1

Government of South Australia

SACE Board of SA

External Examination 2014

2014 CHEMISTRY

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ATTACH SACE REGISTRATION NUMBER LABEL TO THIS BOX

QUESTION BOOKLET

1

14 pages, 4 questions

Wednesday 12 November: 9 a.m.

Time: 3 hours

Question Booklet 1

Examination material: Question Booklet 1 (14 pages)
Question Booklet 2 (11 pages)
Question Booklet 3 (13 pages)
one SACE registration number label

Approved dictionaries and calculators may be used.

Instructions to Students

1. You will have 10 minutes to read the paper. You must not write in your question booklets or use a calculator during this reading time but you may make notes on the scribbling paper provided.

2. You will be expected to extract information such as atomic number and relative atomic mass from the periodic table on page 3 of Question Booklet 1, which you may remove from this booklet before the examination begins. Tables showing the relative activities of metals and SI prefixes are on the back of page 3.

3. This paper consists of twelve questions, four in Question Booklet 1, four in Question Booklet 2, and four in Question Booklet 3:

   Question Booklet 1 (Questions 1 to 4)
   Answer *all parts* of Questions 1 to 4 in the spaces provided in this question booklet.
   You may write on page 14 if you need more space to finish your answers.

   Question Booklet 2 (Questions 5 to 8)
   Answer *all parts* of Questions 5 to 8 in the spaces provided in Question Booklet 2.
   You may write on page 11 of Question Booklet 2 if you need more space to finish your answers.

   Question Booklet 3 (Questions 9 to 12)
   Answer *all parts* of Questions 9 to 12 in the spaces provided in Question Booklet 3.
   You may write on page 13 of Question Booklet 3 if you need more space to finish your answers.

4. There is no need to fill all the space provided; clearly written, well-expressed answers are required. If you delete part or all of an answer you should clearly indicate your final answer.

5. The total mark is 180. The twelve questions are of approximately equal value.

6. Attach your SACE registration number label to the box at the top of this page. Copy the information from your SACE registration number label into the boxes on the front covers of Question Booklet 2 and Question Booklet 3.

7. At the end of the examination, place Question Booklet 2 and Question Booklet 3 inside the back cover of Question Booklet 1.

STUDENT'S DECLARATION ON THE USE OF CALCULATORS

By signing the examination attendance roll I declare that:

- my calculators have been cleared of all memory
- no external storage media are in use on these calculators.

I understand that if I do not comply with the above conditions for the use of calculators I will:

- be in breach of the rules
- have my results for the examination cancelled or amended
- be liable to such further penalty, whether by exclusion from future examinations or otherwise, as the SACE Board of South Australia determines.

PERIODIC TABLE OF THE ELEMENTS

1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminium 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.90	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.70	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (97)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Caesium 132.9	56 Ba Barium 137.3	57[1] La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89[2] Ac Actinium (227)	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (270)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)		114 Fl Flerovium (289)		116 Lv Livermorium (293)		

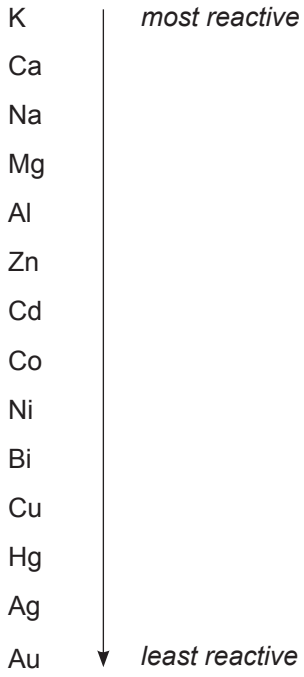
Lanthanide Series[1]	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinide Series[2]	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

You may remove this page from the booklet by tearing along the perforations.

PLEASE TURN OVER

You may refer to the following table, which shows the relative activities of a number of metals, when answering questions that involve metals:

Metal Activity



You may refer to the following table, which shows SI prefixes, their symbols, and their values, when answering questions that involve the conversion of units:

SI Prefix	Symbol	Value
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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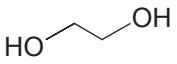
QUESTION 1

PET (polyethylene terephthalate) is a non-biodegradable polymer extensively used in making bottles. It is made in a reaction between two petroleum-sourced monomer units, the structural formulae of which are shown below:

monomer A



monomer B

(a) Name the functional group formed in the reaction of monomer A with monomer B.

_____ (1 mark)

(b) Name the type of reaction that occurs between monomer A and monomer B.

_____ (1 mark)

(c) Monomer B is an example of a polyol.

(i) Give the systematic name of monomer B.

_____ (2 marks)

(ii) State the meaning of the term 'polyol'.

_____

_____ (1 mark)

(iii) Cross-linking between polymer chains can occur if monomer B is replaced with a different monomer.

(1) Draw the structural formula of a 3-carbon monomer that would allow cross-linking between polymer chains.

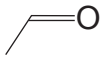
(2 marks)

(2) State one physical property that is affected when more cross-linking occurs between polymer chains.

_____

_____ (1 mark)

(d) When PET degrades, one compound formed has the structural formula shown below:



State the systematic name of this compound.

_____ (2 marks)

(e) Some companies have begun to manufacture monomer B from plant sources instead of from petroleum.

(i) Explain one benefit of using monomers sourced from plants instead of from petroleum.

_____

_____

_____

_____ (2 marks)

(ii) Explain whether sourcing monomer B from plants will have an effect on the biodegradability of PET.

_____

_____

_____

_____ (2 marks)

TOTAL: 14 marks

QUESTION 2

Bismuth is an element that is commonly found in ores containing bismuth oxide, Bi_2O_3.

(a) State the block of the periodic table where bismuth is found.

_____(1 mark)

(b) Bi_2O_3 reacts with acid.

Write an equation for the reaction of Bi_2O_3 with H^+.

(2 marks)

(c) One of the compounds used to extract bismuth from its ores is 3-methylbutan-2-one (also known as 3-methyl-2-butanone).

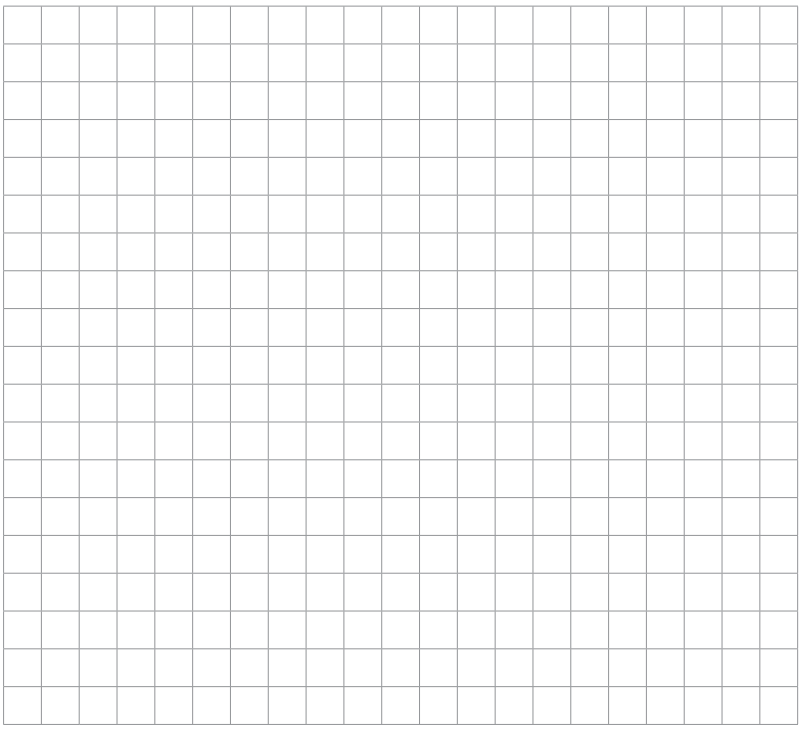
Draw the structural formula of this compound.

(2 marks)

(d) An ore sample containing bismuth was analysed using atomic absorption spectroscopy (AAS). Standard solutions of bismuth were used to calibrate the spectrometer and the following data were recorded:

Bismuth concentration (ppm)	Absorbance
0.0	0.00
5.0	0.25
10.0	0.56
15.0	0.81
20.0	1.08

(i) Using the data in the table on the page opposite, plot a calibration line on the grid below.



(5 marks)

(ii) State the characteristic of a calibration graph that provides information about the precision of the results obtained.

_____ (1 mark)

(iii) The absorbance of the sample containing bismuth was found to be 0.51.

Determine the concentration, in ppm, of bismuth in the sample.

_____ (1 mark)

(iv) Explain why other trace elements in the sample containing bismuth will not interfere with the AAS analysis of bismuth.

_____

_____

_____

_____

_____

_____ (3 marks)

TOTAL: 15 marks

QUESTION 3

Sulfur dioxide (SO_2) is an antimicrobial compound and preservative that has been used in winemaking for centuries.

(a) Draw a diagram that shows the bonding and shape of a molecule of SO_2.

(2 marks)

(b) During the winemaking process hydrogensulfite salts are added to wine to produce SO_2.
An equilibrium exists between hydrogensulfite ions and SO_2 as shown in the equation below:

$$HSO_3^- + H^+ \rightleftharpoons SO_2 + H_2O$$

(i) In terms of Le Châtelier's principle, explain the effect that decreasing the pH of the wine would have on the SO_2 concentration.

_____

_____

_____

_____

_____

_____ (3 marks)

(ii) If the temperature of the wine is increased the concentration of SO_2 increases.

Determine whether the reaction shown in the equation above is exothermic or endothermic.

_____ (1 mark)

Credit will be given for the correct use of significant figures in answers to part (c). (1 mark)

(c) A sample of white wine was treated to ensure all of the sulfur present was in the form of SO_2. The SO_2 concentration was then determined by titration. In one titration procedure, white wine was pipetted into a conical flask and titrated with an iodine solution.

(i) State which one of the following should have been used to rinse the conical flask immediately before use: iodine solution, white wine, or distilled water.

_____ (1 mark)

(ii) In one 20.0 mL sample of white wine, the SO_2 concentration was calculated to be 4.76×10^{-3} mol L^{-1}.

Calculate the volume of 0.0120 mol L^{-1} iodine solution that would have reacted in this titration, given that the equation for the reaction is:

$$SO_2 + I_2 + 2H_2O \longrightarrow 4H^+ + SO_4^{2-} + 2I^-$$

(4 marks)

(iii) Determine whether the SO_2 concentration of 4.76×10^{-3} mol L^{-1} in this sample was lower than the Australian legal limit of 250 mg L^{-1} for wine.

(3 marks)

TOTAL: 15 marks

QUESTION 4

Petroleum frequently contains a variety of sulfur compounds such as ethanethiol (C_2H_5SH).

(a) When ethanethiol, a liquid at room temperature, undergoes combustion it produces SO_2 as well as other products. Each mole of ethanethiol releases 2173 kJ of heat.

Write a thermochemical equation for the complete combustion of ethanethiol.

(4 marks)

(b) Ethanethiol reduces the effectiveness of catalysts used in the processing of petroleum. One method of removing ethanethiol from petroleum uses a reaction with hydrogen at a temperature of 350°C and a pressure of 100 atmospheres. The reaction is:

$$C_2H_5SH + H_2 \rightleftharpoons C_2H_6 + H_2S$$

(i) Under these reaction conditions all of the reactants and products in the mixture are gases.

Explain why the reaction is performed at high pressure.

(2 marks)

(ii) A number of metals, such as cobalt, are used to catalyse the reaction.

(1) Write the electron configuration of cobalt.

(2 marks)

(2) Explain how the use of a catalyst increases the rate of a chemical reaction.

(3 marks)

(3) The use of a catalyst allows a chemical reaction to be carried out at a lower temperature.

Explain why this is an advantage.

_____

_____

_____

_____ (2 marks)

(iii) The H_2S can be extracted from the mixture by reacting it with amines such as CH_3NH_2. The reaction is an acid–base reaction.

Write an equation for the reaction of CH_3NH_2 with H_2S.

(2 marks)

(iv) H_2S reacts with SO_2 to produce sulfur and water.

Write an equation for the reaction of SO_2 with H_2S.

(2 marks)

TOTAL: 17 marks

You may write on this page if you need more space to finish your answers to Question Booklet 1. Make sure to label each answer carefully (e.g. 1(c)(iii)(1) continued).

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QUESTION BOOKLET

2

11 pages, 4 questions

Wednesday 12 November: 9 a.m.

Question Booklet 2

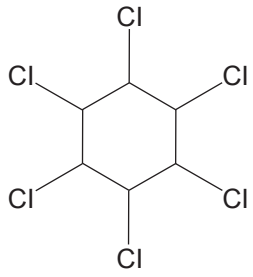
Write your answers to Questions 5 to 8 in this question booklet.

2

QUESTION 5

Lindane is used as a pesticide in some countries, although it has been banned in others.

(a) The structural formula of lindane is given below:



(i) Write the molecular formula for lindane.

_____ (2 marks)

(ii) The lindane molecule contains polar C — Cl bonds yet lindane is non-polar.

(1) Explain why C — Cl bonds are polar.

_____

_____

_____

_____ (2 marks)

(2) Explain how a substance that contains polar bonds can be non-polar.

_____

_____

_____

_____ (2 marks)

(3) Lindane has been used in mosquito control, and is therefore present in the environment. It has been estimated that the daily human intake is approximately 14 ng per kilogram of body weight.

Calculate in μg the daily intake of lindane for a 70 kg person.

(2 marks)

(b) The presence of lindane and other pesticides can be detected using chromatography.

(i) Explain the principles of chromatography.

_____

_____

_____

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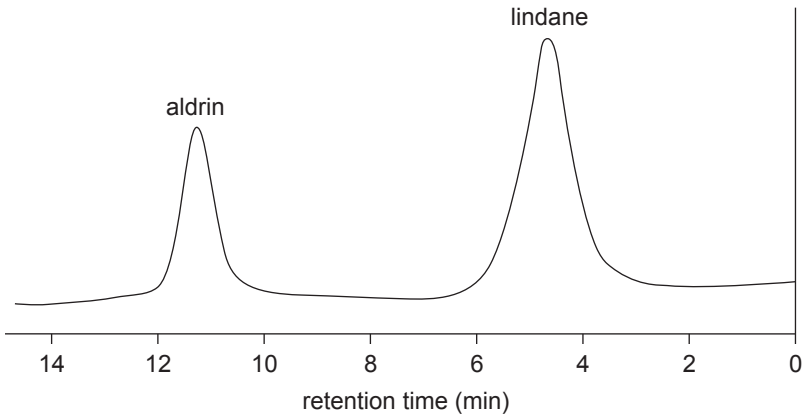
_____

_____ (4 marks)

(ii) An analysis for the pesticides lindane and aldrin was undertaken using gas chromatography in which the column used was packed with a non-polar form of silica. The following chromatogram was obtained:



(1) State the retention time for lindane.

_____ (1 mark)

(2) State whether aldrin is more polar or less polar than lindane.

_____ (1 mark)

TOTAL: 14 marks

QUESTION 6

Some geologists have proposed that the present time in the Earth's history be named 'Anthropocene' because of the profound influence of humans on natural processes.

(a) The pH of rain has been influenced by humans.

(i) Explain why rain is naturally acidic.

(2 marks)

(ii) State one example of a human activity that contributes to increased acidity of rain and explain why it has this effect.

(3 marks)

(b) It is believed that the average temperature of the atmosphere has increased due to human activity that has increased the concentration of greenhouse gases.

(i) Identify two greenhouse gases.

(2 marks)

(ii) Explain how humans have caused an increase in concentration of one of the greenhouse gases you identified in part (b)(i).

(2 marks)

Credit will be given for answers to part (c) which correctly use appropriate chemical terms and effectively communicate knowledge and understanding of chemistry.

Your answer, which must include at least one equation, should be confined to the space provided.

(c) Human activity has caused increases in the levels of nitrogen oxides in the atmosphere.

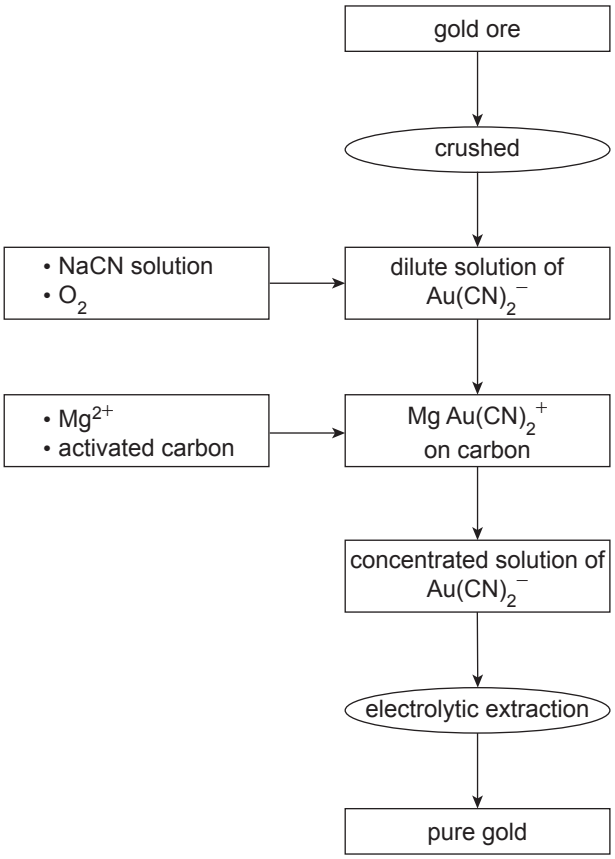
Explain how one human activity has contributed to an increase in the levels of nitrogen oxides in the atmosphere, and explain one action taken to reduce the levels of nitrogen oxides in the atmosphere.

(7 marks)

TOTAL: 16 marks

QUESTION 7

The extraction of gold from its ore is shown in the flow chart below:



(a) Explain the benefit of crushing the ore prior to chemical processing.

_____

_____

_____

_____ (2 marks)

(b) The crushed ore is mixed with an NaCN solution.

Identify the other reactant added at this step.

_____ (1 mark)

(c) Ions present in the ore are readily oxidised.

State why this would be a problem for the efficient dissolving of gold in the NaCN solution.

_____

_____ (1 mark)

(d) In acidic solution CN^- undergoes a reaction and forms HCN.

Draw the structural formula of HCN.

(2 marks)

(e) Mg^{2+} and activated carbon are added to produce a more concentrated solution of $Au(CN)_2^-$. The Mg^{2+} reacts with $Au(CN)_2^-$ to form $Mg\,Au(CN)_2^+$ which is then adsorbed onto the activated carbon.

(i) Identify the charge on the activated carbon.

_____ (1 mark)

(ii) Explain why the ability of $Mg\,Au(CN)_2^+$ to adsorb onto the activated carbon would be reduced if the concentration of Mg^{2+} were greater.

_____

_____

_____

_____ (2 marks)

(f) A solution containing $Au(CN)_2^-$ is obtained from the activated carbon. Gold can be obtained by passing an electric current through this solution.

(i) State the charge on the cathode in this cell.

_____ (1 mark)

(ii) The half-equation for the production of gold at the cathode is:

$$Au(CN)_2^- \longrightarrow Au + CN^-$$

(1) Balance the above half-equation. (1 mark)

(2) State whether the half-equation represents oxidation or reduction.

_____ (1 mark)

(3) Determine the oxidation state of gold in $Au(CN)_2^-$.

_____ (1 mark)

(g) Another method of producing gold from its ions is to react Au^+ with zinc metal.

(i) Write an equation for the reaction of zinc metal with Au^+.

(2 marks)

(ii) State the function of zinc metal in this reaction.

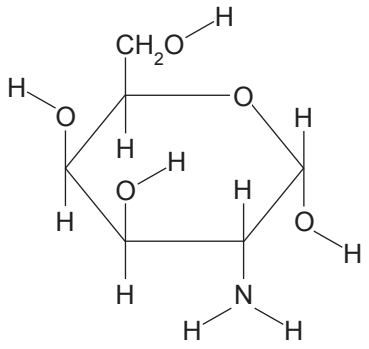
_____ (1 mark)

TOTAL: 16 marks

QUESTION 8

Glucosamine, commonly used as a medication for arthritis, is present in shellfish, animal bones and marrow, and fungi.

(a) The structural formula of glucosamine is shown below:



(i) Name two functional groups present in the structural formula above.

_____

_____ (2 marks)

(ii) Glucosamine is classified as a carbohydrate.

Given the structural formula shown above, explain why glucosamine is classified as a carbohydrate.

_____

_____

_____

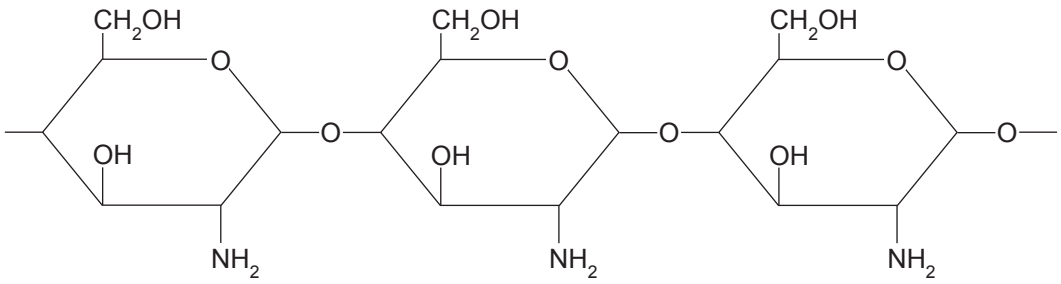
_____ (2 marks)

(iii) Glucosamine is soluble in water.

(1) Label the diagram above with $\delta+$ and $\delta-$ to indicate one polar bond between atoms that could hydrogen bond with water. (1 mark)

(2) On the diagram above, draw a water molecule and show a hydrogen bond between glucosamine and the water molecule. (2 marks)

(b) Chitosan is a polysaccharide made from glucosamine. The structural formula of chitosan is shown below:



(i) On the structural formula above, indicate a repeating unit. (1 mark)

(ii) Chitosan can be converted into glucosamine using a protein catalyst.

(1) State the name given to a protein that acts as a catalyst.

_____ (1 mark)

(2) The optimum temperature for this reaction is 50°C.

Explain the effect on the catalytic behaviour of the protein if the temperature were raised to 75°C.

_____

_____

_____

_____

_____

_____ (3 marks)

(3) The conversion of chitosan into glucosamine is an exothermic reaction.

(A) State whether an exothermic reaction takes in or gives out heat.

_____ (1 mark)

(B) State whether the ΔH value for an exothermic reaction is greater than or less than zero.

_____ (1 mark)

TOTAL: 14 marks

You may write on this page if you need more space to finish your answers to Question Booklet 2. Make sure to label each answer carefully (e.g. 7(e)(ii) continued).

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QUESTION BOOKLET

3

13 pages, 4 questions

Wednesday 12 November: 9 a.m.

Question Booklet 3

Write your answers to Questions 9 to 12 in this question booklet.

QUESTION 9

Alkanes and alcohols are used as fuels.

(a) To minimise the load carried, a camper decided to carry only the mass of butane needed to generate 600 kJ of energy for heating water.

(i) Calculate the mass of butane required to generate 600 kJ of energy, given that the complete combustion of 1 mole of butane releases 2874 kJ of energy.

(3 marks)

(ii) Calculate the mass of water that can be heated from 27°C to boiling point using 600 kJ of energy.

Assume that the specific heat capacity of water is 4.18 $Jg^{-1}K^{-1}$.

(3 marks)

(iii) The camper found that although all of the butane had been used the water had not reached boiling point.

Explain two reasons why the mass of butane was not enough to heat the water to boiling point.

(4 marks)

(b) Ethanol is a common alcohol fuel produced by the fermentation of glucose.
Write an equation for the conversion of glucose into ethanol.

(2 marks)

(c) Explain why ethanol has a higher boiling point than butane.

_____

_____

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_____

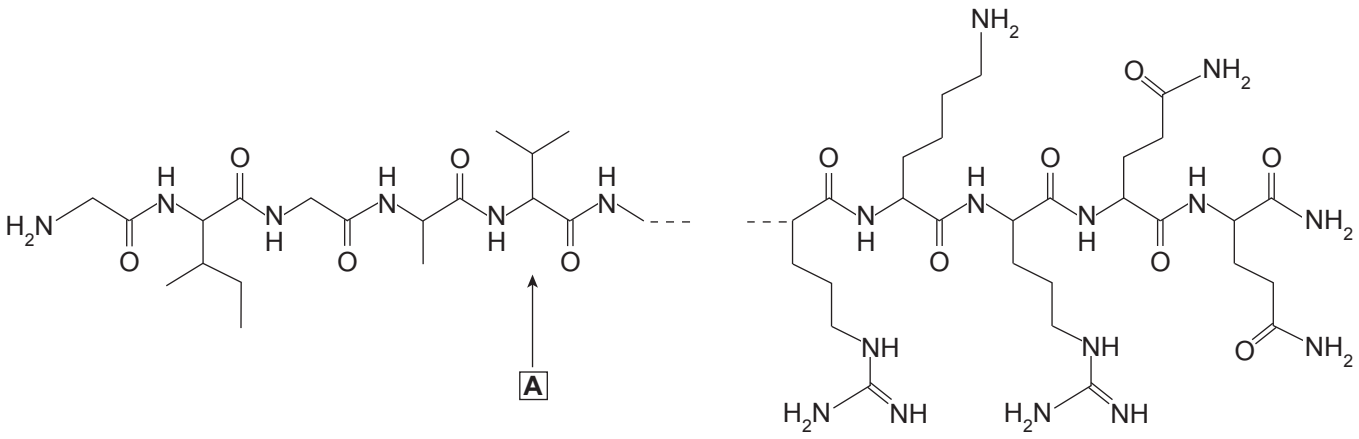
_____

_____ (3 marks)

TOTAL: 15 marks

QUESTION 10

The protein melittin is the major component of bee venom. The two ends of protein chains are known as the N-terminal and the C-terminal. The structural formulae of the two ends of melittin are shown below:



N-terminal **C-terminal**

(a) Name the functional group that links amino acid units in a protein.

_____ (1 mark)

(b) In the space below, draw the structural formula of the amino acid that was used to produce the monomer unit indicated at **A**.

(2 marks)

(c) State why the C-terminal is more polar than the N-terminal.

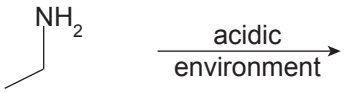
_____

_____ (1 mark)

(d) Bee venom is acidic. The acidic environment affects the structure of the C-terminal of melittin.

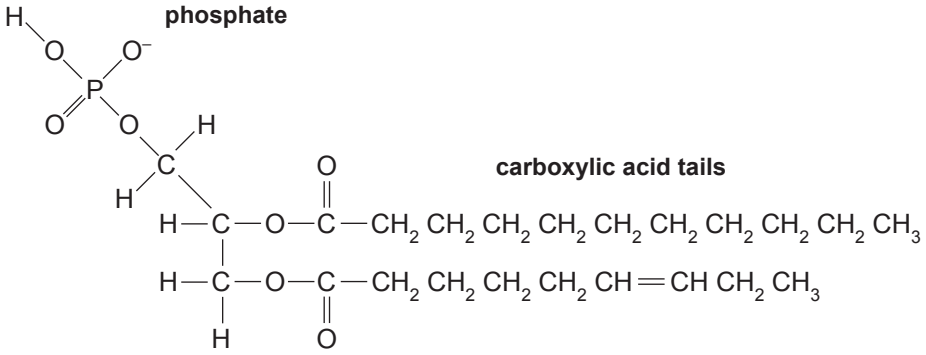
(i) One of the functional groups in the C-terminal is shown below.

Draw the structure as it would occur in an acidic environment.



(2 marks)

(ii) Because of the structure of the C-terminal, melittin in bee venom interacts with phospholipids in cells. This leads to destruction of the cells. A diagram of a phospholipid is shown below:



(1) Explain why the C-terminal of melittin is attracted to the phosphate in the phospholipid.

_____

_____

_____

_____ (2 marks)

(2) Explain why the ability of melittin to destroy cells would be less if the C-terminal had fewer amino acid monomer units.

_____

_____

_____

_____ (2 marks)

(e) Synthetic polymers have been created that can neutralise the toxic effects of melittin. Mice that have been injected with doses of melittin show a significantly higher recovery rate when injected with these polymers immediately after the melittin dose.

(i) State a hypothesis for the experiment described above.

_____

_____

_____

_____ (2 marks)

(ii) Identify the dependent variable in this experiment.

_____

_____ (1 mark)

(iii) Suggest one variable that would need to be held constant in this experiment.

_____

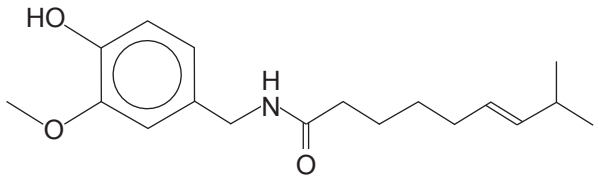
_____ (1 mark)

TOTAL: 14 marks

QUESTION 11

The vanilloids are naturally occurring molecules that have similar molecular structures but distinctly different flavours.

(a) Capsaicin is a vanilloid that creates a spicy taste in foods. The structural formula of capsaicin is shown below:



(i) Milk is more effective than water in eliminating the hot sensation felt in the mouth when capsaicin is eaten.

(1) Circle the non-polar end of the capsaicin molecule. (1 mark)

(2) Explain why capsaicin readily dissolves in the fatty component of milk.

_____

_____

_____

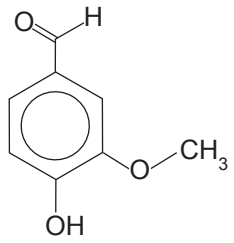
_____ (2 marks)

(ii) Capsaicin can be hydrolysed under alkaline conditions to form an amine and another organic product.

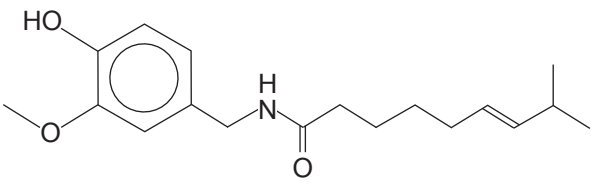
Draw the structural formula of the other organic product.

(2 marks)

(b) Vanillin, another vanilloid, is used as a flavouring agent in foods, beverages, and pharmaceuticals. Its structural formula is shown below, along with that of capsaicin:



vanillin



capsaicin

Both vanillin and capsaicin were tested with Tollens' reagent.

Explain how the test results could be used to differentiate between vanillin and capsaicin.

_____

_____

_____

_____

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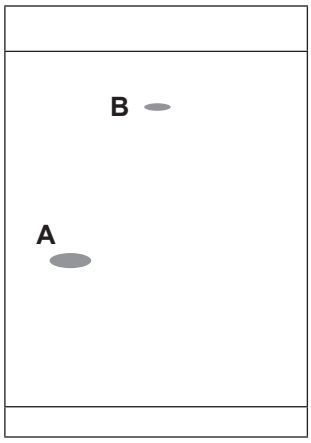
_____

_____ (4 marks)

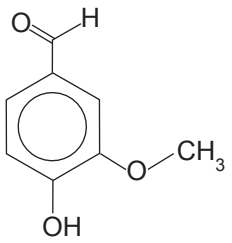
(c) Thin-layer chromatography using a polar stationary phase was used to identify the two vanilloids vanillin and eugenol. The diagram below shows the chromatogram produced:



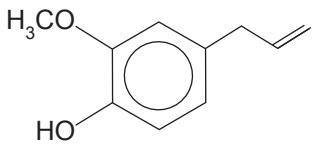
(i) Calculate the R_F value for **B**.

(2 marks)

(ii) The structural formulae of vanillin and eugenol are shown below:



vanillin



eugenol

State the likely identity of **A** in the chromatogram. Explain your answer.

(3 marks)

TOTAL: 14 marks

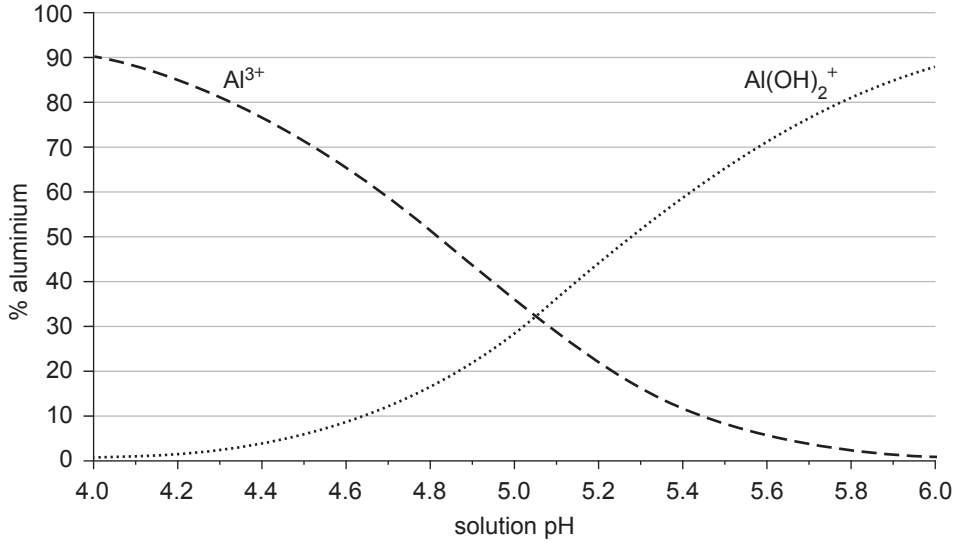
QUESTION 12

Aluminium is the most common metal in the Earth's crust.

(a) Aluminium toxicity to plants affects some wheat-growing regions of Australia. In the pH range 4.0–6.0 aluminium is present in soil as three species in equilibrium:

$$Al^{3+} \rightleftharpoons Al(OH)^{2+} \rightleftharpoons Al(OH)_2^{+}$$

The graph below shows the variation in the proportions of Al^{3+} and $Al(OH)_2^{+}$ over the pH range 4.0–6.0:



(i) State what happens to the percentage of aluminium present as $Al(OH)_2^{+}$ as pH increases from 4.0 to 6.0.

_____

_____ (1 mark)

(ii) Using the graph above, determine the pH when 65% of the aluminium is present as Al^{3+}.

_____ (1 mark)

(iii) The graph does not show the percentage of aluminium present as $Al(OH)^{2+}$ across the pH range 4.0–6.0.

Using the graph above, determine the percentage of aluminium present as $Al(OH)^{2+}$ at pH 5.5. Show your working.

(2 marks)

(iv) Write a balanced equation to show the equilibrium between Al^{3+} and $Al(OH)^{2+}$ in an aqueous acidic solution.

(2 marks)

(v) A wheat farmer found that the total concentration of aluminium in a soil was 43 μmol L^{-1}.

(1) Using the graph on the page opposite, determine the concentration, in μmol L^{-1}, of Al^{3+} in this soil if it has a pH of 4.2.

(2 marks)

(2) Determine the H^+ concentration in a solution that has a pH of 4.2.

(2 marks)

(3) Al^{3+} is the most toxic of the three aluminium species.

Explain why a wheat farmer might add chemicals to a soil that has a pH of 4.2 to increase its pH.

_____

_____

_____

_____ (2 marks)

(b) Analysis of a soil sample demonstrated the presence of the aluminosilicate sanidine, which contains the ion $AlSi_3O_x^-$.

(i) State the type of bonding that exists between the atoms in aluminosilicate ions.

_____ (1 mark)

(ii) Determine the value of *x*.

(1 mark)

(iii) In one sample of sanidine the potassium ions and sodium ions were found to be in the ratio of 3:1 respectively.

Determine the formula of the sample.

(2 marks)

TOTAL: 16 marks

You may write on this page if you need more space to finish your answers to Question Booklet 3. Make sure to label each answer carefully (e.g. 10(d)(ii)(1) continued).