(a) 

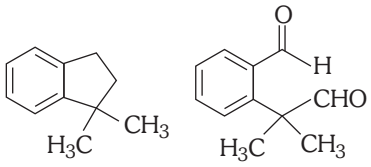
(b) 

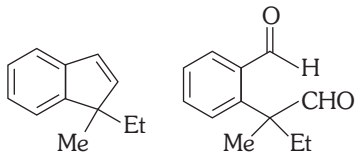
(c) 

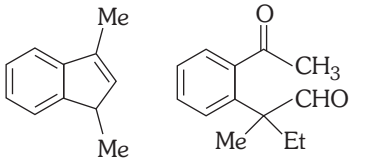
(d) 

14. The structures of the products *Q* and *R*, respectively, are

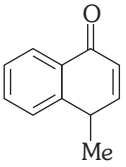
(a) 

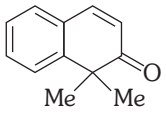
(b) 

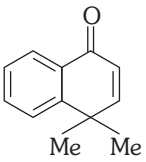
(c) 

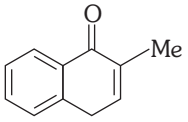
(d) 

14. The structure of the product *S*, is

(a) 

(b) 

(c) 

(d) 

Paragraph (for Q. Nos. 16 *to* 18*)*

p-amino-N, N-dimethylaniline is added to a strongly acidic solution of *X*. The resulting solution is treated with a few drops of aqueous solution of *Y* to yield blue colouration due to the formation of methylene blue. Treatment of the aqueous solution of *Y* with the reagent potassium hexacyanoferrate(II) leads to the formation of an intense blue precipitate. The precipitate dissolves an excess addition of the reagent. Similarly, treatment of the solution of *Y* with the solution of potassium hexacyanoferrate(III) leads to a brown colouration due to the formation of *Z*.

16. The compound *X*, is

(a) $NaNO_3$ (b) NaCl

(c) Na_2SO_4 (d) Na_2S

17. The compound *Y*, is

(a) $MgCl_2$ (b) $FeCl_2$

(c) $FeCl_3$ (d) $ZnCl_2$

18. The compound *Z*, is

(a) $Mg_2[Fe(CN)_6]$ (b) $Fe[Fe(CN)_6]$

(c) $Fe_4[Fe(CN)_6]_3$ (d) $K_2Zn_3[Fe(CN)_6]_2$

SECTION IV

Matrix-Match Type

This section contains 2 questions. Each question contains statements given in two columns, which have to be matched. Statements in Column I are labelled as A, B, C and D, whereas statements in Column II are labelled as p, q, r,s and t. The answer to these questions have to be appropriately bubbles as illustrated in the following example.

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

If the correct matches are A→p, s and t; B→q and r; C→p and q; and D→s and t; then the correct darkening of bubbles will look like the following.

19. Match each of the compounds is Column I with its characteristic reaction(s) is Column II.

Column I		Column II
A. $CH_3CH_2CH_2CN$	p.	Reduction with Pd-C/H_2
B. $CH_3CH_2OCOCH_3$	q.	Reduction with $SnCl_2$/HCl
C. $CH_3 \cdot CH{=}CH \cdot CH_2OH$	r.	Development of foul smell on treatment with chloroform and alc. KOH
D. $CH_3CH_2CH_2CH_2NH_2$	s.	Reduction with disobutylaluminium hydride
	t.	Alkaline hydrolysis

20. Match each of the diatomic molecules in Column I with its property/properties in Column II.

Column I		Column II
A. B_2	p.	Paramagnetic
B. N_2	q.	Undergoes oxidation
C. O_2^-	r.	Undergoes reduction
D. O_2	s.	Bond order ≥ 2
	t.	Mixing of '*s*' and '*p*' orbitals

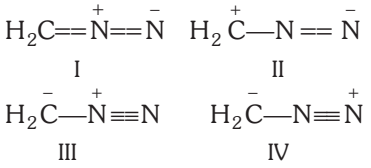
Paper 2

SECTION I

Single Correct Choice Type

This section contains 4 multiple choice questions numbered 1 to 4. Each question has 4 choices (a), (b), (c) and (d), out of which ***ONLY ONE*** *is correct.*

1. The correct stability order of the following resonance structure is



I II III IV

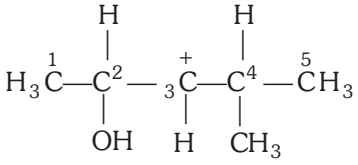
(a) I > II > IV > III

(b) I > III > II > IV

(c) II > I > III > IV

(d) III > I > IV > II

2. In the following carbocation, H / CH_3 that is most likely to migrate to the positively charged carbon is



(a) CH_3 at C- 4 (b) H at C- 4
(c) CH_3 at C- 2 (d) H at C- 2

3. For a first order reaction, $A \rightarrow P$, the temperature (T) dependent rate constant (k) was found to follow the equation,

$$\log k = -(2000)/T + 6.0$$

The pre-exponential factor A and the activation energy (E_a), respectively, are
(a) $1.0 \times 10^6 s^{-1}$ and 9.2 kJ mol^{-1}
(b) 6.0 s^{-1} and 16.6 kJ mol^{-1}
(c) $1.0 \times 10^6 s^{-1}$ and 16.6kJ mol^{-1}
(d) $1.0 \times 10^6 s^{-1}$ and 38.3 kJ mol^{-1}

4. The spin only magnetic moment value (in Bohr magneton units) of $Cr(CO)_6$ is
(a) 0 (b) 2.84
(c) 4.90 (d) 5.92

SECTION II

Multiple Correct Choice Type

This section contains 5 multiple correct answer(s) type questions. Each question has 4 choices (a), (b), (c) and (d), out of which ***ONE*** *or* ***MORE*** *is/are correct.*

5. In the reaction,

$$2X + B_2H_6 \longrightarrow [BH_2(X)_2]^+[BH_4]^-$$

The amine (s) X, is (are)
(a) NH_3
(b) CH_3NH_2
(c) $(CH_3)_2NH$
(d) $(CH_3)_3N$

6. The nitrogen oxide(s) that contain(s) N.N bond(s) is (are)
(a) N_2O (b) N_2O_3
(c) N_2O_4 (d) N_2O_5

7. For the reduction of NO_3^- ion in an aqueous solution $E°$ is $+0.96$ V. Values of $E°$ for some metal ions are given below.

$V^{2+}(aq) + 2e^- \longrightarrow V; E° = -1.19$ V

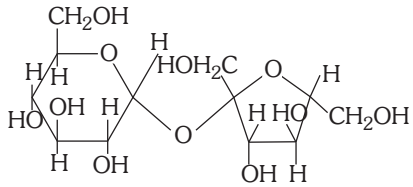
$Fe^{3+}(aq) + 3e^- \longrightarrow Fe; E° = -0.04$ V

$Au^{3+}(aq) + 3e^- \longrightarrow Au; E° = +1.40$ V

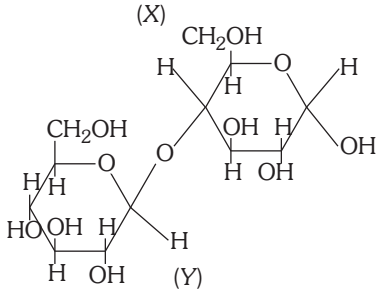
$Hg^{2+}(aq) + 2e^- \longrightarrow Hg; E° = +0.86$ V

The pair(s) of metals that is (are) oxidised by NO_3^- in aqueous solution is (are)
(a) V and Hg
(b) Hg and Fe
(c) Fe and Au
(d) Fe and V

8. The correct statement(s) about the following sugars X and Y is (are)



(X)



(Y)

(a) X is a reducing sugar and Y is a non-reducing sugar
(b) X is a non-reducing sugar and Y is a reducing sugar
(c) the glucosidic linkages in X and Y are α and β, respectively
(d) the glucosidic linkages in X and Y are β and α, respectively

9. Among the following, the state function(s) is (are)
(a) internal energy
(b) irreversible expansion work
(c) reversible expansion work
(d) molar enthalpy

SECTION III

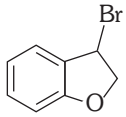
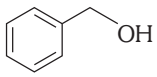
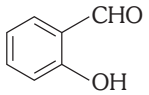
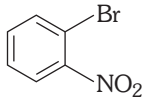
Matrix-Match Type

This section contains 2 questions. Each question contains statements given in two columns, which have to be matched. Statements in Column I are labelled as A, B, C and D, whereas statements in Column II are labelled as p, q, r, s are t The answer to these questions have to be appropriately bubbles as illustrated in the following example.

If the correct matches are A→p, s and t; B→q and r; C→p and q; and D→s and t; then the correct darkening of bubbles will look like the following.

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

10. Match each of the compounds given in Column I with the reaction (s) that they can undergo, given in Column II.

Column I		Column II
A. 	p.	Nucleophilic substitution
B. 	q.	Elimination
C. 	r.	Nucleophilic addition
D. 	s.	Esterification with acetic anhydride
	t.	Dehydrogenation

11. Match each of the reactions given in Column I with the corresponding products(s) given in Column II.

Column I		Column II
A. Cu + dil. HNO_3	p.	NO
B. Cu + conc. HNO_3	q.	NO_2
C. Zn + dil. HNO_3	r.	N_2O
D. Zn + conc. HNO_3	s.	$Cu(NO_3)_3$
	t.	$Zn(NO_3)_2$

SECTION IV

Integer Answer Type

This section contains 8 questions. The answer to each of the questions is a single digit integer, ranging from 0 to 9. The appropriate bubbles below the respective question numbers in the ORS have to be darkened. e.g. if the correct answers to question numbers X, Y, Z and W (say) are 6,0,9 and 2, respectively then the correct darkening of bubbles will look like the following.

X	Y	Z	W
0	**0**	0	0
1	1	1	1
2	2	2	**2**
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	**9**	9

12. The total number of α and β-particles emitted in the nuclear reaction

$$_{92}U^{238} \longrightarrow {}_{82}Pb^{214}$$ is

13. The number of water molecule(s) directly bonded to the metal centre in $CuSO_4 \cdot 5H_2O$ is

14. The oxidation number of Mn in the product of alkaline oxidative fusion of MnO_2 is

15. The coordination number of Al in the crystalline state of $AlCl_3$ is

16. In a constant volume calorimeter, 3.5 g of a gas with molecular weight = 28 was burnt in excess oxygen at 298.0 K. The temperature of the calorimeter was found to increases from 298.0 K to 298.45 K due to the combustion process. Given, that the heat capacity of the calorimeter is 2.5 kJ K^{-1}, the numerical value for the enthalpy of combustion of the gas in kJ mol^{-1} is

17. The total number of cyclic structural as well as stereoisomers possible for a compound with the molecular formula = C_5H_{10} is

18. The dissociation constant of a substituted benzoic acid at 25°C is 1.0×10^{-4}. The pH of 0.01 M solution of its sodium salt is

19. At 400 K, the root mean square (rms) speed of a gas *X* (molecular weight = 40) is equal to the most probable speed of gas *Y* at 60 K. The molecular weight of the gas *Y* is

ANSWERS

Paper 1

1. (c) **2.** (b) **3.** (a) **4.** (b) **5.** (d) **6.** (a)
7. (b) **8.** (b) **9.** (a, d) **10.** (a, b) **11.** (b, c) **12.** (c, d)
13. (b) **14.** (a) **15.** (b) **16.** (d) **17.** (c) **18.** (b)
19. A → p, q, s, t ; B → p, s, t; C → p; D → r **20.** A → p, r, t; B → s, t; C → p, q, r; D → p, r, s

Paper 2

1. (b) **2.** (d) **3.** (d) **4.** (a) **5.** (a, b, c) **6.** (a, b, c)
7. (a, b, d) **8.** (b, c) **9.** (a, c, d) **10.** A → p, q, t; B → p, s, t; C → r, s; D → p
11. A → p, s; B → q, s; C → r, t; D → q, t **12.** (8) **13.** (4) **14.** (6)
15. (6) **16.** (9) **17.** (7) **18.** (8) **19.** (4)

Hints & Solutions

Paper-I

1. Sb_2S_3 is an anionic sol_2, therefore cation of highest valency (Al^{3+} in the present case) would be most effective coagulating agent.

2. In the van der Waals' equation

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

The pressure correction factor (n^2a / V^2) accounts for intermolecular attraction in real gas.

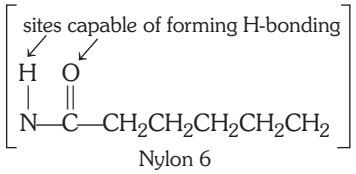
3. $P_{N_2} = K_H \times$ mole-fraction (N_2) mole-fraction

$$N_2 \frac{1}{10^5} \times 0.8 \times 5 = 4 \times 10^{-5} \text{ mol}^{-1}$$

In 10 mole solubility in 4×10^{-4}.

4. White phosphorus on reaction with limited supply of oxygen gives lower oxide P_4O_6. Therefore, air ($O_2 + N_2$) is a good source for controlled supply of oxygen and the best choice for controlled oxidation of white phosphorus into lower oxide P_4O_6.

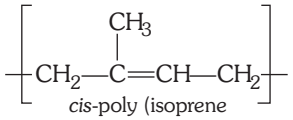
5. Nylon has amid linkage capable of forming intermolecular H-bonding as



Nylon 6

Due to H-bonding, nylon has strong intermolecular attraction.

Cellulose is a polyhydroxy compound, also capable of forming strong intermolecular H-bonding. Polyvinyl chloride is a polar polymer due to carbon chlorine bond and it possess strong dipole-dipole attraction. Natural rubber is poly (isoprene), a hydrocarbon, possess weak van der Waal's attraction.



cis-poly (isoprene
Natural rubber

6. A carboxylic acid is stronger acid than phenol, hence both III and IV are stronger acids than both I and II. Also IV has a methyl group that gives electron donating inductive effect and decreases the acid strength. Therefore, III is stronger acid that IV. Between I and II, the dominant electron withdrawing inductive effect of chlorine increases acid strength of phenol slightly, hence II is stronger acid than I. Thus, the overall order is :

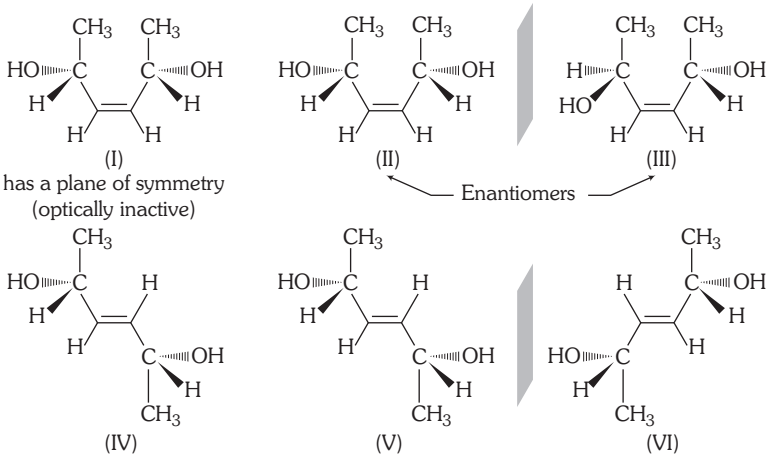
(a) III > IV > II > I

7. Average atomic weight

$$\frac{54 \times 5 + 56 \times 90 + 57 \times 5}{100} = 55.95$$

8. Cyano group has the highest priority therefore, parent name must be benzonitrile. Br occurs at 2-position, and hydroxyl at 3-position, hence clockwise numbering will be the correct one.

9. The various isomers of *X* are,



X has six stereoisomers (I-VI). The total number of diasteromers of *X* are more than three e.g, I + II, I + III, I + IV, I + V, I + VI etc. When stereochemistry at double bond is *trans* it has only two enantiomers (V and VI). When stereochemistry at doubld bond is *cis*, it has two enantiomers II and III. Hence, only *A* and *D* are correct answers.

10. Sodium on heating in air forms both normal oxide and peroxides.

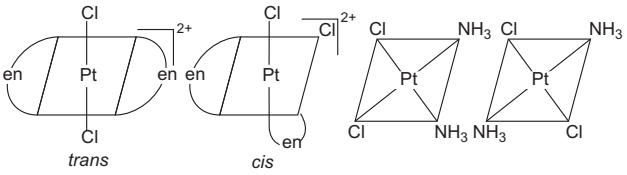
11. (a) **Wrong** Frenkel defect is favoured when the difference in ionic radii is very large. In the given case Schottky defect is favoured.

(b) **Correct** Frenkel defect arises due to dislocation of smaller ion from its normal lattice point to the interstitial space.

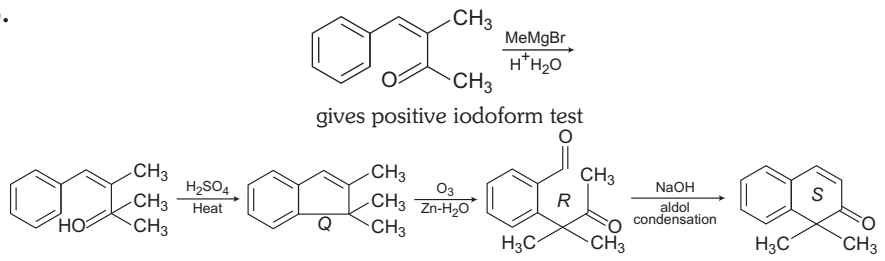
(c) **Correct** When alkali metal in the gaseous state is passed over salts like NaCl, electrons from metal are trapped in the interstitial space giving rise to F-centre defect which is a type of Frenkel defect.

(d) **Wrong** Schottky defect affects physical properties of solids.

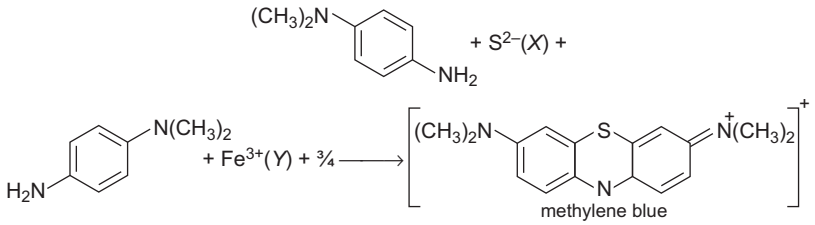
12. Only *C* and *D* can show geometrical isomerism as



15.



18. *p*-amino-N, N-dimethylaniline reacts with sulphide ion (S^{2-}) in presence of Fe^{3+} ion to form blue coloured solution of methylene blue :



The compound *Z*, is

$Fe[Fe(CN)_6] : Fe^{3+} + [Fe(CN)_6]^{3-} \longrightarrow \underset{\text{(brown precipitate)}}{Fe[Fe(CN)_6]}$

Paper 2

1. (I) has maximum covalent bonds and negative charge on electronegative nitrogen, most stable. III has more covalent bond than both II and IV, III is second most stable. Between II and IV, II is more stable since it has negative charge on nitrogen while IV has negative charge on carbon.

2. Hydride shift from C-2 will give most stable resonance stabilised carbocation as

Fig.

3. Comparing the slope and intercept of the given equation with the following Arrhenius equation :

$$\log k = -\frac{E_a}{2.303RT} + \log A$$

Hence, $\log A = 6$ i.e. $A = 10^6\,s^{-1}$.

Comparing slope gives $E_a = 38.3$ kJ/mol.

4. CO is a strong ligand, all the six electron of the valence shell of Cr is paired and spin only magnetic moment = 0.

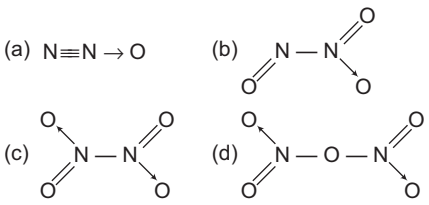
5. Small amines such as $NH_3 \cdot CH_3NH_2$ and $(CH_3)_2NH$ give unsymmetrical cleavage of diborane according to following reaction,

$B_2H_6 + 2NH_3 \longrightarrow [H_2B(NH_3)_2]^+[BH_4]^-$

Large amines, such as $(CH_3)_3N$ give symmetrical cleavage of diborane according to following reaction,

$B_2H_6 + 2N(CH_3)_3 \longrightarrow 2H_3B \longleftarrow N(CH_3)_3$

6.



7. The species having less reduction potential with respect to NO_3^- ($E° = 0.96$ V) will be oxidised by NO_3^-; These species are V, Fe, Hg.

8. *X* has acetal linkage and *Y* has hemiacetal linkage. Carbohydrate with hemiacetal linkage are reducing sugars and carbohydrate with acetal linkage are non reducing sugars.

X is α anomer and *Y* is β-anomer of D(+) glucose.

9. State function are internal energy and molar enthalpy. Work is a path dependent function, however in reversible process the path is fixed i.e. between a given initial and final state there is just on reversible path and one work. Hence, reversible work is also a state function.

12. $_{92}U^{238} \rightarrow {}_{82}U^{214} + 6_2He^{H}(\alpha) + 2_{-1}e^{0}(\beta)$

13. $[Cu(H_2O)_4]SO_4 \cdot H_2O$. Coordination number of Cu is 4.

14. $2MnO_2 + 4KOH + O_2 \xrightarrow{\text{Fusion}} 2K_2MnO_4 + 2H_2O$

15. Coordination number of Al = 6.

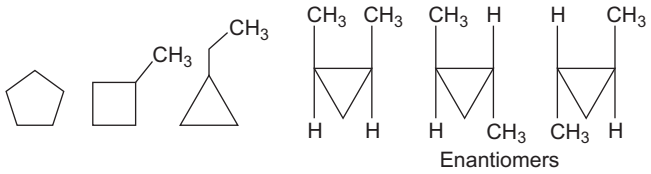
16. The temperature rise is : $\Delta T = T_2 - T_1 = 298.45 - 298 = 0.45$ K

This indicates that heat produced from combustion of 3.5 g of compound rises temperature of calorimeter by 0.45 K.

Heat produced = 0.45 K× 2.5 k JK^{-1} = 1.125 kJ

$\Rightarrow$ Heat produced from 28 g of compound (1.0 mol) = $\frac{1.125}{3.5} \times 28 = 9$ kJ

17. The total number of cyclic isomers are seven as shown below.



18. The hydrolysis reaction of conjugate base of acid is

$$A^-(aq) + H_2O \longrightarrow HO^- + HA$$

$$K_h = \frac{K_w}{K_a} = \frac{10^{-14}}{10^{-4}} = 10^{-10}$$

Since, degree of hydrolysis is negligible;

$[OH^-] = \sqrt{K_h C} = 10^{-6} \cdot p[OH] = 6$ and pH = 14 – 6 = 8

19. $V_{rms} = V_{mps}$

$$\sqrt{\frac{3RT}{M(X)}} = \sqrt{\frac{2RT'}{M(Y)}}$$

$\Rightarrow$ $$\sqrt{\frac{3R \times 400}{40}} = \sqrt{\frac{2R \times 60}{M(Y)}}$$

$\Rightarrow$ $$M(Y) = 4$$