ANDERSON SERANGOON JUNIOR COLLEGE

2019 JC 2 PRELIMINARY EXAMINATIONS

NAME:_____ ( ) **CLASS:** 19 /____

CHEMISTRY **9729/02**

Higher 2 **4 September 2019**

Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number and class on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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.

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.

For Examiner's Use		
Paper 2	1	/ 12
	2	/ 11
	3	/ 18
	4	/ 13
	5	/ 12
	6	/ 9
	Total	**/ 75**

This document consists of **26** printed pages and **2** blank pages.

1 **(a)** Use the data from Table 1.1 to state and explain the relative reactivity of Group 2 elements as reducing agents.

Table 1.1

Element	$E^{\ominus}$ [M^{2+}(aq)/M(s)] / V
Mg	–2.38
Ca	–2.87
Sr	–2.89
Ba	–2.90

……

……

……

…… [2]

(b) Table 1.2 gives data about some physical properties of calcium and copper.

Table 1.2

	calcium	copper
relative atomic mass	40.1	63.5
atomic radius (metallic) / nm	0.197	0.128
ionic radius (2+) / nm	0.099	0.069
electrical conductivity / 10^6 S cm^{-1}	0.298	0.596
density / g cm^{-3}	1.54	8.92

(i) Explain why the electrical conductivity of copper is higher than that of calcium.

……

……

……

…… [2]

(ii) Using relevant data from Table 1.2, explain why the density of copper is significantly greater than that of calcium (no calculations are required).

……..

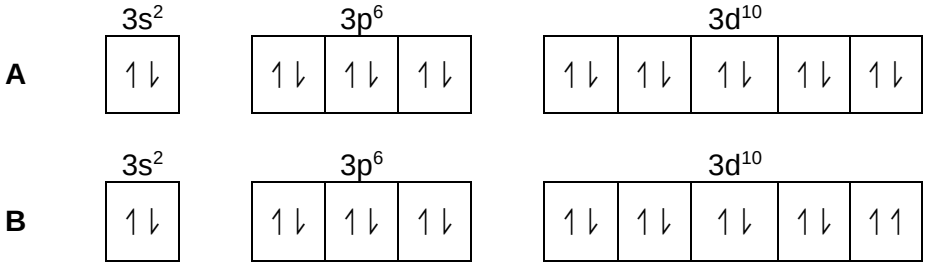
……..

……..

…… [2]

(c) **(i)** Copper is a typical transition element and is used in alloys for aircraft engine parts.

Which of the following "electrons–in–boxes" diagrams best describes the valence ground–state electronic configuration of a Cu^+ ion? Explain your answer.



……..

…… [1]

(ii) Using the Cartesian axes shown in Fig. 1.1, draw fully–labelled diagrams of any **two** d–orbitals of **different shapes** found in a Cu^+ ion.

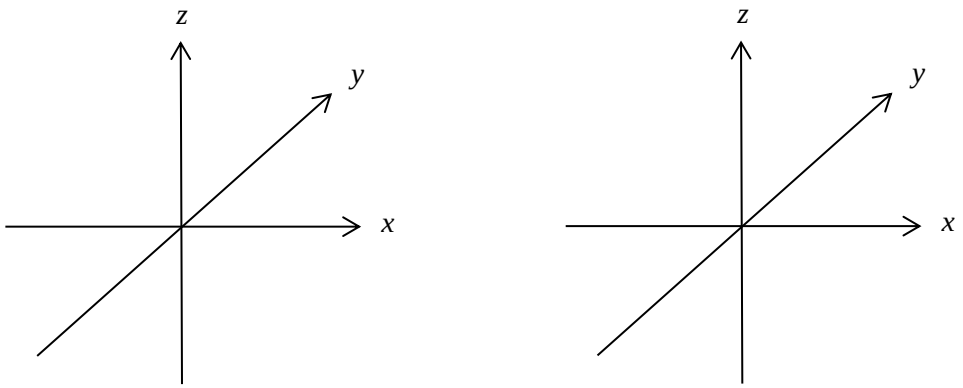


Fig. 1.1

[2]

(d) Silicon is the eighth most common element in the universe by mass. It very rarely occurs as the pure element in the Earth's crust.

Table 1.3 shows the melting points of silica (SiO_2) and silicon.

Table 1.3

	melting point / °C
silica	1710
silicon	1414

Silica and silicon each form a solid with the same type of structure.

(i) State the type of structure present in solid silica and silicon.

…….. [1]

(ii) Using relevant data from the *Data Booklet*, suggest why the melting point of silica is higher than that of silicon.

…….

…….

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……..

…… [2]

[Total: 12]

Question 2 starts on the next page.

2 **(a)** Alkene **C**, C_7H_{10}, on treatment with hot, concentrated potassium manganate(VII) forms an optically inactive compound **D**, $C_5H_8O_3$, and carbon dioxide gas.

D reacts with both Na_2CO_3 and alkaline aqueous iodine.

(i) Suggest **two** structural features that are present in **D**.

……..

……..

…… [2]

(ii) Hence, deduce the structures of **C** and **D**.

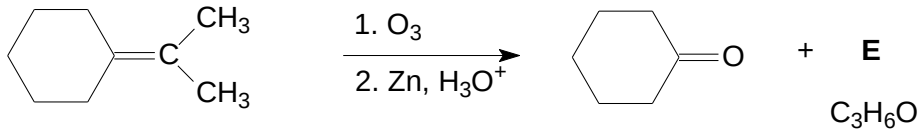
C	**D**

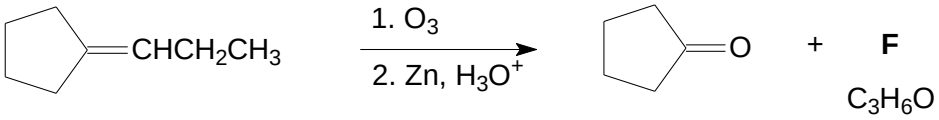
[2]

Ozone, O_3, is an oxidising agent that causes carbon–to–carbon double bond cleavage.

When an alkene is treated with ozone, followed by zinc metal in acetic acid, two carbonyl–containing products are obtained.

The following reactions illustrate two oxidations using ozone as the oxidising agent.





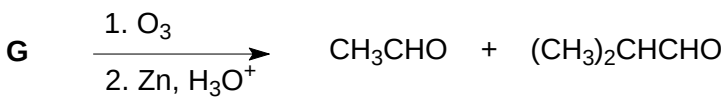
Both **E** and **F** react with 2,4–dinitrophenylhydrazine but only **F** reacts with Fehling's solution. **E** reacts with alkaline aqueous iodine but not **F**.

(iii) Suggest the identities of **E** and **F**.

E	**F**

[2]

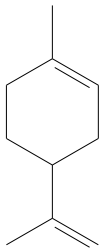
(iv) Use the above information and your answers to **(a)(iii)** to suggest the structure for compound **G** in the following reaction.



G

[1]

(b) **(i)** Limonene occurs in oil of lemons and is used to flavour some citrus drinks.



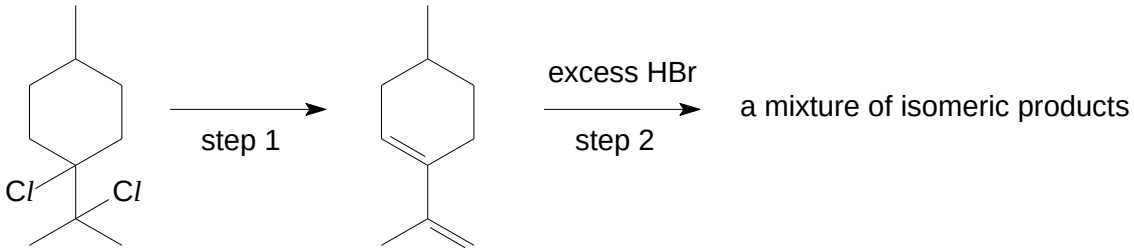
limonene

Draw the structural formula of the product, and describe what you might observe, when limonene reacts with bromine in an inert solvent, until in excess.

observation …….

……..... [2]

Fig. 2.1 shows a reaction scheme involving an isomer of limonene, **H**.



H

Fig. 2.1

(ii) Suggest reagents and conditions for step 1.

…… [1]

(iii) Draw the structure of the major product for step 2.

[1]

[Total: 11]

3 Transition metals are building blocks for life and they make up the middle block of the Periodic Table.

(a) Catalase is an important enzyme that reduces the damaging effects of hydrogen peroxide in the biological system. It contains four iron–containing heme groups that allow the enzyme to react with the hydrogen peroxide.

It catalyses the decomposition of hydrogen peroxide into water and molecular oxygen.

$$H_2O_2 \rightarrow H_2O + \tfrac{1}{2}O_2$$

(i) With the aid of a sketch of the Boltzmann distribution, explain why the addition of catalase speeds up the decomposition of hydrogen peroxide.

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……..

……..

……..

……..

…… [3]

An investigation to study the rate of the catalysed decomposition of H_2O_2 can be conducted as follows:

1 cm^3 of catalase, extracted from a liver sample, was added to a 50 cm^3 of 2 mol dm^{-3} H_2O_2 solution connected to a sealed glass pressure tube which measures the volume of O_2 collected. The time taken for 20 cm^3 of O_2 to produce was then measured.

(ii) Outline how you would determine the effect of changing the concentration of H_2O_2 on the rate of the catalysed decomposition of H_2O_2.

You are provided with the same solution used in the experiment described above.

State clearly the measurements you would take.

No details regarding use of specific glassware are required.

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……..

……. [3]

(iii) Sketch a graph to show how, for a fixed concentration of catalase, the rate of decomposition varies with the concentration of H_2O_2 and explain the shape of the graph.

……..

……..

……..

……. [2]

(b) Transition metal sulfides are generally insoluble in water.

Metal ions can be precipitated as metal sulfides by the following reaction.

$$M^{2+}(aq) + S^{2-}(aq) \rightarrow MS(s)$$

Solution **J** containing 0.100 mol dm^{-3} of Fe^{2+} and 0.100 mol dm^{-3} of Mn^{2+} can be separated easily by selective precipitation of the metal sulfides.

The K_{sp} values of two metal sulfides are shown in Table 3.1.

Table 3.1

	K_{sp} / $mol^2\ dm^{-6}$
FeS	3.7×10^{-19}
MnS	3.7×10^{-13}

(i) State which metal ion, Fe^{2+} or Mn^{2+}, precipitates first when solid sodium sulfide is slowly added to 100 cm^3 of solution **J**.

…… [1]

(ii) Hence, calculate the concentration, in mol dm^{-3}, of sulfide ions when first trace of the precipitate appears.

[1]

(iii) Determine the concentration, in mol dm^{-3}, of the metal ion you have stated in **(b)(i)** remaining in the solution when the other metal ion just starts to precipitate.

[1]

(iv) An effective separation means that less than 1% of the metal ion should remain in the solution when the other metal ion just starts to precipitate. Using your answer to **(b)(iii)**, deduce if the separation is effective.

……..

……..... [1]

One advantage of using sulfide ion as a precipitating reagent is that its concentration can be controlled by regulating the pH of the solution.

Hydrogen sulfide behaves as a weak dibasic acid that dissociates in two steps:

Equilibrium (1) $H_2S \rightleftharpoons H^+ + HS^-$ $K_a = 9.1 \times 10^{-8}$

Equilibrium (2) $HS^- \rightleftharpoons H^+ + S^{2-}$ $K_a = 1.0 \times 10^{-15}$

(v) Using the above equilibria, explain how varying the pH of a mixture containing solution **J** and sulfide ions can allow selective precipitation to take place.

You are **not** expected to perform any calculations.

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……..

……..

……..

……. [2]

(c) The most important ore of chromium is the mineral ferrous chromite, $FeO.Cr_2O_3$.

Fig. 3.1 shows a reaction scheme illustrating many of the characteristic properties of transition metal compounds.

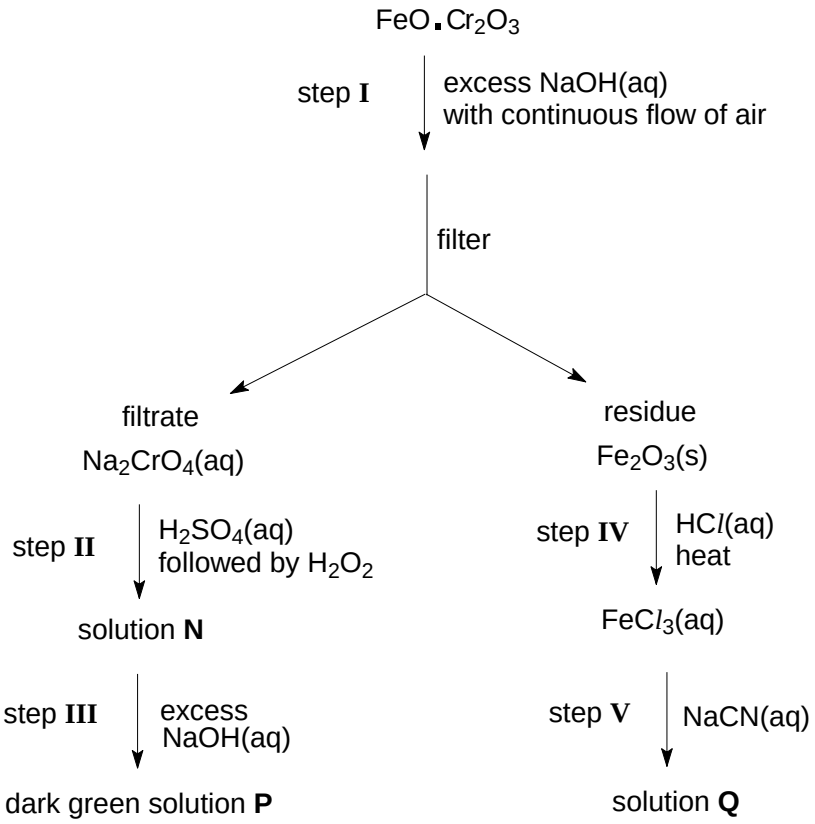


Fig. 3.1

(i) Construct a balanced equation for the reaction involving Cr_2O_3 in step **I**, by using changes in oxidation numbers, or otherwise. In this reaction, H_2O is a by–product.

…….... [1]

(ii) State the series of colour changes that occurs in step **II**.

……. [1]

(iii) State the type of reaction that occurs in step **III** and give the formula of the complex ion in solution **P**.

type of reaction ……...

formula of complex ion …… [1]

The oxidation number of iron in the iron–containing complex ion in solution **Q** and in $FeCl_3(aq)$ is the same.

(iv) Suggest the formula of the compound in solution **Q**.

…… [1]

[Total: 18]

4 Ethylamine, $CH_3CH_2NH_2$, and phenylamine, $C_6H_5NH_2$, are both weak bases, with pK_b values of 3.35 and 4.63 respectively.

(a) Explain why the pK_b value of ethylamine is lower than that of phenylamine.

……

……

……

…… [2]

(b) 20.0 cm^3 of an aqueous solution of ethylamine was titrated against 0.20 mol dm^{-3} hydrochloric acid, HC*l*. It was found that the pH at the equivalence point was 5.91.

(i) Suggest an appropriate indicator for the titration, giving a reason for your choice.

……..

……..

…… [1]

(ii) Calculate the concentration of $CH_3CH_2NH_3^+$, in mol dm^{-3}, at the equivalence point.

[1]

(iii) Hence, calculate the volume of hydrochloric acid needed to neutralise the ethylamine.

[1]

(iv) Prove that the initial concentration of ethylamine is 0.102 mol dm^{-3}.

[1]

(v) Hence, calculate the initial pH of ethylamine.

[1]

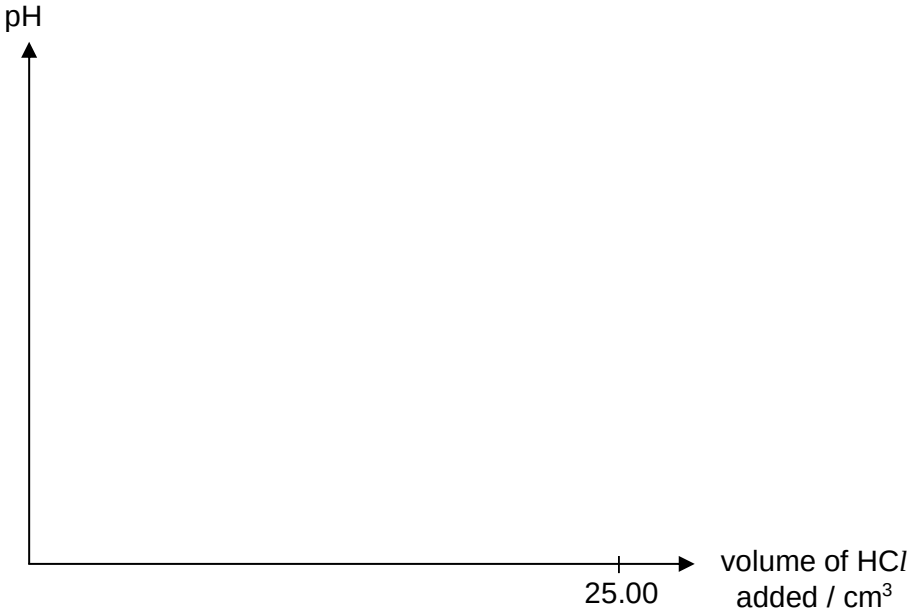
(vi) A total of 25.00 cm^3 HC*l* was added in this titration. Calculate the final pH of the resulting solution.

[1]

(vii) Using the information given in the question and your answers to **(b)(iii)**, **(b)(v)** and **(b)(vi)**, sketch the pH changes that occur during the titration when a total of 25.00 cm^3 of HC*l* was added to 20.0 cm^3 of an aqueous solution of ethylamine.

Label the following points on your sketch:

- pH and volume at maximum buffer capacity
- pH and volume at equivalence point
- final pH



[2]

(c) A buffer solution was prepared by mixing 200 cm^3 of 0.15 mol dm^{-3} of phenylamine and 100 cm^3 of 0.20 mol dm^{-3} of HC*l*.

(i) Calculate the pH of this buffer solution.

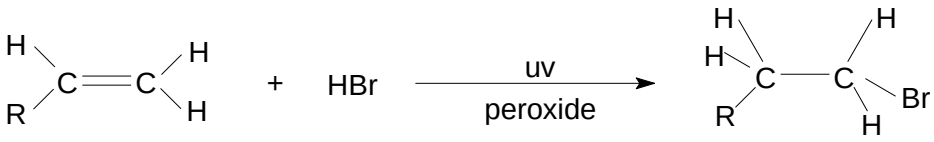
[2]

(ii) Write an equation to show how this solution can act as a buffer on the addition of an alkali.

…….... [1]

[Total: 13]

5 Radical initiators are substances that can produce radicals under mild conditions and promote radical reactions. These substances generally possess weak bonds. An example of a radical reaction involving peroxide as the initiator is shown below:



(a) Explain what is meant by the term *radical* and explain, with the aid of a diagram, how the bond in the peroxide initiator, R–O–O–R, would break to produce radicals.

……

……

…… [2]

(b) The mechanism continues with the following steps.

Step 1: The radical produced from the peroxide initiator reacts with a HBr molecule to generate a •Br radical and an alcohol molecule.

Step 2: The •Br radical formed approaches an alkene molecule, $RCH{=}CH_2$, to form a stable alkyl radical.

Step 3: The alkyl radical reacts with another HBr molecule to form the organic product and regenerates the •Br radical.

Draw the displayed formula of the stable alkyl radical formed in Step 2 and the final organic product formed when 2–methylbut–2–ene undergoes this radical reaction with HBr.

stable alkyl radical	final organic product

[2]

(c) Benzoic acid is often added to soft drinks as a preservative in the form of its salt, e.g. sodium benzoate. However, it is reported that in the presence of ascorbic acid, benzoic acid can undergo decarboxylation to form benzene, which is a known carcinogen.

The mechanism of this reaction is thought to involve four steps:

Step I: The hydroxyl radical, •OH, is produced from the catalysed reduction of oxygen by ascorbic acid.

Step II: The hydroxyl radical abstracts a proton from benzoic acid to form an intermediate.

Step III: This intermediate then forms a phenyl radical and carbon dioxide gas.

Step IV: The phenyl radical abstracts a proton from water to produce benzene and regenerates the hydroxyl radical.

Complete Fig. 5.1 to suggest the mechanism for Step III and Step IV. Show the structural formulae of the intermediates, the movement of unpaired electron by using curly arrow ( ) and indicate any unpaired electron with a dot (●).

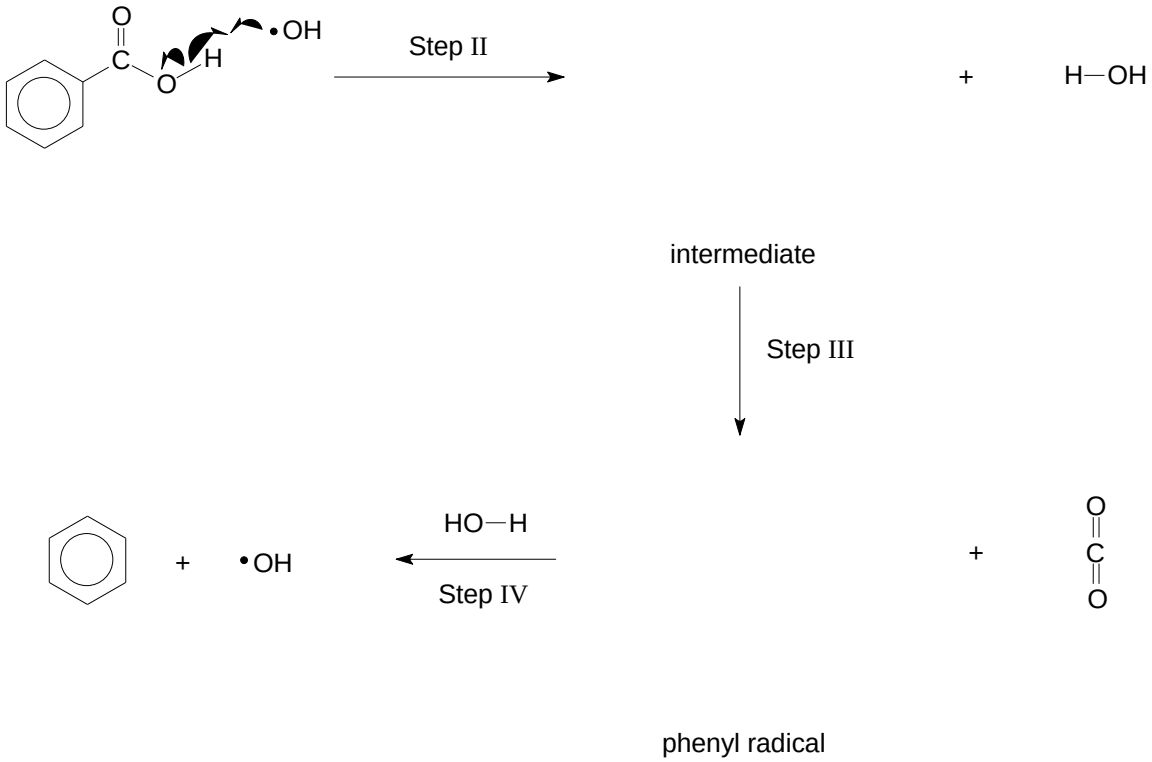


Fig. 5.1

[3]

(d) Fig. 5.2 shows the food label of a bottle of coffee.

Nutrition Facts

1 serving per bottle

Serving size 1 bottle (325 mL)

	% Daily Value
Total Fat 4.5 g	**6%**
Saturated Fat 0 g	**0%**
Trans Fat 0 g	
Cholesterol 0 mg	**0%**
Sodium 250 mg	**11%**
Total Carbohydrate 20 g	**7%**
Dietary Fiber <1 g	**3%**
Total Sugars 13 g	
Includes 12 g Added Sugars	**24%**
Protein 15 g	**30%**

Vit. D 0 mcg 0% • Calcium 60 mg 4%

Iron 3.3 mg 15% • Potas. 200 mg 4%

*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet.

Fig. 5.2

Table 5.1 shows the fuel values of some substances found in the bottle of coffee. The fuel value is the amount of energy generated when one gram of a substance undergoes complete combustion.

Table 5.1

substance	**fuel value / kJ g^{-1}**
carbohydrate	17
protein	17
fat	38

(i) Energy is provided by the carbohydrates, proteins and fats in the food and drinks consumed.

If a student uses on average 7 kJ of energy per minute while studying, how many minutes of this activity can be sustained by the energy obtained from one serving of bottled coffee?

[2]

Fats are metabolised into carbon dioxide and water when subjected to combustion in a bomb calorimeter. The reaction of a typical unsaturated fat (triglyceride), $C_{55}H_{98}O_6$, found in the bottle of coffee is as follows:

$$C_{55}H_{98}O_6 + \frac{153}{2}O_2 \rightarrow 55CO_2 + 49H_2O \qquad \Delta H = -x \text{ kJ mol}^{-1}$$

(ii) Using relevant data from Table 5.1, determine the value of x.

[1]

(e) Compounds **R** and **S** are structural isomers with the molecular formula of $C_6H_{12}O$.

Table 5.2 shows results of the chemical tests carried out on **R** and **S**.

Table 5.2

test	reagent	observation	
		R	**S**
1	Tollens' reagent	grey solid formed	grey solid not formed
2	aqueous bromine	orange solution remained	orange solution remained

When **R** and **S** were separately subjected to chlorine in the presence of sunlight, both gave only two monochlorinated products (not including stereoisomers).

Suggest a possible structure for **R** and **S**.

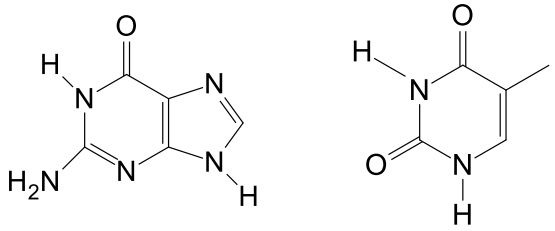
R	**S**

[2]

[Total: 12]

6 Nitrogenous bases such as guanine and thymine contribute to the structure of deoxyribonucleic acid (DNA). If the compositions of these bases are altered significantly, it may lead to a change in the DNA structure, which could cause cancer.

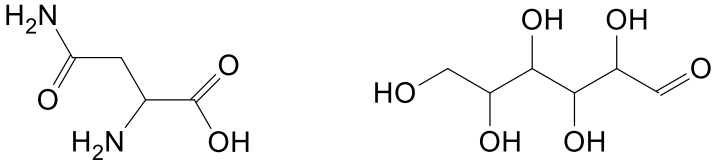
The structures of guanine and thymine are given below:



guanine thymine

Studies have suggested that consumption of overcooked carbohydrates such as french fries may lead to cancer. This is partly contributed by the Maillard reaction that takes place during cooking, which typically occurs on the surface of the cooked food. This reaction occurs at temperatures above 140 ^{o}C.

This question focuses on the Maillard reaction between asparagine and glucose, both of which are found in potatoes. Fig 6.1 shows the structures of asparagine and glucose.

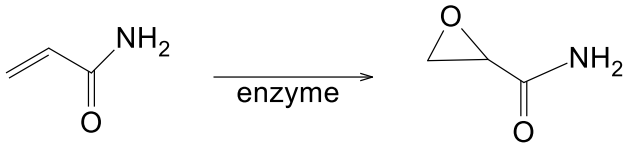


asparagine glucose

Fig 6.1

Nucleophilic attack by the amine group in asparagine on the electrophilic carbon of the aldehyde group in glucose results in an imine, characterised by a carbon–nitrogen double bond. Water is produced as a by–product.

If food containing this imine is consumed, gastric acid breaks down the imine to produce acrylamide, a carcinogen. Acrylamide is then metabolised by an enzyme in the body, producing glycidamide.



acrylamide glycidamide

Glycidamide has a highly reactive epoxide group (a three–membered ring of two carbon atoms and an oxygen atom). The lone pair of electrons on a nitrogen atom in guanine (one of the nitrogenous bases) attacks one of the electrophilic carbon atoms of the epoxide group in glycidamide. This eventually changes the DNA structure and causes cancer.

(a) Table 6.1 shows the acrylamide content in some potato products.

Table 6.1

potato product	preparation method	amount of acrylamide (μg / kg)
boiled potato	cut into half, lengthwise	69
baked potato	cut into half, lengthwise	1270
deep fried potato (french fries)	cut into strips, lengthwise	4080

(i) Explain why boiled potato has the lowest amount of acrylamide.

……

…… [1]

(ii) By considering the preparation method, suggest why deep fried potato has a higher amount of acrylamide compared to baked potato.

……

…… [1]

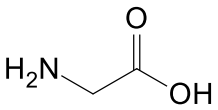
(b) Some recommendations have been proposed to reduce the production of acrylamide. Explain why the following methods are effective.

(i) Soak the sliced potatoes in a weak acid, such as vinegar.

……

…… [1]

(ii) Soak the sliced potatoes in a solution of amino acid, such as glycine.



glycine

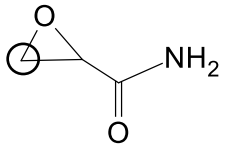
……

…… [1]

(c) Using the structures of asparagine and glucose given in Fig 6.1, draw the structure of the specific imine produced.

[1]

(d) **(i)** With reference to the structure of glycidamide below, explain why the circled carbon atom in the epoxide group is more susceptible to nucleophilic attack by guanine.



glycidamide

……

…… [1]

(ii) State why the reaction between guanine and glycidamide affects the DNA structure.

……

…… [1]

(iii) Guanine reacts with glycidamide as described on page 24. Suggest why glycidamide does **not** undergo the same nucleophilic attack by thymine.

……

…… [1]

(iv) Phenylethene is a suspected carcinogen like acrylamide. Suggest an explanation for this.

……

…… [1]

[Total: 9]

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