TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS
HIGHER 2

For Examiner's Use

CANDIDATE NAME									
CIVICS GROUP			/						
CENTER NUMBER	S					INDEX NUMBER			

CHEMISTRY
9647/02

Paper 2 Structured Questions

29th August 2014

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Civics Group and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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1	/12
2	/8
3	/10
4	/16
5	/10
6	/16
Total	

This document consists of **22** printed pages.

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1 Planning (P)

Chromatography is used to separate mixtures of substances into their components. The components move at different speeds when they are carried by a liquid or a gas called the "mobile phase" over an adsorbent material, called the "stationary phase".

(a) A quick and convenient method of chromatographic analysis for organic compounds is thin-layer chromatography (TLC). The stationary phase is silica gel which is coated onto sheets of glass, and the sheets are cut into thin strips.

A solution of a mixture of two organic compounds to be analysed is spotted near the bottom of the plate. The plate is then stood in a closed jar which is saturated with an appropriate solvent as the mobile phase. The reason for covering the jar is to make sure that the atmosphere in the beaker is saturated with solvent vapour. As the solvent travels up the plate by capillary action, the components of the mixture travel upwards at different rates and thus separate. The solvent is allowed to rise until it almost reaches the top of the plate (indicated by the solvent front), giving a maximum separation of the mixture components. The TLC plate is then removed from the jar for further analysis.

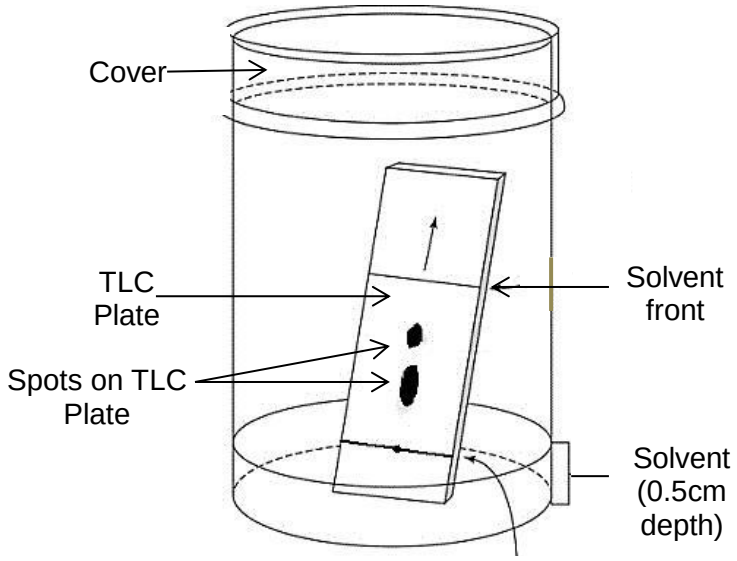

Figure 1: TLC analysing a solution of a mixture of two organic compounds

(i) A pencil line is drawn near the bottom of the TLC plate. Suggest a reason why any labeling on the TLC plate has to be drawn in pencil and not in ink.

• If any labeling were to be done in ink, <u>dyes from the ink would also move and separate</u> as the chromatogram developed.

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Silica gel is a form of silicon dioxide. At the surface of the silica gel, the silicon atoms are attached to –OH groups. The diagram below shows a small part of the silica surface.

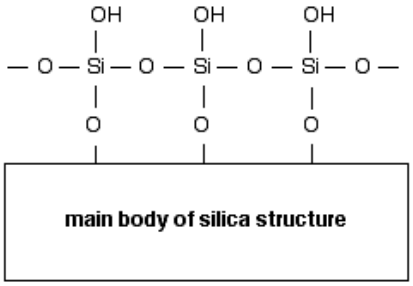

Figure 2: Silica surface

(ii) It is noticed that polar compounds travel a shorter distance on the TLC plate than non-polar compounds. In terms of bonding involved, suggest reasons for the above observation.

•The surface of the silica gel is <u>very polar</u> due to the <u>numerous –OH groups.</u>

<u>Polar compounds</u> can form <u>hydrogen bonds OR strong permanent dipole-permanent dipole (pd-pd) interactions</u> with the surface of the silica gel and thus, is carried much slower in the mobile phase.

Choosing of an appropriate solvent system is very crucial in a thin-layer chromatography (TLC) analysis. The distance at which the compound travel up the plate depends on 2 factors: how soluble the compound is in the mobile phase (solvent) and how strongly the compound is attracted to the stationary phase.

Student **A** chose hexane as the solvent while Student **B** chose methanol as the solvent. The results of their thin-layer chromatography (TLC) plates are as follows:

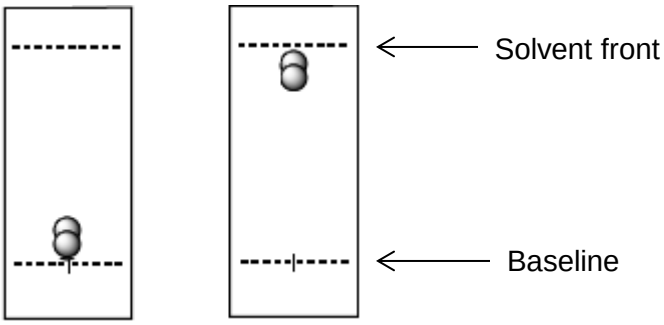

Figure 3: TLC plate of Student **A** Figure 4: TLC plate of Student **B**

(iii) In terms of bonding involved, suggest reasons why the spots on Student **A**'s TLC plate are close to the baseline while the spots on Student **B**'s TLC plate are close to the solvent front.

• The spots on Student A's TLC plate are close to the baseline indicate that the solvent chosen, hexane is <u>not polar enough</u> to separate the mixture and the <u>compounds are bonded more strongly to the stationary phase (silica gel) more than the mobile phase (hexane).</u>

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• The spots on Student B's TLC plate are close to the solvent front indicate that the solvent chosen, <u>methanol, is too polar</u> and thus, the organic compounds are both <u>bonded more strongly to the mobile phase (methanol) than the stationary phase (silica gel).</u>

(iv) Given the following list of solvent and with reference to both students' TLC plates in **(iii)**, suggest the most appropriate solvent which can better separate the mixture above. Explain your answer.

List of solvent: water, benzene, dichloromethane

- **Dichloromethane**
- **The polarity of the solvent is more polar than hexane but less polar than methanol. (Intermediate polarity)**

[6]

(b) You are to determine the dye contents of the shell coating of M&M candies through analysis using thin-layer chromatography (TLC). The colours of the shells of M&M candies contain food colouring dye that are FDA approved organic compounds.

Write a plan to identify the possible food colouring dye that are present in the shell coating of a sample of blue M&M candies.

You may assume that you are provided with:

- A sample of a solution containing the shell-coating colouring of M&M candies
- Food colouring dye blue #1
- Food colouring dye blue #2
- TLC plate
- Jar with cover
- Appropriate solvent

Your plan should include details of:

- an outline of how thin-layer chromatography (TLC) is to be carried out
- a sketch of the TLC plate at the start of the experiment which you will use to determine the food dyes present in M&M shell-coating
- how you would determine the food dyes present in the sample of M&M shell-coating.

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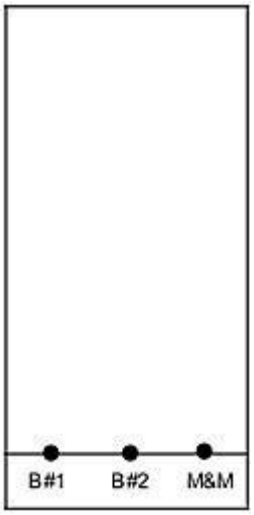
- **1) Fill the jar with the <u>appropriate solvent</u> about 0.5 cm depth. <u>Cover the jar</u> to ensure that the air in the jar is <u>saturated with solvent vapour</u>.**
  2) Using a <u>pencil</u>, draw a baseline <u>about 1 cm</u> *(must be <u>more than the depth of the solvent in the jar</u>)* from the bottom.
- **3) Label the TLC plate as follows:**



- **4) Using forceps, dip the TLC plate into the jar. Cover the jar and allow the solvent to move up the TLC plate. Remove the TLC plate from the jar <u>when the solvent reaches about the top of the plate.</u>**
  5) <u>Compare and match the spots of the</u> various food dyes and the components present in the M&M shell-coating travelled on the TLC plate.
- **6) The shell-coating of the M&M candies would contain food-dyes that move the same distance as the various food-dyes sample. E.g. If M&M has a spot which move the same distance as B#1, then the shell-coating of M&M candies contain the food dye B#1.**

<u>Marks allocation</u>:
1m – preparation of the jar (point 1)
1m – spotting of the TLC plate & diagram (point 2-3)
1m – outline of dipping of TLC plate into solvent and how the experiment is carried out. (point 4-5)
1m – outline on how the food dyes present in the sample of M&M shell-coating are determined (point 6)

[4]

(c) Student **C** is provided with another sample solution containing the shell-coating colouring of M&M candies. The composition of the food dyes present in the sample of M&M shell-coating is determined by comparison of R_f values.

Given that retention factor, R_f, is defined as

$$R_f = \frac{distance\ travelled\ by\ the\ spot}{distance\ travelled\ by\ the\ solvent}$$

where the R_f value is a characteristic property of a given compound in a given solvent on a particular stationary phase.

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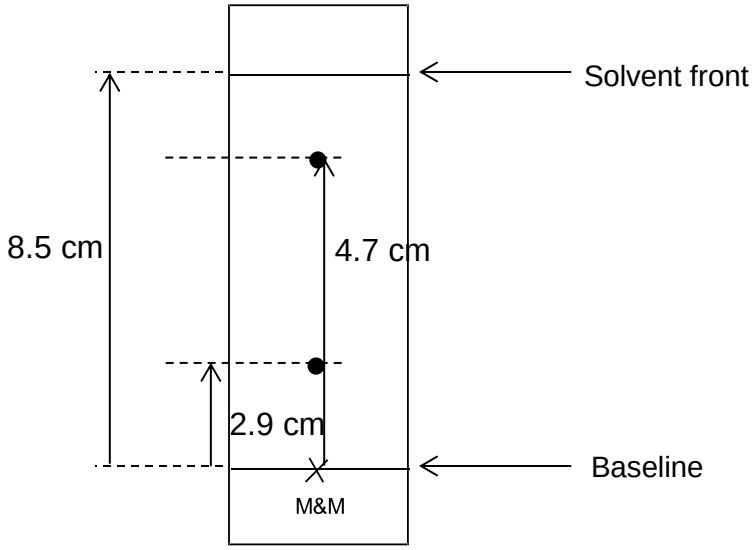
The following TLC plate is developed by Student **C,** using an appropriate solvent **Y**:



Given that the following food dyes have the following characteristics R_f values:

Food colouring dye	**Rf value in solvent Y**
Food colouring dye red #40	0.24
Food colouring dye blue #1	0.34
Food colouring dye blue #2	0.43
Food colouring dye yellow #6	0.55
Food colouring dye yellow #5	0.62

Calculate the R_f values of the 2 components in the shell-coating of M&M candies and determine the composition of the food-dyes present in the shell-coating of M&M candies.

• **R_f value (spot 1) = $\frac{2.9}{8.5}$ = 0.34**

R_f value (spot 2) = $\frac{4.7}{8.5}$ = 0.55

• **composition → Food colouring dye blue #1 and yellow #6**

[2]

[Total:12]

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2 (a) The first, second and third ionisation energies of manganese and iron are given in the table below:

	First Ionisation Energy / kJ mol^{-1}	Second Ionisation Energy/ kJ mol^{-1}	Third Ionisation Energy/ kJ mol^{-1}
Manganese	716	1510	3250
Iron	762	1560	2960

(i) Why is there an increasing trend in successive ionisation energies?

• As the electrons are removed, the number of protons remains unchanged hence the <u>nuclear charge remains constant</u>. The remaining <u>electrons are held more strongly by the nucleus</u> hence more energy is required to remove the next electron.

(ii) State the electronic configurations of Mn^{2+} and Fe^{2+}.

Mn^{2+}: **$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^5$**

Fe^{2+}: **$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^6$**

(1m for both correct ans)

(iii) Account for the difference between the third ionisation energies of manganese and iron.

• The 3rd IE of Fe is smaller than that of Mn due to the <u>inter–electronic repulsion between the 3d paired electrons in Fe</u>. Lesser energy is required to remove the paired electron.

[3]

(b) Sorbic acid (hex-2,4-dienoic acid) is a natural organic compound used as a food preservative. It has the following structure:

1 2 3 4 5 6
$CH_3CH=CH-CH=CH-COOH$

(i) Although both **C1**–**C2** and **C3**–**C4** bonds are single bonds, they have different bond strengths. Suggest which bond is stronger and explain your answer.

•C3-C4 bond is stronger.

C1–C2 bond: sp^3 – sp^2 overlap
C3–C4 bond: sp^2 – sp^2 overlap
• As the sp^2 hybrid orbitals of C3 and C4 contains <u>greater s-character, there is greater orbital overlap leading to a stronger bond.</u>

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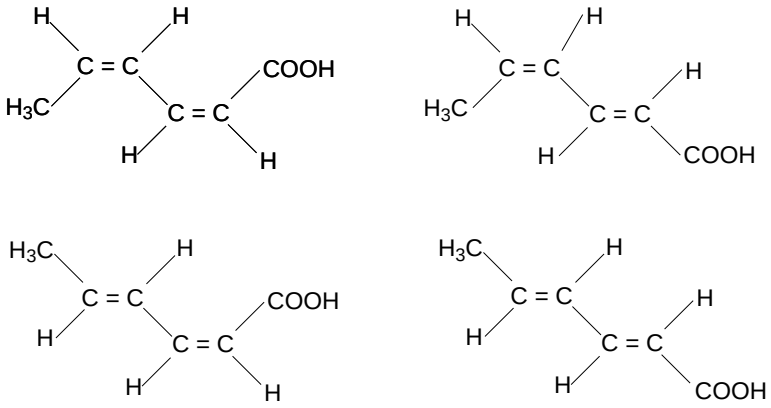
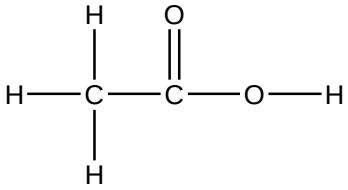
(ii) Draw diagrams to illustrate all the geometrical isomers of sorbic acid.

●●



(iii) On oxidation of sorbic acid with hot acidified $KMnO_4(aq)$, compound **R** is obtained. Draw the full displayed formula of compound **R.**

●



[5]

[Total: 8]

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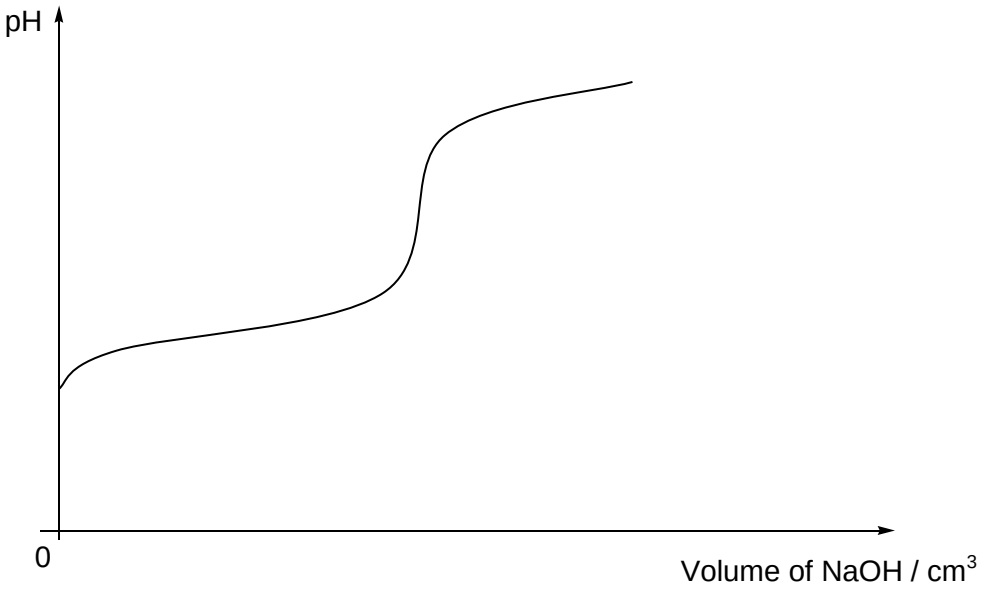
3 Lactic acid, $CH_3CH(OH)CO_2H$ is an α-hydroxy acid (AHA) used as an important flavouring component of many foods such as cheese, yoghurt and pickled cabbage.

(a) 0.200 g of lactic acid (M_r = 90.0) was dissolved in 20.0 cm^3 water, and the solution was titrated with 0.100 mol dm^{-3} aqueous NaOH. The following titration curve was obtained.
(K_a of lactic acid = 1.38 x 10^{-4} mol dm^{-3})



(i) Explain the term acid dissociation constant, K_a as applied to lactic acid.

- **The acid dissociation constant, K_a, is an equilibrium constant which measures the extent to which lactic acid is dissociated, *i.e.* measures the strength of lactic acid. [or give K_a expression]**

(ii) Calculate the volume of NaOH required to reach the equivalence point in the titration.

no. of moles of lactic acid = 0.20/90.0 = 2.22 x 10^{-3} mol

- **volume of NaOH required = (2.22 x 10^{-3}/0.10) x 1000 = 22.2 cm^3**

(iii) Calculate the pH of the solution at the equivalence point.

no. of moles of $CH_3CH(OH)CO_2^-$ salt formed at equivalence point = 2.22 x 10^{-3} mol

- **conc. of $CH_3CH(OH)CO_2^-$ salt = $\frac{2.22 \times 10^{-3} \times 1000}{(22.2 + 20.0)}$ = 0.0526 moldm^{-3}**

- **K_b of $CH_3CH(OH)CO_2^-$ = K_w/K_a of $CH_3CH(OH)CO_2H$ = 1x 10^{-14}/ 1.38 x 10^{-4} = 7.25 x 10^{-11} mol dm^{-3}**

- **$[OH^-] = \sqrt{(K_b\ c)} = \sqrt{(7.25 \times 10^{-11} \times 0.0526)} = 1.95 \times 10^{-6}$ mol dm^{-3}**

pOH = 5.71

pH = 14 – 5.71 = 8.29

For Examiner's Use

(iv) The table below lists the working ranges of some acid-base indicators.

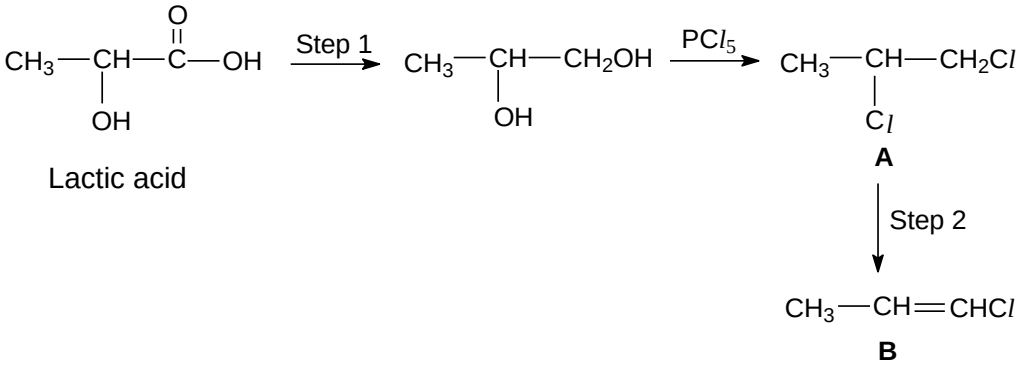
Indicator	Working range	Low pH color	High pH color
Tetrabromophenol blue	3.0 – 4.6	yellow	blue
Methyl red	4.4 – 6.2	red	yellow
Bromothymol blue	6.0 – 7.2	yellow	blue
Cresol red	7.2 – 8.8	yellow	red
Thymolphthalein	9.3–10.5	colorless	blue

Suggest the best indicator that can be used for this titration and give a reason for your choice.

● **Cresol red because the pH at the equivalence point is within the working range of the indicator. (equivalence pH = 8.29).**

[6]

(b) Lactic acid can undergo a series of reactions as shown below.



Lactic acid

A

B

(i) What reagents and conditions are required for the following steps?

Step 1: **LiA*l*H$_4$ in dry ether solvent, room temperature**

Step 2: **NaOH in ethanol, heat or reflux**

(ii) Arrange the two compounds **A** and **B** in order of increasing ease of hydrolysis, giving your explanations clearly.

● **B undergoes hydrolysis <u>less easily than A</u> .**

●**This is because in B, the C–C*l* bond has <u>partial double bond character</u> due to the <u>overlap of the p-orbital of C*l* with the π-electron</u> cloud of the adjacent alkene carbons. Thus the C–C*l* bond in B is much stronger than C–C*l* in A, and is harder to break.**

OR

The <u>carbon of C–C*l* in B</u> is <u>less electron deficient</u> than that in A due to the <u>presence of the electron-rich π electron</u> cloud of the double bond.

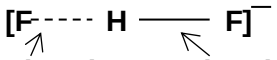
[4]

[Total: 10]

For Examiner's Use

4 The halogens are reactive non-metals which often react by gaining electrons to form halides ions. The halogens are commonly extracted by the electrolysis of their salts. For fluorine, it is obtained by electrolysis of molten potassium hydrogen difluoride, KHF_2, which is an ionic compound containing one cation and one anion.

(a) Suggest a structure for the anion and state what type(s) of bonding occur within it.



hydrogen bond **covalent bond**

[1 mark for structure & 1 mark for bondings] [2]

(b) Complete the table to show the colours and physical states of chlorine, bromine and iodine at room temperature and pressure.

Halogen	Colour	Physical state
Chlorine	green-yellow/yellow-green	gas
Bromine	red-brown	liquid
Iodine	Grey-black/black	solid

[1 mark for colour & 1 mark for physical state] [2]

(c) **(i)** How do the bromide and iodide ions differ in their reactions with silver nitrate, followed by ammonia?

Cream AgBr ppt, soluble in concentrated NH_3 for Br^- and

Yellow AgI ppt, insoluble in concentrated NH_3 for I^-

[colour of ppt: ●1 mark, solubilities in concentrated NH_3: ●1 mark]

(ii) Explain the differences in their reactions.

- In the presence of NH_3, Ag^+ forms complex with NH_3, thus decreasing $[Ag^+]$.
  $Ag^+ + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+$ …….(1)
- When $[Ag^+]$ decreases, ionic products for silver bromide & silver iodide decrease, but since silver bromide has a larger K_{sp} than silver iodide, ionic product of silver bromide becomes less than its K_{sp} more readily and it dissolves in concentrated ammonia while silver iodide does not. [4]

(d) Solid samples of calcium fluoride, calcium chloride, calcium bromide and calcium iodide can be distinguished using concentrated sulfuric acid.

(i) Write equations for the reactions of calcium bromide with concentrated sulfuric acid.

- $CaBr_2 + 2H_2SO_4 \rightarrow Ca(HSO_4)_2 + 2HBr$
  $2HBr + H_2SO_4 \rightarrow Br_2 + 2H_2O + SO_2$ [1]

Ionic equation for 1st reaction is accepted – $Br^- + H_2SO_4 \rightarrow HSO_4^- + HBr$

For Examiner's Use

(ii) Name **one** other reduction product which is formed when concentrated sulfuric acid is added to calcium iodide.

- hydrogen sulfide, H_2S, or sulfur [1]

When calcium fluoride reacts with concentrated sulfuric acid, gaseous hydrogen fluoride is produced. Hydrogen fluoride is unique in attacking glass, and is used in etching apparatus and making decorative glass. The most common constituent of sand is silicon dioxide, SiO_2. When HF reacts with silicon dioxide, gaseous silicon tetrafluoride and steam are formed. The enthalpy change for this reaction is -1032 kJ mol^{-1}.

(iii) Write an equation, with state symbol, for the reaction between hydrogen fluoride and silicon dioxide.

- $SiO_2(s) + 4HF(g) \rightarrow SiF_4(g) + 2H_2O(g)$ [1]

Wrong or omission of state symbols are penalized.

(iv) Using relevant data from the *Data Booklet*, calculate the bond energy of the Si-F bond.

- Bond energy of Si-O = 444 kJ mol^{-1}, H-F = 562 kJ mol^{-1}, H-O = 460 kJ mol^{-1}
- -1032 = 2(+444) + 4(+562) – [4(Si-F) + 4(460)]
  - 1032 = +1296 – 4(Si-F)
  - 4(Si-F) = - 2328
- Bond energy of Si-F = 582 kJ mol^{-1}

[data : 1 mark; working & answer: 2 marks]

(v) Sodium fluoride is added to toothpaste to strengthen tooth enamel. The data on a 50 g tube of toothpaste states that it contains "1450 ppm fluoride" and the density of the toothpaste is 1.6 g cm^{-3}. Calculate the concentration of sodium fluoride in the toothpaste.

$NaF \equiv F^-$

Number of moles of sodium fluoride in the 50 g tube

$= 1450/10^6 \times 50 \div 19 = 3.816 \times 10^{-3}$ mol

Volume of toothpaste in the 50 g tube = 50/1.6 = 31.25 cm^3 or 0.03125 dm^3

Concentration of sodium fluoride in the toothpaste

$= 3.816 \times 10^{-3} \div 31.25 \times 1000 = 0.122$ mol dm^{-3} or 0.000122 mol cm^{-3}

OR concentration of sodium fluoride = 5.12 g dm^{-3} or 5.12 x 10^{-3} g cm^{-3}.

[working: 1 mark, answer: 1 mark]

[8]

[Total:16]

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5 Corrosion is a common problem for structures made from metals. For example, iron can undergo electrochemical oxidation, i.e. rusting.

(a) A ship's hull made from steel contains iron that, when exposed to moisture in air or aerated seawater, rusts easily. Rusting is a multi-step process, involving first the formation of iron(II) ions, which then precipitates as iron(II) hydroxide. Iron(II) hydroxide readily becomes further oxidised, and in the final step, forms rust, iron(III) oxide.

(i) Seawater has a typical pH range of 7.5 to 8.4.

With reference to the *Data Booklet*, explain why the oxidation of iron to iron(II) ions is spontaneous when both moisture and air are present.

$E^{\ominus}_{Fe^{2+}/Fe} = -0.44$ V

When both oxygen (air) and water (moisture) are present,

$E^{\ominus}_{O_2/OH^-} = +0.40$ V (●quoting both correct $E^{\ominus}$ values)

$E^{\ominus}_{cell} = E^{\ominus}_{red} - E^{\ominus}_{oxid}$

$= +0.40 - (-0.44) =$ ●+0.84 V

Since $E^{\ominus}_{cell}$ is positive, the reaction is spontaneous.

(ii) Explain how the formation of iron(II) hydroxide causes the actual cell potential to be more positive than the calculated value at standard conditions.

$Fe^{2+} + 2e \rightleftharpoons Fe$ ----------(1)

$O_2 + 2H_2O + 4e \rightleftharpoons 4OH^-$ ----------(2)

●When $Fe(OH)_2$ is formed, Fe^{2+} is removed and [Fe^{2+}] decreases. By Le Chatelier's Principle (LCP), position of equilibrium(1) shifts to the left, favouring oxidation, and therefore $E_{Fe^{2+}/Fe}$ (which is E_{ox}) becomes less positive.

●The formation of $Fe(OH)_2$ causes [OH^-] to decrease as well. By LCP, position of equilibrium(2) shifts to the right, favouring reduction, and therefore E_{O_2/OH^-} (which is E_{red}) becomes more positive. Both changes cause the cell potential to become more positive.

(iii) With reference to the *Data Booklet*, explain why iron(II) hydroxide readily becomes further oxidised.

$E^{\ominus}_{Fe(OH)_3/Fe(OH)_2} = -0.56$ V

$E^{\ominus}_{cell} = E^{\ominus}_{red} - E^{\ominus}_{oxid}$

$= +0.40 - (-0.56) =$ ●+0.96 V

Since $E^{\ominus}_{cell}$ is positive, $Fe(OH)_2$ readily becomes further oxidised.

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(iv) Write a balanced equation for the oxidation of iron(II) hydroxide to iron(III) hydroxide.

●$4Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3$

(v) Write a balanced equation for the conversion of iron(III) hydroxide to iron(III) oxide.

●$2Fe(OH)_3 \longrightarrow Fe_2O_3 + 3H_2O$

[7]

(b) In ship construction, in order to protect the iron in the hull, another metal is placed on the hull within the ship, in physical and electrical contact with the iron. Even when the iron is the metal exposed to moisture and air, this metal eventually corrodes in place of iron through establishing a galvanic reaction with iron.

Suggest a suitable metal that can be used, and explain how it protects the iron in the ship's hull.

- **Magnesium/ Aluminium/ Zinc can be used *(accept any metal that has $E^{\ominus} < -0.44V$ and is not too reactive to be a safety hazard).***

When the Fe becomes oxidised to Fe^{2+},

$E^{\ominus}_{Fe^{2+}/Fe} = -0.44$ V

$E^{\ominus}_{Al^{3+}/Al} = -1.66$ V

$E^{\ominus}_{cell} = -0.44 - (-1.66) = +1.22$ V

●Since $E^{\ominus}_{cell}$ is positive, the <u>Al</u> in contact with Fe <u>will become oxidised to Al^{3+}</u> while <u>Fe^{2+}</u> formed from the reaction of Fe with air and moisture will be <u>reduced to Fe</u>.

OR

- **$E^{\ominus}_{Al^{3+}/Al}$ is more negative than $E^{\ominus}_{Fe^{2+}/Fe}$, aluminium is more readily oxidised than iron.**

  $E^{\ominus}_{O_2/OH^-} = +0.40$ V

  $E^{\ominus}_{Al^{3+}/Al} = -1.66$ V
- **$E^{\ominus}_{cell} = +0.40 - (-1.66) = +2.06$ V**
  Reaction of aluminium with oxygen and water is more spontaneous.

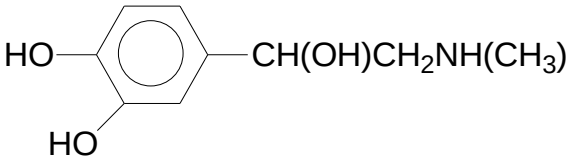
  Note: mark deducted for any mention of formation of protective layer of metal oxide or metal hydroxide in order to prevent rusting of iron.

[Total:10]

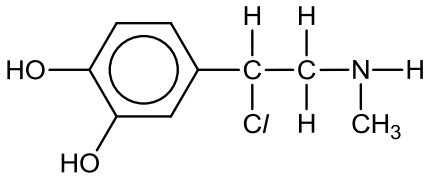
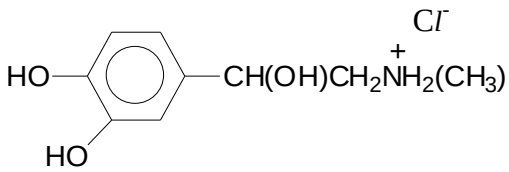
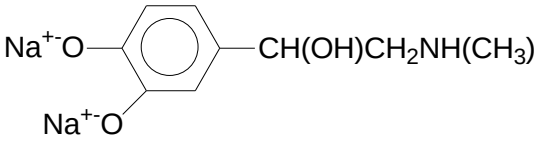
For Examiner's Use

6 This question is about adrenaline and a specialty compound **C** whose structure is to be determined.

(a) Adrenaline is an important hormone concerned with 'fight' and 'flight' situations.

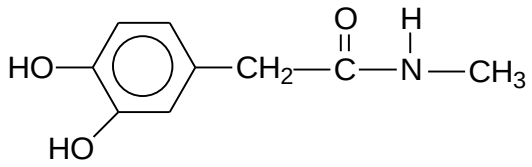


In the boxes below, give the structural formulae of the organic products formed when adrenaline reacts with each of the following reagents.

Reagents and conditions	Product
(i) $SOCl_2$	
(ii) Dilute hydrochloric acid	
(iii) Excess NaOH(aq)	

For Examiner's Use

(iv) Suggest a simple chemical test that can be used to distinguish between adrenaline and the following compound **Z**:



Z

[5]

- Test: Heat both compounds with NaOH(aq) separately
- Observations: For compound **Z**, alkaline gas liberated turning moist red litmus paper blue.

  For adrenaline, no alkaline gas liberated.

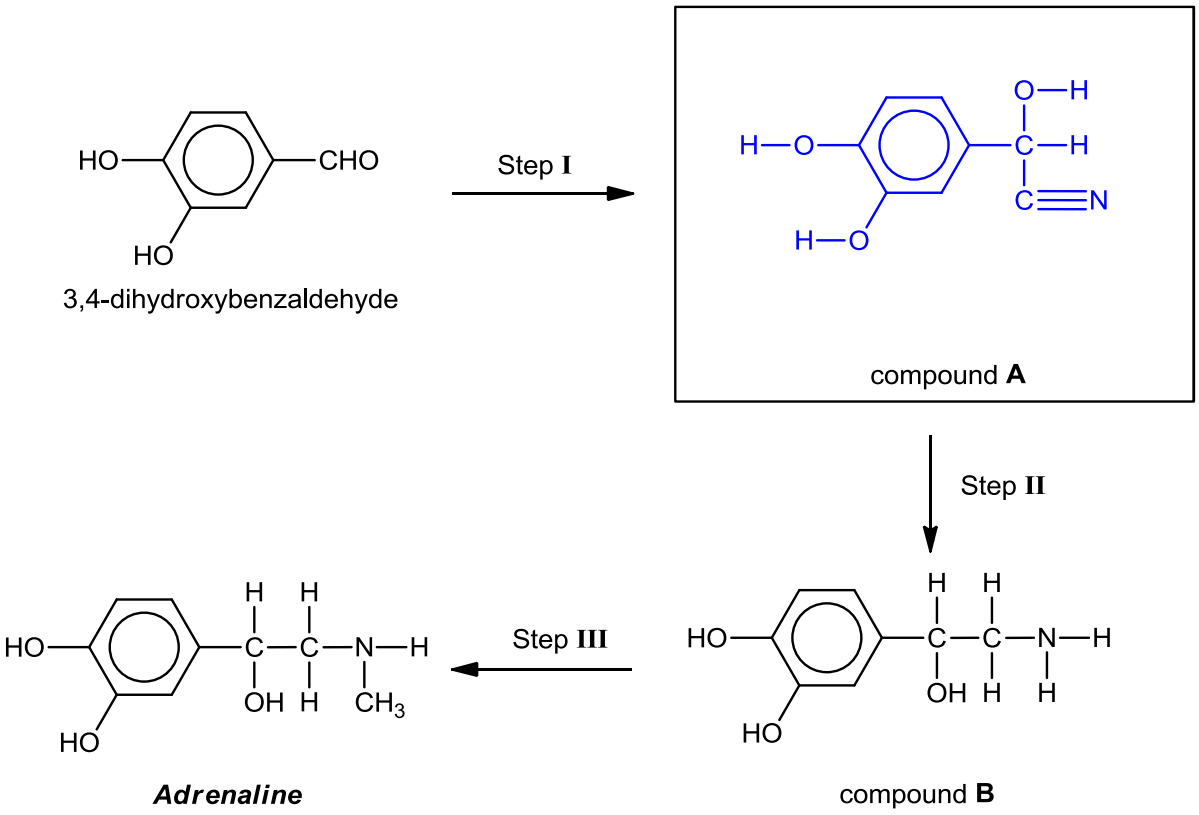
or

- Test: Add PCl_5(s) to both compounds separately in the cold.
- Observations: For adrenaline, copious white fumes will be observed.

  For the compound **Z**, no white fumes will be observed.

For Examiner's Use

(b) Adrenaline can be synthesised from 3,4-dihydroxybenzaldehyde via the following reaction pathway with a hydroxynitrile being the intermediate.



(i) Draw the structural formula of compound **A** in the box provided above.

(ii) State the reagents and conditions required for Steps **I** – **III** by completing the table below.

Steps	Reagents and conditions
I	HCN, trace amount of NaOH, 10-20°C
II	LiA/H_4 in dry ether, room conditions
III	CH_3Br, heat

[4]

For Examiner's Use

(c) Compound **C** is a specialty product for proteomics research. Refluxing **C** in dilute sulfuric acid produces **D** and ethanoic acid.

Elemental analysis of compound **D** gives the following results:

Elemental Analysis (% by mass)		
C	**H**	**O**
60.8	4.4	34.8

Some reactions of **D** are given below:

Reaction 1 : **D** + $Br_2(aq)$ ⟶ White solid, **E** (M_r = 374.7)
Reaction 2 : **D** + $Na_2CO_3(aq)$ ⟶ Effervescence of gas.

(i) When vaporised in a suitable vessel, 1g of **D** occupies a volume of 282 cm^3 at 200 ^oC and a pressure of 101 kPa. Calculate the M_r of **D**.

- **$(101\,000)(282 \times 10^{-6}) = (1 / M_r)(8.31)(200+273)$**
  $M_r = 138$

(ii) Using the elemental analysis results and your answer in **(c)(i)** , deduce the molecular formula of **D**.

	Elemental Analysis (%)		
	C	**H**	**O**
% by mass	60.8	4.4	34.8
No of moles	5.06	4.4	2.18
Divide by smallest	2.32	2.0	1
Simplest ratio	7	6	3

- **Empirical formula of D is $C_7H_6O_3$**
- Molecular formula of **D :$\underline{C_7H_6O_3}$**

(iii) Name the functional groups present in **D**.

- **Carboxylic acid and phenol**

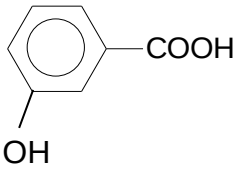
(vi) State the molecular formula of **E** in reaction **1**.

Molecular formula of **E** : **$\underline{C_7H_3O_3Br_3}$**

(v) Draw the structure of **D** below.

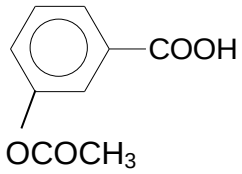
For Examiner's Use

- **D:**



(vi) Hence deduce the structure of compound **C**.

- **C:**



[7]

[Total 16]

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