YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CG		INDEX NO	

CHEMISTRY 9729/02

Paper 2 Structured Questions

29 August 2022

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use		
1	/ 14	
2	/ 17	
3	/ 12	
4	/ 15	
5	/ 17	
Penalty	units	significant figures
Overall	/ 75	

This document consists of **24** printed pages and **4** blank pages.

Answer **all** the questions in the spaces provided.

1 Gallium, chromium and iron are metals that are found in Period 4 of the Periodic Table.

(a) (i) Naturally occurring gallium, Ga, is a mixture of two isotopes.

Table 1.2 shows the relative percentage abundance of the two isotopes.

Table 1.2

relative mass	relative % abundance
68.9256	60.11
70.9247	39.89

Calculate the relative atomic mass of Ga to four significant figures.
Show your working

. [2]

(ii) Gallium reacts with nitrogen to form gallium nitride, GaN.

Calculate the volume of nitrogen gas needed to react with 10 kg of gallium at s.t.p..

[2]

(b) Chromium(III) hydroxide, $Cr(OH)_3$, is sparingly soluble in water.

$$Cr(OH)_3(s) \rightleftharpoons Cr^{3+}(aq) + 3OH^-(aq)$$

(i) Write an expression for the solubility product, K_{sp}, of chromium(III) hydroxide, stating its units.

K_{sp} = units ..... [2]

(ii) Calculate the concentration of $OH^-(aq)$ in a saturated solution of chromium(III) hydroxide, given the value of K_{sp} is 6.7×10^{-31}.

[2]

(iii) Describe and explain how the solubility of chromium (III) hydroxide is affected by adding $Cr_2(SO_4)_3(aq)$.

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..... [1]

(c) Iron(II) oxide, FeO, is used to form Fe_3O_4 as shown.

$$4FeO(s) \rightarrow Fe(s) + Fe_3O_4(s)$$

Each formula unit of Fe_3O_4 contains one Fe^{2+} and two Fe^{3+} ions.

(i) Using oxidation number, show how the reaction can be described as a *disproportionation* reaction.

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..... [1]

$Fe_3O_4(l)$ can be electrolysed using inert electrodes to form Fe.

(ii) Write the half-equation for the reaction that occurs at the anode during the electrolysis of $Fe_3O_4(l)$.

..... [1]

(iii) Calculate the maximum mass of iron metal formed when $Fe_3O_4(l)$ is electrolysed for 6 hours using a current of 50 A.

Assume that one Fe^{2+} and two Fe^{3+} ions are discharged at the same rate.

[3]

[Total: 14]

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2 **(a)** An organic compound **A**, C_5H_yO, undergoes complete combustion to produce CO_2 and H_2O.

The value of y in the molecular formula of **A** can be determined by exploding it with an excess oxygen and analysing the products of the combustion.

(i) Balance the following equation, in terms of y, for the complete combustion of one mole of compound **A** at 300 ^oC and 1 atm.

$C_5H_yO(g)$ + ... $O_2(g)$ $\rightarrow$ ..... $CO_2(g)$ + ... $H_2O(g)$

[1]

(ii) When 10 cm^3 of gaseous compound **A** was mixed with an excess oxygen at 300 ^oC and 1 atm, there is an expansion of volume by 25 cm^3.

Determine the value of y.

[2]

(iii) Draw the arrangement of the hybridised orbitals of one of the carbon atoms in Compound **A**.

[1]

(b) Draw the displayed formula of all the constitutional (structural) isomers with the formula C_5H_{12}.

[1]

(c) Cyanamide, NH_2CN, is an organic compound used in agriculture and in the synthesis of pharmaceuticals.

The carbon atom is bonded to both nitrogen atoms in the cyanamide molecule.

(i) Draw a 'dot-and-cross' diagram of the cyanamide molecule.
You should distinguish carefully between electrons originating from the central atom and those from the other atoms.

[1]

(ii) Cyanamide can be produce by the hydrolysis of calcium cyanamide in the presence of carbon dioxide.

$$CaCN_2 + H_2O + CO_2 \rightarrow CaCO_3 + NH_2CN$$

Table 2.1 gives the melting points of $CaCN_2$ and NH_2CN.

Table 2.1

compound	melting point / ^oC
$CaCN_2$	1340
NH_2CN	44

Explain, in terms of structure and bonding, the difference in melting point between $CaCN_2$ and NH_2CN

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..... [2]

(d) When CO_2 reacts with H_2, methanol, CH_3OH, is produced according to equation.

$$CO_2(g) + 3H_2(g) \rightarrow CH_3OH(l) + H_2O(l)$$

Table 2.2 shows the standard enthalpy and entropy changes of reaction for this process at 298K.

Table 2.2

$\Delta H^{\ominus}$ at 298 K	-131 kJ mol^{-1}
$\Delta S^{\ominus}$ at 298 K	-410 J K^{-1} mol^{-1}

(i) Explain why the process shows an overall negative value for $\Delta S^{\ominus}$.

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..... [1]

(ii) Calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, for this reaction at 298 K.

[1]

(iii) Predict the effect of increasing the temperature on the spontaneity of this reaction. Explain your answer.

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..... [2]

(e) **(i)** Define the term *standard enthalpy change of combustion*.

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..... [1]

(ii) Use of the *Data Booklet* is relevant to this question.

In an experiment to determine the standard enthalpy change of combustion of ethanol, CH_3CH_2OH, 0.230 g of ethanol was burned, and the heat given off raised the temperature of 100 g of water by 16.3 °C.

Calculate the enthalpy change of combustion, $\Delta H_c^{\ominus}$, of ethanol.

[2]

(iii) Suggest one reason why the value for the enthalpy change of combustion of ethanol determined by a simple laboratory calorimetry experiment is likely to be lower than the true value.

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..... [1]

(f) The equation below represents the standard enthalpy change of formation of propan-1-ol.

$$3C(s) + 4H_2(g) + \frac{1}{2}O_2(g) \rightarrow CH_3CH_2CH_2OH(l)$$

Calculate the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of liquid propan-1-ol using the data given in Table 2.3.

Table 2.3

standard enthalpy change of combustion of $CH_3CH_2CH_2OH(l)$	-2021 kJ mol^{-1}
standard enthalpy change of combustion of C(s)	-393.5 kJ mol^{-1}
standard enthalpy change of formation of $H_2O(l)$	-285.8 kJ mol^{-1}

[1]

[Total: 17]

3 Iodide ions react with peroxodisulfate ions to form iodine and sulfate ions as shown in the equation.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

The rate of the reaction can be determined by mixing 50.0 cm^3 of 0.200 mol dm^{-3} of aqueous potassium iodide with 50.0 cm^3 of 2.00 mol dm^{-3} aqueous potassium peroxodisulfate. At various time intervals, a portion of the reaction mixture would be drawn, quenched and titrated against a standard solution of aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$.

The volume of sodium thiosulfate used is directly proportional to the volume of iodine produced.

(a) Outline how you would collect sufficient data to allow a graph of volume of sodium thiosulfate against time to be drawn. You are provided with the same solutions which were used in the experiment described.

No details regarding use of specific glassware are required.

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..... [3]

(b) The order of reaction with respect to [KI] is one.

Use this information and the procedure given in **(a)** to sketch a graph on Fig. 3.1 showing the relationship between the time taken to draw out the reaction mixture and the volume of sodium thiosulfate added.
No calculations for volume of sodium thiosulfate are required. [2]

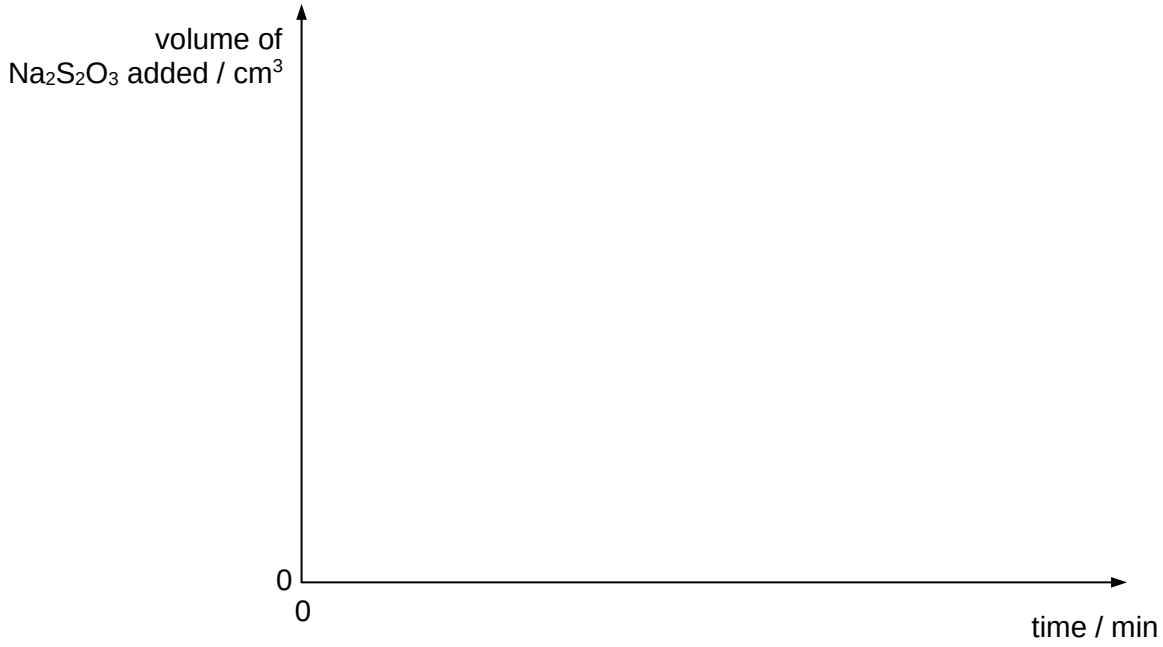

Fig. 3.1

(c) The concentration of peroxodisulfate ions was halved and a new series of experiments carried out at the same temperature. When a similar graph was plotted, the gradient at each point was half that obtained from **(b)**.

What is the order of reaction with respect to peroxodisulfate ions? Explain your answer.

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..... [2]

(d) The reaction between iodide and peroxodisulfate ions is very slow. If a small amount of aqueous iron(II) ions is added to the mixture, the rate of reaction increases.

(i) Explain why the iron(II) ions can be described as a *homogeneous catalyst*.

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..... [2]

(ii) State the property, typical of transition metals, which allows iron(II) ions to behave as a catalyst in this reaction.

Include relevant chemical equations to support you answer.

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..... [3]

[Total: 12]

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4 **(a)** Amphetamine is a synthetic stimulant drug that stimulates the nervous system. It is used for treatment of attention-deficit hyperactivity disorder (ADHD).

Amphetamine can be synthesised from phenylpropanone as shown in Fig. 4.1.

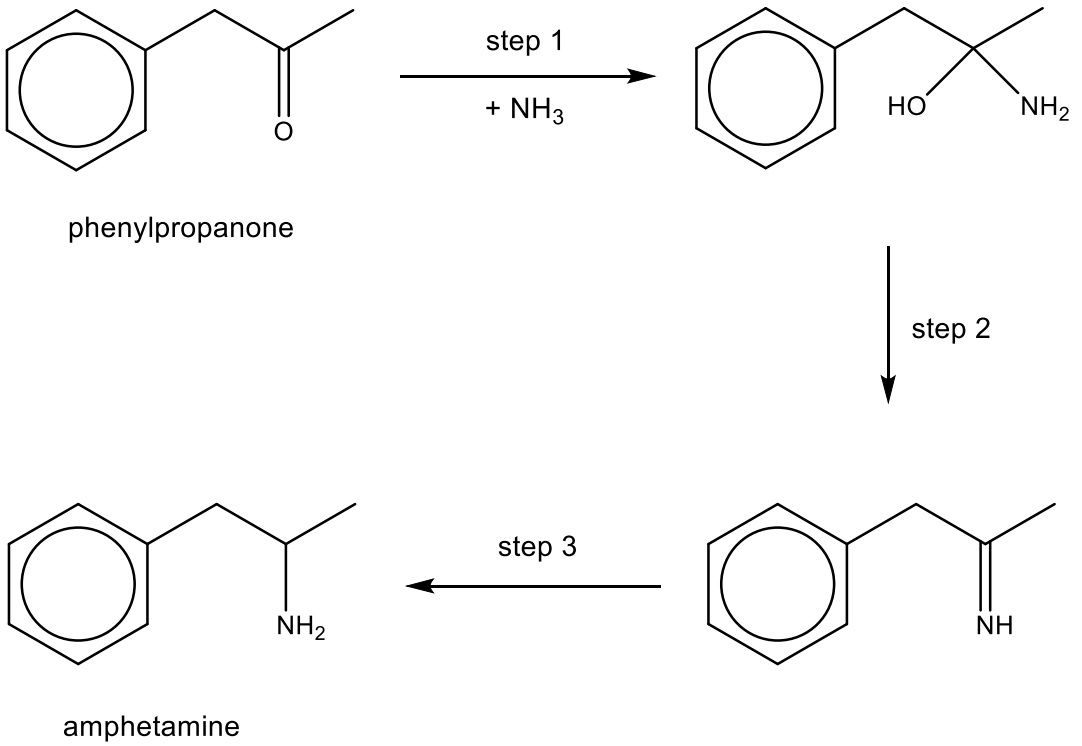


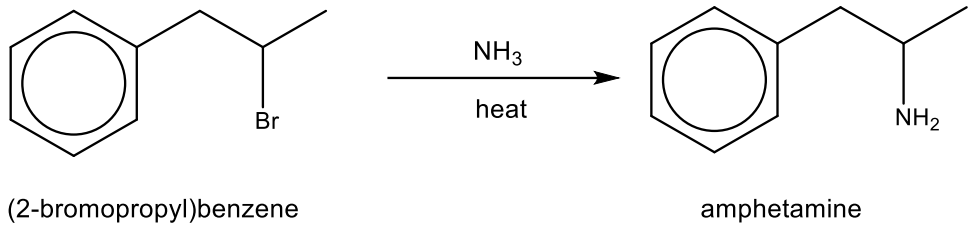
Fig. 4.1

(i) State the *type of reactions* that occur during each of the steps 1, 2 and 3.

step	type of reaction
1	
2	
3	

[3]

(ii) Amphetamine can be also synthesised from (2-bromopropyl)benzene with ammonia as shown in Fig. 4.2.



(2-bromopropyl)benzene amphetamine

Fig. 4.2

When plane-polarised light is passed through the amphetamine that is synthesised using this reaction, there is no effect.

Draw a mechanism that can explain the above observation. Show relevant lone pairs and dipole, and use curly arrows to indicate the movement of electrons pairs.
Use R to represent - $CH_2C_6H_5$.

[3]

The building blocks of proteins are α-amino acids that have the general structure as shown.

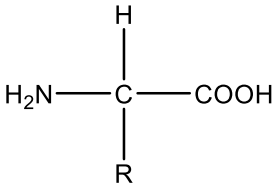


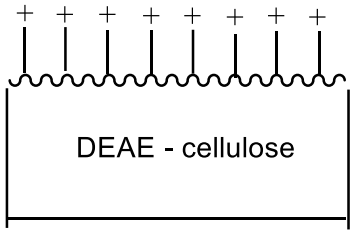
Table 4.1 shows the pK_a values of the different functional groups present in three α-amino acids.

Table 4.1

amino acid	R group	pK_a of α-carboxyl group	pK_a of α-amino group	pK_a of side chain
aspartic acid	$-CH_2CO_2H$	2.09	9.82	3.86
lysine	$-(CH_2)_4NH_2$	2.15	9.16	10.67
glutamine	$-(CH_2)_2CONH_2$	2.20	9.10	–

(b) Mixtures of α-amino acids can be separated by ion-exchange chromatography.
This technique involves pouring the mixture of α-amino acids dissolved in water at pH 7 down a column containing an ion-exchange resin called DEAE-cellulose.

The structure of the DEAE-cellulose can be presented as shown below.



The '+' signs on the diagram show that the DEAE-cellulose is positively charged at pH 7.

The separation of the α-amino acids from the mixture is based on the net charge of their predominant species at pH 7.0.

(i) A mixture of aspartic acid, lysine, and glutamine are dissolved in water and poured down the ion-exchange column as shown in Fig. 4.1.

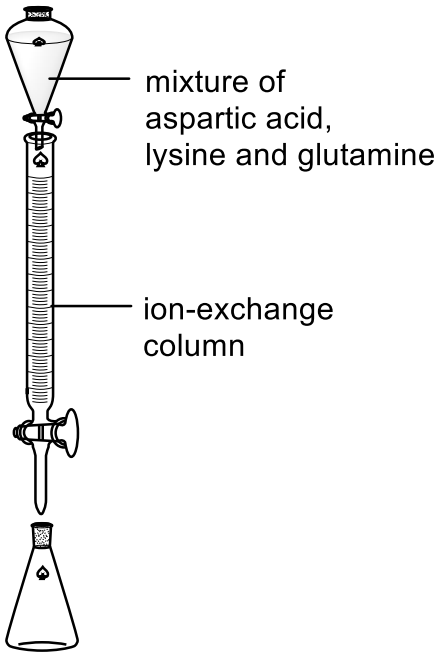


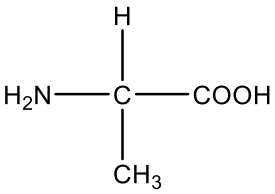
Fig. 4.1

Draw the structure of the predominant species of the three α-amino acids at pH 7.0 and suggest the order in which the α-amino acids will be collected.
Explain your answer.

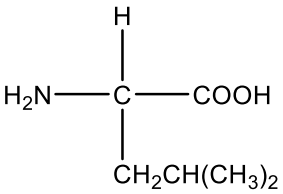
order of α-amino acids collected	structure of predominant species of α-amino acid at pH 7.0	explanation
first		
second		
last		

[4]

(ii) Alanine and leucine are also α-amino acids.



alanine



leucine

Explain why DEAE-cellulose cannot be used to separate a mixture of these two α-amino acids.

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..... [1]

(c) A tripeptide can be made by reacting aspartic acid, lysine and glutamine.

amino acid	R group
aspartic acid	$-CH_2CO_2H$
lysine	$-(CH_2)_4NH_2$
glutamine	$-(CH_2)_2CONH_2$

(i) Name the type of reaction occurring when a tripeptide in formed from the three amino acids.

..... [1]

(ii) State the maximum number of different tripeptides that can be formed from the three amino acids.

..... [1]

(iii) Draw the skeletal formula of one of the possible tripeptides that can be formed from the three amino acids.

[2]

[Total: 15]

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5 The alcoholic drinks industry produces a vast range of products every year. Alcohol in the body depressed the activity of the central nervous system and so drinking alcohol reduces vigilance, slows reaction times and impair judgement. Most countries in the world have introduced laws to control the use of alcohol, particularly in relation to operating machines and driving.

Blood alcohol concentration (BAC) is a good measure of the extent to which the activity of the central nervous system is depressed. It is usually defined as follows.

BAC = mg of ethanol per 100 cm^3 of blood

After the consumption of too much alcoholic beverage, people sometimes experience a hangover the following day. There are a variety of causes of a hangover, one of these is the accumulation of the toxic metabolites of ethanol in the body.

Ethanol is removed from the blood by enzymes in a two-step process as shown in Fig. 5.1.
Ethanol first converted to ethanal by a group of enzymes known as alcohol dehydrogenase, and the ethanal formed is then converted to ethanoic acid by another enzyme, acetaldehyde dehydrogenase.

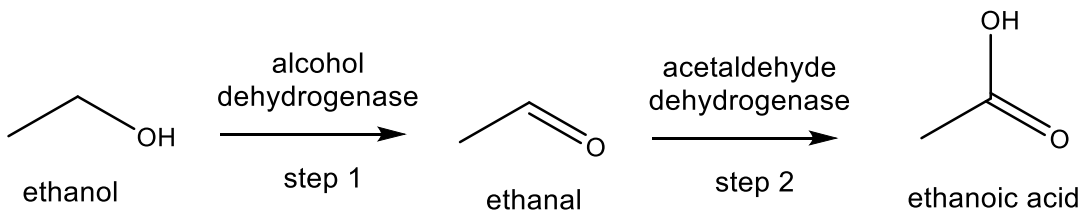

Fig. 5.1

Ethanal is relatively toxic and it is responsible for alcohol-related facial flushing, headaches, nausea and increased heart rate.

(a) In step 1 of Fig. 5.1, ethanol reacts with nicotinamide adenine dinucleotide, NAD^+, a coenzyme, to form ethanal, H^+ and a compound called NADH.

(i) State the type of reaction that has occurred for NAD^+ in this reaction.

.....

[1]

(ii) Both ethanal and ethanoic acid can be obtained from ethanol in the laboratory.
State the reagents you could use to carry out these reactions. How would you ensure that the main product was ethanal rather than ethanoic acid.

.....

[1]

(iii) State a reagent you could use to convert ethanoic acid into ethanol.

.....

[1]

(b) Alcohol dehydrogenase enzyme combines with ethanol to form an enzyme-substrate complex which will then be converted into ethanal.

Fig. 5.2 shows the relationship between the [ethanol] and the rate of reaction, using a fixed amount of the alcohol dehydrogenase enzyme.

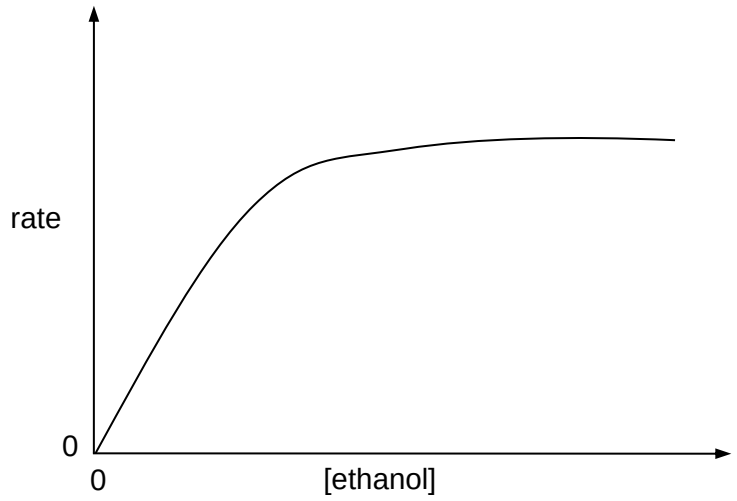

Fig. 5.2

Explain the relationship between [ethanol] and the rate of the enzyme catalysed reaction.

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..... [2]

(c) The rate equation for the conversion of ethanol to ethanal by the alcohol dehydrogenase enzyme is

$$\text{rate} = \frac{k_{cat}[AD][S]}{K_M + [S]}$$

Where: [AD] is the concentration of the alcohol dehydrogenase enzyme,
[S] is the concentration of the substrate, ethanol,
k_{cat} is the rate constant,
K_M is a constant that measures the ease of dissociation of the enzyme-substrate complex back to the reactants.

Table 5.1 gives the values of k_{cat} and K_M for ethanol.

Table 5.1

k_{cat} / s^{-1}	K_M / mol dm^{-3}
1.33	1.00×10^{-3}

At present in Singapore the legal limit to drive a car is 80 mg of ethanol per 100 cm^3 of blood.

(i) The concentration of ethanol at the Singapore legal limit to drive a car, when expressed in mol dm^{-3}, is 1.74×10^{-2} mol dm^{-3}.

Using the information given above, show that the rate equation of this reaction is

$$\text{rate} = k_{cat}[AD]$$

when [ethanol] is at the Singapore's legal limit to drive a car.

[1]

Drivers who consume too much alcoholic beverages will need to wait for the BAC in their blood to fall below the legal limit. This process of waiting is known as sobering up.

The rate of loss of ethanol per 100 cm^3 of blood is 18.33 mg hr^{-1} and is a constant value.

(ii) Calculate the rate loss of ethanol, in mol dm^{-3} s^{-1}, when a person is sobering up.

[3]

(iii) Use your answer to **(c)(i)** and **(c)(ii)** to calculate the concentration of alcohol dehydrogenase enzyme in this person.

[1]

(iv) Calculate the time, in hours, required for the person with a BAC of 345 mg of ethanol per 100 cm^3 of blood to fall to the Singapore's legal limit to drive a car immediately after he has stopped consuming any more alcoholic beverages.

[1]

(d) Methanol and ethane-1,2-diol are poisonous chemicals. When ingested, alcohol dehydrogenase metabolises these alcohols to form acidic metabolites that are highly toxic.

(i) Write an equation of the oxidation of ethane-1,2-diol to its corresponding acid.
Use [O] to present the formula of the oxidising agent.

..... [1]

(ii) Ethanol is used to treat victims of methanol or ethane-1,2-diol poisoning. This is because ethanol is a better substrate for alcohol dehydrogenase, and it will be metabolised preferentially by the enzyme.

Describe a simple chemical test that could be used to distinguish ethanol from methanol and state your observations clearly

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..... [2]

(iii) Ethane-1,2-diol dissolves in water readily.

Draw a diagram to show how water molecules interact with the ethane-1,2-diol molecule. Label the diagram to show the interaction involved.

[1]

(e) The first four members of the series of carboxylic acids represented by the general formula $H\text{-}(CH_2)_n\text{-}CO_2H$ (n = 0, 1, 2, 3...) are fully soluble in water, but as the value of n increases from 4 upwards, the acids become increasingly insoluble.

By considering the relevant interactions between the molecules of the carboxylic acids with each other, and also with the solvent, suggest reason for this decreasing solubility.

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..... [2]

[Total: 17]

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