IIT JEE
SOLVED PAPER 2008

Chemistry

Paper 1

Section I

Straight Objective Type

This section contains 6 multiple choice questions numbered 1 to 6. Each question has 4 choices (a), (b), (c), and (d), out of which ***ONLY ONE*** *is correct.*

2.5 mL of $\frac{2}{5}$ M weak monoacidic base ($K_b = 1 \times 10^{-12}$ at 25°C) is titrated with $\frac{2}{15}$ M HCl in water at 25°C. The concentration of H^+ at equivalence point is ($K_w = 1 \times 10^{-14}$ at 25°C)

(a) 3.7×10^{-13} M (b) 3.2×10^{-7} M (c) 3.2×10^{-2} M (d) 2.7×10^{-2} M

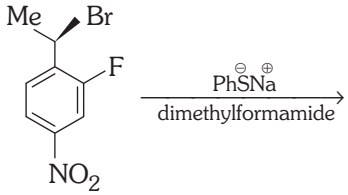
Native silver metal forms a water soluble complex with a dilute aqueous solution of NaCN in the presence of

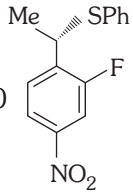
(a) nitrogen (b) oxygen (c) carbon dioxide (d) argon

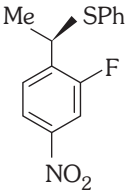
Under the same reaction conditions, initial concentration of 1.386 mol dm^{-3} of a substance becomes half in 40s and 20s through first-order and zero-order kinetics, respectively. Ratio $\left(\frac{k_1}{k_0}\right)$ of the rate constants for first order (k_1) and zero order (k_0) of the reaction is

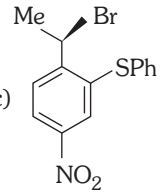
(a) 0.5 $mol^{-1}dm^3$ (b) 1.0 mol dm^3 (c) 1.5 mol dm^3 (d) 2.0 $mol^{-1}dm^3$

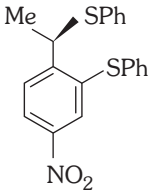
The major product of the following reaction is



(a) 

(b) 

(c) 

(d) 

Aqueous solution of $Na_2S_2O_3$ on reaction with Cl_2 gives

(a) $Na_2S_4O_6$ (b) $NaHSO_4$ (c) NaCl (d) NaOH

Hyperconjugation involves overlap of the following orbitals

(a) $\sigma - \sigma$ (b) $\sigma - p$ (c) $p - p$ (d) $\pi - \pi$

Section II

Multiple Correct Answer Type

This section contains 4 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.*

A gas described by van der Waals' equation

(a) behaves similar to an ideal gas in the limit of large molar volumes

(b) behaves similar to an ideal gas in the limit of large pressures

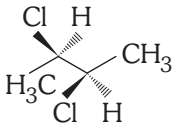
(c) is characterised by van der Waals' coefficients that are dependent on the identity of the gas but are independent of the temperature

(d) has the pressure that is lower than the pressure exerted by the same gas behaving ideally

A solution of colourless salt *H* on boiling with excess NaOH produces a non-flammable gas. The gas evolution ceases after sometime. Upon addition of Zn dust to the same solution, the gas evolution restarts. The colourless salt (s) *H* is (are)

(a) NH_4NO_3 (b) NH_4NO_2 (c) NH_4Cl (d) $(NH_4)_2SO_4$

The correct statement(s) about the compound given below is are



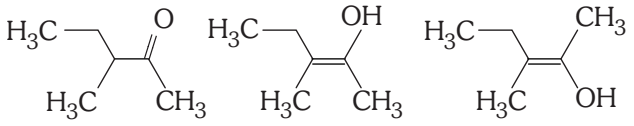
(a) the compound is optically active

(b) the compound possesses centre of symmetry

(c) the compound possesses plane of symmetry

(d) the compound possesses axis of symmetry

The correct statement(s) concerning the structures *E*, *F* and *G* is are



(*E*) (*F*) (*G*)

(a) *E*, *F* and *G* are resonance structures (b) *E*, *F* and *E*, *G* are tautomers

(c) *F* and *G* are geometrical isomers (d) *F* and *G* are diastereomers

Section III

Assertion-Reason Type

This section contains 4 reasoning type questions. Each question has 4 choices (a), (b), (c) and (d) of which ***ONLY ONE*** *is correct.*

Directions *For the following questions, choose from the correct codes (a) (b) (c) and (d) defined as follows*

(a) Statements 1 is true, Statement 2 is also true; Statement 2 is the correct explanation of Statement 1
(b) Statement 1 is true, Statement 2 is also true; Statement 2 is not the correct explanation of Statement 1
(c) Statement 1 is true, Statement 2 is false
(d) Statement 1 is false, Statement 2 is true

Statement 1 Pb^{4+} compounds are stronger oxidising agents than Sn^{4+} compounds.

Statement 2 The higher oxidation states for the group 14 elements are more stable for the heavier members of the group due to 'inert pair effect'.

Statement 1 The plot of atomic number (*y*-axis) *versus* number of neutrons (*x*-axis) for stable nuclei shows a curvature towards *x*-axis from the line of 45° slope as the atomic number is increased

Statement 2 Proton-proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides.

Statement 1 Bromobenzene, upon reaction with Br_2/Fe gives 1, 4-dibromobenzene as the major product.

Statement 2 In bromobenzene, the inductive effect of the bromo group is more dominant than the mesomeric effect in directing the incoming electrophile.

Statement 1 For every chemical reaction at equilibrium, standard Gibbs energy of reaction is zero.

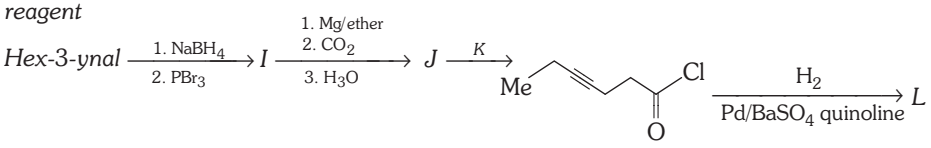
Statement 2 At constant temperature and pressure, chemical reactions are spontaneous in the direction of decreasing Gibbs energy.

Section IV

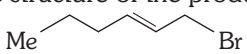
Linked Comprehension Type

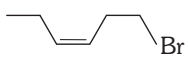
This section contains 3 paragraphs C 15-17, C 18-20 and C 21-23. Based upon each paragraph, 3 multiple choice questions have to be answered. Each question has 4 choices (a), (b), (c) and (d) out of which ***ONLY ONE*** *is correct*

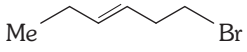
C_{15-17} *In the following reaction sequence, product I. J and L are formed. K represent a reagent*

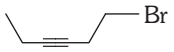


The structure of the product *I* is

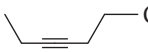
(a) 

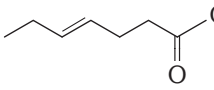
(b) 

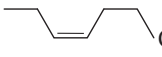
(c) 

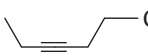
(d) 

The structures of compounds *J* and *K*, respectively, are

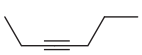
(a) Me  and SO_2Cl_2

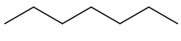
(b) Me  and SO_2Cl_2

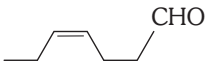
(c) Me  and $SOCl_2$

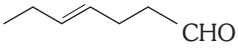
(d) Me  and CH_3SO_2Cl

The structure of product *L* is

(a) Me 

(b) Me 

(c) Me 

(d) Me 

C$_{18–20}$ *There are some deposits of nitrates and phosphates in earth's crust. Nitrates are more soluble in water. Nitrates are difficult to reduce under the laboratory conditions but microbes do it easily. Ammonia forms large number of complexes with transition metal ions. Hybridisation easily explains the ease of sigma donation capability of* NH_3 *and* PH_3*. Phosphine is a flammable gas and is prepared from white phosphorus.*

Among the following, the correct statement is

(a) phosphates have no biological significance in humans

(b) between nitrates and phosphates, phosphates are less abundant in earth's crust

(c) between nitrates and phosphates, nitrates are less abundant in earth's crust

(d) oxidation of nitrates is possible in soil

Among the following, the correct statement is

(a) between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies spherical '*s*' orbital and is less directional

(b) between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional

(c) between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional

(d) between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies spherical '*s*' orbital and is less directional

White phosphorus on reaction with NaOH gives PH_3 as one of the products. This is a

(a) dimerisation reaction

(b) disproportionation reaction

(c) condensation reaction

(d) precipitation reaction

C$_{21–23}$ *Properties such as boiling point, freezing point and vapour pressure of a pure solvent change when solute molecules are added to get homogeneous solution. These are called colligative properties. Applications of colligative properties are very useful in day-to-day life. One of its examples is the use of ethylene glycol and water mixture as anti-freezing liquid in the radiator automobiles.*

A solution M is prepared by mixing ethanol and water. The mole fraction of ethanol in the mixtrue is 0.9

Given *Freezing point depression constant of water* (k^{water}) = 1.86 K kg mol^{-1}

Freezing point depression constant of ethanol ($k_f^{ethanol}$) = 2.0 Kkg mol^{-1}

Boiling point elevation constant of water (k_b^{water}) = 0.52 Kkg mol^{-1}

Boiling point elevation constant of ethanol ($k_b^{ethanol}$) = 1.2 Kkg mol^{-1}

Standard freezing point of water = 273 K

Standard freezing point of ethanol = 155.7 K

Standard boiling point of water = 373 K

Standard boiling point of ethanol = 351.5 K

Vapour pressure of pure water = 32.8 mm of Hg

Vapour pressure of pure ethanol = 40 mm of Hg

Molecular weight of water = 18 g mol^{-1}

Molecular weight of ethanol = 46 g mol^{-1}

In answering the following questions, consider the solutions to be ideal dilute solutions and solutes to be non-volatile and non-dissociative.

The freezing point of the solution *M* is

(a) 268.7 K (b) 268.5 K (c) 234.2 K (d) 150.9 K

The vapour pressure of the solution *M* is

(a) 39.3 mm Hg (b) 36.0 mm Hg (c) 29.5 mm Hg (d) 28.8 mm Hg

Water is added to the solution *M* such that the mole fraction of water in the solution becomes 0.9 The boiling point of this solutions is

(a) 380.4 K (b) 376.2 K (c) 375.5 K (d) 354.7 K

PAPER 2

Section I

Straight Objective Type

This section contains 9 multiple choice questions numbered 1 to 9. Each question has 4 choices (a), (b), (c) and (d), out of which ***ONLY ONE*** *is correct.*

Solubility product constant (K_{sp}) of salts of types MX, MX_2 and M_3X at temperature '*T*' are 4.0×10^{-8}, 3.2×10^{-14} and 2.7×10^{-15}, respectively. Solubilities (mol dm^{-3}) of the salts at temperature '*T*' are in the order

(a) $MX > MX_2 > M_3X$ (b) $M_3X > MX_2 > MX$

(c) $MX_2 > M_3X < MX$ (d) $MX > M_3X > MX_2$

Electrolysis of dilute aq. NaCl solution was carried out by passing 10 mA current. The time required to liberate 0.01 mole of H_2 gas at the cathode is (1 Faraday = 96500 C mol^{-1})

(a) 9.65×10^4s (b) 19.3×10^4s (c) 28.95×10^4s (d) 38.6×10^4s

Among the following, the surfactant that will form micelles in aqueous solution at the lowest molar concentration at ambient conditions is

(a) $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$ (b) $CH_3(CH_2)_{11}OSO_3^-Na^+$

(c) $CH_3(CH_2)_6COO^-Na^+$ (d) $CH_3(CH_2)_{11}N^+(CH_3)_3Br^-$

Both $[Ni(CO)_4]$ and $[Ni(CN)_4]^{2-}$ are diamagnetic. The hybridisations of nickel in these complexes, respectively, are

(a) sp^3, sp^3 (b) sp^3, dsp^2 (c) dsp^2, sp^3 (d) dsp^2, dsp^2

The IUPAC name of $[Ni(NH_3)_4]$ $[NiCl_4]$ is

(a) tetrachloronickel (II) - tetraamminenickel (II)

(b) tetraamminenickel (II) - tetrachloronickel (II)

(c) tetraamminenickel (II) - tetrachloronickelate (II)

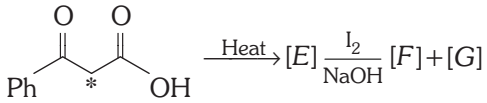
(d) tetrachloronickel (II) - tetraamminenickelate (0)

Among the following, the coloured compound is

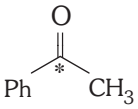
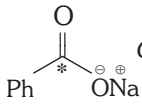
(a) CuCl (b) $K_3[Cu(CN)_4]$

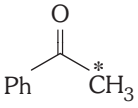
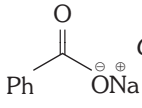
(c) CuF_2 (d) $[Cu(CH_3CN_4)]BF_4$

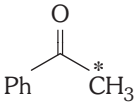
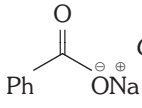
In the following reaction sequence, the correct structures of *E*, *F* and *G* are

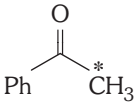
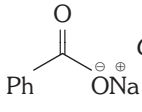


(*implies ^{13}C labelled carbon)

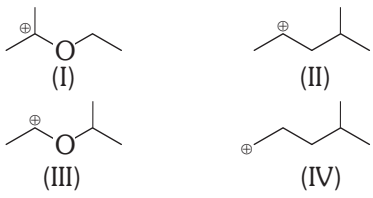
(a) *E* =  *F* =  *G* = CHI_3

(b) *E* =  *F* =  *G* = CHI_3

(c) *E* =  *F* =  *G* = $\overset{*}{C}HI_3$

(d) *E* =  *F* =  *G* = $\overset{*}{C}H_3I$

The correct stability order for the following species is



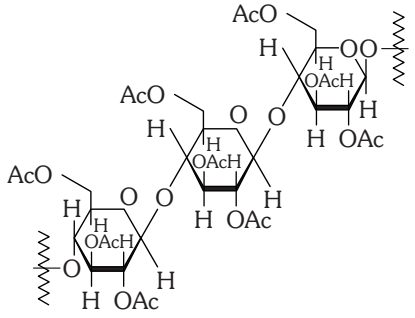
(a) (II) > (IV) > (I) > (III)

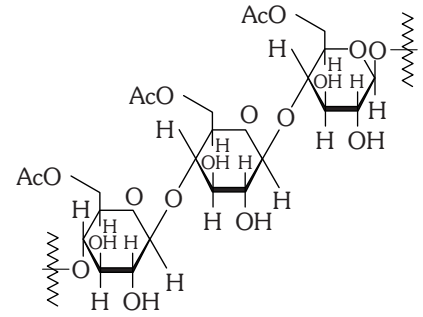
(b) (I) > (II) > (III) > (IV)

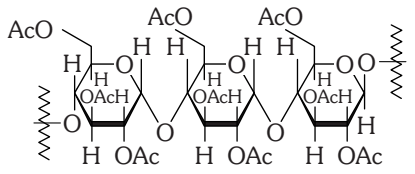
(c) (II) > (I) > (IV) > (III)

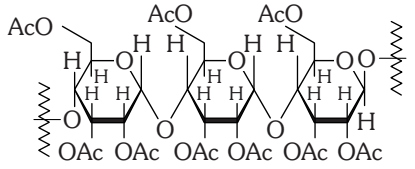
(d) (I) > (III) > (II) > (IV)

Cellulose upon acetylation with excess acetic anhydride/H_2SO_4 (catalytic) gives cellulose triacetate whose structures is

(a)


(b)


(c)


(d)


Section II

Assertion Reason Type

This section contains 4 *reasoning type questions. Each question has* 4 *choices (a), (b), (c) and (d) of which* ***ONLY ONE*** *is correct.*

Directions *For the following questions, choose from the correct codes (a), (b), (c) and (d) defined as follows :*

(a) Statements 1 is true, statement 2 is also true; statement 2 is the correct explanation of statement 1

(b) Statement 1 is true, statement 2 is also true, statement 2 is not the correct explanation of statement 1

(c) Statement 1 is true, statement 2 is false

(d) Statement 1 is false, statement 2 is true

Statement 1 $[Fe(H_2O)_5NO]SO_4$ is paramagnetic.

Statement 2 The Fe in $[Fe(H_2O)_5NO]SO_4$ has three unpaired electrons.

Statement 1 The geometrical isomer of the complex $[M(NH_3)_4Cl_2]$ are optically inactive.

Statement 2 Both geometrical isomers of the complex $[M(NH_3)_4Cl_2]$ possess axis of symmetry.

Statement 1 There is a natural asymmetry between converting work to heat and converting heat to work.

Statement 2 No process is possible in which the sole result in the absorption of heat from a reservoir and its complete conversion into work.

Statement 1 Aniline on reaction with $NaNO_2$ / HCl at 0°C followed by coupling with β-naphthol gives a dark coloured precipitate.

Statement 2 The colour of the compound formed in the reaction of aniline with $NaNO_2$ / HCl at 0°C followed by coupling with β-naphthol is due to the extended conjugation.

Section III

Linked Comprehension Type

*This section contains 2 paragraphs C 14-16 and C 17-19. 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.*

C$_{14-16}$ *In hexagonal system of crystals, a frequently encountered arrangement of atoms is described as a hexagonal prism. Here, the top and bottom of the cell are regular hexagons and three atoms are sandwiched in between them. A space-filling model of this structure, called hexagonal close-packed (HCP), is constituted of a sphere on a flat surface surrounded in the same plane by six identical spheres as closely as possible. Three spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of the three spheres touches three spheres of the bottom layer. Finally, the second layer is covered with a third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be 'r'.*

The number of atoms in this HCP unit cell is

(a) 4 (b) 6 (c) 12 (d) 17

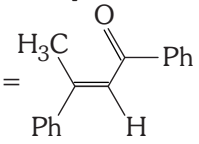
The volume of this HCP unit cell is

(a) $24\sqrt{2}r^3$ (b) $16\sqrt{2}r^3$ (c) $12\sqrt{2}r^3$ (d) $\frac{64}{3\sqrt{3}}r^3$

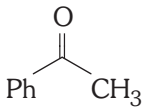
The empty space in this HCP unit cell is

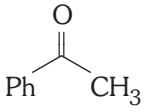
(a) 74% (b) 47.6% (c) 32% (d) 26%

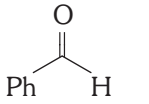
C$_{17-19}$ *A tertiary alcohol H upon acid catalysed dehydration gives a product I. Ozonolysis of I leads to compounds J and K. Compound J upon reaction with KOH gives benzyl alcohol and a compound L, where K on reaction with KOH gives only M.*

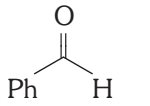
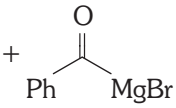
$M =$ 

Compound *H* is formed by the reactions of

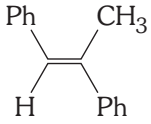
(a)  + PhMgBr

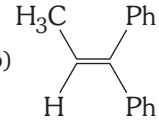
(b)  + $PhCH_2MgBr$

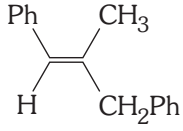
(c)  + $PhCH_2MgBr$

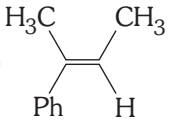
(d)  + 

The structure of compound *I* is

(a) 

(b) 

(c) 

(d) 

The structures of compounds *J*, *K* and *L*, respectively, are

(a) $PhCOCH_3$, $PhCH_2COCH_3$ and $PhCH_2COO^-K^+$

(b) PhCHO, $PhCH_2CHO$ and $PhCH_2COO^-K^+$

(c) $PhCOCH_3$, $PhCH_2CHO$ and $CH_3COO^-K^+$

(d) PhCHO, $PhCOCH_3$ and $PhCOO^-K^+$

Section IV

Matrix-Match Type

This section contains 3 questions. Each question contains statements given is 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 and s. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

If the correct matches are A-q, A-r, B-p, B-s, C-r, C-s and D-q, then the correctly bubbled matrix will look like the following

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

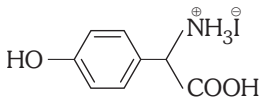
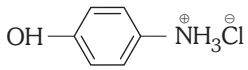
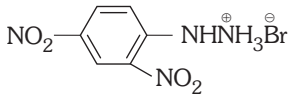
Match the conversions in **Column I** with the type(s) given in **Column II.** Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

	Column I	**Column II**
A.	$PbS \longrightarrow PbO$	p. Roasting
B.	$CaCO_3 \longrightarrow CaO$	q. Calcination
C.	$ZnS \longrightarrow Zn$	r. Carbon reduction
D.	$Cu_2S \longrightarrow Cu$	s. Self-reduction

Match the entries in **Column I** with the correctly related quantum number(s) in **Column II**. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

	Column I		**Column II**
A.	Orbital angular momentum of the electron in a hydrogen like atomic orbital	p.	Principal quantum number
B.	A hydrogen-like one electron wave function obeying Pauli principle	q.	Azimuthal quantum number
C.	Shape, size and orientation of hydrogen-like atomic orbitals	r.	Magnetic quantum number
D.	Probability density of electron at the nucleus in hydrogen-like atom	s.	Electron spin quantum number

Match the compounds in **Column I** with their characteristic test(s)/reactions(s) given in **Column II.** Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

	Column I		**Column II**
A.	$H_2N—\overset{\oplus}{N}H_3\ \overset{\ominus}{Cl}$	p.	Sodium fusion extract of the compound gives Prussian blue colour with $FeSO_4$
B.		q.	Gives positive $FeCl_3$ test
C.		r.	Gives white precipitate with $AgNO_3$
D.		s.	Reacts with aldehydes to form the corresponding hydrazone derivative

ANSWER

Paper-1

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

Paper-2

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

19. (d) **20.** A → p; B → q; C → p, r; D → p, r, s

21. A → q; B → p, q, r, s; C → p, q, r; D → p, q, r

22. A → r, s; B → p, q; C → p, q, r; D → p

PAPER 1

1. Weak monoacidic base, e.g. BOH is neutralised.

$$BOH + HCl \longrightarrow BCl + H_2O$$

At equivalence point all BOH gets converted into salt and remember! the concentration of H^+ (or pH of solution) is due to hydrolysis of resultant salt (BCl, cationic hydrolysis here)

$$\underset{C(1-h)}{B^+} + H_2O \rightleftharpoons \underset{Ch}{OH} + \underset{Ch}{H^+}$$

Volume of HCl used up,

$$V_a = \frac{N_b V_b}{N_a} = \frac{2.5 \times 2 \times 15}{2 \times 5} = 7.5 \text{ mL}$$

Concentration of salt,

$$[BCl] = \frac{\text{Concentration of base}}{\text{Total volume}} = \frac{2 \times 2.5}{5(7.5 + 2.5)} = \frac{1}{10} = 0.1$$

$$K_h = \frac{Ch^2}{1-h} = \frac{K_w}{K_b}$$

(h should be estimated whether that can be neglected or not) on calculating $h = 0.27$ (significant, not negligible)

$[H^+] = Ch = 0.1 \times 0.27 = 2.7 \times 10^{-2}$ M

When $[H^+]$ is asked to calculate in connection with neutralisation, it

Should be calculated :	
Before neutralisation	Using Oslwald's dilution law
During neutralisation	Considering buffer solution
	Half neutralisation pH = pK_a and pK_b
At the end of neutralisation	Considering hydrolysis of salt

2. A water soluble complex of silver with a dilute aqueous solution of NaCN is sodium argentocyanide. In the cyanide process, the native form is crushed and treated with 0.1 – 0.2% solution of NaCN and aerated.

$$4Ag + 8NaCN + 2H_2O + O_2 \longrightarrow 4Na[Ag(CN)_2] + 4NaOH$$

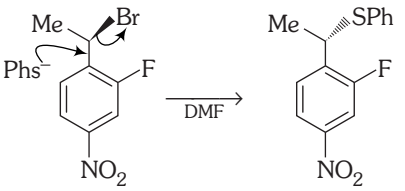
Argentocyanide is soluble. Further, metals are recovered from the complex by reduction with zinc

3. First order kinetics, $k_1 = \frac{0.693}{t_{1/2}} = \frac{0.693}{40} s^{-1}$

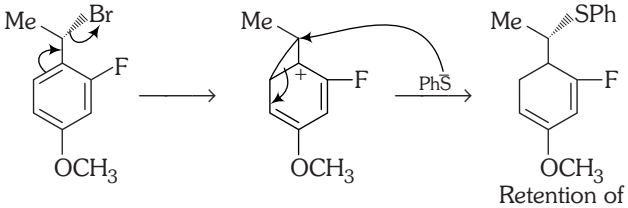
Zero order kinetics, $k_1 = \frac{C_0}{2t_{1/2}} = \frac{1.386}{2 \times 20}$

Hence, $\frac{k_1}{k_0} = \frac{0.693}{1.386} = 0.5$

4. PhS^- is a strong nucleophile and dimethylformamide (DMF) is a highly polar aprotic solvent. Condition indicates that nucleophilic substitution (S_N2) takes place at 2° benzylic place, stereochemically it involves inversion of configuration.



Aryl group can exhibit neighbouring group or can show anchimeric assistance but not possible here due to deactivity imparted by —NO_2 and —F. It can be if —OCH_3 would have been instead of —NO_2.



Retention of configuration

5. Sodium thiosulphate, $Na_2S_2O_3$ gets oxidised by chlorine water.

$$Na_2S_2O_3 + 4Cl_2 + 5H_2O \longrightarrow 2NaHSO_4 + 8HCl$$

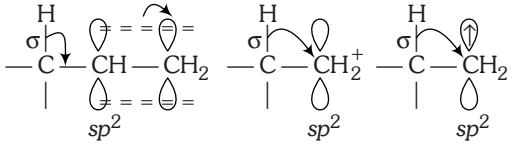
$Na_2S_2O_3$ gets oxidised by $FeCl_3$ into $Na_2S_4O_6$

$$2Na_2S_2O_3 + 2FeCl_3 \longrightarrow Na_2S_4O_6 + 2FeCl_2 + 2NaCl$$

Further, $Na_2S_2O_3$ decomposes on treatment with dilute acids

$$Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + SO_2 + S + H_2O$$

6. Hyperconjugation is one kind of delocalisation of σ (C—H) bonded electron to unshared *p*-orbital.



7. The gas described by van der Waals' equation in the limit of large molar volume, in the intermediate range of pressure experience balancing by two factors.

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT \quad \Rightarrow \quad pV = \frac{a}{V} - pb + \frac{ab}{V^2} = RT$$

(We can neglect the product of two very small constants, $\frac{ab}{V^2}$)

So, $$pV + \frac{a}{V} - pb = RT$$

As $$\frac{a}{V} = pb$$

The gas behaves ideally, $pV = RT$

- The van der Waals' constants '*a*' and '*b*' are characteristics of the gas. The value of these constants are determined by the critical constants of the gas

$$a = 3p_CV_C^2 = 3p_C\left(\frac{3RT_C}{8p_C}\right)^2 = \frac{27(RT_C)^2}{64\,p_C};\ b = \frac{1}{3}\left(\frac{3RT_C}{8p_C}\right) = \frac{RT_C}{8p_C}$$

Question is based on description by van der Waals' equation, that's why we have to ignore the effect of temperature on *a* and *b*. Actually, the so-called constant varies to some extent with temperature and this shows that the van der Waals' equation is not a complete solution of the behaviour of real gas

$$P_{ideal} = \underbrace{P_{real}}_{\text{Observed pressure}} + \underbrace{\frac{an^2}{V^2}}_{\text{Correction term}}$$

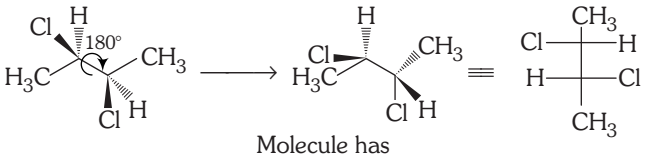
8. $NH_4NO_3 + NaOH \longrightarrow NaNO_3 + NH_3 + H_2O$

$NaNO_3 + 8\,[H] \longrightarrow NaOH + NH_3 + 2H_2O$

$NH_4NO_2 + NaOH \longrightarrow NaHO_2 + NH_3 + H_2O$

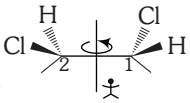
$NaNO_2 + 6[H] \longrightarrow NaOH + NH_3 + H_2O$

9.



Molecule has non-superimposable mirror image

The compound does not possess centre of symmetry and plane of symmetry but possesses the proper axis of symmetry (C_n). A C_n axis of symmetry is an axis about which the molecule can be rotated by 360°/*n* and thereby produce a molecule indistinguishable from the original molecule.



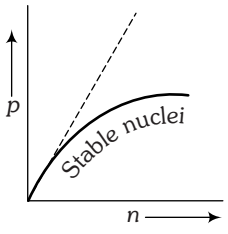
From this face H (on right) and Cl (on left) are facing towards us and again on rotating at 180° C-2 comes at C-1 place and again H (on right) and Cl (on left) are facing. We get an indistinguishable form on 180° rotation, so it has a proper axis of symmetry (C_2).

If a molecule is not superimposable on its mirror image, that molecule can exhibit optical activity, if these have proper axis but no improper axis or if a C_n axis be the only symmetry element present in a molecule, that molecule is optically active.

10. *E* and *F* possess different place of atoms, in addition to electron pair, can be isomers only and not the resonance structures. Geometrical isomers are stereoisomers but not enantiomers called diastereomers

11. In early *p*-block, on moving top to bottom, the stability of lower oxidation state increases due to inert pair effect. Pb^{4+} is less stable than Sn^{4+}, making it a better oxidising agent The lower oxidation state for the group 14 elements are more stable for the heavier members.

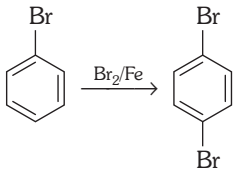
12. The stability relationship can be represented by a line with a slope of 45°, i.e. the maximum stability is attained, when $N = Z$.



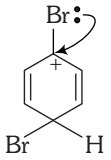
Right or the curve a radioactive nuclide would be neutron rich and would decay be β-emission to produce a daughter nucleus with a lower $\frac{n}{p}$ ratio.

For heavier nuclides, *p*-*p* repulsions start to offset the attractive forces and an excess of neutrons over protons, is required for stability

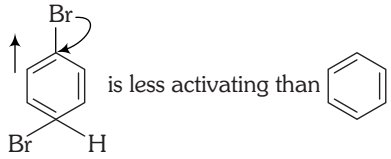
13.



Bromine orientation is controlled by its mesomeric effect, its stabilisation of arenium ion by + *M* activity

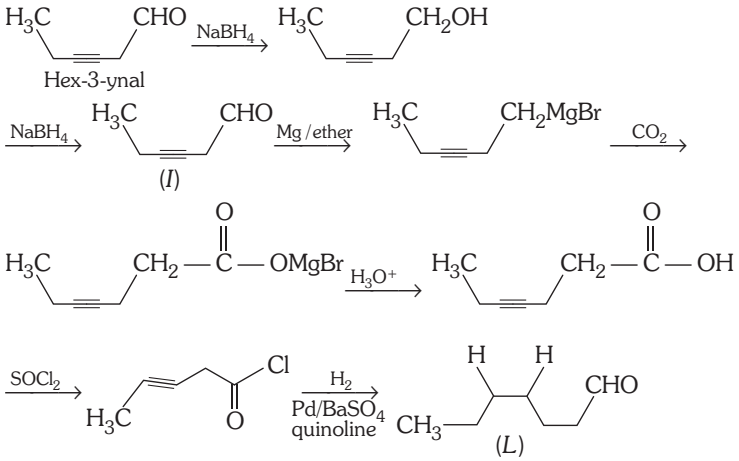


In bromobenzene, the inductive effect of the bromo group is more dominant than the mesomeric effect in the activity of ring.



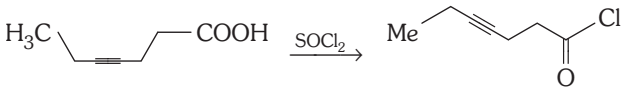
14. At equilibrium, its free energy change, is zero and for a spontaneous process, $\Delta G < 0$ but at equilibrium standard free energy is not zero.

Analysis of the Paragraph



15. $NaBH_4$ reduces —CHO selectively into —CH_2OH, which is further converted into corresponding bromide by PBr_3 without affecting the triple bond.

16. Bromide converted into Grignard reagent and further carbonation (I. CO_2, II. H_3O^+) produces carboxylic acid (*J*)



17. H_2, Pd / $BaSO_4$, quinoline is well known reagent.

Rosenmund's reaction (conversion of acyl halide to aldehyde) H_2, Pd, $BaSO_4$ is known as Lindlar's reagent and reduces triple bond to double bond (*syn* addition) giving *cis* product. Reagent has simultaneous action because usually reaction is not selective—follows radical mechanism.

18. Due to greater solubility and nature to be prone to microbial action, nitrates are less abundant in earth's crust.

19. NH_3 is better electron donor because the lone pair of electrons occupies sp^3-orbital and is more directional.

20. White phosphorus on reaction with NaOH gives PH_3 as one of the product in disproportionation reaction

$$P_4 + 3NaOH + 3H_2O \longrightarrow 3NaH_2PO_2 + PH_3$$

21. Solution *M* is mixture of ethanol and water.

Mole fraction of ethanol is 0.9 $\Rightarrow$ Solvent is C_2H_5OH

Mole fraction of water is 0.1 $\Rightarrow$ H_2O is solute

Molality of $H_2O = \dfrac{n_2}{n_1 M_1} = \dfrac{0.1}{0.9 \times 46} \times 1000 = 2 \cdot 415$

$$\Delta T_f = k_f \cdot m = 2 \times 2.415 = 4.83$$

or Freezing point of solution = 155.7 – 4.83 = 150.87 K

22. Total vapour pressure, $p = p_A^{\circ} \chi_A$

$$p = 40 \times 0.9 = 36 \text{ mm of Hg}$$

In the paragraph, it has been directed to take solute as non-volatile, thus H_2O do not contribute in the total vapour pressure.

23. $\chi_{H_2O} = 0.9$ (solvent) $\chi_{C_2H_5OH} = 0.1$ (solute)

$$\Delta T_b = k_b \times m = 0.52 \times \frac{1.0 \times 1000}{0.9 \times 18} = 3.2\,\text{K}$$

Boiling point, $T_b = 373 + 3.2 = 376.2\,\text{K}$

PAPER 2

1.

Salt	Solubility product	Solubility
MX	$S_1^2 = 4.0 \times 10^{-8}$	$S_1 = 2 \times 10^{-4}$
MX_2	$4S_2^3 = 3.2 \times 10^{-14}$	$S_2 = 2 \times 10^{-5}$
M_3X	$27S_3^4 = 27 \times 10^{-15}$	$S_3 = 1 \times 10^{-4}$

Thus, solubility order = $MX > M_3X > MX_2$.

2. $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

For 0.01 mole of H_2, 0.02 mole of electrons are consumed

Charge required = $0.02 \times 96500\,\text{C} = i \times t$

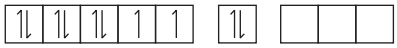
Time required = $\dfrac{0.02 \times 96500}{10 \times 10^{-3}} = 19.3 \times 10^4\,\text{s}$

3. Sodium dodecylsulphate (SDS) | Hexadecyl trimethylammonium bromide (CTAB)

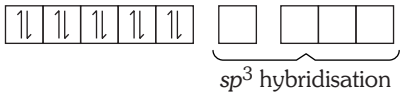
CMC (mm) > –10 | 1

4. In $[Ni(CO)_4]$, the oxidation state of Ni is zero (0).

Ni (28) [Ar] $4s^2, 3d^8$

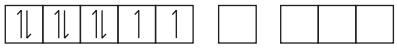


CO is a strong ligand, causes coupling, thus

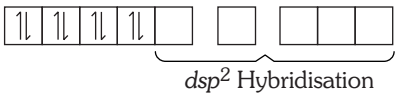


In $[Ni(CN)_4]^{2-}$, the oxidation state of Ni is +2

Ni^{2+} = [Ar] $3d^8, 4s^0$



CN^- is strong ligand causes coupling.

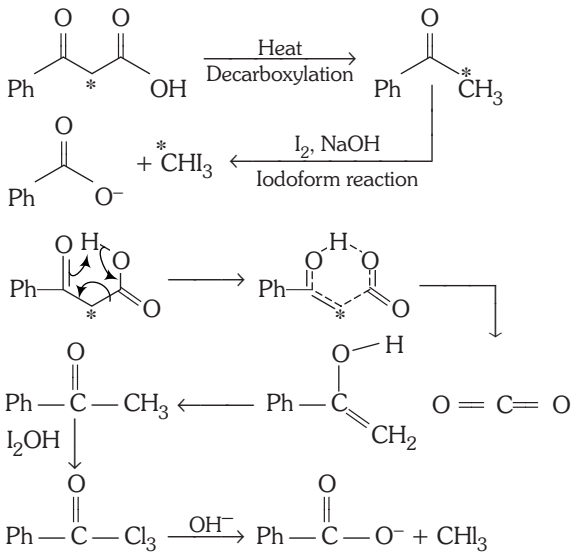


5. IUPAC name is tetraamminenickel (II) tetrachloronickelate (II).

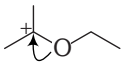
6. In CuF_2, Cu^{2+} ions exist, having d^9-configuration. Unpaired electron causes colour ($d - d$ transition)

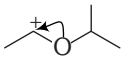
In the crystalline form, CuF_2 is blue coloured

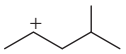
7.

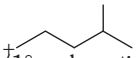


8. I > III > II > IV


+ *M*-effect, hyperconjugation (6Hs) and +*I*-effect (2 Me groups)


+ *M*-effect, hyperconjugation (3Hs) and +*I*-effect (1 Me group)


Hyperconjugation (5Hs) and +*I*-effect (2° carbocation)


Hyperconjugation (2Hs) and +*I*-effect (1° carbocation)

9. Cellulose is a straight chain polysaccharide composed of D-glucose units, which are joined by β-glycosidic linkages between C-1 of one glucose and C-4 of the next glucose. In one, unit only three hydroxy groups are free to form acetate, that's why called cellulose triacetate

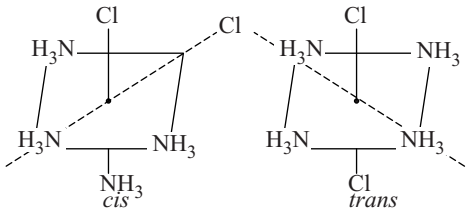
10. The oxidation number of Fe in the complex, $[Fe(H_2O)_5NO]SO_4$ is + 1 [NO has +1 charge]

$$Fe^+ = [Ar]\ 3d^6 4s^1$$

NO^+ causes pairing of 4*s* electron inside.

Thus, the configuration is $3d^7$ and number of unpaired electrons = 3

11. The *cis* and *trans* both form of complex $[M(NH_3)_4Cl_2]$ are optically inactive



There are plane of symmetry in addition to that there is alternate axis of symmetry (C_n) which also causes their optical inactivity.

A molecule possesses *n* fold alternating axis of symmetry, if when rotated through an angle of 360°/*n* about the axis and then followed by reflection in a plane perpendicular to the axis, the molecule is indistinguishable from the original molecule.

12. There is natural asymmetry between converting work to heat and converting heat to work because of the lapse of energy in this process which has been generalised in the form of second law of thermodynamics (Statement II).

13. Statement II is correct. Statement I appears correct in the light of Statement II. What is the colour of a dye that dye is not in included in JEE syllabus but what is the cause and understanding behind a colour could be essentially expected.

Concept Usually a certain proportion of the flight is absorbed and the rest reflected, the substance has the colour of the reflected light.

If only a single band is absorbed, the substance has the complementary colour.

- The wavelength of photon absorbed depends on the energy difference between the excited and ground states. The **smaller the difference, the longer being the wavelength.**

- The larger the number of electrons involved in resonance, the smaller is the energy difference between the ground and excited state. Hence, the more extended the conjugation in a molecule and the greater the contribution of charged structures, the longer is the wavelength of the photon required to excite the molecule.
- Especially, the presence of $+I$ / $+M$ and $-I$ / $-M$ groups in the conjugated system will both extend the conjugation and increase the contributions of charged structures to the resonance hybrid. Therefore, in these circumstances, the wavelength should become progressively longer.
- Depending on this discussion it is apparent that the concerned resultant azodye will absorb higher wavelength.

Wavelength	Colour absorbed	Complimentary colour
490-500	Blue-green	Red
580-595	Yellow	Blue
605-750	Red	Blue-green

14. The effective number of atoms in the hcp is $= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 6$

15. Height of unit cell $= \sqrt{\frac{2}{4}} 4r$

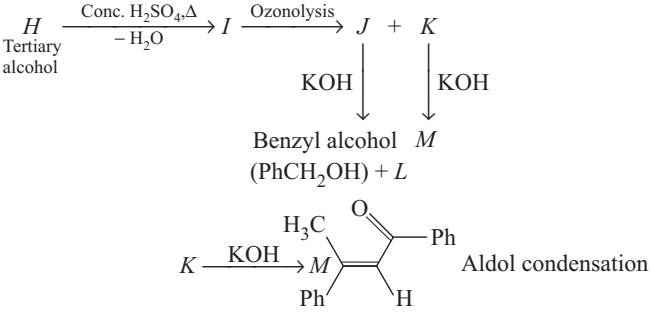
$$\text{Base area} = 6 \times \frac{\sqrt{3}}{4}(2r)^2$$

$$\text{Volume} = \frac{6\sqrt{3}}{4}(2r)^2 \cdot \sqrt{\frac{2}{3}} 4r = 24\sqrt{2}\, r^3$$

16. Packing fraction $= \frac{\text{Volume of the atoms in one unit cell}}{\text{Volume of one unit cell}} = 74\%$

Empty space = 26%

Analysis of the paragraph



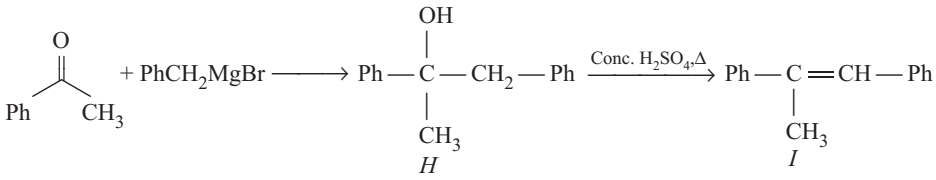
Hence, K = PH—C(=O)—CH_3

$K \xrightarrow{KOH} PhCH_2OH + L$ Cannizzaro reaction

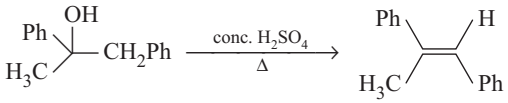
Hence, J = PhCH = O and $L = PhCOO^-$

So, I = Ph—Ch = C(Ph)(CH_3)

17.

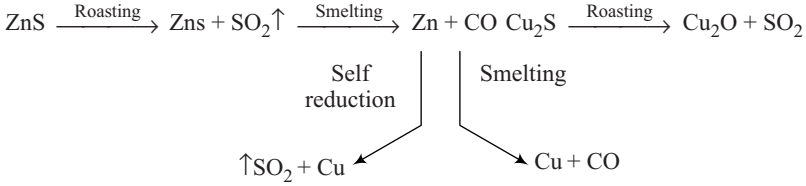


18.



19. $J = PhCH{=}O$ $K = PhCOCH_3$ $L = PhCOO^-K^+$

20. A—p; B—q; C—p, r; D—p, r, s



21. A—q; B —p, q, r, s; C—p, q, r; D—p, q, r

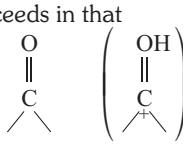
(B) **A hydrogen-like one electron wave function obeying Pauli's principle** First, as it is the wave function so it will be characterised by n, l and m. Further, it obeys the Pauli's principle, that's why it will be characterised completely by adding spin quantum number also.

(D) Radial probability density of electron at the nucleus basically depends on azimuthal quantum number, but as it is the function of radius depends on principal quantum number, When angular probability density is included, that depends on magnetic quantum number.

22. A—r; B—p, q; C— p, q, r; D—p

Sodium fusion extract gives Prussian blue when nitrogen is present alongwith carbon. Phenolic group and carboxylate gives positive $FeCl_3$ test — white precipitate comes with AgCl.

Hydrazone formation occurs effectively at pH ≈ 4.5. The reaction proceeds in that condition only when H^+ concentration is merely sufficient to activate. As H^+ concentration raises, sufficient molecule of hydrazone gets converted into hydrazonium which is not nucleophilic and reaction becomes impossible. Further, low concentration of H^+ (in the case of hydrolysis of 2, 4-dinitrophenyl hydrazonium bromide) is not effective to proceed elimination (rate determining step).



If it is assumed that the given hydrazonian bromiate is the result as salt main HBr is used as acid catalyst. Remember! hydrazone formation involves first addition and then elimination (res). In the second step substitution dominates over elimination (HBr is not a dehydrating reagent mutually).

IIT JEE
SOLVED PAPER 2008

Physics

Paper 1

Section I

Straight Objective Type

This section contains 6 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d), out of which **ONLY ONE** is correct.

An ideal gas is expanding such that pT^2 = constant. The coefficient of volume expansion of the gas is

(a) $\frac{1}{T}$ (b) $\frac{2}{T}$

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

Two beams of red and violet colours are made to pass separately through a prism (angle of the prism is 60°). In the position of minimum deviation, the angle of refraction will be

(a) 30° for both the colours

(b) greater for the violet colour

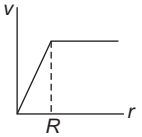
(c) greater for the red colour

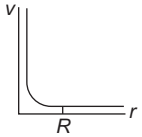
(d) equal but not 30° for both the colours

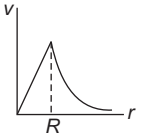
A spherically symmetric gravitational system of particles has a mass density

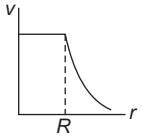
$$\rho = \begin{cases} \rho_0 \text{ for } r \le R \\ 0 \text{ for } r > R \end{cases}$$

where ρ_0 is a constant. A test mass can undergo circular motion under the influence of the gravitational field of particles. Its speed v as a function of distance r $(0 < r < \infty)$ from the centre of the system is represented by

(a) 

(b) 

(c) 

(d) 

Which one of the following statement is **WRONG** in the context of X-rays generated from X-ray tube?

(a) Wavelength of characteristic X-rays decreases when the atomic number of the target increases

(b) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target

(c) Intensity of the characteristics X-rays depends on the electrical power given to the X-ray tube

(d) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

Students I, II and III perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and/or record time for different number of oscillations. The observations are shown in the table.

Least count for length = 0.1 cm

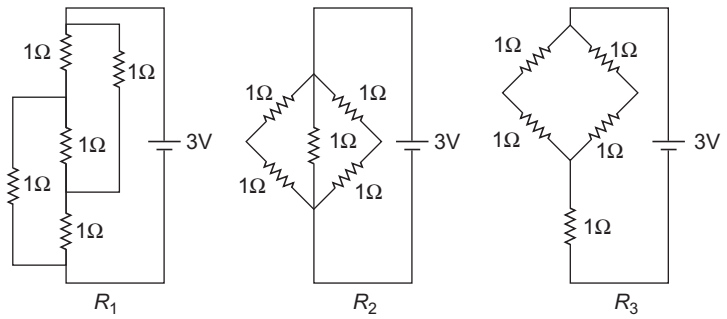
Least count for time = 0.1 s

Student	**Length of the pendulum** (cm)	**Number of oscillations** (n)	**Total time for** (n) **oscillations** (s)	**Time period** (s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

If E_I, E_{II} and E_{III} are the percentage errors in g, i.e., $\left(\frac{\Delta g}{g} \times 100\right)$, for students I, II and III, respectively.

(a) $E_I = 0$ (b) E_I is minimum (c) $E_I = E_{II}$ (d) E_{II} is maximum

Figure shows three resistor configurations R_1, R_2 and R_3 connected to 3V battery. If the power dissipated by the configuration R_1, R_2 and R_3 is P_1, P_2 and P_3, respectively, then



(a) $P_1 > P_2 > P_3$ (b) $P_1 > P_3 > P_2$

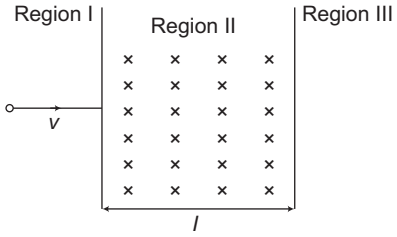
(c) $P_2 > P_1 > P_3$ (d) $P_3 > P_2 > P_1$

Section II

Multiple Correct Answers Type

This section contains 4 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.

A particle of mass m and charge q, moving with velocity v enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is l. Choose the correct choice(s)



(a) The particle enters Region III only if its velocity $v > \frac{qlB}{m}$

(b) The particle enters Region III only if its velocity $v < \frac{qlB}{m}$

(c) Path length of the particle in Region II is maximum when velocity $v = \frac{qlB}{m}$

(d) Time spent in Region II is same for any velocity v as long as the particle returns to Region I

In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice(s),

(a) If $d = \lambda$, the screen will contain only one maximum

(b) If $\lambda < d < 2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen

(c) If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase

(d) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1, the intensities of the observed dark and bright fringes will increase

Two balls, having linear momenta $\vec{\mathbf{p}}_1 = p\hat{\mathbf{i}}$ and $\vec{\mathbf{p}}_2 = -p\hat{\mathbf{i}}$, undergo a collision in free space. There is no external force acting on the balls. Let $\vec{\mathbf{p}}_1'$ and $\vec{\mathbf{p}}_2'$ be their final momenta. The following option(s) is/are **NOT ALLOWED** for any non-zero value of p, a_1, a_2, b_1, b_2, c_1 and c_2

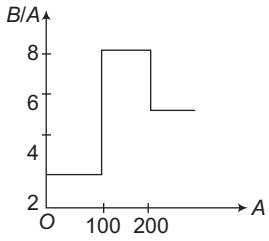
(a) $\vec{\mathbf{p}}_1' = a_1\hat{\mathbf{i}} + b_1\hat{\mathbf{j}} + c_1\hat{\mathbf{k}}$, $\vec{\mathbf{p}}_2' = a_2\hat{\mathbf{i}} + b_2\hat{\mathbf{j}}$

(b) $\vec{\mathbf{p}}_1' = c_1\hat{\mathbf{k}}$, $\vec{\mathbf{p}}_2' = c_2\hat{\mathbf{k}}$

(c) $\vec{\mathbf{p}}_1' = a_1\hat{\mathbf{i}} + b_1\hat{\mathbf{j}} + c_1\hat{\mathbf{k}}$
$\vec{\mathbf{p}}_2' = a_2\hat{\mathbf{i}} + b_2\hat{\mathbf{j}} - c_1\hat{\mathbf{k}}$

(d) $\vec{\mathbf{p}}_1' = a_1\hat{\mathbf{i}} + b_1\hat{\mathbf{j}}$
$\vec{\mathbf{p}}_2' = a_2\hat{\mathbf{i}} + b_1\hat{\mathbf{j}}$

Assume that the nuclear binding energy per nucleon (B/A) *versus* mass number (A) is as shown in the figure. Use this plot to choose the correct choice (s) given below.



(a) Fusion of two nuclei with mass numbers lying in the range of $1 < A < 50$ will release energy

(b) Fusion of two nuclei with mass numbers lying in the range of $51 < A < 100$ will release energy

(c) Fission of a nucleus lying in the mass range of $100 < A < 200$ will release energy when broken into two equal fragments

(d) Fission of a nucleus lying in the mass range $200 < A < 260$ will release energy when broken into two equal fragments

Section III

Assertion-Reason Type

This section contains 4 reasoning type questions. Each question has 4 choices (a), (b), (c) and (d), out of which **ONLY ONE** is correct.

(a) Statement 1 *is True, Statement* 2 *is True; Statement* 2 *is a correct explanation for Statement* 1.

(b) Statement 1 *is True, Statement* 2 *is True; Statement* 2 *is not a correct explanation for Statement* 1.

(c) Statement 1 *is True, Statement* 2 *is False.*

(d) Statement 1 *is False, Statement* 2 *is True.*

Statement 1 An astronaut in an orbiting space station above the earth experiences weightlessness.

and **Statement 2** An object moving around the earth under the influence of earth's gravitational force is in state of 'free fall'.

Statement 1 Two cylinders, one hollow (metal) and the other solid (wood) with the same mass and identical dimensions are simultaneously allowed to roll without slipping down an inclined plane from the same height. The hollow cylinder will reach the bottom of the inclined plane first.

and **Statement 2** By the principle of conservation of energy, the total kinetic energies of both the cylinders are identical when they reach the bottom of the incline.

Statement 1 The stream of water flowing at high speed from a garden hose pipe tends to spread like a fountain when held vertically up, but tends to narrow down when held vertically down.

and **Statement 2** In any steady flow of an incompressible fluid, the volume flow rate of the fluid remains constant.

Statement 1 In a Meter Bridge experiment, null point for an unknown resistance is measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.

and **Statement 2** Resistance of a metal increase with increase in temperature.

Section IV

Linked Comprehension Type

This section contains 3 paragraph. 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 Question Nos. 15 to 17

In a mixture of $H—H^+$ *gas (*He^+ *is singly ionised* He *atom), H atoms and* He^+ *ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to* He^+ *ions (by collisions). Assume that the Bohr model of atom is exactly valid.*

The quantum number n of the state finally populated in He^+ ions is

(a) 2 (b) 3 (c) 4 (d) 5

The wavelength of light emitted in the visible region by He^+ ions after collisions with H atoms is

(a) 6.5×10^{-7} m (b) 5.6×10^{-7} m

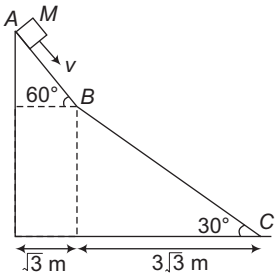
(c) 4.8×10^{-7} m (d) 4.0×10^{-7} m

The ratio of the kinetic energy of the $n=2$ electron for the H atom to that of He^+ ion is

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) 1 (d) 2

Paragraph for Question Nos. 18 to 20

A small block of mass M moves on a frictionless surface of an inclined plane, as shown in figure. The angle of the incline suddenly changes from 60° to 30° at point B. The block is initially at rest at A. Assume that collisions between the block and the incline are totally inelastic ($g=10$ m/s^2)



The speed of the block at point B immediately after it strikes the second incline is

(a) $\sqrt{60}$ m/s (b) $\sqrt{45}$ m/s

(c) $\sqrt{30}$ m/s (d) $\sqrt{15}$ m/s

The speed of the block at point *C*, immediately before it leaves the second incline is

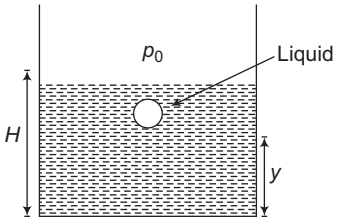
(a) $\sqrt{120}$ m/s (b) $\sqrt{105}$ m/s (c) $\sqrt{90}$ m/s (d) $\sqrt{75}$ m/s

If collision between the block and the incline is completely elastic, then the vertical (upward) component of the velocity of the block at point *B*, immediately after it strikes the second incline is

(a) $\sqrt{30}$ m/s (b) $\sqrt{15}$ m/s (c) zero (d) $-\sqrt{15}$ m/s

Paragraph for Question Nos. 21 to 23

A small spherical monoatomic ideal gas bubble $\left(\gamma = \frac{5}{3}\right)$ *is trapped inside a liquid of density* ρ_l *(see figure). Assume that the bubble does not exchange any heat with the liquid. The bubble contains n moles of gas. The temperature of the gas when the bubble is at the bottom is* T_0*, the height of the liquid is H and the atmospheric pressure is* p_0 *(Neglect surface tension).*



As the bubble moves upwards, besides the buoyancy force the following forces are acting on it.

(a) Only the force of gravity

(b) The force due to gravity and the force due to pressure of the liquid

(c) The force due to gravity, the force due to the pressure of the liquid and the force due to viscosity of the liquid

(d) The force due to gravity and the force due to viscosity of the liquid

When the gas bubble is at height *y* from the bottom, its temperature is

(a) $T_0\left(\frac{p_0+\rho lgH}{p_0+\rho lgy}\right)^{\frac{2}{5}}$ (b) $T_0\left(\frac{p_0+\rho lg(H-y)}{p_0+\rho lgH}\right)^{\frac{2}{5}}$

(c) $T_0\left(\frac{p_0+\rho lgH}{p_0+\rho lgy}\right)^{\frac{3}{5}}$ (d) $T_0\left(\frac{p_0+\rho lg\,(H-y)}{p_0+\rho lgH}\right)^{\frac{3}{5}}$

The buoyancy force acting on the gas bubble is (Assume *R* is the universal gas constant)

(a) $\rho_l nRgT_0\,\frac{(\rho_0+\rho_l gH)^{\frac{2}{5}}}{(\rho_0+\rho_l gy)^{\frac{7}{5}}}$ (b) $\frac{\rho_l nRgT_0}{(\rho_0+\rho_l gH)^{\frac{2}{5}}\,[\rho_0+\rho_l g(H-y)]^{\frac{3}{5}}}$

(c) $\rho_l nRgT_0\,\frac{(\rho_0+\rho_l gH)^{\frac{3}{5}}}{(\rho_0+\rho_l gy)^{\frac{8}{5}}}$ (d) $\frac{\rho_l nRgT_0}{(\rho_0+\rho_l gH)^{\frac{3}{5}}\,[\rho_0+\rho_l g\,(H-y)]^{\frac{2}{5}}}$

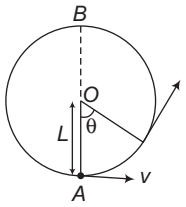
Paper 2

SECTION I

Straight Objective Type

This section contains 9 multiple choice questions. Each question has 4 choices (a), (b), (c), and (d), out of which **ONLY ONE** is correct.

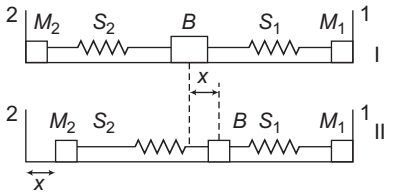
A bob of mass M is suspended by a massless string of length L. The horizontal velocity v at position A is just sufficient to make it reach the point B. The angle θ at which the speed of the bob is half of that at A, satisfies



(a) $\theta = \frac{\pi}{4}$ (b) $\frac{\pi}{4} < \theta < \frac{\pi}{2}$

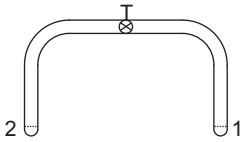
(c) $\frac{\pi}{2} < \theta < \frac{3\pi}{4}$ (d) $\frac{3\pi}{4} < \theta < \pi$

A block (B) is attached to two unstretched S_1 and S_2 with spring constants k and $4k$, respectively (see figure I). The other ends are attached to identical supports M_1 and M_2 not attached to the walls. The springs and supports have negligible mass. There is no friction anywhere. The block B is displaced towards wall 1 by a small distance x (figure II) and released. The block returns and moves a maximum distance y towards wall 2. Displacements x and y are measured with respect to the equilibrium position of the block B. The ratio $\frac{y}{x}$ is



(a) 4 (b) 2 (c) $\frac{1}{2}$ (d) $\frac{1}{4}$

A glass tube of uniform internal radius (r) has a valve separating the two identical ends. Initially, the valve is in a tightly closed position. End 1 has a hemispherical soap bubble of radius r. End 2 has sub-hemispherical soap bubble as shown in figure. Just after opening the valve,



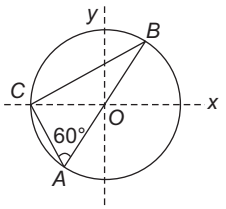
(a) air from end 1 flows towards end 2. No change in the volume of the soap bubbles

(b) air from end 1 flows towards end 2. Volume of the soap bubble at end 1 decreases

(c) no change occurs

(d) air from end 2 flows towards end 1. Volume of the soap bubble at end 1 increases

Consider a system of three charges $\frac{q}{3}$, $\frac{q}{3}$ and $-\frac{2q}{3}$ placed at points *A*, *B* and *C*, respectively, as shown in the figure. Take *O* to be the centre of the circle of radius *R* and angle *CAB* = 60°.



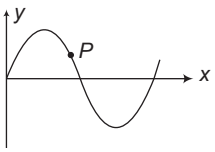
(a) The electric field at point *O* is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative *x*-axis

(b) The potential energy of the system is zero

(c) The magnitude of the force between the charges at *C* and *B* is $\frac{q^2}{54\pi\varepsilon_0 R^2}$

(d) The potential at point *O* is $\frac{q}{12\pi\varepsilon_0 R}$

A transverse sinusoidal wave moves along a string in the positive *x*-direction at a speed of 10 cm/s. The wavelength of the wave is 0.5 m and its amplitude is 10 cm. At a particular time *t*, the snap-shot of the wave is shown in figure. The velocity of point *P* when its displacement is 5 cm is



(a) $\frac{\sqrt{3}\pi}{50}\hat{\mathbf{j}}$ m/s (b) $-\frac{\sqrt{3}\pi}{50}\hat{\mathbf{j}}$ m/s (c) $\frac{\sqrt{3}\pi}{50}\hat{\mathbf{i}}$ m/s (d) $-\frac{\sqrt{3}\pi}{50}\hat{\mathbf{i}}$ m/s

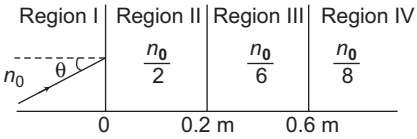
A radioactive sample S_1 having an activity of 5 μCi has twice the number of nuclei as another sample S_2 which has an activity of 10 μCi. The half lives of S_1 and S_2 can be

(a) 20 yr and 5 yr, respectively (b) 20 yr and 10 yr, respectively
(c) 10 yr each (d) 5 yr each

A vibrating string of certain length *l* under a tension *T* resonates with a mode corresponding to the first overtone (third harmonic) of an air column of length 75 cm inside a tube closed at one end. The string also generates 4 beat/s when excited along with a tuning fork of frequency *n*. Now when the tension of the string is slightly increased the number of beats reduces to 2 per second. Assuming the velocity of sound in air to be 340 m/s, the frequency *n* of the tuning fork (in Hz) is

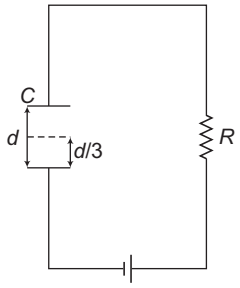
(a) 344 (b) 336 (c) 117.3 (d) 109.3

A light beam is travelling from Region I to Region IV (refer figure). The refractive index in Region I, II, III and IV are n_0, $\frac{n_0}{2}$, $\frac{n_0}{6}$ and $\frac{n_0}{8}$, respectively. The angle of incidence θ for which the beam just misses entering Region IV is



(a) $\sin^{-1}\left(\frac{3}{4}\right)$ (b) $\sin^{-1}\left(\frac{1}{8}\right)$ (c) $\sin^{-1}\left(\frac{1}{4}\right)$ (d) $\sin^{-1}\left(\frac{1}{3}\right)$

A parallel plate capacitor C with plates of unit area and separation d is filled with a liquid of dielectric constant $K = 2$. The level of liquid is $\frac{d}{3}$ initially. Suppose the liquid level decreases at a constant speed v, the time constant as a function of time t is



(a) $\frac{6\varepsilon_0 R}{5d + 3vt}$ (b) $\frac{(15d + 9vt)\varepsilon_0 R}{2d^2 - 3dvt - 9v^2t^2}$

(c) $\frac{6\varepsilon_0 R}{5d - 3vt}$ (d) $\frac{(15d - 9vt)\varepsilon_0 R}{2d^2 + 3dvt - 9v^2t^2}$

Section II

Assertion-Reason Type

This section contains 4 reasoning type questions. Each question has 4 choices (a), (b), (c) and (d), out of which **ONLY ONE** is correct.

(a) Statement 1 *is True, Statement* 2 *is True; Statement* 2 *is a correct explanation for Statement* 1.

(b) Statement 1 *is True, Statement* 2 *is True; Statement* 2 *is NOT a correct explanation for Statement* 1.

(c) Statement 1 *is True, Statement* 2 *is False.*

(d) Statement 1 *is False, Statement* 2 *is True.*

Statement 1 The sensitivity of a moving coil galvanometer is increased by placing a suitable magnetic material as a core inside the coil.

and **Statement 2** Soft iron has a high magnetic permeability and cannot be easily magnetized or demagnetized.

Statement 1 For an observer looking out through the window of a fast moving train, the nearby objects appear to move in the opposite direction to the train, while the distant objects appear to be stationary.

and **Statement 2** If the observer and the object are moving at velocities $\vec{\mathbf{v}}_1$ and $\vec{\mathbf{v}}_2$ respectively with reference to a laboratory frame, the velocity of the object with respect to the observer is $\vec{\mathbf{v}}_2 - \vec{\mathbf{v}}_1$.

Statement 1 It is easier to pull a heavy object than to push it on a level ground.

and **Statement 2** The magnitude of frictional force depends on the nature of the two surfaces in contact.

Statement 1 For practical purposes, the earth is used as a reference at zero potential in electrical circuits.

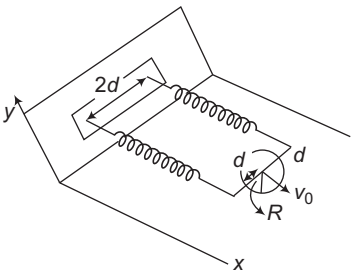
and **Statement 2** The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

Section III

Linked Comprehension Type

This section contains 2 paragraphs. 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 Question Nos. 14 to 16



A uniform thin cylindrical disk of mass M and radius R is attached to two identical massless springs of spring constant k which are fixed to the wall as shown in the figure. The springs are attached to the axle of the disk symmetrically on either side at a distance d from its centre. The axle is massless and both the springs and the axle are in a horizontal plane. The unstretched length of each spring is L. The disk is initially at its equilibrium position with its centre of mass (CM) at a distance L from the wall. The disk rolls without slipping with velocity $\mathbf{v}_0 = v_0\hat{\mathbf{i}}$. *The coefficient of friction is* μ.

The net external force acting on the disk when its centre of mass is at displacement x with respect to its equilibrium position is

(a) $-kx$ (b) $-2kx$ (c) $-\frac{2kx}{3}$ (d) $-\frac{4kx}{3}$

The centre of mass of the disk undergoes simple harmonic motion with angular frequency ω equal to

(a) $\sqrt{\frac{k}{M}}$ (b) $\sqrt{\frac{2k}{M}}$ (c) $\sqrt{\frac{2k}{3M}}$ (d) $\sqrt{\frac{4k}{3M}}$

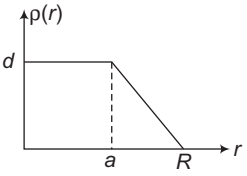
The maximum value of v_0 for which the disk will roll without slipping is

(a) $\mu g\sqrt{\frac{M}{k}}$ (b) $\mu g\sqrt{\frac{M}{2k}}$

(c) $\mu g\sqrt{\frac{3M}{k}}$ (d) $\mu g\sqrt{\frac{5M}{2k}}$

Paragraph for Question Nos. 17 to 19

The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density ρ(r) [charge per unit volume] is dependent only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction.



The electric field at $r = R$ is

(a) independent of a (b) directly proportional to a

(c) directly proportional to a^2 (d) inversely proportional to a

For $a = 0$, the value of d (maximum value of ρ as shown in the figure) is

(a) $\frac{3Ze}{4\pi R^3}$ (b) $\frac{3Ze}{\pi R^3}$ (c) $\frac{4Ze}{3\pi R^3}$ (d) $\frac{Ze}{3\pi R^3}$

The electric field within the nucleus is generally observed to be linearly dependent on r. This implies

(a) $a = 0$ (b) $a = \frac{R}{2}$ (c) $a = R$ (d) $a = \frac{2R}{3}$

Section IV

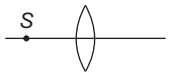
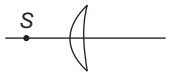
Matrix Match Type

This section contains 3 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 and s. The answers to these questions have to be appropriately bubbled as illustrated in the following example.

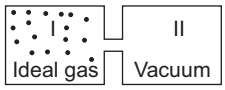
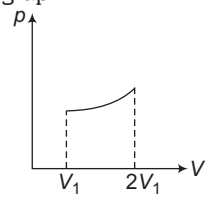
If the correct matches are A-q, A-r, B-p, B-s, C-r, C-s and D-q, then the correctly bubbled matrix will look like the following :

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

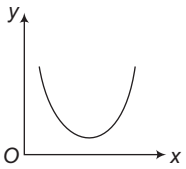
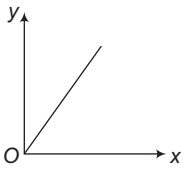
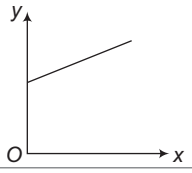
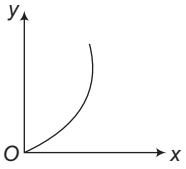
An optical component and an object S placed along its optic axis are given in Column I. The distance between the object and the component can be varied. The properties of images are given in Column II. Match all the properties of images from Column II with the appropriate components given in Column I. Indicate your answer by darkening the appropriate bubble of the 4×4 matrix given in the ORS.

	Column I		Column II
(A)		(p)	Real image
(B)		(q)	Virtual image
(C)		(r)	Magnified image
(D)		(s)	Image at infinity

. Column I contains a list of processes involving expansion of an ideal gas. Match this with Column II describing the thermodynamic change during this process. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

	Column I		Column II
(A)	An insulated container has two chambers separated by a valve. Chamber I contains an ideal gas and the Chamber II has vacuum. The valve is opened. 	(p)	The temperature of the gas decreases
(B)	An ideal monoatomic gas expands to twice its original volume such that its pressure $p \propto \frac{1}{V^2}$, where V is the volume of the gas.	(q)	The temperature of the gas increases or remains constant
(C)	An ideal monoatomic gas expands to twice its original volume such that is its pressure $p \propto \frac{1}{V^{4/3}}$ where V is its volume	(r)	The gas loses heat
(D)	An ideal monoatomic gas expands such that its pressure p and volume V follows the behaviour shown in the graph 	(s)	The gas gains heat

Column I gives a list of possible set of parameters measured in some experiments. The variations of the parameters in the form of graphs are shown in Column II. Match the set of parameters given in Column I with the graphs given in Column II. Indicate your answer by darkening the appropriate bubble of the 4 × 4 matrix given in the ORS.

	Column I		**Column II**
(A)	Potential energy of a simple pendulum (*y* axis) as a function of displacement (*x* axis)	(p)	
(B)	Displacement (*y* axis) as a function of time (*x* axis) for a one dimensional motion at zero or constant acceleration when the body is moving along the positive *x* direction.	(q)	
(C)	Range of a projectile (*y* axis) as a function of its velocity (*x* axis) when projected at a fixed angle	(r)	
(D)	The square of the time period (*y* axis) of a simple pendulum as a function of its length (*x* axis)	(s)	

ANSWER– Keys

Paper 1

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

Paper 2

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

20. (A)p, q, r, s (B) q (C) p, q, r, s (D) p, q, r, s

21. (A) *q* *(B) q, p* *(C) p, s* *(D) q, s*

21. (A) p or p, s (B) q, s or q, r, s (C) s (D) q

PAPER 1

1. $pT^2 = \text{constant}$

$\therefore \quad \left(\frac{nRT}{V}\right)T^2 = \text{constant}$

or $\quad T^3V^{-1} = \text{constant}$

Differentiating the equation, we get

$$\frac{3T^2}{V}\cdot dT - \frac{T^3}{V^2}\cdot dV = 0$$

or $$3\cdot dT = \frac{T}{V}\cdot dV \qquad \text{...(i)}$$

From the equation, $dV = V\gamma\cdot dT$

γ = coefficient of volume expansion of gas = $\frac{dV}{V\cdot dT}$

From Eq. (i) $\gamma = \frac{dV}{V\cdot dT} = \frac{3}{T}$

$\therefore$ correct answer is (c).

2. At minimum deviation ($\delta = \delta_m$):

$$r_1 = r_2 = \frac{A}{2} = \frac{60^\circ}{2} = 30^\circ \qquad \text{(For both colours)}$$

$\therefore$ correct answer is (a).

3. **For $r \le R$:**

$$\frac{mv^2}{r} = \frac{G\cdot mm'}{r^2} \qquad \text{...(i)}$$

Here, $m' = \left(\frac{4}{3}\pi r^3\right)\rho_0$

Substituting in Eq. (i) we get, $v \propto r$

i.e., $v - r$ graph is a straight line passing through origin.

For $r > R$:

$$\frac{mv^2}{r} = \frac{G\cdot m\left(\frac{4}{3}\pi R^3\right)\rho_0}{r^2}$$

or $$V \propto \frac{1}{\sqrt{r}}$$

The corresponding $v - r$ graph will be as shown in option (c).

$\therefore$ correct option is (c).

4. Cut-off wavelength depends on the applied voltage not on the atomic number of the target. Characteristic wavelengths depend on the atomic number of target.

5. $$T = 2\pi\sqrt{\frac{l}{g}} \qquad \text{or} \qquad \frac{t}{n} = 2\pi\sqrt{\frac{l}{g}}$$

$\therefore \quad g = \frac{(4\pi^2)(n^2)\,l}{t^2}$

$$\% \text{ error in } g = \frac{\Delta g}{g} \times 100 = \left(\frac{\Delta l}{l} + \frac{2 \cdot \Delta t}{t}\right) \times 100$$

$$E_{\text{I}} = \left(\frac{0.1}{64} + \frac{2 \times 0.1}{128}\right) \times 100 = 0.3125\%$$

$$E_{\text{II}} = \left(\frac{0.1}{64} + \frac{2 \times 0.1}{64}\right) \times 100 = 0.46875\% \quad E_{\text{III}} = \left(\frac{0.1}{20} + \frac{2 \times 0.1}{36}\right) \times 100 = 1.055\%$$

Hence, E_{I} is minimum.

$\therefore$ correct option is (b).

6. Applying $P = \frac{V^2}{R}$

$R_1 = 1\Omega, R_2 = 0.5\Omega$ and $R_3 = 2\Omega$, $V_1 = V_2 = V_3 = 3$ volt

$\therefore \quad P_1 = \frac{(3)^2}{1} = 9$ W

$P_2 = \frac{(3)^2}{0.5} = 18$ W and $P_3 = \frac{(3)^2}{2} = 4.5$ W

$\therefore \quad P_2 > P_1 > P_3$

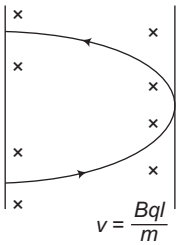
$\therefore$ correct option is (c).

7. $\vec{\mathbf{V}} \perp \vec{\mathbf{B}}$ in region II. Therefore, path of particle is circle in region II. Particle enters in region III if, radius of circular path, $r > l$

or $\frac{mv}{Bq} > 1$ or $v > \frac{Bql}{m}$

If $v = \frac{Bql}{m}, r = \frac{mv}{Bq} = l$, particle will turn back and path length will be maximum as shown in figure in region II. If particle returns to region I, time spent in region II will be

$t = \frac{T}{2} = \frac{\pi m}{Bq}$, which is independent of v.



$\therefore$ correct options are (a), (c) and (d).

8. For $d = \lambda$, there will be only one, acentral maxima.

For $\lambda < d < 2\lambda$, there will be three maximas on the screen corresponding to path difference, $\Delta x = 0$ and $\Delta x = \pm \lambda$.

correct options are (a) and (b).

9. Initial momentum of the system $\vec{\mathbf{p}}_1 + \vec{\mathbf{p}}_2 = 0$

$\therefore$ Final momentum $\vec{\mathbf{p}}_1' + \vec{\mathbf{p}}_2'$ should also be zero.

Option (b) is allowed because if we put $c_1 = -c_2 \neq 0$, $\vec{\mathbf{p}}_1' + \vec{\mathbf{p}}_2'$ will be zero. Similarly, we can check other options.

$\therefore$ correct options are (a) and (d).

10. In fusion two or more lighter nuclei combine to make a comparatively heavier nucleus. In fission, a heavy nucleus breaks into two or more comparatively lighter nuclei.
Futher, energy will be released in a nuclear process if total binding energy increases.

$\therefore$ correct options are (b) and (d).

11. Force acting on astronaut is utilised in providing necessary centripetal force; thus he feels weightlessness or he is in a state of free fall.

$\therefore$ correct option is (a)

12. In case of pure rolling on inclined plane,

$$a = \frac{g \sin\theta}{1 + I / mR^2}$$

$$I_{solid} < I_{hollow}$$

$\therefore$ $a_{solid} > a_{hollow}$

$\therefore$ solid cylinder will reach the bottom first.

Further, in case of pure rolling on stationary ground, work done by friction is zero. Therefore, mechanical energy of both the cylinders will remain constant.

$\therefore$ $(KE)_{Hollow} = (KE)_{solid}$ = decrease in PE = mgh

$\therefore$ correct option is (d)

13. From continuity equation,

$$Av = \text{constant or } A \propto \frac{1}{v}$$

At lower heights, speed will be more. Therefore, area of cross-section will be less.

$\therefore$ correct option is (a).

14. With increase in temperature, the value of unknown resistance will increase.

In balanced Wheatstone bridge condition, $\frac{R}{X} = \frac{l_1}{l_2}$

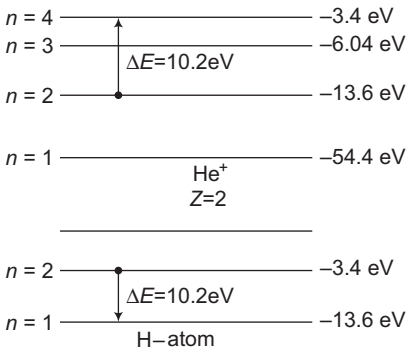
Here, R = value of standard resistance,

X = value of unknown resistance.

To take null point at same point or $\frac{l_1}{l_2}$ to remain unchanged, $\frac{R}{X}$ should also remain unchanged. Therefore, if X is increasing R should also increase.

$\therefore$ correct option is (d).

15.



Energy given by H-atom in transition from $n = 2$ to $n = 1$ is equal to energy taken by He^+ atom in transition from $n = 2$ to $n = 4$.

$\therefore$ correct option is (c).

16. Visible light lies in the range, $\lambda_1 = 4000$ Å to $\lambda_2 = 7000$ Å.

Energy of photons corresponding to these wavelengths (in eV) would be;

$$E_1 = \frac{12375}{4000} = 3.09 \text{ eV}$$

$$E_2 = \frac{12375}{7000} = 1.77 \text{ eV}$$

From energy level diagram of He^+ atom we can see that in transition from $n = 4$ to $n = 3$, energy of photon released will lie between E_1 and E_2.

$\Delta E_{43} = -3.4 - (-6.04) = 2.64$ eV

Wavelength of photon corresponding to this energy.

$$\lambda = \frac{12375}{2.64} \text{ Å} = 4687.5 \text{ Å} = 4.68 \times 10^{-7} \text{ m}$$

Therefore, (c) is the most correct option.

17. Kinetic energy $K \propto Z^2$

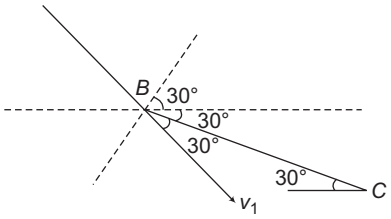
$$\frac{K_H}{K_{He^+}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

$\therefore$ correct option is (a).

18. Between A and B, height fallen by block $h_1 = \sqrt{3} \tan 60° = 3$ m.

$\therefore$ speed of block just before striking the second incline,

$$v_1 = \sqrt{2gh_1} = \sqrt{2 \times 10 \times 3} = \sqrt{60} \text{ ms}^{-1}$$



In perfectly inelastic collision, component of v_1 perpendicular to BC will become zero, while component of v_1 parallel to BC will remain unchanged.

$\therefore$ speed of block B immediately after it strikes the incline is,

$$v_2 = \text{component of } v_1 \text{ along } BC$$
$$= v_1 \cos 30°$$
$$= (\sqrt{60})\left(\frac{\sqrt{3}}{2}\right) = \sqrt{45} \text{ ms}^{-1}$$

$\therefore$ correct option is (b)

19. Height fallen by the block from B to C.

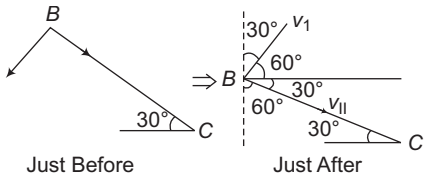
$$h_2 = 3\sqrt{3} \tan 30° = 3\text{m}$$

Let v_3 be the speed of block, at point C, just before it leaves the second incline, then

$$v_3 = \sqrt{v_2^2 + 2gh_2}$$
$$= \sqrt{45 + 2 \times 10 \times 3}$$
$$= \sqrt{105} \text{ ms}^{-1}$$

$\therefore$ correct option is (b).

20. In elastic collision, component of v_1 parallel to BC will remain unchanged, while component perpendicular to BC will remain unchanged in magnitude but its direction will be reversed.



$$v_{\|} = v_1 \cos 30° = (\sqrt{60})\left(\frac{\sqrt{3}}{2}\right) = \sqrt{45}\ \text{ms}^{-1}$$

$$v_{\perp} = v_1 \sin 30° = (\sqrt{60})\left(\frac{1}{2}\right) = \sqrt{15}\ \text{ms}^{-1}$$

Now vertical component of velocity of block :

$$v = v_{\perp}\cos 30° - v_{\|}\cos 60°$$
$$= (\sqrt{15})\left(\frac{\sqrt{3}}{2}\right) - (\sqrt{45})\left(\frac{1}{2}\right) = 0$$

$\therefore$ correct option is (c).

21. As the bubble moves upwards, besides the buoyancy force (cause of which is pressure difference) only force of gravity and force of viscosity will act.

$\therefore$ correct otion is (d).

22. As there is no exchange of heat. Therefore, process is adiabatic. Applying,

$$T\,p^{\frac{1-\gamma}{\gamma}} = \text{constant}$$

$\therefore$ $$T_2\,p_2^{\frac{1-\gamma}{\gamma}} = T_1 p_1^{\frac{1-\gamma}{\gamma}}$$

or $$T_2 = T_1\left(\frac{p_1}{p_2}\right)^{\frac{1-\gamma}{\gamma}} = T_1\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

Substituting the values we have,

$$T_2 = T_0\left[\frac{p_0 + \rho lg\,(H-y)^T}{p_0 + \rho\, lg\, H}\right]^{\frac{5/3-1}{5/3}}$$

$$= T_0\left[\frac{p_0 + \rho lg(H-y)}{p_0 + \rho lgH}\right]^{2/5}$$

$\therefore$ correct option is (b).

23. Buoyancy force F = (volume of bubble) $(\rho_l)\, g$

$$= \left(\frac{nRT_2}{p_2}\right) p_l g$$

Here, $$T_2 = T_0\left[\frac{p_0 + p_l g\,(H-y)}{p_0 + \rho_l gH}\right]$$

and $$p_2 = p_0 + p_l(H-y)$$

Substituting the values we get,

$$F = \frac{\rho_l nRgT_0}{(p_0 + \rho_l gH)^{2/5}\,[p_0 + \rho_l g\,(H - y)]^{3/5}}$$

$\therefore$ correct option is (b).

PAPER 2

1. $v = \sqrt{5gL}$ ... (i)

$$\left(\frac{v}{2}\right)^2 = v^2 - 2gh \quad \text{... (ii)}$$

$$h = L(1 - \cos\theta) \quad \text{... (iii)}$$

Solving Eqs. (i), (ii) and (iii) we get,

$$\cos\theta = -\frac{7}{8} \qquad \text{or } \theta = \cos^{-1}\left(-\frac{7}{8}\right) = 151°$$

$\therefore$ correct option is (d).

2. From energy conservation,

$$\frac{1}{2}kx^2 = \frac{1}{2}(4k)y^2$$

$$\frac{y}{x} = \frac{1}{2}$$

$\therefore$ correct option is (c).

3. $\Delta p_1 = \frac{4T}{r_1}$ and $\Delta p_2 = \frac{4T}{r_2}$

$$r_1 < r_2$$

$\therefore$ $$\Delta p_1 > \Delta p_2$$

Air will flow from 1 to 2 and volume of bubble at end-1 will decrease.

Therefore, correct option is (b).

4. Distance $BC = AB \sin 60° = (2R)\frac{\sqrt{3}}{2} = \sqrt{3}R$

$\therefore$ $|F_{BC}| = \frac{1}{4\pi\varepsilon_0}\frac{(q/3)(2q/3)}{(\sqrt{3}R)^2} = \frac{q^2}{54\pi\varepsilon_0 R^2}$

$\therefore$ correct option is (c).

5. Particle velocity $v_p = -v$ (slope of y–x graph)

Here, $v = +ve$, as the wave is travelling in positive x-direction.

Slope at P is negative.

$\therefore$ Velocity of particle is in positive $y(+\vec{j})$ direction.

$\therefore$ correct option is (a).

6. Activity of $S_1 = \frac{1}{2}$ (activity of S_2)

or $$\lambda_2 N_1 = \frac{1}{2}(\lambda_2 N_2) \text{ or } \frac{\lambda_1}{\lambda_2} = \frac{N_2}{2N_1}$$

or $$\frac{T_1}{T_2} = \frac{2N_1}{N_2}\left(T = \text{half-life} = \frac{\ln 2}{\lambda}\right)$$

Given $$N_1 = 2N_2$$

$\therefore$ $$\frac{T_1}{T_2} = 4$$

$\therefore$ correct option is (a).

7. With increase in tension, frequency of vibrating string will increase. Since number of beats are decreasing. Therefore, frequency of vibrating string or third harmonic frequency of closed pipe should be less than the frequency of tuning fork by 4.

$\therefore$ Frequency of tuning fork = Third harmonic frequency of closed pipe + 4

$$= 3\left(\frac{v}{4l}\right) + 4 = 3\left(\frac{340}{4 \times 0.75}\right) + 4 = 344 \text{ Hz.}$$

$\therefore$ correct option is (a).

8. Critical angle from region III to region IV

$$\sin\theta_c = \frac{n_0/8}{n_0/6} = \frac{3}{4}$$

Now applying Snell's law in region I and region III :

$$n_0 \sin\theta = \frac{n_0}{6}\sin\theta_c$$

or $$\sin\theta = \frac{1}{6}\sin\theta_c = \frac{1}{6}\left(\frac{3}{4}\right) = \frac{1}{8}$$

$\therefore$ $$\theta = \sin^{-1}\left(\frac{1}{8}\right)$$

$\therefore$ correct option is (b).

9. After time t, thickness of liquid will remain $\left(\frac{d}{3} - vt\right)$.

Now, time constant as function of time

$\tau_c = CR$

$$= \frac{\varepsilon_0(1)\cdot R}{\left(d - \frac{d}{3} + vt\right) + \frac{d/3 - vt}{2}} \qquad \left(\text{Applying } C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}}\right)$$

$$= \frac{6\varepsilon_0 R}{5d + 3vt}$$

$\therefore$ correct option is (a).

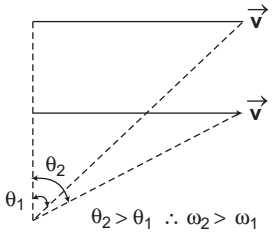
10. $c\phi = BINA$

$\therefore$ $$\phi = \left(\frac{BNA}{c}\right) I$$

Using iron core, value of magnetic field increases. So, deflection increases for same current. Hence, sensitivity increases. Soft iron can be easily magnetized or demagnetized.

$\therefore$ correct option is (c).

11.



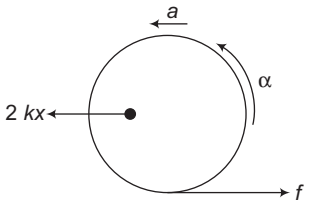
Statement-2, is formula of relative velocity. But it does not explain statement-1 correctly. The correct explanation of statement-1 is due to visual perception of motion. The object appears to be moving faster, when its angular velocity is greater *w.r.t* observer.

∴ correct answer is (b).

12. Both statements are correct. But statement-2, does not explain correctly, statement-1. Correct explanation is : ''There is increase in normal reaction when the object is pushed and there is decrease in normal reaction when the object is pulled (but strictly not horizontally).

13. No solution is required.

14.



$a = R\alpha$

$$\therefore \quad \frac{2kx - f}{M} = R\left[\frac{f \cdot R}{\frac{1}{2}MR^2}\right]$$

Solving this equation, we get $f = \frac{2kx}{3}$

$$\therefore \quad |F_{net}| = 2kx - f = 2kx - \frac{2kx}{3} = \frac{4kx}{3}$$

This is opposite to displacement.

$$\therefore \quad F_{net} = -\frac{4kx}{3}$$

∴ correct option is (d).

15. $F_{net} = -\left(\frac{4k}{3}\right) \cdot x$

$$\therefore \quad a = \frac{F_{net}}{M} = -\left(\frac{4k}{3M}\right) x = -\omega^2 x$$

$$\therefore \omega = \sqrt{\frac{4k}{3M}}$$

∴ correct option is (d).

16. In case of pure rolling, mechanical energy will remain conserved.

$$\therefore \quad \frac{1}{2}Mv_0^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\left(\frac{v_0}{R}\right)^2 = 2\left[\frac{1}{2}kx_{max}^2\right]$$

$$\therefore \quad x_{max} = \sqrt{\frac{3M}{4k}}v_0$$

As $$f = \frac{2kx}{3}$$

$$f_{max} = \mu Mg = \frac{2kx_{max}}{3} = \frac{2k}{3}\sqrt{\frac{3M}{4k}}v_0$$

$$\therefore \quad v_0 = \mu g\sqrt{\frac{3M}{k}}$$

$\therefore$ correct option is (c).

17. At $r = R$, from Gauss's law

$$E(4\pi R^2) = \frac{q_{net}}{\varepsilon_0} = \frac{Ze}{\varepsilon_0}$$

or $$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze}{R^2}$$

E is independent of 'a'

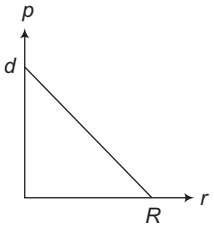
$\therefore$ correct option is (a).

18. For $a = 0$

$$\rho(r) = \left(-\frac{d}{R}\cdot r + d\right)$$

Now $\int_0^R (4\pi r^2)\left(d - \frac{d}{R}r\right)dr$ = net charge = Ze

Solving this equation, we get $d = \frac{3Ze}{\pi R^3}$



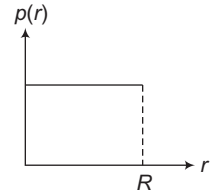
19. In case of solid sphere of charge of uniform volume density.

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^3}\cdot r \text{ or } E \propto r$$

Thus, for E to be linearly dependent on r, volume charge density should be constant.

or $a = R$

$\therefore$ correct option is (c).



20. (A) : (C) and (D) : In case of concave mirror or convex lens image can be real, virtual, diminished magnified or of same size. (B) : In case of convex mirror image is always virtual (for real object)

21. (A) : In case of free expansion under adiabatic conditions, change in internal energy $\Delta U = 0$.

$\therefore$ Internal energy and temperature will remain constant.

(B) $p \propto \frac{1}{v^2}$

$\therefore \quad pV^2 = \text{constant}$ … (i)

or $\left(\frac{nRT}{V}\right)V^2 = \text{constant}$ … (ii)

$\therefore \quad T \propto \frac{1}{V}$

If volume is doubled, temperature will decrease as per Eq. (ii).

Further, molar heat capacity in process $pV^x =$ constant is

$$C = C_V + \frac{R}{1-x}$$

From Eq. (i), $x = 2$

$\therefore$ $$C = \frac{3}{2}R + \frac{R}{1-2} = +\frac{R}{2}$$

Since molar heat capacity is positive, according to $Q = nC\Delta T$, Q will be negative it ΔT is negative. Or gas loses heat if temperature is decreasing.

(C) : $$p \propto \frac{1}{V^{1/3}}$$

$$PV^{4/3} = \text{constant}$$

$$\left(\frac{nRT}{V}\right)V^{4/3} = \text{constant}$$

$$T \propto \frac{1}{V^{1/3}}$$

Further, with increase in volume temperature will decrease.

Here, $x = 4/3$

$\therefore$ $$C = \frac{3}{2}R + \frac{R}{1-4/3} = -1.5\,R$$

As molar heat capacity is negative, Q will be positive, if ΔT is negative or gas gains heat with decrease in temperature.

(D) $T \propto pV$

In expansion from V_1 or $2V_1$, product of pV is increasing. Therefore, temperature will increase or $\Delta U = +$ ve.

Further, in expansion work done is also positive.

Hence, $Q = W + \Delta U = +$ ve

or gas gains heat.

22. (A) Potential energy is minimum at mean position.

(B) For $a = 0$, $s = vt \longrightarrow$ option (q)

or $\quad s = s_0 + vt \longrightarrow$ option (r)

For $a =$ constant,

$$s = ut + \frac{1}{2}at^2 \longrightarrow \text{option } (s)$$

(C) $R = \frac{v^2 \sin 2\theta}{g} \therefore \; R \propto v^2 \longrightarrow$ option (s)

(D) $T = 2\pi\sqrt{\frac{l}{g}} \; \therefore T^2 \propto l \longrightarrow$ option (q)