YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	**SUGGESTED ANSWERS**		
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	/ 16	
5	/ 16	
Penalty	units	significant figures
Overall	/ 75	

This document consists of **28** printed 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]

Relative atomic mass of Ga = $\frac{(68.9256 \times 60.11) + (70.9247 \times 39.89)}{100}$ = **69.72**

(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]

$Ga(s) + \frac{1}{2}N_2(g) \longrightarrow GaN(s)$

Amount of Ga = 10000 ÷ 69.7 = 143.47 mol
Amount of N_2 needed = 0.5 × 143.47 = **71.736 mol**
Volume of N_2 needed = 71.736 × 22.7 = **1630 dm^3**

(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. [2]

$K_{sp} = [Cr^{3+}][OH^-]^3$, units: mol^4 dm^{-12}

(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]

Let the solubility of $Cr(OH)_3$ be x mol dm^{-3}

$[Cr^{3+}] = x$ mol dm^{-3}; $[OH^-] = 3x$ mol dm^{-3}
$K_{sp} = [Cr^{3+}][OH^-]^3 = (x)(3x)^3$

$6.7 \times 10^{-31} = 27x^4$
$x =$ **1.2550×10^{-8} mol dm^{-3}**
$[OH^-] = 3 \times (1.2550 \times 10^{-8}) =$ **3.77×10^{-8} mol dm^{-3}**

(iii) Describe and explain how the solubility of chromium(III) hydroxide is affected by adding $Cr_2(SO_4)_3(aq)$. [1]

When $Cr_2(SO_4)_3(aq)$ is added, it **increases the concentration of Cr^{3+}**. This cause the **position of equilibrium to shift to the left** to **decrease $[Cr^{3+}]$**, hence **solubility of $Cr(OH)_3$ decreases**.

(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. [1]

The oxidation number of Fe is simultaneously decreased from +2 in FeO to 0 in Fe and +2 in FeO to +3 in Fe_3O_4.

$Fe_3O_4(l)$ 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]

$2O^{2-}(l) \rightarrow O_2(g) + 4e^-$

(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]

$Q = I \times t = 50 \times (6 \times 60 \times 60) = 1.08 \times 10^6\ C = n_eF$
$n_e = (1.08 \times 10^6) \div (96500) = 11.19$ mol

$Fe^{2+}(l) + 2Fe^{3+}(l) + 8e^- \rightarrow 3Fe(s)$
Amount of Fe formed = $3/8 \times 11.19 = 4.20$ mol
Mass of Fe formed = $4.20 \times 55.8 =$ **234 g**

[Total: 14]

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 °C and 1 atm.

$C_5H_yO(g)$ + ... $O_2(g)$ $\rightarrow$ ..... $CO_2(g)$ + ... $H_2O(g)$ [1]

$C_5H_yO(g) + \left(\frac{\mathbf{18+y}}{\mathbf{4}}\right)O_2(g) \rightarrow \mathbf{5}CO_2(g) + \left(\frac{\mathbf{y}}{\mathbf{2}}\right)H_2O(g)$

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

Determine the value of y. [2]

Using Avogadro's Law where mole ratio = volume ratio,

$$C_5H_yO(g) + \left(\frac{18+y}{4}\right)O_2(g) \rightarrow 5CO_2(g) + \left(\frac{y}{2}\right)H_2O(g)$$

Mole	1	$\left(\frac{18+y}{4}\right)$	5	$\left(\frac{y}{2}\right)$
Volume	10	$\left(\frac{18+y}{4}\right) \times 10$	50	$\left(\frac{y}{2}\right) \times 10$

Volume of gases used up = Volume of **A** + Volume of O_2 reacted = $10 + \left(\frac{18+y}{4}\right) \times 10 = \left(\frac{110+5y}{2}\right)\ cm^3$

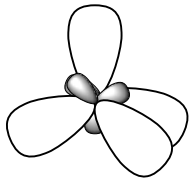
Volume of gases produced = Volume of CO_2 + Volume of H_2O = $50 + \left(\frac{y}{2}\right) \times 10 = (50 + 5y)\ cm^3$

Expansion in volume = Volume of gases produced – Volume of gases used up

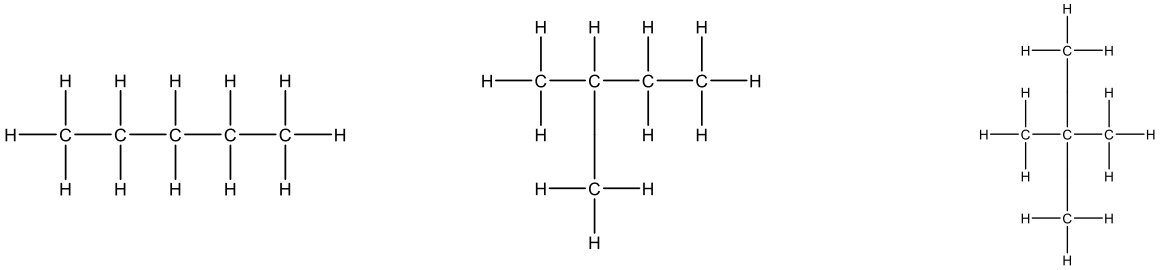
$25 = (50 + 5y) - \left(\frac{110 + 5y}{2}\right)$

y = **12**

(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]

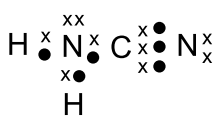


(c) Cyanamide, NH_2CN, is an organic compound used in agriculture and in the synthesis of pharmaceuticals.
The carbon atom is bonded to both nitrogen atoms in the cyanamide molecule.

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

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

(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) 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 [2]

- $CaCN_2$ has a higher melting point than NH_2CN.
- NH_2CN has a **simple molecular structure** with **hydrogen bonds between its molecules**.
- $CaCN_2$ has a **giant ionic lattice** held together by the **electrostatic attractions between Ca^{2+} and CN_2^{2-} ions**.
- As the **ionic bonds in $CaCN_2$ is stronger than the hydrogen bonds between NH_2CN molecules**, **more energy** is required to overcome them during melting.

(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 $\Delta S^\ominus$. [1]

The $\Delta S^\ominus$ is negative as there is a **decrease in number of moles of gaseous molecules**. There is a **decrease in the number of ways to arrange the gaseous molecules**. Hence the **disorder of the system decreases**.

(ii) Calculate the standard Gibbs free energy change, $\Delta G^\ominus$, for this reaction at 298 K. [1]

$\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$
$\Delta G^\ominus = -131 - (298)(-0.41) = -8.82$ kJ mol^{-1}

(iii) Predict the effect of increasing the temperature on the spontaneity of this reaction. Explain your answer. [2]

$\Delta H^{\ominus}$ is negative, $\Delta S^{\ominus}$ is negative
$\Delta G^{\ominus} = \Delta H - T\Delta S$

As temperature increases, **magnitude of $T\Delta S^{\ominus}$ > magnitude of $\Delta H^{\ominus}$**
$\Delta G > 0$ reaction so reaction become **less spontaneous** as temperature increases.

or

As temperature increases, **$-T\Delta S$ becomes more positive**, hence **ΔG becomes more positive** (ΔH is negative). So reaction become **less spontaneous** as temperature increases.

(e) **(i)** Define the term *standard enthalpy change of combustion*. [1]

Standard enthalpy change of combustion is the **heat evolved when 1 mole of a substance is completely burnt in excess oxygen at 298 K and 1 bar**.

(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]

Heat transferred = 100 × 4.18 × 16.3 = **6813.4 J**
Amount of ethanol burnt = 0.230 ÷ 46.0 = 0.00500 mol
$\Delta H_c^{\ominus}$ = – (6813.4 ÷ 0.00500) = – **1360 kJ mol^{-1}**

(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. [1]

- Heat loss to the surrounding
- Incomplete combustion of the ethanol
- Some ethanol evaporated before weighing
- Heat capacity of the calorimeter is not accounted for

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

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

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]

$\Delta H_f^{\ominus}$ of $H_2O(l)$ = $\Delta H_c^{\ominus}$ of $H_2(g)$
$\Delta H_f^{\ominus}$ of $CH_3CH_2CH_2OH(l)$) = $3(-393.5) + 4(-285.8) - (-2021.0)$ = **-303 kJ mol^{-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. [3]

Step 1: Using a measuring cylinder, add 50 cm^3 of KI(aq) into a beaker.

Step 2: Using another measuring, add 50 cm^3 of $K_2S_2O_8(aq)$ into the beaker.

Step 3: Start the stopwatch immediately.

Step 4: At t = 2 minute, pipette 10.0 cm^3 of the reaction mixture into a conical flask.

Step 5: Pour ice/cold water into the conical flask immediately to quench the reaction.

Step 6: Titrate the solution in the conical flask with $Na_2S_2O_3(aq)$. When the solution turns pale yellow, add a few drops of starch and continue to titrate the blue-black solution decolourises.

Step 7: Repeat step 4 to 6 for t = 4, 6, 8 and 10 mins

(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]

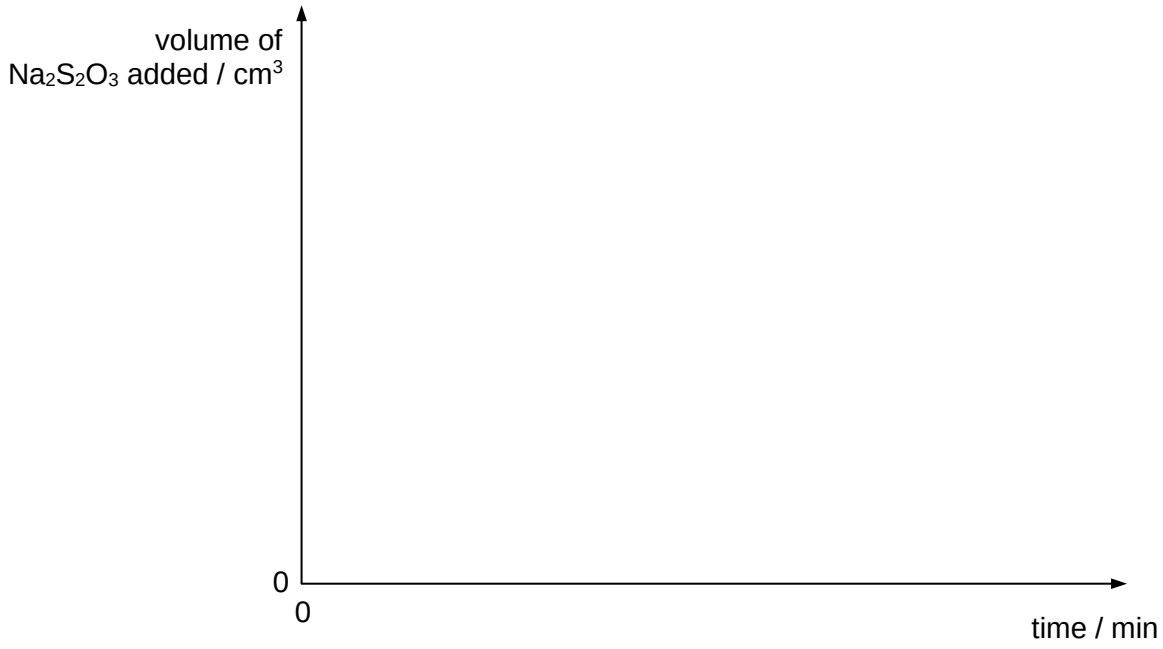
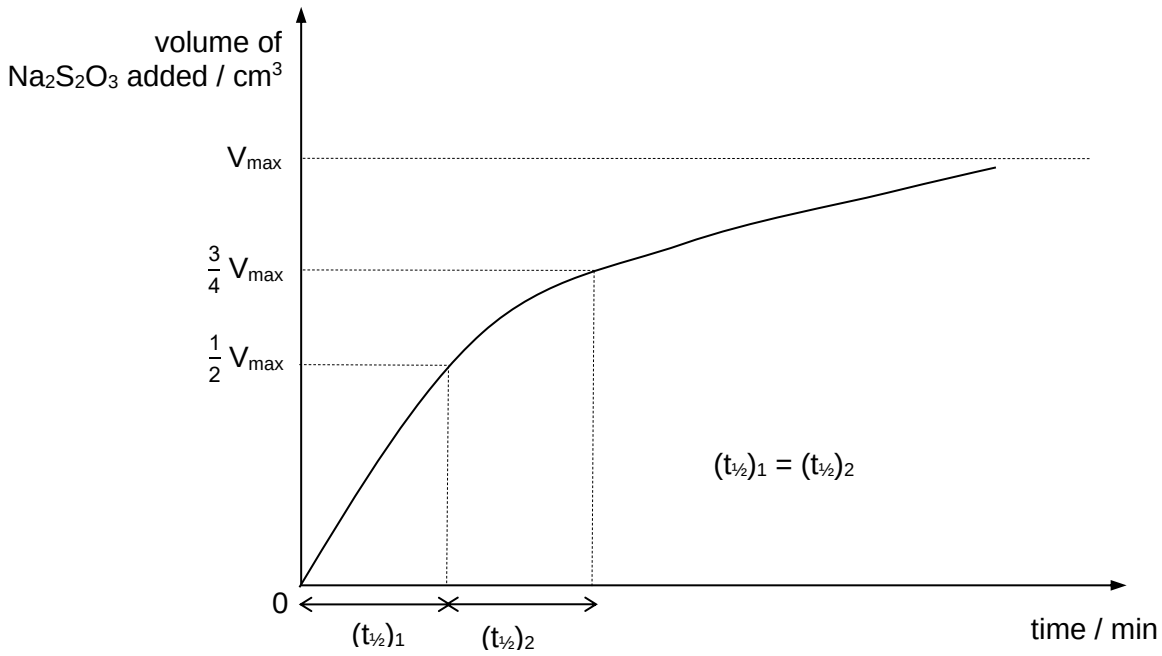


Fig. 3.1



(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. [2]

When the **concentration of peroxodisulfate is halved**, the **rate of the reaction is halved**.

Since **rate of reaction is directly proportional to the concentration of peroxodisulfate**, order of reaction is **one**.
or

rate = $k[I^-][S_2O_8^{2-}]^x$ where x is the order of reaction with respect to $[S_2O_8^{2-}]$
When $[S_2O_8^{2-}]$ is halved, the new gradient = $k[\frac{1}{2} \times S_2O_8^{2-}]^x$.
Since the new gradient is half of the old gradient,

$$\frac{k(\frac{1}{2})^x[S_2O_8^{2-}]^x}{k[S_2O_8^{2-}]^x} = \frac{1}{2}$$

$(\frac{1}{2})^x = \frac{1}{2}$
$x = 1$

(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*. [2]

Fe^{2+} is described as a homogeneous catalyst because it is in the **same physical state as the two reactants** and it is **not being consumed/used up by the reaction/amount left at the end as the same as the beginning**.

(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. [3]

Transition elements are able to exhibit variable oxidations state and hence they can gain or lose electrons readily.

$2Fe^{2+}(aq) + S_2O_8^{2-}(aq) \rightarrow 2Fe^{3+}(aq) + 2SO_4^{2-}(aq)$
$2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$

[Total: 12]

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.

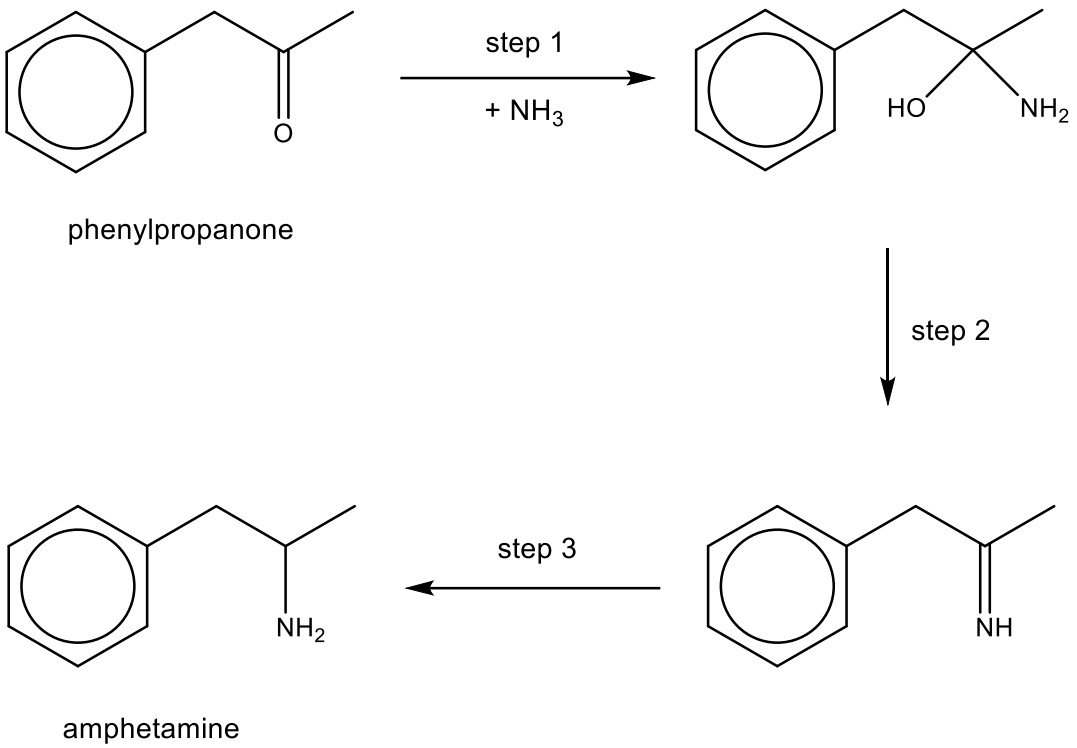


Fig. 4.1

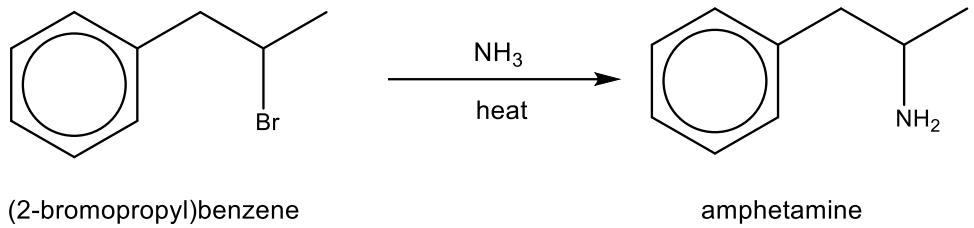
(i) State the *type of reactions* that occur during each of the steps 1, 2 and 3.

step	type of reaction
1	
2	
3	

[3]

step	type of reaction
1	**nucleophilic addition**
2	**elimination**
3	**reduction**

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



(2-bromopropyl)benzene amphetamine

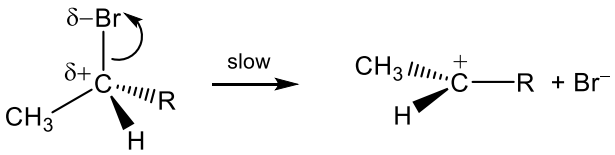
Fig. 4.2

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

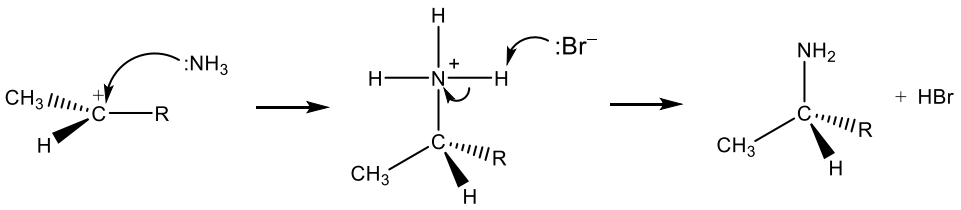
Draw a mechanism that can explain the above observation. Show relevant lone pairs and dipole, and use curly arrows to indicate the movement of electrons pairs.
Use R to represent - $CH_2C_6H_5$. [3]

Name of mechanism: Nucleophilic substitution, S_N1

step 1



step 2



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

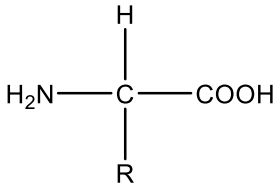


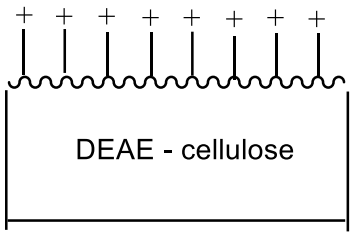
Table 4.1 shows the pK_a values of the different functional groups present in three α-amino acids.

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 7.0 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 7.0.

The separation of the α-amino acids from the mixture is based on their 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.

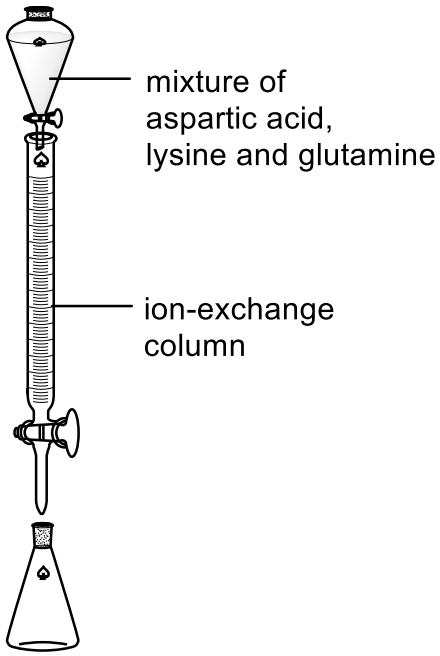
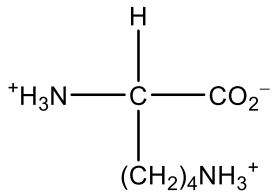
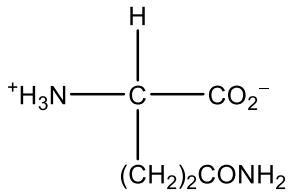
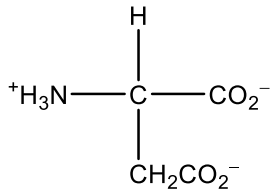


Fig. 4.1

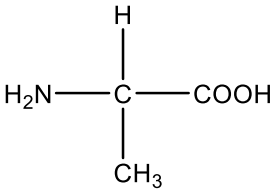
Draw the structure of the predominant species of the three α-amino acids at pH 7.0 and suggest the order in which the α-amino acids will be collected.
Explain your answer.

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

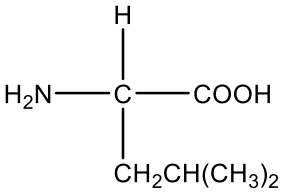
[4]

order of α-amino acids washed off the column	structure of predominant species of α-amino acid at pH 7.0	explanation
first		At pH 7, lysine is **positively charged** and there will be **repulsion** with the positively charged DEAE-cellulose.
second		At pH 7, glutamine is **electrically neutral**.
last		At pH 7, aspartic acid will be **negatively charged** and there will be **attraction** with the positively charged DEAE-cellulose.

(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. [1]

At pH 7, both alanine and leucine will be electrically neutral. R groups in both alanine and leucine are **not charged**. Both will not be attracted to DEAE cellulose and **will be washed off together at the same rate**.

(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	$-(CH_2)_2CONH_2$

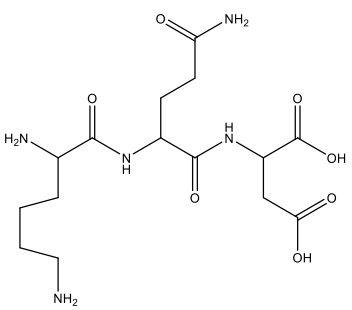
(i) Name the type of reaction occurring when a tripeptide in formed from the three amino acids. [1]

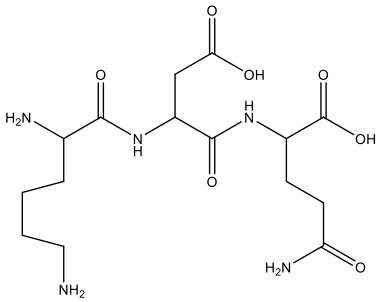
condensation reaction

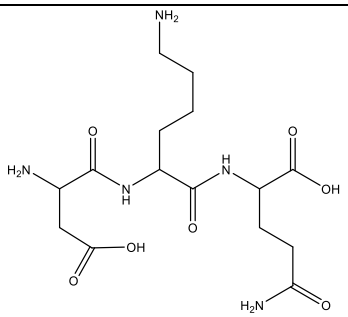
(ii) State the maximum number of different tripeptides that can be formed from the three amino acids. [1]

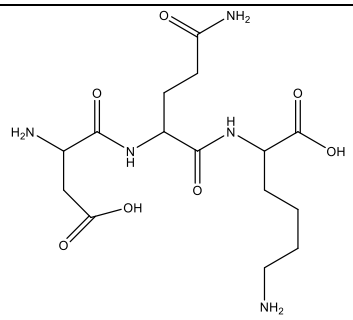
Maximum number of different tripeptides = 3! = 6

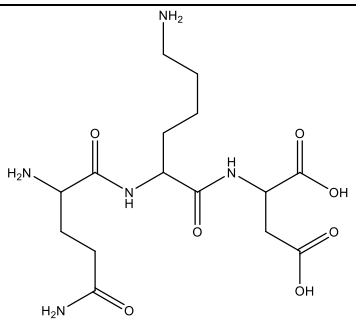
(iii) Draw the skeletal formula of one of the possible tripeptides that can be formed from the three amino acids. [2]

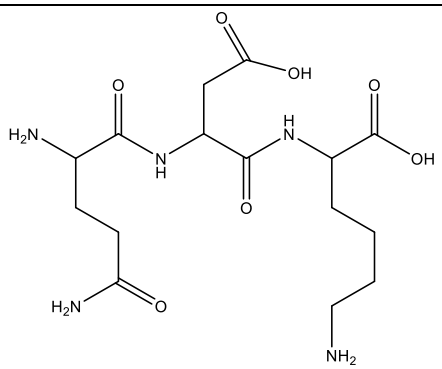

lys-glu-asp


lys-asp-glu


asp-lys-glu


asp-glu-lys


glu-lys-asp


glu-asp-lys

[Total: 15]

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.

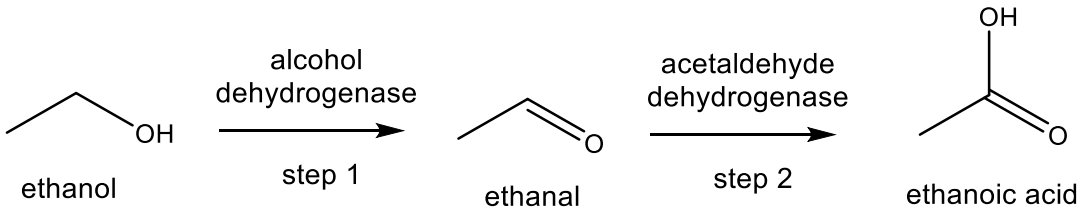


Fig. 5.1

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]

reduction

(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]

$K_2Cr_2O_7$, dilute H_2SO_4, heat with immediate distillation

(iii) State a reagent you could use to convert ethanoic acid into ethanol. [1]

LiA*l*H_4 (in dry ether)

(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.

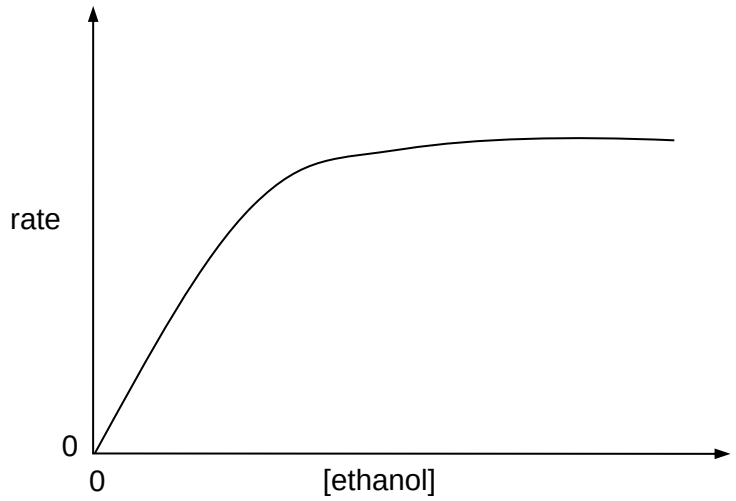


Fig. 5.2

Explain the relationship between [ethanol] and the rate of the enzyme catalysed reaction. [2]

For a fixed amount of enzyme, there are a finite number of active sites on the enzyme.

- At low [ethanol], **not all of the active sites are occupied**.
  rate $\propto$ [ethanol]
  reaction is **first order** with respect to the [ethanol].

- At high [ethanol], **all the active sites are occupied**.
  At this point, any increase in [ethanol] will not have any effect on the reaction rate.
  The reaction is **zero order** with respect to the [ethanol].

(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 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]

Since the [ethanol] at the legal limit of 1.74×10^{-2} mol dm^{-3} is larger than K_M value of 1.00×10^{-3} mol dm^{-3}, $K_M < [S]$ the rate equation becomes

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

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]

rate loss of ethanol in g per 100 cm^3 of blood per hour = 18.333×10^{-3} g
rate loss of ethanol in g per 1 dm^3 of blood per hour = 0.18333 g
rate loss of ethanol in mol per 1 dm^3 of blood per hour = $0.18333 \div 46.0 = 3.9854 \times 10^{-3}$ mol
rate loss of ethanol in mol per 1 dm^3 of blood per sec = $3.9854 \times 10^{-3} \div (60 \times 60) = 1.11 \times 10^{-6}$ mol

(iii) Use your answer to **(c)(i)** and **(c)(ii)** to calculate the concentration of alcohol dehydrogenase enzyme in this person. [1]

rate = k[AD]
[AD] = rate ÷ k = $(1.107 \times 10^{-6}) \div 1.33 = 8.32 \times 10^{-3}$ mol dm^{-3}

(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]

Let t = time required
rate of loss of ethanol per 100 cm^3 of blood = 18.33 mg hr^{-1} = $\frac{345 - 80}{\Delta t} = \frac{345 - 80}{t - 0}$
t = 14.45 = 14.5 hours

(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]

$HOCH_2CH_2OH + 4[O] \longrightarrow (CO_2H)_2 + 2H_2O$

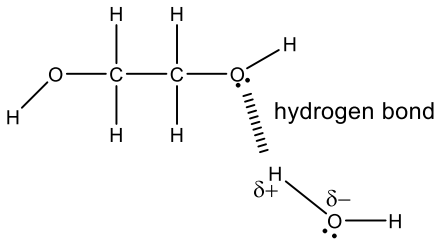
(ii) Ethanol is used to treat victims of methanol or ethane-1,2-diol poisoning. This is because ethanol is a better substrate for alcohol dehydrogenase, and it will be metabolised preferentially by the enzyme.

Describe a simple chemical test that could be used to distinguish ethanol from methanol and state your observations clearly [2]

chemical test	ethanol	methanol
To each unknown in separate test-tubes, add I_2(aq), NaOH(aq) and warm	(pale) yellow precipitate	no precipitate
To each unknown in separate test-tubes, add $KMnO_4$(aq), H_2SO_4(aq) and warm	purple $KMnO_4$ decolourises	purple $KMnO_4$ decolourises and effervescence. Gas evolved gives a white precipitate with limewater

(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.

As the value of n increases, the **instantaneous dipole-induced dipole interactions between RCO_2H molecules becomes increasingly significant** and **interferes with the hydrogen bonding between themselves and with H_2O molecules**.

The energy released by forming **the more predominant instantaneous dipole-induced dipole interactions** with water molecules is insufficient to overcome the **hydrogen bonding between water molecules** and the more predominant **instantaneous dipole-induced dipole interactions between the long chain carboxylic acid molecules**.

[Total: 17]