

Solutions and Marking grid for the Theoretical Problems of the 27th IChO

Problem 1 (total 17 points)

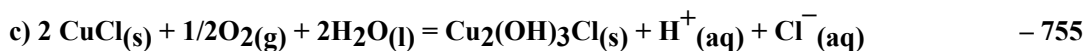
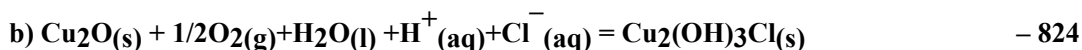
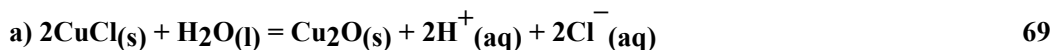
1.

i)

chemical equation

ii) (1. total 6 points)

$$\frac{\Delta_f G_m^\ominus(298\text{K})}{\text{kJ} \cdot \text{mol}^{-1}}$$



i) 2 points

ii) 2 points

iii) Calculation (dilute HCl solution can be considered as an ideal solution)

$$\begin{aligned} \Delta_r G_m(298\text{K}) &= \Delta_r G_m^\ominus(298\text{K}) + 2RT \ln [C_{\text{H}^+} / C_{\text{H}^+}^\ominus \cdot C_{\text{Cl}^-} / C_{\text{Cl}^-}^\ominus] \\ &= -22.3 \text{ kJ mol}^{-1} < 1 \end{aligned}$$

A. →

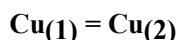
iii) 2 points

2. i) Formula : $\ln \frac{k_c(T_2)}{k_c(T_1)} = \frac{E_a}{R} \left[\frac{1}{T_1} - \frac{1}{T_2} \right]$ (2. total 4 points) i) 1 point

$$E_a = 34.2 \text{ kJ} \cdot \text{mol}^{-1} \quad \text{+ 1 point}$$

ii) overall reaction order = 0 ii) 1 point

when $bp_{\text{O}_2} \gg 1$, $r = k_c \theta = \frac{k_c b P_{\text{O}_2}}{1 + b P_{\text{O}_2}}$; $r = k_c$, zero order + 1 point

3. i) (C) $E > 0$ (3. total 3 points)ii) Net cell reaction: i) 1 point

Thermodynamic reason for choosing 3 (C) is

$$\Delta_r G_m < 0, \Delta_r G_m = -nFE \quad \therefore E > 0 \quad \text{ii) 2 points}$$

4. $r = 1.30 \times 10^{-10} \text{ m}$ (4. total 4 points)

formula: $a = 2\sqrt{2}r$ 1 point

$$d = \frac{4(63.5 \times 0.75 + 65.4 \times 0.25) \times 10^{-3}}{a^3 N_A} \quad \text{1.5 points}$$

$$= 8.51 \times 10^{-3} \text{ kg} \cdot \text{m}^{-3}$$

$$r^3 = 2.209 \times 10^{-30} \text{ m}^3 \quad \text{1 point}$$

$$r = 1.30 \times 10^{-10} \text{ m} \quad \text{0.5 point}$$

total (17 points)

Problem 2 (total 20 points)

1. A 1 point

2. B 2 points

$$(1.4 \times 10^{-3} \times 0.01) \div [\text{Cl}^-] = 4.9 \times 10^{-4} \text{ mol dm}^{-3},$$

$$[\text{Cl}^-] = 2.9 \times 10^{-4} \text{ mol dm}^{-3} \quad 1 \text{ point}$$

$$\begin{aligned} \text{Excess } [\text{Cl}^-] &= 1.6 \times 10^{-2} - 2.9 \times 10^{-3} \\ &\cong 1.6 \times 10^{-2} \text{ mol dm}^{-3} \quad 1 \text{ point} \end{aligned}$$

To reduce the interference of Cl^- , at least $1.6 \times 10^{-2} \text{ mol Ag}^+$ ion, or $8.0 \times 10^{-3} \text{ Ag}_2\text{SO}_4$ has to be added to 1 dm^3 sample solution.

1 point

(2. total 5 points)

$$3. DE = E_2 - E_1 = 0.059 \lg \{(C_X V_X + C_S V_S) / (C_X [V_X + V_S])\}$$

2 points

$$0.03 = 0.059 \lg [(25.00 V_X + 0.10) / (26.00 \times C_X)] \quad 1 \text{ point}$$

$$C_X = 1.7 \times 10^{-3} \text{ mol dm}^{-3} \quad 1 \text{ point}$$

$$\text{pNO}_3 = 2.77 \quad 1 \text{ point}$$

(3. total 5 points)

4. pH = 4.4 1 point

$$(1.4 \times 10^{-3} \times x) \div 1.6 \times 10^{-2} = 2.7 \times 10^{-3} \quad 2 \text{ points}$$

$$x = 3.1\% > 1\% \quad 1 \text{ point}$$

$$(1.4 \times 10^{-3} \times 0.01) \div [\text{CH}_3\text{COO}^-] = 2.7 \times 10^{-3} \quad 1 \text{ point}$$

$$[\text{CH}_3\text{COO}^-] = 5.2 \times 10^{-3} \text{ mol dm}^{-3} \quad 1 \text{ point}$$

$$1.6 \times 10^{-2} - 5.2 \times 10^{-3} = 1.08 \times 10^{-2} \text{ mol dm}^{-3} \quad 1 \text{ point}$$

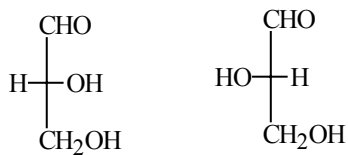
$$\{[\text{H}^+] \times 5.2 \times 10^{-3}\} \div (1.08 \times 10^{-2}) = 2.2 \times 10^{-5} \quad 1 \text{ point}$$

$$[\text{H}^+] = 4.3 \times 10^{-5} \text{ mol dm}^{-3} \quad 1 \text{ point}$$

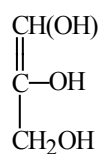
$$\text{pH} = 4.4 \quad (4. \text{ total 9 points})$$

Problem 3 (total 15 points)

1.

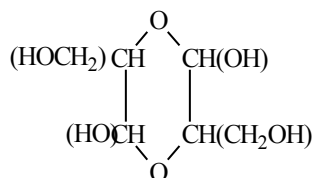
D(+)
1 pointL(-)
1 point

2.



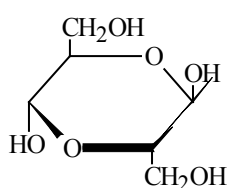
2 points

3.

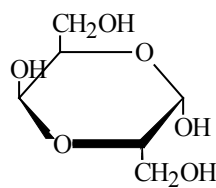


3 points

4.

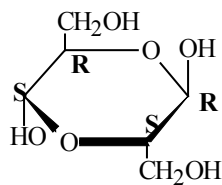


2 points

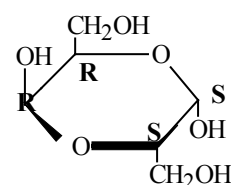


2 points

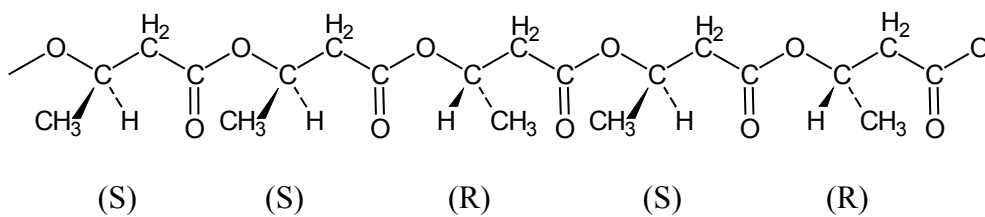
5.



2 points



2 points

Problem 4 (total 16 points)**1. Atactic PHB:**

1 point

other arrangements with (R) and (S) randomly distributed along the chain are correct, e.g.,

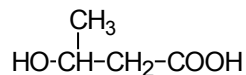
RSRRS, SRSSR, RRSRS, etc.

Syndiotactic PHB: This polymer has (R) and (S) units positioned along the chain in an alternating manner: RSRSR (or SRSRS). **1 point**

Isotactic PHB: All the chiral centers have the same configuration. There are 2 types of the isotactic PHBs: SSSSS and RRRRR **2 points**

(ref. Preparatory Problem 52)

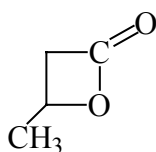
2. Monomer 1



3-hydroxybutanoic acid

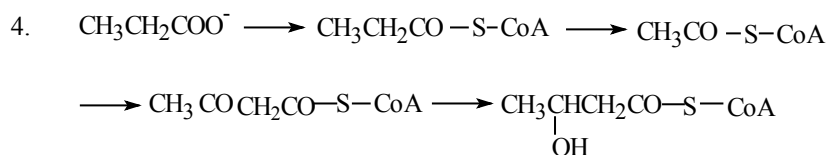
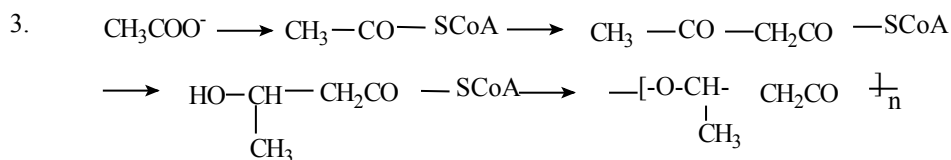
2 points

Monomer 2



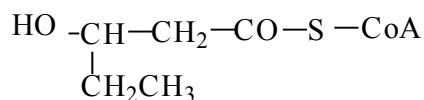
(Ref. Preparatory Problem 52)

2 points

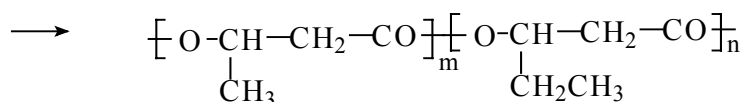


(coenzyme A activated monomer 3-hydroxypentanoic acid)

This monomer may also be written in the following way:



Polymerization together of these two monomers will result in the desired copolymer:



(Ref. Preparatory Problem 52 and 55) 4 points for Question 3
4 points for Question 4

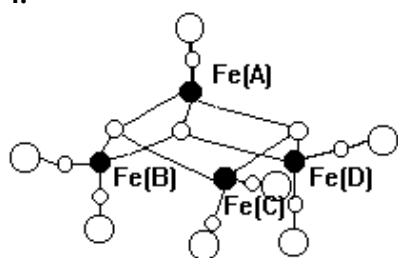
Problem 5 (total 18 points)

1. The HOMO of NO molecule is π^* , its electron arrangement is \uparrow ;
the LUMO of NO molecule is π^* . 1+1+1= 3 points

2. B. 1 point

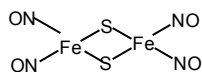
3. B. 2 points

4.



Fe(A) having $3d^7$ configuration; Fe(B), Fe(C),
Fe(D) having $3d^9$ configuration.
 $0.5 \times 4 + 0.5 \times 4 + 2 = 6$ points

5. i) 2 points



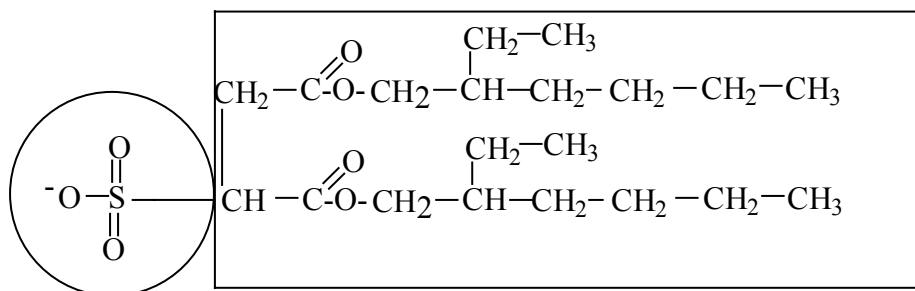
ii) Fe (-1) Fe (-1) 1+1 = 2 points

iii) The species added to S atom is $\underline{\text{CH}_3^+}$; n = 0.

1+1= 2 points

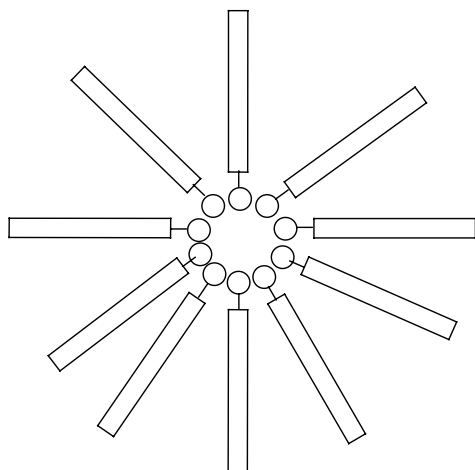
Problem 6 (total 13 points)

1. i) AOT molecule model: 1 point for PH; 1 point for NT.



ii) B. 1 point (3 points for question 1)

2. i)



1 point for direction of the molecules

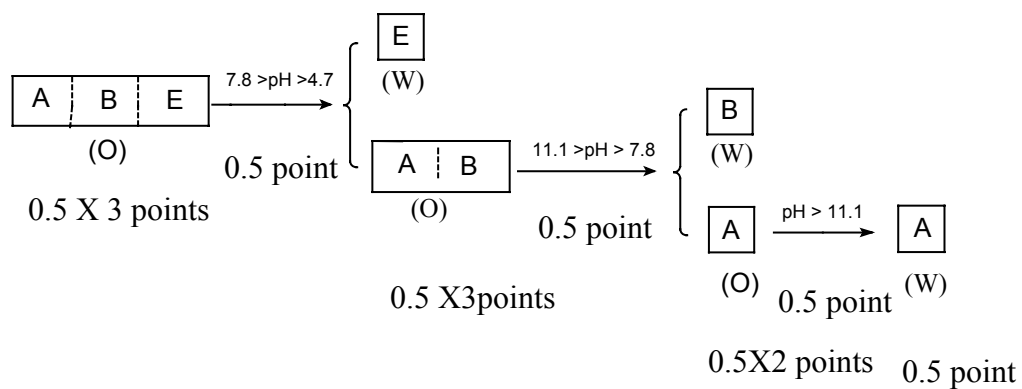
ii) H_2O , Na^+

1 point for species in the cavity

(2 Points for question 2)

3. A. B. E. (3 Points For question 3)

4. Fill the letters represented the extracted proteins in the frames and the separation conditions above the arrows respectively: (6 points for question 4)



The Conceptual Links between the Preparatory Problems and the Theoretical Problems

Theoretical Problem	Preparatory Problem
1	2, 5, 38-47
2	21-32
3	11-20
4	33-36, 52, 54-55
5	3-4, 8-9, 56-57
6	10, 48

Marking Grid for the Theoretical Problems

Problem	Blue points	Red points	
1		17	10
2		20	10
3		15	10
4		16	10
5		18	10
6		13	10
		total	60