Neap

Trial Examination 2022

Suggested Solutions

QCE Chemistry Units 3&4

Paper 2

SECTION 1

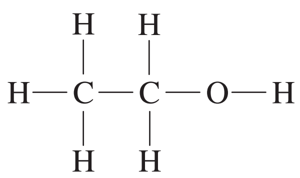
QUESTION 1 (8 marks)

a) The infrared spectrum shows the characteristic broad O–H stretching vibration around 3360 cm^{-1}. It also shows a C–O stretch strongly absorbing at 1050 cm^{-1}.

The mass spectrum shows the following.

- fragment at 31 m/z = base ion peak (CH_2OH^+)
- fragment at 46 m/z = molecular ion peak (M^+)
- fragment at 15 m/z = CH_3^+
- fragment at 29 m/z = $C_2H_5^+$
- fragment at 45 m/z = $C_2H_5O^+$

Therefore, the molecular formula is C_2H_5OH. The spectrum is for ethanol.



[6 marks]
1 mark for identifying the vibration around 3360 cm^{-1}.
1 mark for identifying the peak at 1050 cm^{-1}.
1 mark for identifying relevant fragments.
Note: Responses are not required to state all fragments, but must identify 31 m/z and/or 29 m/z, which are common for alcohols.
1 mark for determining the molecular formula.
1 mark for determining that the spectrum is for ethanol.
1 mark for drawing the structural formula of ethanol.

b) The ester is methyl butanoate, which is synthesised through the reaction butanoic acid + methanol → methyl butanoate + water. Therefore, ethanol was not used to synthesise the ester.

[2 marks]
1 mark for identifying the ester and the rection.
1 mark for stating that ethanol was not used.

QUESTION 2 (8 marks)

a) Half-reactions and cell potentials for cell 1:

$Ag^{+}(aq) + e^{-} \rightleftharpoons \rightarrow Ag(s) \quad E^{\circ} = +0.80 \text{ V}$

$Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s) \quad E^{\circ} = -0.24 \text{ V}$

$E^{\circ}_{cell\ 1} = +0.80 - (-0.24) = 1.04 \text{ V}$

Half-reactions and cell potentials for cell 2:

$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s) \quad E^{\circ} = -0.44 \text{ V}$

$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s) \quad E^{\circ} = +0.34 \text{ V}$

$E^{\circ}_{cell\ 2} = +0.34 - (-0.44) = 0.78 \text{ V}$

Cell 1 has the higher emf, so it will act as a voltaic cell while cell 2 will act as an electrolytic cell. Electrons will flow from Cu to Ag in the outer circuit and from Ni to Fe in the inner circuit. In cell 1, Ag^{+} ions will move to the Ag electrode and deposit, while Ni atoms will release their electrons and form Ni^{2+} ions. In cell 2, Fe^{2+} ions will move to the Fe electrode and deposit, while Cu atoms will release their electrons and form Cu^{2+} ions.

[6 marks]

1 mark for identifying the standard electrode potentials of $Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$ and $Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s)$.

1 mark for calculating $E^{\circ}_{cell\ 1}$.

1 mark for identifying the standard electrode potentials of $Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)$ and $Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)$.

1 mark for calculating $E^{\circ}_{cell\ 2}$.

1 mark for stating that cell 1 will act as a voltaic cell and cell 2 will act as an electrolytic cell.

1 mark for identifying that electrons flow from Cu to Ag and Ni to Fe.

b)

$$\begin{aligned} \text{overall emf} &= E^{\circ}_{cell\ 1} - E^{\circ}_{cell\ 2} \\ &= 1.04 - 0.78 \\ &= 0.26 \text{ V} \end{aligned}$$

[1 mark]

1 mark for calculating the overall emf.

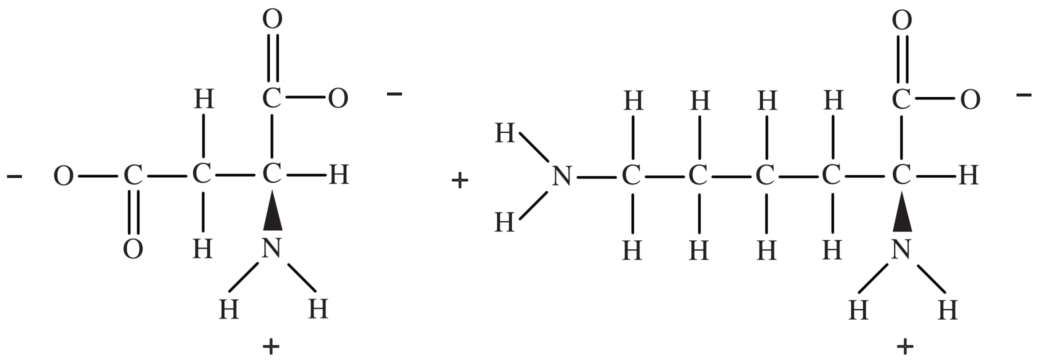
*Note: Consequential on answer to **Question 2a)**.*

QUESTION 3 (8 marks)

a) Amino acids move through chromatography paper at different rates because of their different polarities, meaning they have different solubilities in the stationary and mobile phases. The more polar amino acids attach to the more polar stationary phase (paper) more readily and so move through the paper at a slower rate. Alanine is the least polar of the three amino acids, so it moves at a faster rate. Alanine is also the smallest of the three molecules, whereas lysine and aspartic acid are similar in mass, so they will move at a similar rate.

[3 marks]
1 mark for explaining the relationship between polarity and rate of movement.
1 mark for stating that alanine is the least polar and therefore moves at a faster rate.
1 mark for stating that lysine and aspartic acid molecules have similar mass and therefore move at a similar rate.

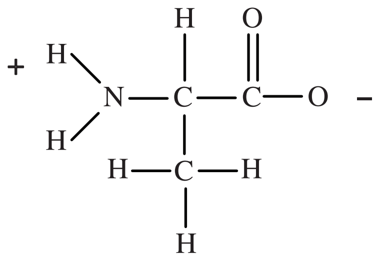
b) Electrophoresis is a method of separating charged particles base on their charges and mobilities. For aspartic acid to move towards the positive electrode, it must be negatively charged. For lysine to move towards the negative electrode, it must be positively charged. At pH = 6.1, aspartic acid is negatively charged overall, and lysine is positively charged overall.



aspartic acid lysine

[3 marks]
1 mark for explaining the charges of the amino acids and their movements towards the electrodes.
1 mark for drawing the structural formula of aspartic acid, clearly showing a negative charge.
1 mark for drawing the structural formula of lysine, clearly showing a positive charge.

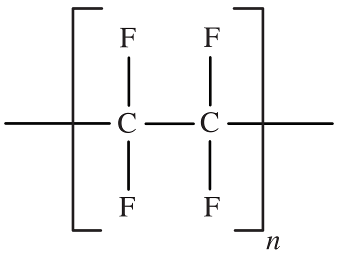
c) Alanine hardly moved in the electrophoresis experiment because its pH of isoelectric point is 6.1. This means it exists with balanced charges at a pH of 6.1 and so did not move to either electrode during electrophoresis.



[2 marks]
1 mark for identifying the pH of isoelectric point and explaining that alanine is neutral at this pH and so did not move.
1 mark for drawing the structural formula of alanine, clearing showing charges.

QUESTION 4 (9 marks)

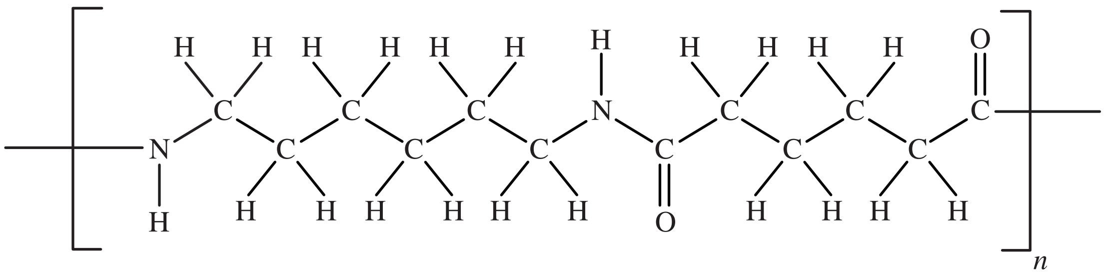
a)



IUPAC name: polytetrafluoroethylene

[2 marks]
1 mark for drawing the structural formula of the polymer.
1 mark for naming the polymer.

b)



[1 mark]
1 mark for drawing the structural formula of the polymer.

c)

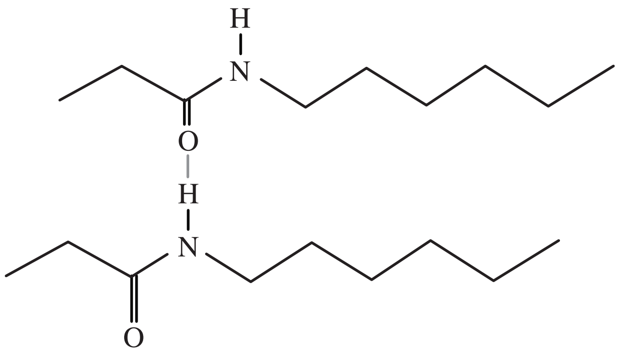
Monomer/s	Type of reaction to form polymer	Does the polymer formed have alternating units?
tetrafluoroethylene	**addition**	**no**
adipic acid and hexamethylene diamine	**condensation (with water as a by-product)**	**yes**

[4 marks]
1 mark for each correct response.

d) i) Nylon 6,6 has two monomers, and each monomer unit has six carbon atoms in the chain.

[1 mark]
1 mark for providing the correct explanation.

ii) In nylon 6,6, the carbonyl oxygen and amide hydrogen bond together. This enables the polymer chains to line up in an orderly structure to form strong fibres.



[1 mark]
1 mark for providing the correct explanation.
Note: A diagram is not required to obtain full marks.

 TEQChem34_SS_P2_2022

QUESTION 5 (7 marks)

a) Reaction 1:

$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + C_2H_4O_2$

Reaction in moles:

$$n = \frac{m}{M}$$

$$n\left(C_7H_6O_3\right) = \frac{100}{138.13}$$
$$= 0.7240 \text{ mol}$$

$$n\left(C_4H_6O_3\right) = \frac{50}{102.1}$$
$$= 0.4897 \text{ mol}$$

$0.7240 \text{ mol} + 0.4897 \text{ mol} \rightarrow \text{RHS}$

Therefore, ethanoic anhydride is the limiting reagent, and 0.4897 mol of aspirin will be produced.

Converting the amount of aspirin to grams:

$$m\left(C_9H_8O_4\right) = n \times M$$
$$= 0.4897 \times 180.17$$
$$= 88.23 \text{ g}$$

Reaction 2:

$C_7H_6O_3 + C_2H_4O_2 \rightarrow C_9H_8O_4 + H_2O$

Reaction in moles:

$$n\left(C_7H_6O_3\right) = \frac{100}{138.13}$$
$$= 0.7240 \text{ mol}$$

$$n\left(C_2H_4O_2\right) = \frac{50}{60.06}$$
$$= 0.8325 \text{ mol}$$

$0.7240 \text{ mol} + 0.8325 \text{ mol} \rightarrow \text{RHS}$

Therefore, salicylic acid is the limiting reagent, and 0.7240 mol of aspirin will be produced.

Converting the amount of aspirin to grams:

$$m\left(C_9H_8O_4\right) = 0.7240 \times 180.17$$
$$= 130.44 \text{ g}$$

[6 marks]

1 mark for calculating the number of moles of aspirin produced by reaction 1.

1 mark for identifying the limiting reagent in reaction 1.

1 mark for calculating the mass of aspirin produced by reaction 1.

1 mark for calculating the number of moles of aspirin produced by reaction 2.

1 mark for identifying the limiting reagent in reaction 2.

1 mark for calculating the mass of aspirin produced by reaction 2.

b) Reaction 2 is a reversible reaction so it is likely to reach equilibrium rather than completion, which results in a lower yield of aspirin.

[1 mark]
1 mark for identifying the reason why reaction 1 is used.

QUESTION 6 (11 marks)

a)

Solution (0.1 M)	**Light bulb brightness**	**Relative electrical conductance**	**pK_a**	**pK_b**
ethanoic acid (CH_3COOH)	dim	4.2	4.74	–
hydrochloric acid (HCl)	very bright	11.7	–5.90	–
nitric acid (HNO_3)	bright	6.8	–1.37	–
sulfuric acid (H_2SO_4)	bright	8.8	–2.00	–
hydroiodic acid (HI)	**very bright**	**13.3**	–9.30	–
sodium hydroxide (NaOH)	very bright	10.6	–	–0.56
methylamine (CH_3NH_2)	**dim**	3.1	–	3.34
ammonia (NH_3)	**dim**	4.2	–	4.75

[4 marks]
1 mark for each correct response.
Note: HI is a strong acid, so the light would be very bright. CH_3NH_2 and NH_3 are both weak bases, so the light would be dim. The question asks for an estimate of the relative electrical conductance of HI; accept values in the range 11.8–14.00.

b) i) HI is the strongest acid and, therefore, has the lowest pH. The lower the pK_a value of an acid, the greater the ionisation of the acid in water. HI has the lowest pK_a value out of the acids, so it has the greatest degree of ionization and the lowest pH.

[2 marks]
1 mark for determining that HI has the lowest pH.
1 mark for explaining reasoning.

ii) NaOH is the strongest base. The lower the pK_b value of a base, the greater the ionisation of the base in water. NaOH has the lowest pK_b value out of the bases. so it has the greatest degree of ionisation.

[2 marks]
1 mark for determining that NaOH is the strongest base.
1 mark for explaining the reasoning.

c) As the concentration of hydrogen ions (H^+) in solution increases, electrical conductivity and light bulb brightness increase.

[1 mark]
1 mark for describing how increased H^+ concentration increases conductivity and brightness.

d) The acid is a weak acid. As the relative electrical conductance was similar to that of CH_3COOH, it can be deduced that the acid is a weak acid.

[2 marks]
1 mark for deducing that the acid is weak.
1 mark for explaining the reasoning.

QUESTION 7 (7 marks)

a) $K_a \times K_b = K_w = 1.0 \times 10^{-14}$ at 25°C

Rearranging the equation to find K_b gives:

$$K_b = \frac{K_w}{K_a}$$
$$= \frac{1.0 \times 10^{-14}}{3.0 \times 10^{-8}}$$
$$= 3.3 \times 10^{-7}$$

[2 marks]
1 mark for rearranging the equation.
1 mark for showing working.

b) $K_b = \frac{[HOCl][OH^-]}{[OCl^-]}$

$= 3.3 \times 10^{-7}$

	$[OCl^-]$	[HOCl]	$[OH^-]$
Initial	0.20	0	0
Change	$-x$	$+x$	$+x$
Equilibrium	≈ 0.20	x	x

At equilbrium, [HOCl] = $[OH^-]$ = x.

$$\therefore \frac{x^2}{0.20} = 3.3 \times 10^{-7}$$

$$x = \sqrt{(3.3 \times 10^{-7}) \times 0.20}$$

$$= 2.5690 \times 10^{-4}\ \text{M}$$

$$\therefore [OH^-] = 2.5690 \times 10^{-4}\ \text{M}$$

$$\text{pOH} = -\log[OH^-]$$

$$= \log(2.5690 \times 10^{-4})$$

$$= 3.5902$$

$$\text{pH} = 14 - \text{pOH}$$

$$= 14 - 3.5902$$

$$= 10.41$$

[5 marks]

1 mark for identifying the initial and equilibrium concentrations of OCl^-.

1 mark for identifying that the concentration of HOCl is the same as the concentration of OH^-.

1 mark for calculating the concentration of OH^-.

1 mark for calculating pOH.

1 mark for calculating pH.

Note: As the K_b value is very small, it can be assumed that the equilibrium concentration of OCl^- is essentially unchanged.

QUESTION 8 (7 marks)

a) i) In the glucose solution, the molecules are straight chain molecules. The C=O group on the first carbon in each straight chain glucose molecule are free to react with the Fehling's solution.

[1 mark]
1 mark for stating that the C=O group reacts.

ii) A sucrose molecule is a disaccharide made of a glucose molecule joined to a fructose molecule, so sucrose does not have C=O groups that are free to react with the Fehling's solution.

[1 mark]
1 mark for stating that sucrose is a disaccharide and does not have C=O groups to react.

iii) Starch is made of glucose molecules joined together, so the molecules do not have C=O groups that are free to react with the Fehling's solution.

[1 mark]
1 mark for stating that starch is made of glucose molecules and does not have C=O groups to react.

b) Glucose is sometimes referred to as a reducing sugar because a glucose molecule can reduce an ion. In the reaction between the glucose solution and Fehling's solution, the copper ion was reduced from Cu^{2+} to Cu^{+}.

[2 marks]
1 mark for stating that glucose can reduce an ion.
1 mark for explaining that Cu^{2+} was reduced.

c) A change would have been observed. Each sucrose molecule would have been broken into two monosaccharides (glucose and fructose), which are reducing sugars, enabling a reaction with the Fehling's solution.

[1 mark]
1 mark for stating that a change would have occurred and providing a brief explanation.

d) Citric acid with OH^{-} ions in solution is sufficient to break the glycosidic bond between the two monosaccharides in sucrose (glucose and fructose), enabling a reaction with the Fehling's solution.

[1 mark]
1 mark for stating that the breaking of glycosidic bonds enables a reaction.
Note: Responses are not required to state the nature of the bond.