Chemistry

General Instructions:

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

  Full Marks   : +3 If **ONLY** the correct option is chosen;

  Zero Marks   : 0 If none of the options is chosen (i.e. the question is unanswered);

  Negative Marks : −1 In all other cases.

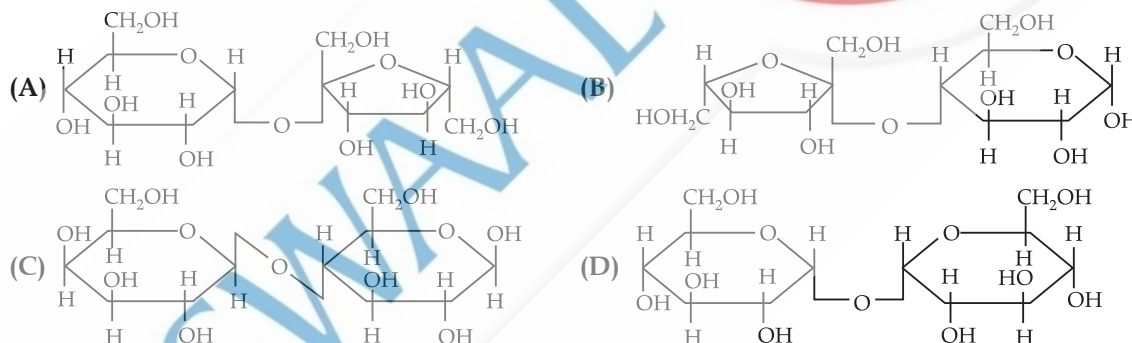**Q. 1.** The correct molecular orbital diagram for F2 molecule in the ground state is
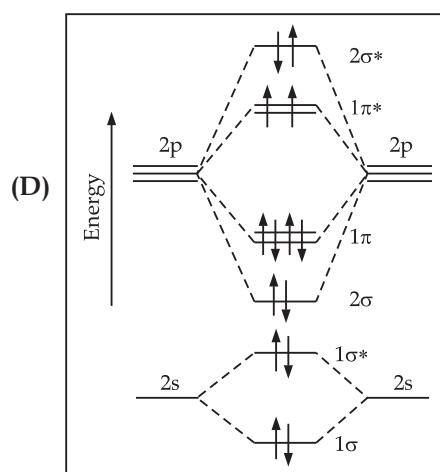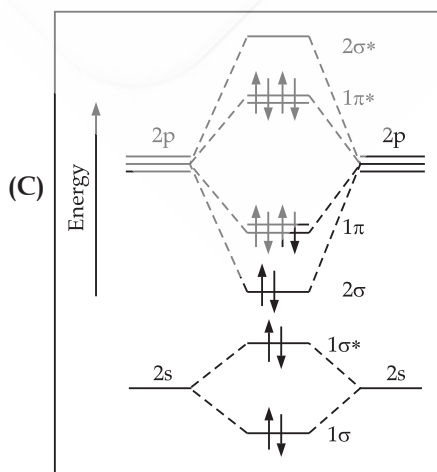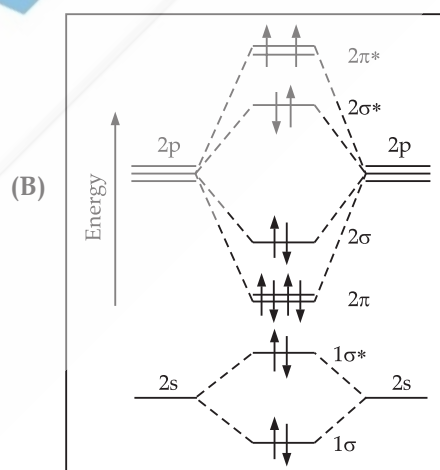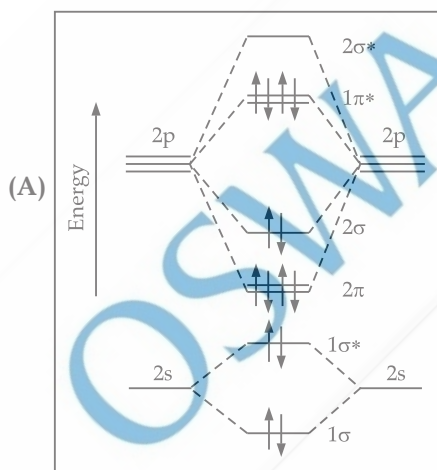
Q. 2. Consider the following statements related to colloids.

(I) Lyophobic colloids are not formed by simple mixing of dispersed phase and dispersion medium.

(II) For emulsions, both the dispersed phase and the dispersion medium are liquid.

(III) Micelles are produced by dissolving a surfactant in any solvent at any temperature.

(IV) Tyndall effect can be observed from a colloidal solution with dispersed phase having the same refractive index as that of the dispersion medium.

The option with the correct set of statements is

(A) (I) and (II)　　　　**(B)** (II) and (III)

(C) (III) and (IV)　　　**(D)** (II) and (IV)

Q. 3. In the following reactions, P, Q, R, and S are the major products.

The correct statement about P, Q, R, and S is

(A) P is a primary alcohol with four carbons.

(B) Q undergoes Kolbe's electrolysis to give an eight-carbon product.

(C) R has six carbons and it undergoes Cannizzaro reaction.

(D) S is a primary amine with six carbons.

Q. 4. A disaccharide X cannot be oxidised by bromine water. The acid hydrolysis of X leads to a laevorotatory solution. The disaccharide X is

General Instructions:

SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 ONLY if (all) the correct option(s) is(are) chosen;

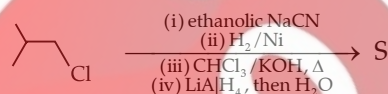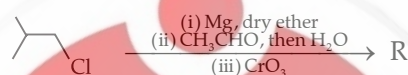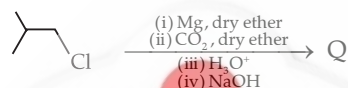*Partial Marks* : +3 If all the four options are correct but ONLY three options are chosen;
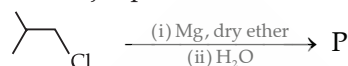
Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;

Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option;

Zero Marks : 0 If unanswered;

Negative Marks : −2 In all other cases.

- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to correct answers, then

  choosing ONLY (A), (B) and (D) will get +4 marks;

  choosing ONLY (A) and (B) will get +2 marks;

  choosing ONLY (A) and (D) will get +2 marks;

  choosing ONLY (B) and (D) will get +2 marks;

  choosing ONLY (A) will get +1 mark;

  choosing ONLY (B) will get +1 mark;

  choosing ONLY (D) will get +1 mark;

  choosing no option(s) (i.e. the question is unanswered) will get 0 marks and

  choosing any other option(s) will get −2 marks.

Q. 5. The complex(es), which can exhibit the type of isomerism shown by $[Pt(NH_3)2Br_2]$, is(are)

[en = $H_2NCH_2CH_2NH_2$]

(A) $[Pt(en)(SCN)_2]$

(B) $[Zn(NH_3)_2Cl_2]$

(C) $[Pt(NH_3)_2Cl_4]$

(D) $[Cr(en)_2(H_2O)(SO_4)]^+$
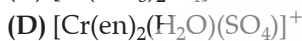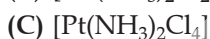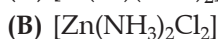
Q. 6. Atoms of metals x, y, and z form face-centred cubic (fcc) unit cell of edge length L_x, body-centred cubic (bcc) unit cell of edge length L_y, and simple cubic unit cell of edge length L_z, respectively.

If $r_z = \dfrac{\sqrt{3}}{2} r_y$; $r_y = \dfrac{8}{\sqrt{3}} r_x$; $M_z = \dfrac{3}{2} M_y$ and $M_Z = 3M_x$, then the correct statement(s) is(are)

[Given: M_x, M_y, and M_z are molar masses of metals x, y, and z, respectively.

r_x, r_y, and r_z are atomic radii of metals x, y, and z, respectively.]

(A) Packing efficiency of unit cell of $x>$ Packing efficiency of unit cell of $y>$ Packing efficiency of unit cell of z

(B) $L_y > L_z$

(C) $L_x > L_y$

(D) Density of $x >$ Density of y

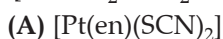**Q. 7.** In the following reactions, P, Q, R, and S are the major products.
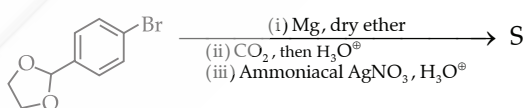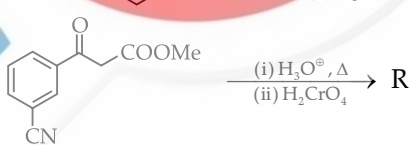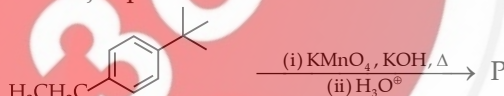
The correct statement(s) about P, Q, R, and S is(are)

(A) P and Q are monomers of polymers dacron and glyptal, respectively.

(B) P, Q, and R are dicarboxylic acids.

(C) Compounds Q and R are the same.

(D) R does not undergo aldol condensation and S does not undergo Cannizzaro reaction.

General Instructions:

SECTION 3 (Maximum Marks: 24)

- This section contains **SIX (06)** questions.
- The answer to each question is a **NON-NEGATIVE INTEGER**.
- For each question, enter the correct integer corresponding to the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated <u>according</u> to the following marking scheme:

Full Marks : +4 If **ONLY** the correct integer is entered;

Zero Marks : 0 In all other cases.

Q. 8. H_2S (5 moles) reacts completely with acidified aqueous potassium permanganate solution. In this reaction, the number of moles of water produced is x, and the number of moles of electrons involved is y. The value of $(x + y)$ is ____.

Q. 9. Among $[I_3]^+$, $[SiO_4]^{4-}$, SO_2Cl_2, XeF_2, SF_4, ClF_3, $Ni(CO)_4$, XeO_2F_2, $[PtCl_4]^{2-}$, XeF_4, and $SOCl_2$, the total number of species having sp^3 hybridised central atom is _____.

Q. 10. Consider the following molecules: Br_3O_8, F_2O, $H_2S_4O_6$, $H_2S_5O_6$, and C_3O_2. Count the number of atoms existing in their zero oxidation state in each molecule.

Their sum is____.

Q. 11. For He^+, a transition takes place from the orbit of radius 105.8 pm to the orbit of radius 26.45 pm. The wavelength (in nm) of the emitted photon during the transition is _____.

[Use:

Bohr radius, a = 52.9 pm

Rydberg constant, $R_H = 2.2 \times 10^{-18}$ J

Planck's constant, h = 6.6×10^{-34} J s

Speed of light, c = 3×10^8 m s^{-1}]

Q. 12. 50 mL of 0.2 molal urea solution (density = 1.012 g mL^{-1} at 300 K) is mixed with 250 mL of a solution containing 0.06 g of urea. Both the solutions were prepared in the same solvent. The osmotic pressure (in Torr) of the resulting solution at 300 K is _____.

[Use: Molar mass of urea = 60 g mol^{-1}; gas constant, R = 62 L Torr K^{-1} mol^{-1}; Assume, $\Delta_{mix}H = 0$, $\Delta_{mix}V = 0$]

Q. 13. The reaction of 4-methyloct-1-ene (P, 2.52 g) with HBr in the presence of $(C_6H_5CO)_2O_2$ gives two isomeric bromides in a 9 : 1 ratio, with a combined yield of 50%. Of these, the entire amount of the primary alkyl bromide was reacted with an appropriate amount of diethylamine followed by treatment with aq. K_2CO_3 to give a non-ionic product S in 100% yield.

The mass (in mg) of S obtained is _____.

[Use molar mass (in g mol^{-1}): H = 1, C = 12, N = 14, Br = 80]

General Instructions:

SECTION 4 (Maximum Marks: 12)

- This section contains **TWO (02)** paragraphs.
- Based on each paragraph, there are **TWO (02)** questions.
- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value of the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:
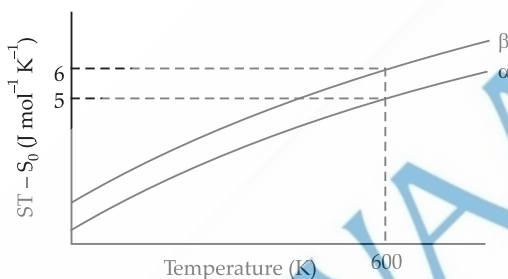
  Full Marks   : +3 If ONLY the correct numerical value is entered in the designated place;

  Zero Marks   :   0 In all other cases.

"PARAGRAPH I"

The entropy versus temperature plot for phases α and β at 1 bar pressure is given.

S_T and S_0 are entropies of the phases at temperatures T and 0 K, respectively.

The transition temperature for α to β phase change is 600 K and $C_{p,\beta} - C_{p,\alpha} = 1$ J mol^{-1} K^{-1}. Assume $(C_{p,\beta} - C_{p,\alpha})$ is independent of temperature in the range of 200 to 700 K. $C_{p,\alpha}$ and $C_{p,\beta}$ are heat capacities of α and β phases, respectively.

Q. 14. The value of entropy change, $S_\beta - S_\alpha$ (in J mol^{-1} K^{-1}), at 300 K is ___.

[Use: ln 2 = 0.69

Given: $S_\beta - S_\alpha = 0$ at 0 K]

Q. 15. The value of enthalpy change, $H_\beta - H_\alpha$ (in J mol^{-1}), at 300 K is ___.

"PARAGRAPH II"

A trinitro compound, 1, 3, 5-tris-(4-nitrophenyl) benzene, on complete reaction with an excess of Sn/HCl gives a major product, which on treatment with an excess of NaNO$_2$/HCl at 0°C provides **P** as the product. P, upon treatment with excess of H$_2$O at room temperature, gives the product **Q**. Bromination of Q in aqueous medium furnishes the product **R**. The compound P upon treatment with an excess of phenol under basic conditions gives the product **S**.

The molar mass difference between compounds Q and R is 474 g mol^{-1} and between compounds P and S is 172.5 g mol^{-1}.

Q. 16. The number of heteroatoms present in one molecule of R is _____ .

[Use: Molar mass (in g mol^{-1}): H = 1, C = 12, N = 14, O = 16, Br = 80, Cl = 35.5

Atoms other than C and H are considered as heteroatoms]

Q. 17. The total number of carbon atoms and heteroatoms present in one molecule of S is _____ .

[Use: Molar mass (in g mol^{-1}): H = 1, C = 12, N = 14, O = 16, Br = 80, Cl = 35.5

Atoms other than C and H are considered as heteroatoms]

Answer Key

Q.No.	Answer key	Topic's name	Chapter's name
Section -I			
1.	(C)	Molecular Orbital Theory	Chemical Bonding And Molecular Structure
2.	(A)	Colloids	Surface Chemistry
3.	(B)	Grignard Reagent	Haloalkanes and Haloarenes
4.	(A)	Carbohydrates	Biomolecules
Section -II			
5.	(C, D)	Isomerism	Coordination Compounds
6.	(A, B and D)	Packing efficiency And Density	Solid State
7.	(C, D)	Preparation of Carboxylic Acids	Organic Chemistry
Section -III			
8.	18	Reaction of $KMnO_4$	D and F Block Element
9.	5	VSEPR Theory	Chemical Bonding And Molecular Structure
10.	6	Oxidation State	Redox Reactions
11.	30	Wavelength on Transition	Structure Of Atom
12.	682	Osmotic Pressure	Solutions
13.	1791	More Concepts and Chemical Properties of alkenes	Organic chemistry
Section -IV			
14.	0.31	Enthalpy Change	Thermodynamics
15.	300	Kirchhoff's law	Thermodynamics
16.	9	Chemical Reactions	Organic Compounds With Nitrogen
17.	51	Chemical Reactions	Organic Compounds With Nitrogen

ANSWERS WITH EXPLANATIONS

Chemistry

1. Correct option is (C).

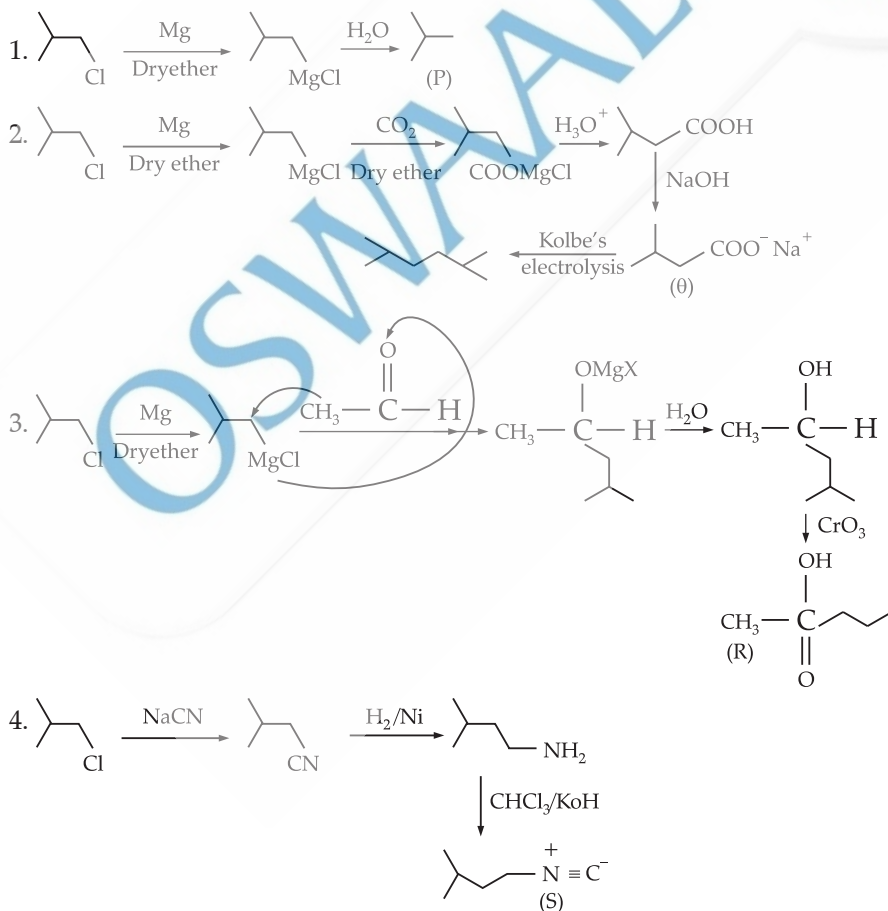Molecular orbital electronic configuration of F_2 molecule is

$$F_2 = KK\sigma(2S)^2, \sigma^*(2S)^2, \sigma(2p_z)^2, \pi(2p_x)^2$$

$$= (\pi 2p_y)^2, \pi^*(2p_x)^2 = \pi^*(2p_y)^2$$

2. Correct option is (A).

(I) Lyophobic colloids are not formed by simple mixing of dispersed phase and dispersion medium.

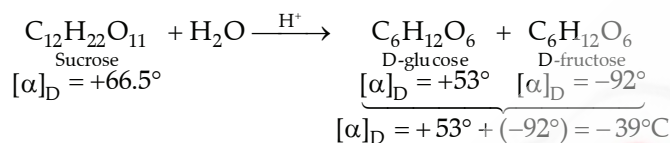(II) For emulsion, both the dispersed phase and dispersion medium are liquid.

3. Correct option is (B).

4. Correct option is (A).

Option (A) is sucrose which is formed by condensation of glucose and fructose.

• Fructose cannot be oxidised by bromine water. Therefore, sucrose cannot be oxidised by bromine water.

$$\underset{\substack{\text{Sucrose}\\ [\alpha]_D = +66.5°}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\substack{\text{D-glucose}\\ [\alpha]_D = +53°}}{C_6H_{12}O_6} + \underset{\substack{\text{D-fructose}\\ [\alpha]_D = -92°}}{C_6H_{12}O_6}$$

$$\underbrace{[\alpha]_D = +53° + (-92°)}_{} = -39°C$$

∴ Resulting mixture is laevorstatory.

5. Correct options are (C and D).

• $[Pt(NH_3)_2Br_2]$ exhibits cis-trans (Geometric) isomers

• (D) $[M(AA)_2ab]$ and (C) $[Ma_2 b_4]$ can exhibit geometric isomers

6. Correct options are (A, B and D).

Packing efficiency

$$\text{P.E. for FCC} = \frac{4 \times \frac{4}{3}\pi r_x^3}{(L_x)^3} = \frac{4 \times \frac{4}{3}\pi r_x^3}{(4r_x/\sqrt{2})^3}$$

$$\text{BCC, P.E.} = \frac{2 \times \frac{4}{3}\pi r_y^3}{(L_y)^3} = \frac{2 \times \frac{4}{3}\pi r_y^3}{(4r_y/\sqrt{3})^3}$$

$$\text{SC, P.E.} = \frac{1 \times \frac{4}{3}\pi r_z^3}{(L_z)^3} = \frac{1 \times \frac{4}{3}\pi r_z^3}{(2r_z)^3}$$

P.E. FCC : BCC : SC

$$\frac{4 \times (\sqrt{2})^3}{(4)^3} : \frac{4 \times (\sqrt{3})^3}{(4)^3} : \frac{1}{(2)^3}$$

$$\frac{2\sqrt{2}}{16} : \frac{2 \times 3 \times \sqrt{3}}{16} : \frac{1}{8}$$

$$8\sqrt{2} : 6\sqrt{3} : 8$$

11.3 : 10.39 : 8

∴ $(\text{P.E.})_x > (\text{P.E.})_y > (\text{P.E.})_z$

So, the option (A) is correct.

$$L_x = \frac{4r_x}{\sqrt{2}}, L_y = \frac{4r_y}{\sqrt{3}}, L_z = 2r_z$$

$$L_x < L_y$$

$$\frac{L_x}{L_y} = \frac{r_x}{r_y} \times \frac{\sqrt{3}}{\sqrt{2}} = \frac{\sqrt{3}}{8} \times \frac{\sqrt{3}}{2} = \frac{3}{8\sqrt{2}}$$

$$L_y = \frac{4r_y}{\sqrt{3}}, L_z = 2r_z$$

∴ $$\frac{L_y}{L_z} = \frac{2r_y}{r_2\sqrt{3}} = \frac{2}{\sqrt{3}} \times \frac{r_y}{r_2} = \frac{3}{\sqrt{3}} = \frac{1}{1}$$

∴ $$\frac{L_y}{L_z} = \frac{2}{\sqrt{3}} \times \frac{3}{\sqrt{3}} = \frac{4}{3}$$

$$L_y = \frac{4}{3}L_z$$

∴ $$L_y > L_z$$

$$(\text{Density})_x = d_x = \frac{4M_x}{N_A(L_x)^3}$$
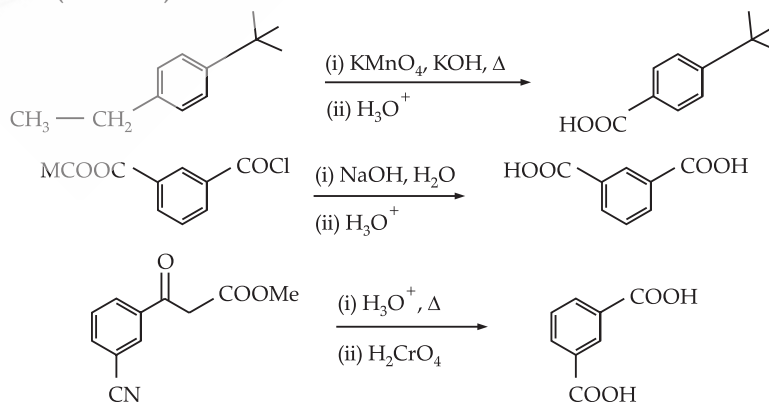
$$d_y = \frac{2M_y}{N_A(L_y)^3}$$

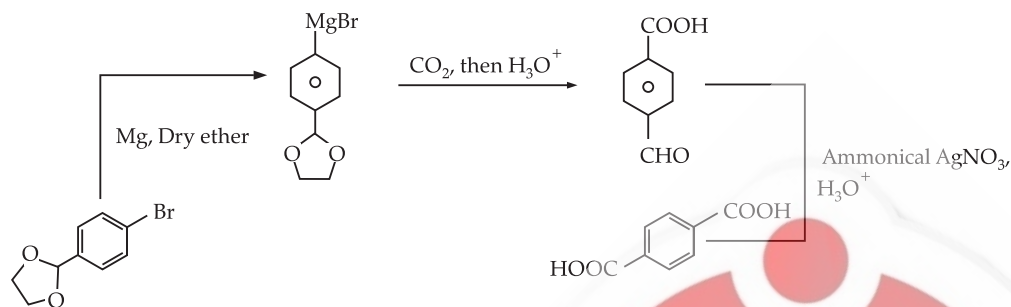$$\frac{d_x}{d_y} = \frac{2M_x}{M_y} \cdot \left(\frac{L_y}{L_x}\right)^3$$

$$= 2 \times \frac{1}{2} \times \left(\frac{8\sqrt{2}}{3}\right)^3$$
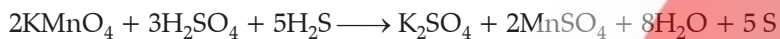
So $d_x > d_y$

So, the options (B and D) are correct.

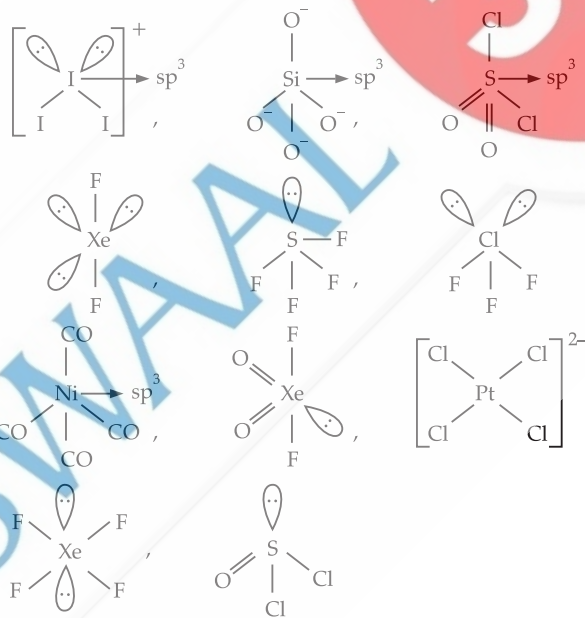**7. Correct options are (C and D).**

8. Correct answer is [18].

$$2KMnO_4 + 3H_2SO_4 + 5H_2S \longrightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5\,S$$

No. of moles of water produced, $x = 8$

No. of moles of electrons involved, $y = 10$

$$x + y = 8 + 10 = 18$$

9. Correct answer is [5].

$[I_3]^+$, $[SiO_4]^{4-}$, SO_2Cl_2, $Ni(CO)_4$, $SOCl_2$

10. Correct answer is [6].

2 Sulphur   2 Sulphur   1 Carbon
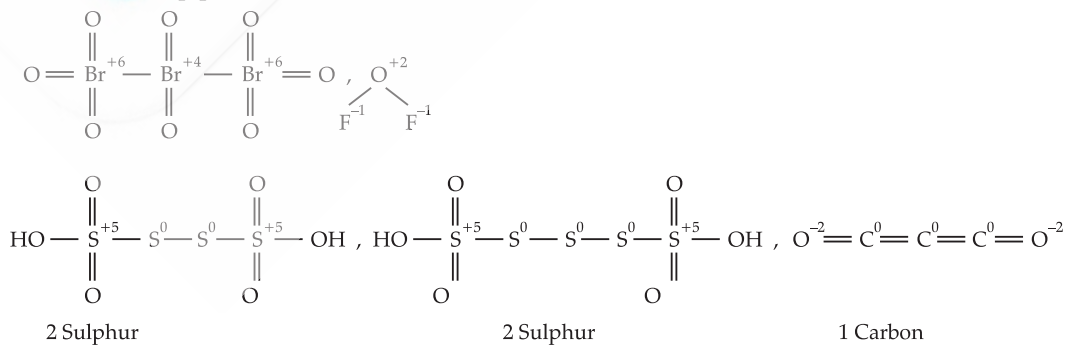
11. Correct answer is [30].

$(\text{Radius})_2 = 105.8 \text{ pm} = 1.058 \text{ Å}$

$(\text{Radius})_1 = 26.45 \text{ pm} = 0.2645 \text{ Å}$

for He $Z = 2$

The radius of nth orbit of He^+ is given by

$\dfrac{0.529n^2}{z}\text{Å}$

$\therefore$ $\dfrac{0.529 \times n_2^2}{2} = 1.058$

On solving $n_2 = 2$

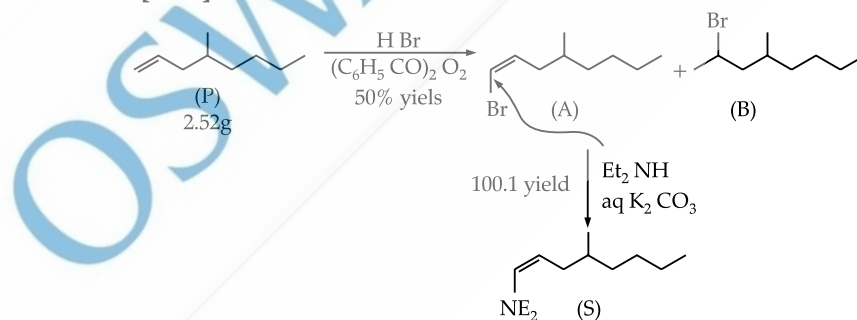$\dfrac{0.529 \times 4n_1^2}{2} = 0.2645$

On solving $n_1 = 1$

Now, use the Rydberg formula

$$\overline{\upsilon} = R_H^{+2}\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right) \times Z^2$$

$\therefore$ $\overline{\upsilon} = 2.2 \times 10^{-18} \times 4 \times \left(\dfrac{1}{(1)^2} - \dfrac{1}{(2)^2}\right)$

Using $\overline{\upsilon} = \dfrac{1}{\lambda} \Rightarrow \lambda = \dfrac{1}{\overline{\upsilon}}$

$\therefore$ $\lambda = \dfrac{1}{2.2 \times 10^{-18} \times 4 \times \left(\dfrac{1}{1} - \dfrac{1}{4}\right)}$

On solving

$$\lambda = 304 \text{ Å} = 30.4 \text{ nm}$$

$$\simeq 30 \text{ nm}$$

12. Correct answer is [682].

$\text{density} = \dfrac{\text{mass}}{\text{volume}}$

$\therefore$ $\text{mass} = \text{density} \times \text{volume}$

$= 1.012 \times 50$

$= 50.6 \text{ g}$

Let x g urea is mixed in solution

$\therefore x$ g of urea $+ (50.6 - x) \text{ g } H_2O = 50.6 \text{ g}$

$\text{Molality} = 0.2 = \dfrac{\dfrac{x}{60}}{\dfrac{50.6 - x}{1000}}$

$\therefore$ $x = 0.6 \text{ g urea}$

$= 0.01 \text{ mol urea}$

Other solution has 0.06 g urea = 0.001 mil urea

$\pi_{\text{resulting}} = \dfrac{(0.01 + 0.001)}{0.3} \times 62 \times 300$

$= \dfrac{0.011 \times 62 \times 300}{0.3} = 682 \text{ torr}$

13. Correct answer is [1791].

$\text{Moles of P} = \dfrac{2.52}{126} = 0.02$

50% yields of A and B combined formed in 9 : 1 ratio

Moles of A = 0.009 and moles of B = 0.001

Moles of S = 0.009

Molecules mass of S = 199

So,   Mass obtained of S = 199 × 0.009 = 1.791 g

1.791 × 1000 = 1791 mg

14. Correct answer is [0.31].

Enthalpy changes

$$\Delta S = \Delta S_{600K} - \Delta S_{300K}$$

$$= (S_\beta - S_\alpha)_{600K} - (S_\beta - S_\alpha)_{300K}$$

$$\Delta S = (6 - 5) - \Delta S_{300}$$

$$\Delta S = 1 - \Delta S_{300} \qquad \ldots(1)$$

Now, $\Delta S = \Delta CP_m \ln \dfrac{T_2}{T_1}$

$$= (C_{P.B.} - C_{P,\alpha}) \ln \dfrac{T_2}{T_1}$$

$$= (1) \ln \dfrac{600}{300}$$

Given $C_{P,\beta} - C_{P,\alpha} = 1 \text{ J mol}^{-1} \text{ K}^-$

$$\Delta S = \ln 2 = 0.69 \qquad \ldots(2)$$

Equate equation (1) and (2), we get

$$1 - \Delta S_{300} = 0.69$$

$$\Delta S_{300} = 1 - 0.69 = 0.31 \text{ J/mol.}$$
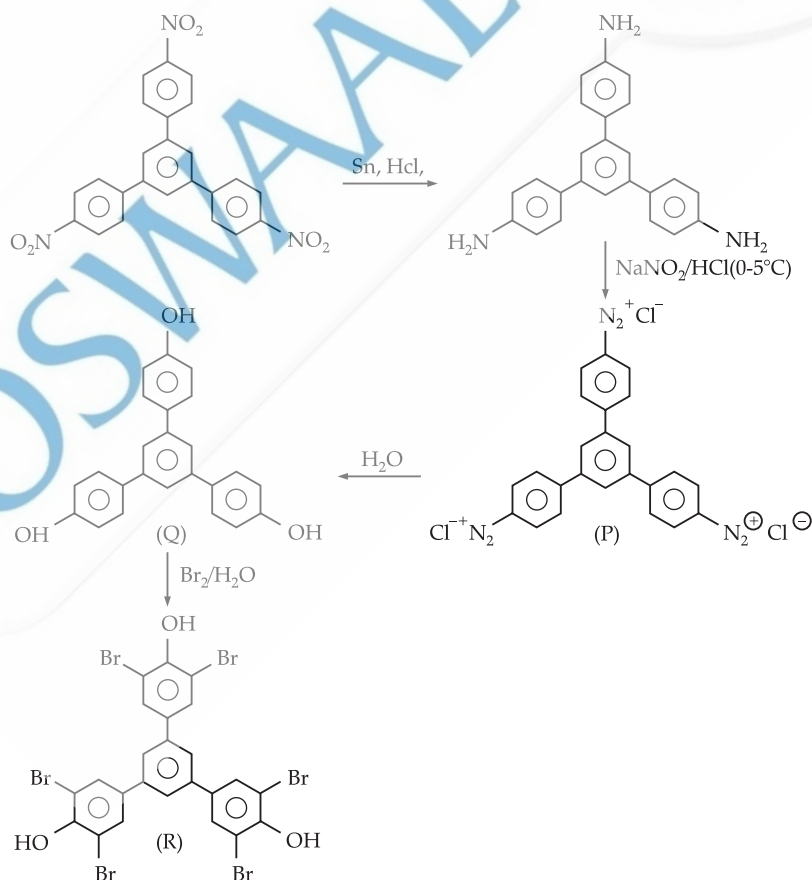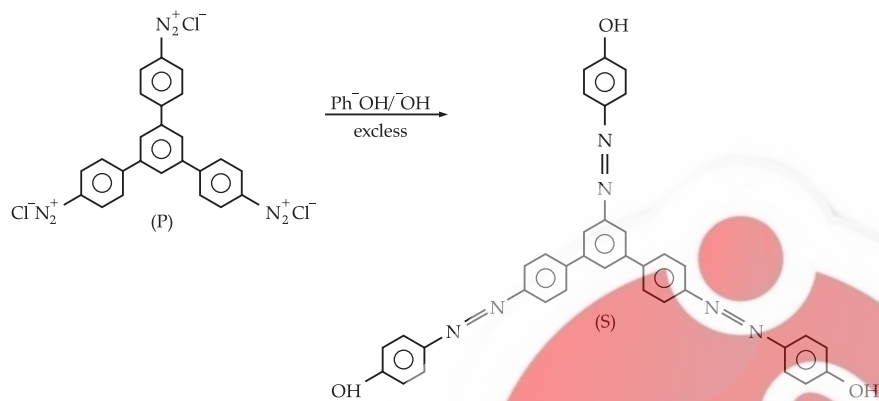
15. Correct answer is [300].

Using Kirchhoff's law

$$\frac{\Delta H_{T_2} - \Delta H_{T_1}}{T_2 - T_1} = \Delta C_P$$

$$\frac{\Delta H_{600} - \Delta H_{300}}{600 - 300} = 1 \qquad \text{Given } \Delta C_P = 1 \text{ J/mol/K}$$

$$\Delta H_{600} - \Delta H_{300} = 300 \qquad \ldots(1)$$

Now, at 600 K

$$\Delta G = 0$$

$$\therefore \quad \Delta H - T\Delta S = 0$$

$$\Delta H_{600} = T\Delta S_{600} \qquad \Delta S_{600} = 1$$

(Solved in previous question)

$$\therefore \quad \Delta H_{600} = 600 \times 1$$

$$\therefore \quad \Delta H_{600} = 600 \text{ J/mol.} \qquad \ldots(2)$$

Put value of equation (2) in equation (1), we get

$$600 - \Delta H_{300} = 300$$

$$\Delta H_{300} = 300 \text{ J/mol.}$$

16. Correct answer is [9].

17. Correct answer is [51].