CHEMISTRY

DATE: 10 JUNE 2009

DURATION OF THE EXAM :
3 hours (180 minutes)

PERMITTED MATERIAL :
Calculator (not graphical and not programmable)

INSTRUCTIONS :

- Answer two A questions and two B questions.
- Indicate which four questions you have answered by putting crosses in the appropriate place on the sheet supplied.
- Use a separate answer sheet for each of the four main questions.

Question A1

Page 1/2

Marks

a) When fish is kept at too high a temperature a characteristic smell is produced after a short while. This is due to the degradation of nitrogen-containing compounds in the fish. The degradation products formed are compounds such as ammonia, NH_3, and trimethylamine, $(CH_3)_3N$.

i. Give the structural formula of trimethylamine. — 1 mark

ii. Explain why trimethylamine is a Brønsted base by referring to its structure. — 2 marks

iii. Write the equations for the reactions of ammonia and trimethylamine with water. — 2 marks

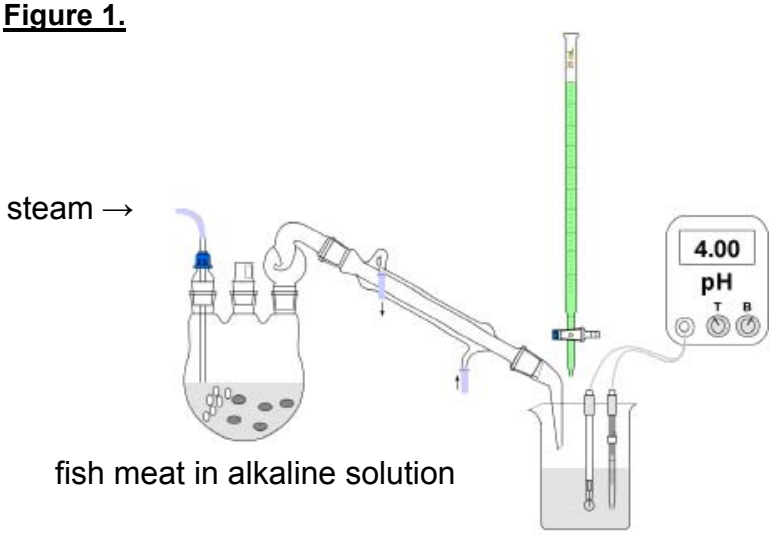
iv. Identify the three acid-base couples involved in these reactions. — 3 marks

v. Give the expression for the base dissociation constant, K_b, of trimethylamine. — 1 mark

vi. By referring to structures of the molecules, state and explain whether ammonia or a secondary amine is the strongest base. — 3 marks

b) The extent of degradation can be determined by a measure of the total volatile nitrogen content (known as a TVN analysis) based on the volatile nitrogen compounds in the fish. **Figure 1.** shows the experimental set-up for this analysis.

Figure 1.



Question A1

Page 2/2 | Marks

The beaker contains 100 cm^3 of dilute hydrochloric acid solution. The pH of this solution is kept constant at 4.00.

i. Calculate the amount (in mol) of oxonium ions, $H_3O^+(aq)$, present in the solution contained in the beaker. — 2 marks

ii. If no pH meter is available for the titration select a suitable indicator from the list below that could be used instead. — 1 mark

Indicator	pH range
thymol blue	1.2 – 2.8
bromophenol blue	3.0 – 4.6
phenolphthalein	8.3 – 9.8

c) 25.0 g of fish is placed in the round-bottom flask. Water is added and the solution is made alkaline. The water steam distillation is carried out. The volatile nitrogen compounds react with the hydrochloric acid in the beaker. The pH of the solution is maintained throughout at 4.00 by the addition of further hydrochloric acid.

i. Give the equation for the reaction between one of the nitrogen compounds and the oxonium ions. — 2 marks

ii. Explain why it is necessary to add hydrochloric acid to the beaker in order to maintain the pH of the solution at 4.00. — 1 mark

During the distillation of all the volatile nitrogen compounds it was necessary to add 26.8 cm^3 of 5.00 x 10^{-2} mol dm^{-3} hydrochloric acid solution. The volatile nitrogen compounds are all monoprotic bases and contain one atom of nitrogen per molecule.

iii. Calculate the total amount of acid (in mol) that reacted. — 2 marks

iv. Calculate the total volatile nitrogen content (TVN) expressed in mg of nitrogen contained in 100 g of fish. — 5 marks

Given: Molar atomic mass (in g mol^{-1}): N: 14.0

Question A2

Page 1/2 | Marks

a) Where necessary, use the standard electrode potential data in the table below to answer the questions that follow.

	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	- 0.76
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	- 0.26
$SO_4^{2-}(aq) + 2H^+(aq) + 2e^- \rightleftharpoons SO_3^{2-}(aq) + H_2O(l)$	+ 0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+ 0.34
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+ 0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+ 1.00
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+ 1.36

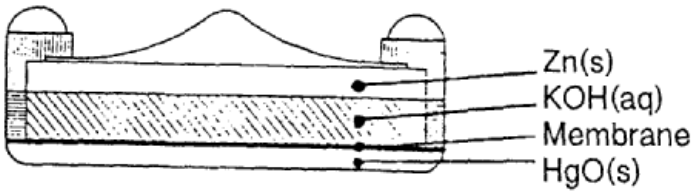
i. Define the term *reducing agent* in terms of electrons. — 1 mark

ii. From the table above select the species which is the most powerful reducing agent. Explain your answer. — 2 marks

iii. Choose a species from the table that in acid solution can reduce $VO_2^+(aq)$ to $VO^{2+}(aq)$ but will not reduce $VO^{2+}(aq)$ to $V^{3+}(aq)$. Explain why you selected this species. — 2 marks

iv. Choose a species from the table that in acid solution can oxidise $VO^{2+}(aq)$ to $VO_2^+(aq)$. Explain why you selected this species. — 2 marks

b) A mercury battery is a non-rechargeable electrochemical cell. The diagram below is a representation of this type of battery.



Given : Standard electrode potentials

$Zn^{2+}(aq) / Zn(s)$	$E^{\ominus}$ = - 0.76 V
$HgO(s) + H_2O(l) / Hg(l) + 2OH^-(aq)$	$E^{\ominus}$ = + 0.79 V

Question A2

Page 2/2 | Marks

i. Give the half-equations for the reactions taking place in the battery and deduce the overall redox equation. — 3 marks

ii. State which is the positive and which is the negative electrode. — 1 mark

iii. State the direction of the flow of electrons in the external circuit when the battery is operating. — 1 mark

iv. Calculate the e.m.f. of the battery operating under standard conditions. — 1 mark

v. The solution of potassium hydroxide, KOH(aq), acts as an electrolyte. With reference to the electrodes show the direction of flow of the $K^+(aq)$ and $OH^-(aq)$ ions. — 1 mark

vi. Calculate the theoretical time (in years) a watch could run if it uses a mercury battery containing 1.60 g of mercury(II) oxide, HgO(s) which produces a current of 2.50×10^{-5} A. — 4 marks
Assume that the zinc is present in excess.

Given:
1 Faraday = 9.65×10^4 C mol^{-1}
Molar atomic masses (in g mol^{-1}): Hg: 201 O: 16.0

c) Mercury is a toxic heavy metal. The amount of mercury absorbed by an individual can be estimated by titrating the $Hg^+(aq)$ ions present in urine. This analysis is based upon the oxidation of $Hg^+(aq)$ ions to $Hg^{2+}(aq)$ ions by acidified potassium permanganate solution, $KMnO_4(aq)$. During the reaction the permanganate ions, $MnO_4^-(aq)$ are reduced to manganese(II) ions, $Mn^{2+}(aq)$

i. Give the balanced equation for the redox reaction taking place. — 3 marks

A 200 cm^3 sample of urine was titrated with 1.00×10^{-6} mol dm^{-3} acidified potassium permanganate solution. The titration required 15.0 cm^3 of the potassium permanganate solution.

ii. Calculate the concentration by mass of mercury in the urine. Express the result in micrograms per dm^3 (1 microgram = 1μg = 1.00×10^{-6} g). — 4 marks

Question A3

Page 1/3

Marks

a) Chlorine, $Cl_2(aq)$, is used in swimming pools as a disinfectant but can also act as an irritant. The optimum level of chlorine lies between the values of 1.00×10^{-3} and 3.00×10^{-3} g dm^{-3}.
The following method was used to determine the amount of chlorine in the water.

Excess potassium iodide, KI(s), was added to a 500 cm^3 sample of water taken from the swimming pool. This converted all the chlorine present in the water to chloride ions, $Cl^-(aq)$. At the same time the iodide ions, $I^-(aq)$ were converted into iodine, $I_2(aq)$.

In a second reaction the iodine produced was titrated with 5.00×10^{-3} mol dm^{-3} sodium thiosulphate solution, $Na_2S_2O_3(aq)$, to convert it into iodide ions. The end-point of the titration occurred when 17.0 cm^3 of the sodium thiosulphate solution had been added.

i. Describe how the end-point is determined in this titration. — 2 marks

ii. Use the half-equations below to give the two balanced redox equations for the reactions taking place in the procedure used. — 2 marks

$$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq) \qquad E^\ominus = +1.36\ V$$
$$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq) \qquad E^\ominus = +0.62\ V$$
$$S_4O_6^{2-}(aq) + 2e^- \rightleftharpoons 2S_2O_3^{2-}(aq) \qquad E^\ominus = +0.09\ V$$

iii. Explain why the two reactions are spontaneous. — 2 marks

iv. Calculate the concentration (in mol dm^{-3}) of chlorine in the swimming pool water. — 4 marks

v. Calculate the concentration by mass of chlorine in g dm^{-3} and comment on the quality of the swimming pool water in terms of the level of chlorine contained in it. — 2 marks

Given:
Molar atomic mass (in g mol^{-1}): Cl: 35.5

Question A3

Page 2/3 | Marks

b) For physiological reasons the ideal pH for swimming pools lies between 7.4 and 7.6.

i. After a first measurement the pH was found to be 6.9. Choose two substances from the list below that could be added to the swimming pool water to increase the pH. Explain how you arrived at your choice. — 3 marks

$NaCl$, $NaOH$, HCl, $NaHSO_4$, Na_2CO_3

Given: $pK_a(HCO_3^-) = 10.3$ $pK_a(HSO_4^-) = 1.92$

ii. After a second measurement it was found that the pH stabilised at 7.9. Choose two other substances from the list that could be added to the swimming pool water to lower the pH. — 2 marks

c) Another method of disinfecting swimming pool water involves electrolysis of the water after adding sodium chloride, NaCl(s).

i. The concentration of NaCl must be 7.50×10^{-2} mol dm^{-3}. Calculate the mass of NaCl(s) that must be added to a swimming pool containing 60.0 m^3 of water. — 3 marks

Given: Molar atomic masses (in g mol^{-1}): Na: 23.0 Cl: 35.5

ii. The disinfectant produced during the electrolysis is the hypochlorite ion, $ClO^-(aq)$. — 1 mark
Complete and balance the following half-equation.

$$Cl^-(aq) + OH^-(aq) \rightarrow ClO^-(aq) + H_2O(l)$$

iii. The hypochlorite ion can also function as a Brønsted base. Give the equation for its reaction with water (protolyses). — 2 marks

Question A3

Page 3/3 | Marks

It might be expected that sodium, Na(s), would be formed at the negative electrode due to the presence of the sodium ions, $Na^+(aq)$, whereas what is actually observed is the evolution of hydrogen gas, $H_2(g)$.

iv. Explain why hydrogen, $H_2(g)$ is formed rather than sodium, Na(s) and give the corresponding half-equation. — 2 marks

Given: Electrode potentials, $E^{\ominus}$, under the conditions of electrolysis (pH = 7.00):

Couple	$E^{\ominus}$ / V (at pH = 7.00)
$H_3O^+(aq) / H_2(g)$	– 0.42
$H_2O(l) / H_2(g)$	– 1.25
$Na^+(aq) / Na(s)$	– 2.71

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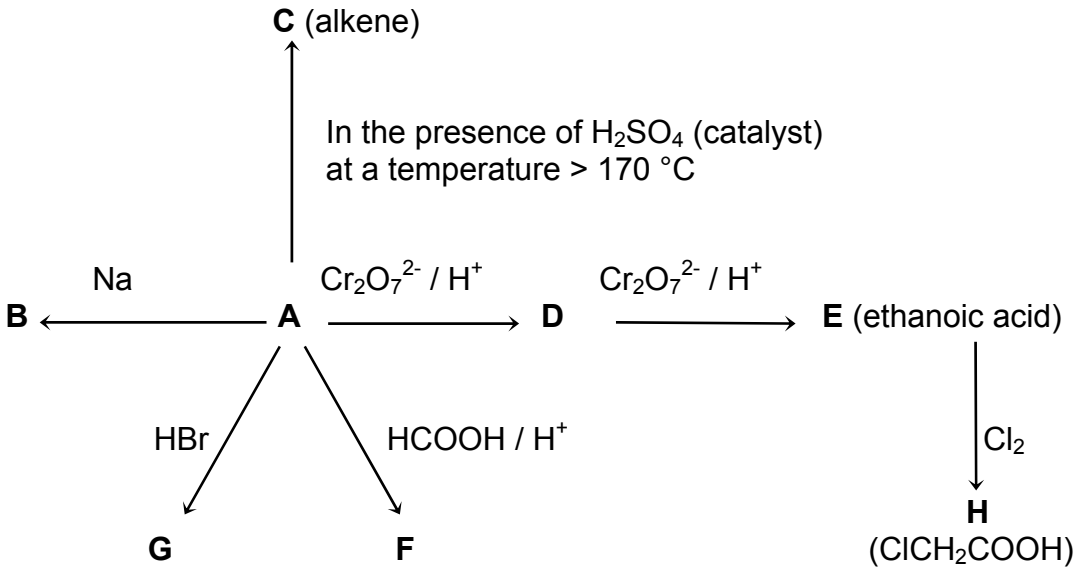
Question B1

Page 1/2 | Marks

a) Compound **A** contains 52.1% carbon, 13.2% hydrogen and 34.7% oxygen by mass.

The diagram below shows a series of different reactions starting with compound **A**.



Given: Molar atomic masses (in g mol^{-1}):

H: 1.01 C: 12.0 O: 16.0

i. Calculate the empirical formula of compound **A**. — 2 marks

ii. Give the structural formula and the IUPAC name of compound **A**. — 2 marks

iii. Give the simplified structural formulas of products **C**, **D** and **E**. — 3 marks

iv. Give the IUPAC names for the organic products **B**, **F** and **G**. — 3 marks

v. Describe the reaction mechanism to explain how product **G** is formed. — 3 marks

vi. State whether **E** or **H** has the lowest pK_a value. Explain your answer. — 2 marks

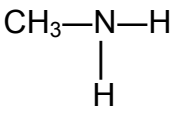
vii. The boiling point of compound **A** is 78 °C, that of compound **C** is –103.7 °C. Explain why these values are different. — 2 marks

Question B1		
	Page 2/2	Marks
viii. Give the balanced equation for the reaction of a solution of compound **E** with calcium carbonate, $CaCO_3(s)$.		2 marks
ix. Compare the solubility of compound **E** in water with that of octadecanoic acid, $C_{17}H_{35}COOH(s)$. Explain your answer.		2 marks
b) Methanal, HCHO(aq), and methanoic acid, HCOOH(aq), can be prepared in the laboratory by oxidising methanol, $CH_3OH(l)$, with a dilute acidifed solution of potassium dichromate, $K_2Cr_2O_7(aq)$.		
i. Describe the different experimental conditions needed to obtain these two different oxidation products separately.		2 marks
The two oxidation products can be distinguished by testing with Fehling's solution.		
ii. State which of the two products gives a positive test with Fehling's solution and give the balanced equation for the corresponding reaction.		2 marks

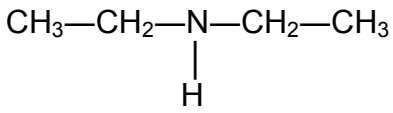
Question B2

Page 1/2 | Marks

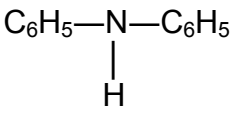
a) Consider the following compounds which contain an amine functional group.



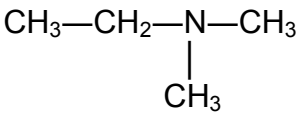
A



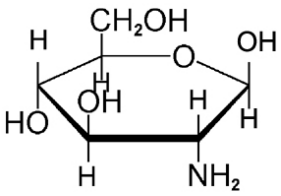
B



C



D N,N-dimethylethylamine



E glucosamine
(used to treat arthritis)

i. From the compounds listed above identify a secondary amine and a tertiary amine. — 2 marks

ii. Give the IUPAC name for compound **A**. — 1 mark

iii. Give the balanced equation for the reaction between glucosamine and water. — 2 marks

iv. Write the equilibrium expression for K_b of glucosamine. — 1 mark

v. Explain why glucosamine is very soluble in water. — 2 marks

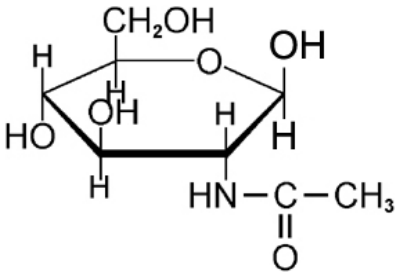
vi. Given the following pK_b values: 3.07, 3.36 and 9.60. Assign each of these values to the amines **A**, **B** and **C**. Explain your answer. — 4 marks

vii. Phenylamine (aniline), C_6H_5-NH_2, is often used in the manufacture of azo dyes. Explain at the molecular level why azo dyes are coloured. — 3 marks

Question B2

Page 2/2 | Marks

b) A molecule of acetyl glucosamine is represented below. It is a monomer which can form the polymer chitin, $(C_8H_{13}NO_5)_n$, present in the exoskeleton of shellfish and insects.
Acetyl glucosamine is formed by the reaction of glucosamine with an oxygen-containing organic compound.



acetyl glucosamine

i. Give the balanced equation for the formation of acetyl glucosamine from glucosamine. — 2 marks

ii. State the term used to describe this type of reaction. — 1 mark

iii. Identify the type of bond formed during the formation of acetyl glucosamine. — 1 mark

iv. The average molar molecular mass of chitin is 8.84×10^5 g mol^{-1}. Calculate the number of monomers that make up a chain of this polymer. — 2 marks

Given: molar atomic masses (in g mol^{-1}) :

H : 1.01 C : 12.0 N : 14.0 O : 16.0

c) High quality nylon can be made from the reaction between 1,5-diaminopentane and decane-1,10-dioic acid.

i. Give the simplified structural formulas of 1,5-diaminopentane and decane-1,10-dioic acid. — 2 marks

ii. Give the formula of the repeating unit in nylon synthesised from 1,5-diaminopentane and decane-1,10-dioic acid. — 2 marks

Question B3

Page 1/2

Marks

a) Chemical raising agents used in baking contain a mixture of sodium hydrogencarbonate, $NaHCO_3(s)$ and an acidic compound **A**, potassium hydrogentartrate, $C_4H_5O_6K(s)$, or HOOC-CH(OH)-CH(OH)-COOK(s).

When these two compounds react with each other a gas is formed. This gas causes the raising action.

i. Give the equation for the reaction between these two substances in aqueous solution using simplified structural formulas for the organic compounds. — 2 marks

ii. Identify the gas which causes the raising action. — 1 mark

b) When compound **A** reacts with hydrochloric acid, HCl(aq) it forms compound **B**. A molecule of compound **B** contains two carboxylic acid functional groups.

i. Give the equation for the reaction of **A** with HCl(aq) using simplified structural formulas. — 2 marks

ii. Give the IUPAC name for the organic product obtained. — 1 mark

iii. Give the structural formula of compound **B** and identify the position of the asymmetric carbon atom(s). — 2 marks

iv. Describe the characteristic physical property of enantiomers. — 2 marks

v. With reference to their structures compare the acidity of compound **B** with butanedioic acid. — 2 marks

Question B3

Page 2/2

Marks

c) Compound **B** can react with methanol, $CH_3OH(l)$, in the presence of concentrated sulphuric acid, $H_2SO_4(l)$ to give two different esters.

i. Give the equation for the reaction occurring between one molecule of each of the organic reactants. — 2 marks

ii. The mechanism for this esterification reaction can be elucidated by incorporating an ^{18}O isotope in one of the reactant molecules. Give a detailed account of this reaction mechanism showing how the use of ^{18}O enables the mechanism to be elucidated. — 3 marks

iii. Give the simplified structural formula of the organic product formed when one molecule of compound **B** reacts with two molecules of methanol. — 1 mark

iv. State the name of one other type of reaction, apart from esterification, that can also take place with same reactants under different conditions. — 1 mark

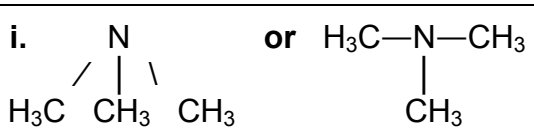
d) Natural fats are formed from propan-1,2,3-triol (glycerol) and different fatty acids. The formulas and common names of several fatty acids are given in the table below.

Common name of fatty acid	Simplified structural formula
stearic acid	CH_3-$(CH_2)_{16}$-COOH
linoleic acid	CH_3-$(CH_2)_4$-CH=CH-CH_2-CH=CH-$(CH_2)_7$-COOH
linolenic acid	CH_3-CH_2-CH=CH-CH_2-CH=CH-CH_2-CH=CH-$(CH_2)_7$-COOH

i. Give the structural formula of a fat formed between one molecule of glycerol and one molecule each of stearic acid, linoleic acid and linolenic acid. — 4 marks

ii. Give the equation for the complete combustion of stearic acid. — 2 marks

EB CHEMISTRY 2009
ANSWERS AND MARKSCHEME

MARKS	QUESTION A 1	PAGE: 1/1
1 mark	**a) i.**  **or**	
2 marks	**ii.** The N atom contains a non-bonding pair of electrons **[1]** that can accept a proton **[1]**.	
2 marks	**iii.** $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ $C_3H_9N(aq) + H_2O(l) \rightleftharpoons C_3H_9NH^+(aq) + OH^-(aq)$	
3 marks	**iv.** Acid H_2O, conjugate base OH- **[1]** Acid NH_4^+, conjugate base NH_3 **[1]** Acid $C_3H_9NH^+$, conjugate base C_3H_9N **[1]**	
1 mark	**v.** $K_b = \frac{[C_3H_9NH^+] \times [OH^-]}{[C_3H_9N]}$	
3 marks	**vi.** A secondary amine is the stronger base **[1]** due to the positive inductive effect of the two methyl groups **[1]** increasing the electron density on the N atom which increases the attraction for a proton. **[1]**	
2 marks	**b) i.** $[H_3O^+] = 10^{-4} = 1.00 \times 10^{-4}$ mol dm^{-3} **[1]** Amount of H_3O^+ in 100 cm^3 = **1.00×10^{-5} mol [1]**	
1 mark	**ii.** bromophenol blue	
2 marks	**c) i.** **Either** $NH_3(aq) + H_3O^+(aq) \rightarrow NH_4^+(aq) + H_2O(l)$ **or** $C_3H_9N(aq) + H_3O^+(aq) \rightarrow C_3H_9NH^+(aq) + H_2O(l)$	
1 mark	**ii.** Base will be carried over in the steam distillation which would otherwise increase the pH. **[1]**	
2 marks	**iii.** Amount of HCl = $\frac{26.8}{1000} \times 5.00 \times 10^{-2}$ = **1.34×10^{-3} mol**	
5 marks	**iv.** The ratio of acid to nitrogen is 1:1 as it is a monprotic base **[1]** Amount of N = 1.34×10^{-3} mol **[1]** Mass of N in 25.0g of fish = $1.34 \times 10^{-3} \times 14.0$ $= 1.876 \times 10^{-2}$ g **[1]** TVN = $\frac{1.876 \times 10^{-2}}{25.0} \times 100 = 7.50 \times 10^{-2}$ g **[1]** = **75.0 mg N/100 g fish [1]**	

MARKS	QUESTION A 2	PAGE: 1/2

1 mark **a) i**. Reducing agents donate one or more electrons.

2 marks **ii.** Zn(s) **[1]**
Zn has the most negative redox potential so loses electrons most readily. **[1]**

2 marks **iii.** Fe^{2+} **[1]**
Fe^{3+} / Fe^{2+} has a less positive E^{θ} value than VO_2^+ / VO^{2+} but a more positive value than VO^{2+} / V^{3+}. **[1]**

2 marks **iv.** Cl_2(aq**) [1]**
Cl_2 / $2Cl^-$ has the most positive E^{θ} value and thus is the strongest oxidizing agent.

3 marks **b) i.** $Zn(s) \rightleftharpoons Zn^{2+}(aq) + 2e^-$ **[1]**

$HgO(s) + H_2O(l) + 2e^- \rightleftharpoons Hg(l) + 2OH^-(aq)$ **[1]**

Overall: $Zn(s) + HgO(s) + H_2O(l) \rightleftharpoons Zn^{2+}(aq) + Hg(l) + 2OH^-(aq)$ **[1]**

1 mark **ii.** Positive: HgO(s); negative: Zn(s)

1 mark **iii.** From the Zn to the HgO

1 mark **iv.** E.m.f. = 0.79 – (-0.76) = **1.55 Volts**

1 mark **v.** $K^+(aq)$ ions move towards the HgO **and** the $OH^-(aq)$ ions move towards the zinc.

4 marks **vi.** Amount of HgO = $\frac{1.60}{217} = 7.373 \times 10^{-3}$ **mol [1]**

$HgO(s) + H_2O(l) + 2e^- \rightleftharpoons Hg(l) + 2OH^-(aq)$
Charge produced = $2 \times 9.65 \times 10^4 \times 7.373 \times 10^{-3} = 1423$ C **[1]**
Charge = current x time
Hence time = $\frac{1423}{2.50 \times 10^{-5}} = 5.692 \times 10^7$ s **[1]**

$= \frac{5.692 \times 10^7}{60 \times 60 \times 24 \times 365}$ = **1.80 years [1]**

MARKS	QUESTION A2	PAGE: 2/2

3 marks

c) i. $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$ **[1]**

$Hg^+(aq) \rightleftharpoons Hg^{2+}(aq) + e^-$ **[1]**

Overall:

$5Hg^+(aq) + MnO_4^- + 8H^+(aq) \rightleftharpoons Mn^{2+}(aq) + 5Hg^{2+}(aq) + 4H_2O(l)$ **[1]**

4 marks

ii. Amount of MnO_4^- in 15.0 cm^3

= 15.0/1000 x 1.00 x 10^{-6} = 1.5O x 10^{-8} mol **[1]**

Amount of Hg^+ in 200 cm^3 of urine = 5 x 1.50 x 10^{-8} mol

= 7.50 x 10^{-8} mol **[1]**

Amount of Hg^+ in 1 dm^3 = 1000/200 x 7.50 x 10^{-7} = 3.75 x 10^{-7} mol **[1]**

Concentration (by mass) of Hg^+ = 3.75 x 10^{-6} x 201 = 7.54 x 10^{-5} g dm^{-3}

= 75.4 µg dm^{-3} [1]

MARKS	QUESTION A 3	PAGE: 1/1

2 marks **a) i.** Starch is used as an indicator. **[1]**
The end point is taken when one drop causes the blue colour to just disappear. **[1]**

2 marks **ii.** (1): $2I^-(aq) + Cl_2(aq) \rightleftharpoons 2Cl^-(aq) + I_2(aq)$ **[1]**
(2): $I_2(aq) + 2S_2O_3^{2-} \rightleftharpoons 2I^-(aq) + S_4O_6^{2-}(aq)$ **[1]**

2 marks **iii.** Reaction 1: E^θ_{total} = +1.36 – (+0.62) = + 0.74 V
Reaction 2: E^θ_{total} =+ 0.62 – (+0.09) = + 0.53 V **[1]**
As both have a positive value for E^θ_{total} they are spontaneous. **[1]**

4 marks **iv.** Amount of thiosulphate added = $17.0/1000 \times 5.00 \times 10^{-3}$
$= 8.50 \times 10^{-5}$ mol **[1]**
Amount of I_2 reacting = ½ x 8.50×10^{-5} mol **[1]**
Amount of Cl_2 in 500 cm^3 = ½ x 8.50×10^{-5} = 4.25×10^{-5} mol **[1]**
$[Cl_2] = \frac{1000}{500} \times 4.25 \times 10^{-5} =$ **8.50×10^{-5} mol dm^{-3}** **[1]**

2 marks **v.** Mass of Cl_2 per dm^3 = $8.50 \times 10^{-5} \times 71.0$ = **6.04×10^{-3} g dm^{-3} [1]**
so it contains more chlorine than the optimum amount**[1]**

3 marks **b) i.** NaOH **[1]** and Na_2CO_3 **[1]**
These are the only basic substances **or** NaCl is neutral and $NaHSO_4$ and HCl are acidic. **[1]**

2 marks **ii.** $NaHSO_4$ **[1]**
HCl **[1]**

3 marks **c) i.** M_r NaCl = 23.0 + 35.5 = 58.5 **[1]**
1 dm^3 contains 58.5 x 0.075 = 4.3875 g **[1]**
60 m^3 contains $60 \times 10^3 \times 4.3875$ = 263250 g = **263 kg [1]**

1 mark **ii.** $Cl^-(aq) + 2OH^-(aq) \rightleftharpoons ClO^-(aq) + H_2O(l) + 2e^-$

2 marks **iii.** $ClO^-(aq) + H_2O(l) \rightleftharpoons HClO(aq) + OH^-(aq)$

2 marks **iv.** Hydrogen has a less negative E^θ value than sodium so H^+ ions will gain electrons at the negative electrode more readily than Na^+ ions.
$2H_2O(l) + 2e^- \rightarrow 2H_2(g) + 2OH^-(aq)$
or $H_3O^+(aq) + 2e^- \rightarrow H_2(g) + 2H_2O(l)$

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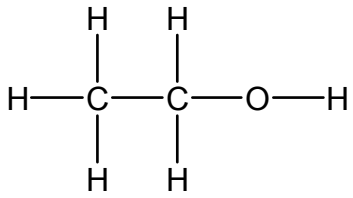
MARKS	QUESTION B 1	PAGE: 1/2

Simplest ratio

2 marks **a) i.** C = 52.1/12.0 = 4.34 2
H = 13.2/1.01 = 13.1 6
O = 34.7/16.0 = 2.17 1 **[1]**
Empirical formula = C_2H_6O. **[1]**

2 marks **ii.**

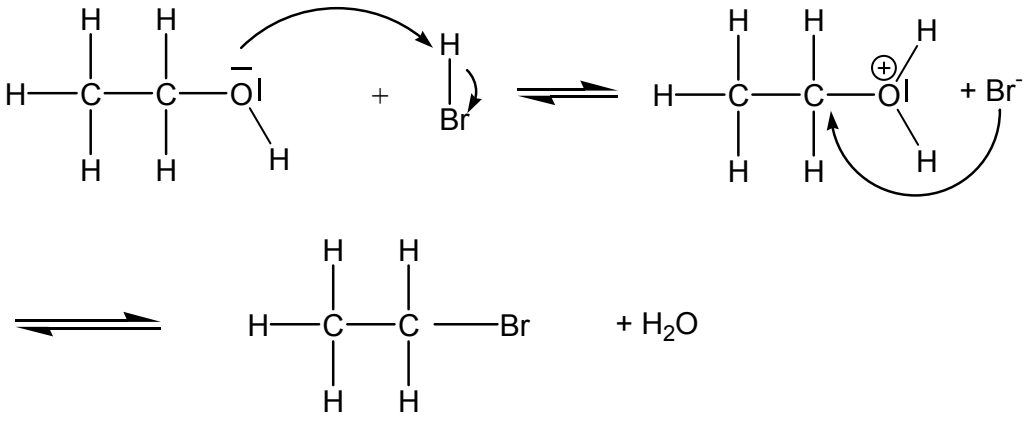


[1] ethanol **[1]**

3 marks **iii. C**: $H_2C{=}CH_2$ **[1]** **D**: H_3CCHO **[1]** **E**: H_3CCOOH **[1]**

3 marks **iv. B**: sodium ethoxide **[1]** **F**: ethyl methanoate **[1]**
G: bromoethane **[1]**

3 marks **v.**



Curly arrow from O to H of H-Br **[1]**
Intermediate showing positive charge on oxygen atom **[1]**
Curly arrow from Br^- to the carbon atom **[1]**

MARKS	QUESTION B 1	PAGE: 2/2

2 marks **vi.** Compound **H** $ClCH_2COOH$ will have the lower pK_a value **[1]**
The electron withdrawing Cl atom results in the carboxyl group more readily losing a proton (or it stabilises the resulting anion). **[1]**

2 marks **vii.** Ethanol (**A**) has hydrogen bonding between molecules. **[1]**
This is stronger than the van der Waals attraction between non-polar molecules of ethene (**C**). **[1]**

2 marks **viii.** $CaCO_3(s) + 2CH_3COOH(aq) \rightarrow 2CH_3COO^-(aq) + Ca^{2+}(aq) + CO_2(g) + H_2O(l)$

2 marks **ix. E** will be much more soluble in water as octadecanoic acid contains a long non-polar hydrocarbon chain **[1]** which significantly reduces the amount of hydrogen bonding that can occur between the –OH group on the acid and water.**[1]**

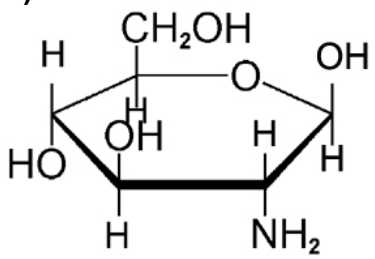
2 marks **b) i.** The aldehyde must be distilled as it is being formed so that it cannot be further oxidized to the carboxylic acid. **[1]**
To form the carboxylic acid the mixture is refluxed before the product is obtained. **[1]**

2 marks ii. Methanal gives a positive test **[1]**
$HCHO(aq) + 2Cu^{2+}(aq) + 5OH^-(aq) \rightarrow HCOO^-(aq) + Cu_2O(s) + 3H_2O(l)$ **[1]**

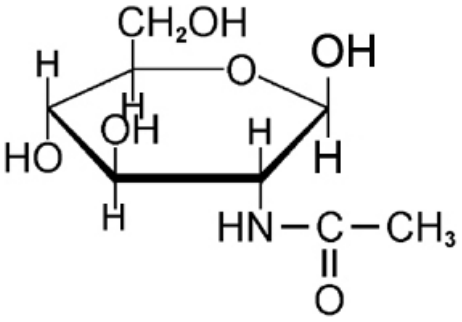
MARKS	QUESTION B 2	PAGE: 1/2
2 marks	**a) i. B or C [1]** **D [1]**	
1 mark	**ii.** Methylamine **or** aminomethane	
2 marks	**iii.** $C_6H_{13}NO_5(aq) + H_2O(l) \rightleftharpoons C_6H_{14}NO_5^+(aq) + OH^-(aq)$	
1 mark	**iv.** $K_b = \frac{[C_6H_{14}NO_5^+] \times [OH^-]}{[C_6H_{13}NO_5]}$	
2 marks	**v.** Glucosamine is soluble in water as it ionises to form a salt.**[1]** It also contains several polar –OH groups.**[1]**	
4 marks	**vi.** **B** (diethylamine) has a pK_b of 3.07 as the positive inductive effect of the ethyl groups increases the electron density on the N atom thus increasing the attraction of a proton by the non-bonding pair **[1]** **A** (methylamine) has a pK_b of 3.36 as it only has one alkyl group providing a positive inductive effect. **[1]** **C** (diphenylamine) has a pK_b of 9.60 as the two phenyl groups withdraw electrons away from the N atom due to delocalisation **[1]** This means the non bonding electron pair on the N has a much weaker attraction to protons. **[1]**	
3 marks	**vii.** Azo dyes are coloured as the –N=N- group increases the conjugation between the two aromatic groups **[1]** so the excitation of pi electrons occurs**[1]** at a lower frequency and takes place in the visible region. **[1]**	

MARKS	QUESTION B 2	PAGE: 2/2

2 marks **b) i**



+ CH_3COOH (**or** CH_3COCl) →



+ H_2O (**or** HCl)

1 mark **ii.** condensation reaction

1 mark **iii.** peptide bond or amide

2 marks **iv.** The molar mass of the repeating unit is:
[(8 x 12,0) + (13 x 1,01) + (5 x 16,0) + (1 x 14,0)] = 203 g mol^{-1} **[1]**
Number of repeating units = $\frac{8.84 \times 10^5}{203}$ = **4355 [1]**

2 marks **c) i.** 1,5-diaminopentane: $H_2N\text{-}(CH_2)_5\text{-}NH_2$ **[1]**

decane-1,10-dioic acid: $HOOC\text{-}(CH_2)_8\text{-}COOH$ **[1]**

2 marks **ii.** $\text{-}[HN\text{-}(CH_2)_5\text{-}NH\text{-}OC\text{-}(CH_2)_8\text{-}CO]_n\text{-}$

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MARKS	QUESTION B 3	PAGE: 1/2

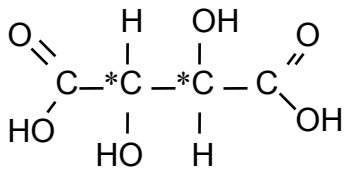
2 marks **a) i.** $HO_2C\text{-}CH(OH)\text{-}CH(OH)\text{-}CO_2K(aq) + NaHCO_3(aq) \rightarrow$
$NaO_2C\text{-}CH(OH)\text{-}CH(OH)\text{-}CO_2K(aq) + CO_2(g) + H_2O(l)$

1 mark **ii.** Carbon dioxide.

2 marks **b) i.** $HO_2C\text{-}CH(OH)\text{-}CH(OH)\text{-}CO_2K\ (aq) + HCl(aq) \rightarrow$
$HOOC\text{-}CH(OH)\text{-}CH(OH)\text{-}COOH(aq) + KCl(aq)$

1 mark **ii.** 2,3-dihydroxybutanedioic acid

2 marks **iii.**



2 marks **iv.** They rotate the plane of plane-polarised light **[1]** by the same amount in opposite directions.**[1]**

2 marks **v.** Compound **B** is more acidic. [**1]**
The two electron-withdrawing –OH groups increase the ability of the –COOH groups to lose a proton (or help to stabilise the Carboxylate ion formed) **[1]**

MARKS	QUESTION B 3	PAGE: 2/2

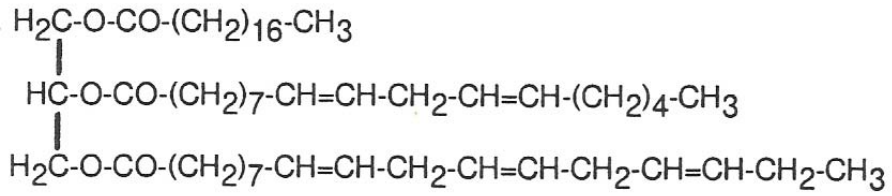
2 marks **c) i.** $HO_2C\text{-}CH(OH)\text{-}CH(OH)\text{-}CO_2H + CH_3OH \rightleftharpoons HO_2C\text{-}CH(OH)\text{-}CH(OH)\text{-}CO\text{-}OCH_3 + H_2O$

3 marks **ii.** The =O on the –COOH acid group is protonated by H^+ from the concentrated sulfuric acid. **[1]**
The ^{18}O in the alcohol reacts as a nucleophile with the C atom bonded to the $=OH^+$, a proton is transfered to the –OH and water is eliminated. **[1]**
The H^+ is removed by HSO_4^- and the ^{18}O remains in the ester. **[1]**

1 mark **iii.** $CH_3O\text{-}CO\text{-}CH(OH)\text{-}CH(OH)\text{-}CO\text{-}OCH_3$

1 mark **iv.** Dehydration or the formation of an ether. Accept the formation of polyesters.

4 marks **d) i.**



2 marks **ii.** $C_{18}H_{36}O_2(s) + 26O_2(g) \rightarrow 18CO_2(g) + 18H_2O(l)$