INCHO 2002

Problem 1 15 marks

A. Wave functions and atomic orbitals

1.1 $2 \times 4 \times (-13.6) = -108.8$ eV.

1.2 $|\psi_1(0.5)|^2 = 2 \times 1^2 = 2$

1.3 Yes ☐ No ☒

1.4 $|\psi(x_0)|^2\,dx$ is the probability of finding the particle in a small interval dx around x_0. Hence $|\psi(x_0)|^2$ can be greater than 1.

1.5

I ⟶ C
II ⟶ B
III ⟶ A

1.6

A 3p
B 3s
C 1s

B. Properties of oxygen molecule and MO theory

1.7 O_2 is paramagnetic
or any other logical choice.

1.8 O_2 : 2

O_2^- : 1.5

1.9 O_2 : 2

O_2^- : 1

Problem 2 20 marks

A. Kinetics of the reaction between Nitric oxide and Oxygen

2.1

$$\frac{d[NO_2]}{dt} = K_2 [N_2O_2][O_2]$$

$$= \frac{k_2 k_1}{k_{-1}} [NO]^2 [O_2]^{k_1}$$

order n = 3

2.2

i) Order n = 3.004

ii) Units of k are $dm^6\ mol^{-2} s^{-1}$

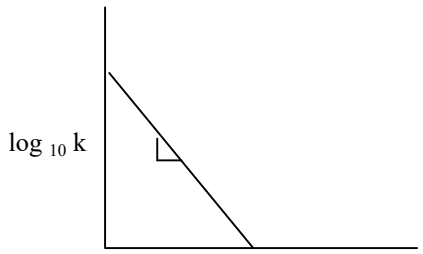
2.3

i) Equilibrium constant $K^* = 12$

$\Delta G^* = -6.20$ kJ

ii) Since ΔG^* is negative, the reaction is spontaneous.

2.4



or any other corre[illegible]

B. Carbon monoxide

2.5 ii) $\Delta S_{system} + \Delta S_{surrounding} > 0$ X

2.6

i) $CO(g) + \frac{1}{2} O_2(g) \longrightarrow CO_2(g)$

ii) $\Delta U = -169.05$ kJ

$\Delta H =$ = -170.31 kJ.

iii) ΔS = – ve ⟶

iv) Entropy decreases as there is a decrease in volume.

2.7

$\Delta S = 1.695 \times 10^{-3}$ kJ.

Work done = $\Delta S \times T = 0.5085$ kJ.

2.8

i) Eff = $\frac{T_2 - T_1}{T_2} = \frac{373 - 77}{373} = 0.794$ or 79.4 %

ii) Use superheated steam in the boiler so that T_2 increases.

Problem 3 10 marks

A. Electrochemical cell

3.1

i) $Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4(s)$.

$$E_{cell} = E^0{}_{cell} - \frac{0.0592}{n}\log\frac{1}{[Pb^{2+}][SO_4^{2-}]}$$

$$0.061 = 0.230 - \frac{0.0592}{2}\log\frac{1}{(2.50\times10^{-5})\times[SO_4^{2-}]}$$

Solving we get $[SO_4^{-2}] = 7.81 \times 10^{-2}$.

The dissociation reaction of HSO_4^- is as follows

$HSO_4^- \rightleftharpoons H^+ SO_4^{-2}$ $\qquad k_2 = \frac{[H^+][SO_4^{2-}]}{[HSO_4^-]}$

Since there is only 1 H^+ produced for 1 SO_4^{-2}. $\therefore$ $[H^+] = [SO_4^{-2}]$.

$[HSO_4^-]eq = 0.600 - (7.81 \times 10 - 2) = 0.522$

$$k_2 = \frac{(7.81\times10^{2-})^2}{(0.522)} = 1.17\times10^{-2}$$

B. Mohr's Method

3.2

i) $[CrO_4^{2-}] = = 1.55 \times 10^{-2}$

ii) Percentage error (%) = 0.038

Problem 4 **15 marks**

A. Carbon dating

4.1

i) $t = 13763$ year

$\therefore$ Date $= 11764$ B.C

ii) $a_o = 0.3145$ dis/min

B. Power production in nuclear fusion

4.2

C. Decomposition of Limestone

4.3

i) Initial moles of $CaCO_3$ = 0.2

ii) n = 0.1316 mole

iii) % of $CaCO_3$ unreacted = 34.2

Problem 5 21 marks

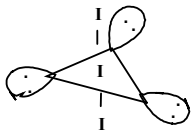
A. Co-ordination chemistry of copper

5.1 i) I^- is a base and I_2 is an acid.

ii) $2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2\ NaI$

iii) I^- is oxidized to I_2.

iv) .



v) Octahedral with tetragonal elongation.

Octahedral

vi) It is a Cu(I) compound in which Cu has a d^{10} configuration. Therefore no d-d transitions are possible and hence colourless.

vii) $[Cu(H_2O)_6]^{++}$ $\mu_s = 1.73$ BM

CuI. $\mu_s = 0$

viii) 151 kJ mol^{-1}

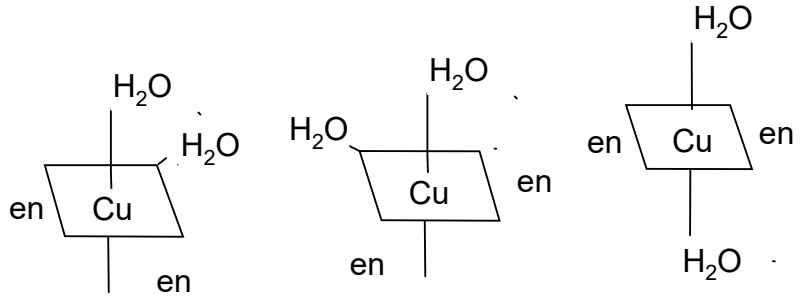
5.2 i) **$[Cu(en)(H_2O)_4]^{++}$** : Tetraaquo(ethylenediamine)Copper(II) ion.

$[Cu(en)_2(H_2O)_2]^{++}$: Diaquobis(ethylenediamine)Copper(II) ion.

$[Cu(en)_3]^{++}$: d or l tris(ethylenediamine)Copper(II) ion.

ii) .

Three structures



Cis Cis trans

B. Complexes of Nickel

5.3 i) **$[Ni(H_2O)_6]^{++}$:** octahedral (d^8)

$Ni(CN)_4^{--}$: Square planar (d^8)

$[Ph_4As]_2[NiCl_4]$: tetrahedral (d^8)

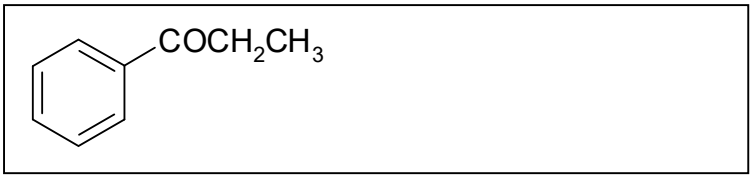
ii) crystal field splitting energy $[NiCl_4]$ = 3778 cm^{-1}

Problem 6 26 marks

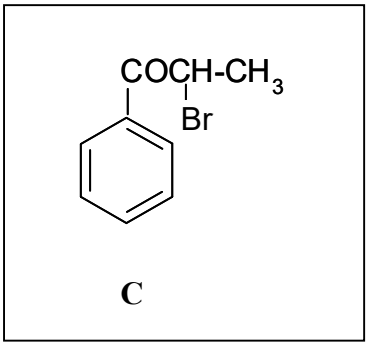
A. Structure elucidation of organic compound

6.1 i)

ii)



6.2 i)



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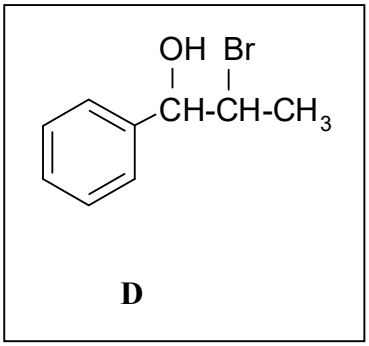
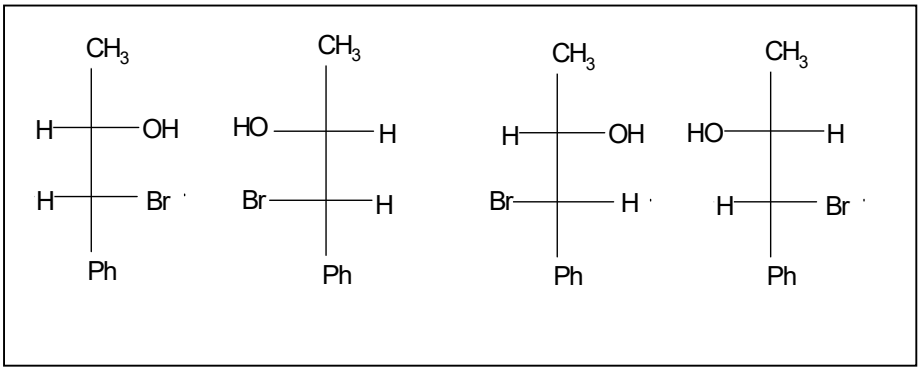
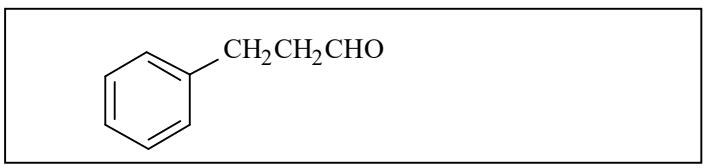


D



6.3 i)

ii)



B. Organic reactions, mechanisms and stereochemistry

6.4 i)

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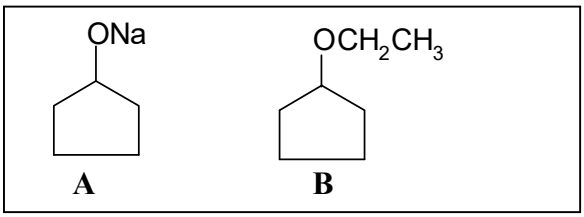
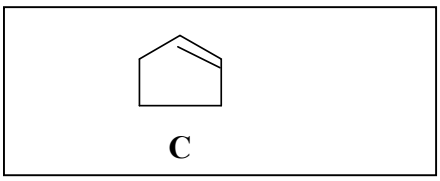


A **B**

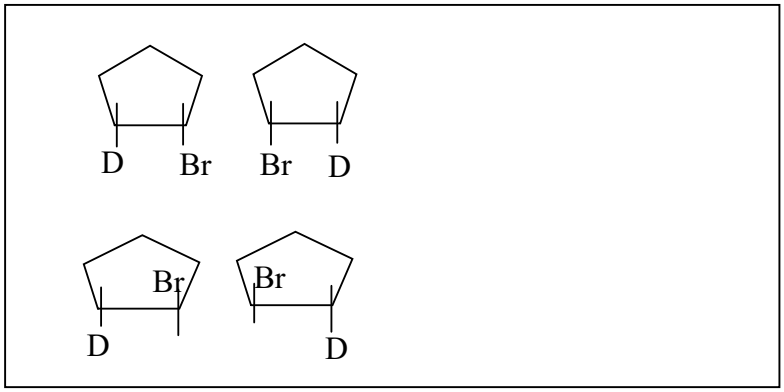
ii)



C

iii) c) Base X

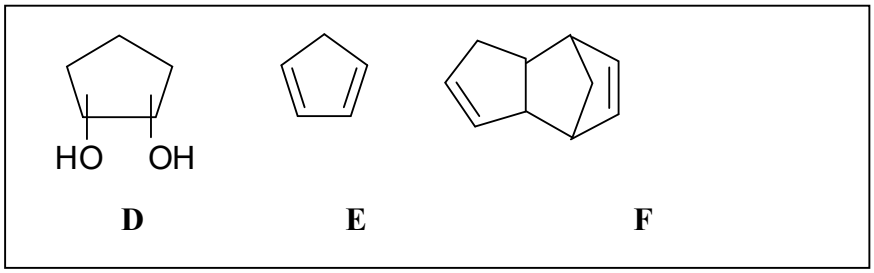
iv)



v) Diastereomers

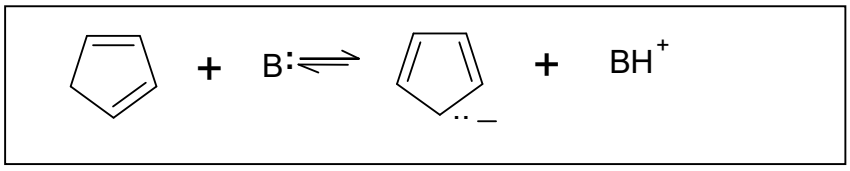
vi) a) Sodium bromide is insoluble, and sodium iodide is soluble in acetone. X

vii)



D **E** **F**

viii)



ix) The conjugate base of **E** is an aromatic anion and the negative charge is delocalised over the entire ring. Hence all hydrogens are identical.

Problem 7 15 marks

A. Amino acids and proteins

7.1 i)

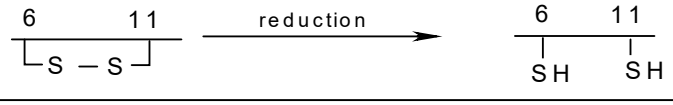
Insulin

ii)

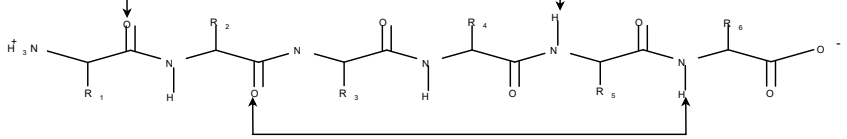
(Cystine) 6 11 (Cystine)

S ----- S

iii)



iv)



v)

Length before treatment: 45 Å

Length after treatment: 108Å

vi)

Average mol wt of amino acid = 128Da

Mol wt of chain A = 2328 Da

7.2

Sample	Direction of migration
A	No migration
B	Cathode
C	Anode

B. Structures and functions of nucleic acids

7.3 i)

total number of codons = 60.

ii)

the total number of bases = 360

iii)

G = 30 % and C = 30 %.

iv)

Nitrogen bases conjugate double bonds. These double bonds are responsible for absorption of U.V. radiation.