South Australian
Certificate of Education

1

Chemistry
2020

Question booklet 1

- Questions 1 to 4 (62 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 12 if you need more space
- Allow approximately 65 minutes

Examination information

Materials
- Question booklet 1
- Question booklet 2
- Periodic table and data sheet
- SACE registration number label

Instructions
- Use black or blue pen
- You may use a sharp dark pencil for diagrams and other representations
- Approved calculators may be used

Total time: 130 minutes
Total marks: 120

Attach your SACE registration number label here

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1. Tea contains a mixture of compounds including minerals, caffeine, and antioxidants such as tannin.

(a) One mineral compound found in tea contains Mn^{2+}, which is vital for many functions in the human body.

(i) Using subshell notation, write the electron configuration of Mn^{2+}.

_____ (2 marks)

(ii) AAS was used to determine the concentration of Mn^{2+} in a sample of tea. Other metal cations were also present in the sample.

Explain why the determination of Mn^{2+} concentration by AAS is ***not*** affected by the presence of other metal cations in the sample.

_____

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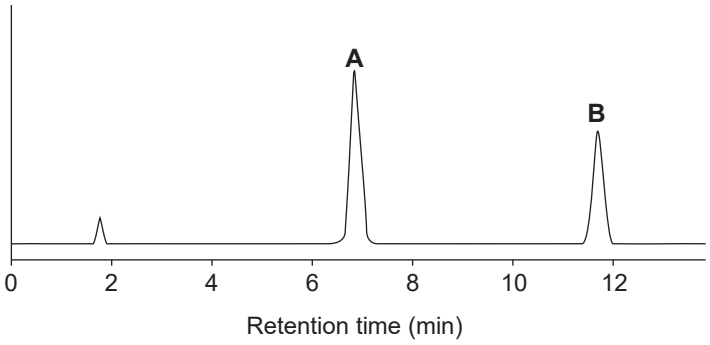
_____

_____ (2 marks)

(b) The compounds in a sample of tea were separated using HPLC with a non-polar stationary phase and a polar mobile phase. Two compounds, **A** and **B**, were identified on the chromatogram below. One of these compounds represents caffeine.



Caffeine is less polar than the other compound.

Identify which compound — **A** or **B** — represents caffeine, and explain your choice.

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_____ (3 marks)

(c) In high-quality tea, the ratio by mass of caffeine : tannin is 1 : 3. A sample of high-quality tea was analysed and found to contain 9.78 μmol of caffeine.

Calculate the mass, in mg, of tannin in this sample of tea.

(Molar mass of caffeine = 194.19 g mol^{-1}.)

(3 marks)

(d)

Tea is the second-most consumed drink in the world, after water. The antioxidants in tea may reduce the risk of developing diseases such as heart disease and cancer. Some studies have shown that women who regularly drink black tea have a decreased risk of developing ovarian cancer.

Many people add milk to their tea. A recent study by university researchers analysed samples of tea that had different types of milk added. The results showed that the addition of milk decreased the beneficial effect of the antioxidants in tea, and that skimmed milk decreased the effect more significantly than full-cream milk.

After reading this information, a tea drinker decided to replace the skimmed milk in her tea with full-cream milk.

One of the key concepts of science as a human endeavour is 'influence'.

Explain how this university study is an example of this key concept.

(2 marks)

2. Disposable paper cups contain a high proportion of cellulose.

(a) (i) Write the molecular formula of cellulose.

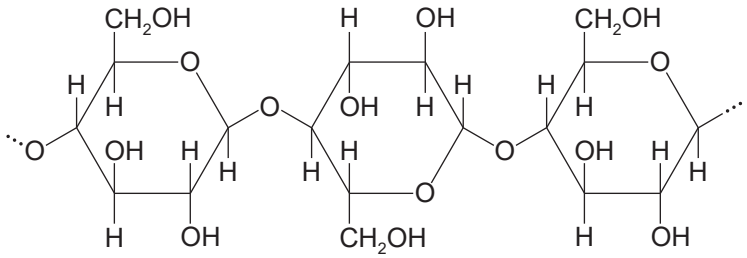
_____ (1 mark)

(ii) The cellulose polymer is made from glucose monomers.

State the type of reaction that occurs when glucose monomers join to form the cellulose polymer.

_____ (1 mark)

(iii) The structural formula of a section of the cellulose polymer chain is shown below.



(1) Draw the structural formula of a glucose monomer.

(2 marks)

(2) With reference to its structural formula, explain why cellulose is hydrophilic yet is insoluble in water.

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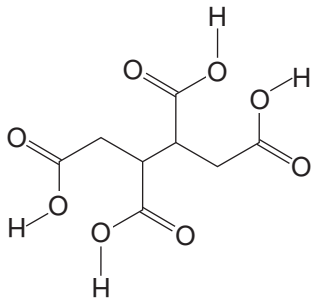
_____ (4 marks)

(b) The paper that is used to make disposable cups can be strengthened by using chemicals that react with cellulose to form cross-links between cellulose chains. The structural formula of one such chemical, BTCA, is shown below.



(i) Name the functional group that forms when BTCA reacts with cellulose.

_____ (1 mark)

(ii) Explain why the reaction of BTCA with cellulose strengthens the paper.

_____

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_____ (2 marks)

(c) Many types of disposable paper cups are not recycled because the paper is lined with wax or plastic.

Explain *one* difficulty associated with recycling these disposable paper cups.

_____

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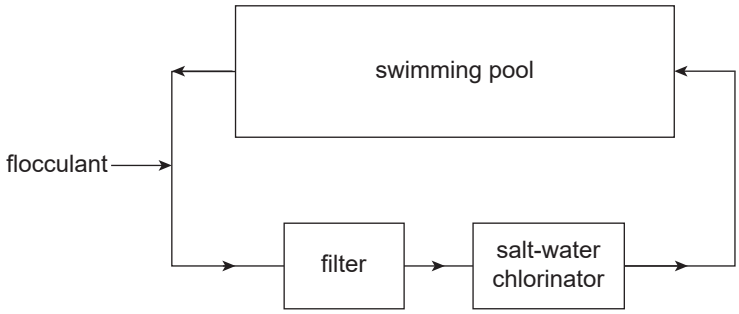
_____ (2 marks)

3. Swimming-pool water is recirculated through a water-treatment system. During this process, NaCl is added to the water and a salt-water chlorinator disinfects the water. A diagram representing the flow of water through this system is shown below.



(a) (i) A flocculant such as $Al_2(SO_4)_3$ is added, to remove suspended clay particles from the water.

State the feature of $Al_2(SO_4)_3$ that makes it a more effective flocculant than Na_2SO_4.

_____ (1 mark)

(ii) The salt-water chlorinator produces Cl_2, which reacts with water to form hypochlorous acid, HClO.

(1) Write an equilibrium equation for the reaction of Cl_2 with water.

(2 marks)

(2) Explain the effect that increasing the pH would have on the position of the equilibrium.

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_____ (3 marks)

(iii) Water that has an NaCl concentration above 0.9% w/v can irritate people's eyes. The manufacturer of one brand of salt-water chlorinator recommends that the concentration of NaCl in pool water should be maintained at 4000 ppm.

Using a calculation, show that water that has an NaCl concentration of 4000 ppm is unlikely to irritate people's eyes.

(3 marks)

(b) HClO ionises in water to produce ClO^-. Titration was used to determine the concentration of ClO^- in one sample of pool water.

A 25.00 mL sample of the water was mixed with a solution containing excess iodide ions, I^-, to produce iodine, I_2. The equation for this reaction is shown below.

$$ClO^-_{(aq)} + 2I^-_{(aq)} + 2H^+_{(aq)} \longrightarrow I_{2(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

The iodine produced was then titrated with a standard solution containing 1.03×10^{-4} mol L^{-1} thiosulfate, $S_2O_3^{2-}$. The equation for this reaction is shown below.

$$2S_2O_3^{2-}{}_{(aq)} + I_{2(aq)} \longrightarrow 2I^-_{(aq)} + S_4O_6^{2-}{}_{(aq)}$$

The end point occurred when 15.08 mL of the thiosulfate solution had been added.

(i) Calculate the moles of $S_2O_3^{2-}$ that were used to reach the end point. Show your working and give your answer to the correct number of significant figures.

(3 marks)

(ii) Hence calculate the moles of ClO^- in the 25.00 mL sample of water, showing your reasoning.

(2 marks)

(iii) Hence determine the concentration, in mol L^{-1}, of ClO^- in the pool water.

(2 marks)

4. Oxides of nitrogen are useful industrial chemicals, but they also pollute the troposphere.

(a) The first step in the industrial preparation of nitric acid is the oxidation of ammonia to produce NO, using a temperature of 920°C and a platinum catalyst.

State the likely effect that ***not*** using a catalyst would have on the temperature required for this reaction.

_____ (1 mark)

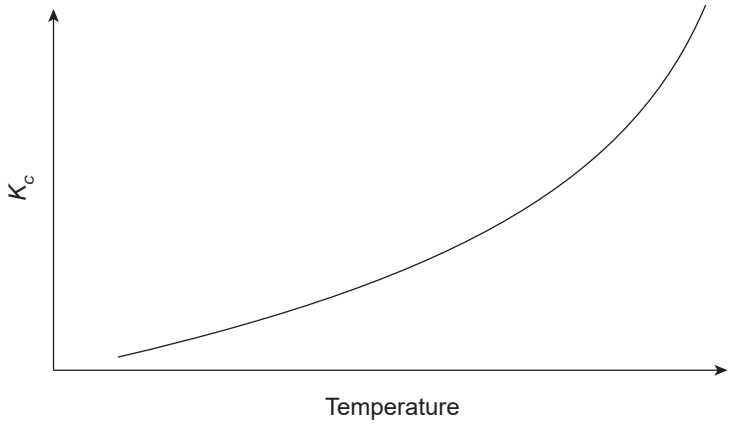
(b) NO can also be produced from the reaction between N_2 and O_2 at very high temperatures, as shown in the equation below.

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$$

(i) Write an expression for the equilibrium constant, K_c, for this reaction.

(2 marks)

(ii) The graph below shows how the value of K_c for this reaction changes with temperature.



Explain how the graph indicates that this reaction is endothermic.

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_____ (3 marks)

(iii) At 1200°C the value of K_c for this reaction is 1×10^{-5}.

Using this K_c value, explain why a manufacturer would ***not*** choose to produce NO using this reaction.

(2 marks)

(c) During the second step in the industrial preparation of nitric acid, NO is converted into NO_2 as shown in the equation below.

$$2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)} \qquad \Delta H = -114 \text{ kJ mol}^{-1}$$

(i) A chemical engineer was investigating a new set of reaction conditions. The temperature was kept constant but the pressure was increased.

(1) Explain the effect that this would have on the position of the equilibrium.

(3 marks)

(2) State the effect that this would have on the value of the equilibrium constant.

(1 mark)

Question 4 continues on page 10.

(ii)

In industry, manufacturers usually convert NO into NO_2 without using a catalyst. During this relatively slow step in the production process, the mixture of gases travels through a large network of pipes to allow enough time for the conversion of NO into NO_2. A significant amount of heat is lost through the pipes during the time taken for the exothermic reaction to take place. Manufacturers try to recover as much of this heat as possible.

A group of scientists investigated whether a faster reaction using a catalyst could increase the amount of heat recovered from the production process. They used a platinum catalyst with various combinations of temperatures, pressures, and proportions of reactants, resulting in 825 different test conditions. The results indicated that a faster reaction would require fewer pipes for the conversion reaction. This would reduce the initial cost of setting up a nitric acid production plant, and would also allow the recovery of up to 10% extra heat from the production process.

Using *one* of the key concepts of science as a human endeavour, explain how this scientific research could result in a positive outcome for the environment.

(4 marks)

(d) The presence of NO_2 in the troposphere leads to the formation of other pollutants, including ozone.

(i) Using at least one equation, describe the role of NO_2 in the formation of ozone in the troposphere.

(3 marks)

(ii) Describe *one* harmful effect of the presence of ozone in the troposphere.

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_____

_____ (2 marks)

You may write on this page if you need more space to finish your answers to any of the questions in this question booklet. Make sure to label each answer carefully (e.g. 2(a)(iii)(2) continued).

South Australian
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Chemistry
2020

Question booklet 2

- Questions 5 to 8 (58 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 12 if you need more space
- Allow approximately 65 minutes

2

Copy the information from your SACE label here

SEQ	FIGURES	CHECK LETTER	BIN

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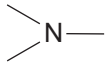
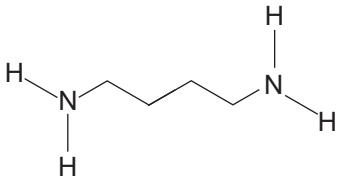
5. Two amines that are produced by the bacterial decomposition of compounds in animal flesh are TMA and putrescine.

(a) The structural formulae of TMA and putrescine are shown below.



TMA



putrescine

(i) Classify TMA as a primary, secondary, or tertiary amine.

_____ (1 mark)

(ii) Write the systematic name of putrescine.

_____ (2 marks)

(b) TMA is an amine that is produced by bacterial decomposition in fish. TMA has a low boiling point of 3°C, which allows it to evaporate easily and cause a fishy smell.

(i) With reference to its structural formula, explain why TMA has a low boiling point.

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_____ (3 marks)

(ii) When lemon juice is added to fish, TMA in the fish reacts with the acid in the juice, which decreases the fishy smell.

(1) Draw the structural formula of TMA after it has reacted with lemon juice.

(2 marks)

(2) Explain why the fishy smell of TMA decreases when lemon juice is added.

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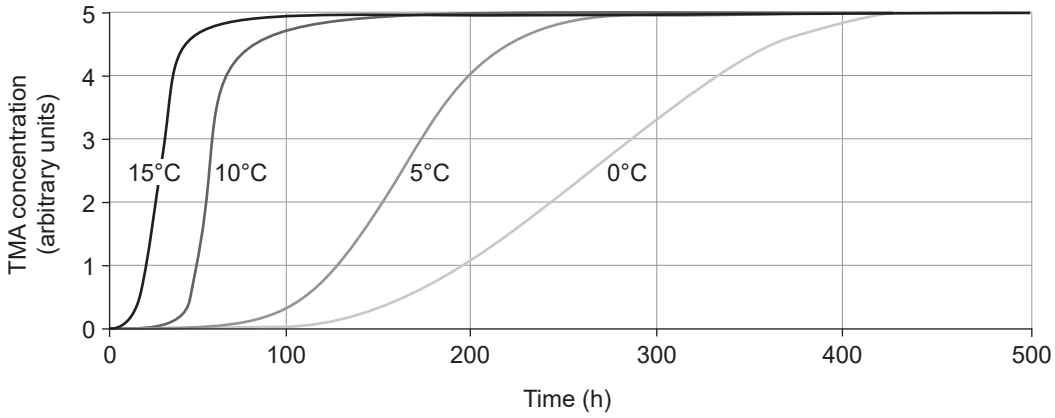
_____ (2 marks)

(iii) As the concentration of TMA in fish increases, the freshness of the fish decreases. A study investigated the effect of temperature on the rate of formation of TMA in fish, and the results are shown in the graph below.



(1) Fish can be classified as fresh when its concentration of TMA is below 1 arbitrary unit.

Using the graph, determine the length of time for which fish can be stored at 5°C and remain fresh.

_____ (1 mark)

(2) Using values from the graph, determine the effect that temperature has on the rate of formation of TMA in fish.

_____

_____

_____

_____

_____ (2 marks)

(3) Using the graph, state the effect that temperature has on the final concentration of TMA in fish.

_____ (1 mark)

6. When a fresh pear is sliced, its enzymes catalyse a reaction between compounds in the pear and oxygen in the air, which causes a brown colour to develop on the pear. This browning is unappealing to consumers. Hence before pears are canned for sale in supermarkets, they undergo a process known as blanching.

(a) During blanching, pears are briefly placed into boiling water to inactivate the enzymes.

Explain how blanching inactivates enzymes.

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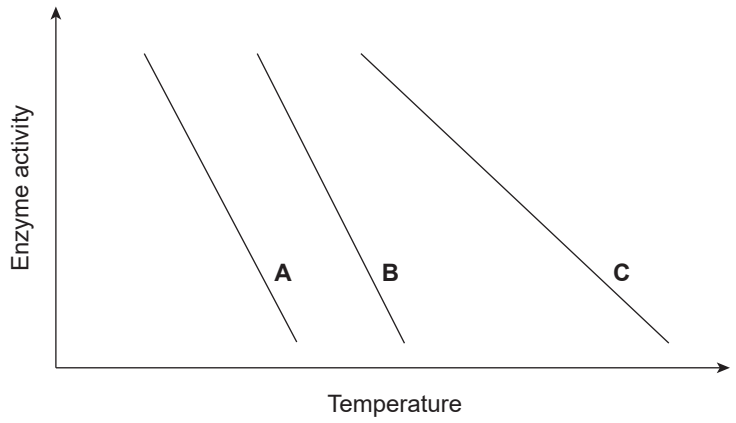
_____ (3 marks)

(b) During blanching, different enzymes are inactivated at different temperatures. The graph below shows the effect of temperature on the level of activity of three enzymes that are present in pears: **A**, **B**, and **C**.



(i) State the common trend shown in the graph.

_____ (1 mark)

(ii) Identify the enzyme that requires the highest temperature in order to be inactivated.

_____ (1 mark)

(c) A student conducted an investigation into the effect of blanching on one of the enzymes in pears.

In one test for this enzyme's level of activity, hydrogen peroxide, H_2O_2, and a reducing agent are added to blanched pear. If the enzyme is active, it catalyses the reaction between H_2O_2 and the reducing agent, and a red-brown colour develops. If the enzyme is inactive then no red-brown colour develops.

The student designed the following procedure:

1. Place a few fresh pear slices into a 500 mL beaker that contains 200 mL of distilled water, then boil for 5 minutes.
2. Remove the pear slices from the boiling water and place them in cold water, to stop the blanching process.
3. Grind a 3 g sample of drained pear slices, then mix with 5 mL of distilled water.
4. Add 1 mL of 0.5% H_2O_2 and 1 mL of reducing agent to the sample. After 3 minutes, observe the colour of the sample.
5. Repeat steps 1–4 using boiling times of 4 minutes, 3 minutes, 2 minutes, and 1 minute.
6. Repeat steps 3 and 4 only, using fresh pear to produce a control sample.

(i) Identify the independent variable in this investigation.

_____ (1 mark)

(ii) Justify why the concentration of H_2O_2 was kept constant in all trials.

_____

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_____ (2 marks)

(iii) The enzyme catalyses the conversion of H_2O_2 into H_2O.

(1) Complete the half-equation below for this reaction.

$$H_2O_2 \longrightarrow H_2O$$

(2 marks)

(2) Explain the effect that grinding the pear would have on the rate of this reaction.

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_____ (3 marks)

7. Beaches around the world are made up of different materials including sand, pebbles, crushed shell (which contains calcium carbonate), and clay (which contains aluminosilicates).

(a) Illite is an aluminosilicate found in clay. One simplified formula of illite is $K_xMg_{2x}AlSi_8O_{20}$.

Showing your working, determine the value of *x*.

(2 marks)

(b) In some coastal areas, as the distance from the sea increases, the percentage of clay in the beach material also increases.

Using this information, explain how the amount of plant growth would change as distance from the sea increases.

(3 marks)

(c) Rain that falls on beaches located near busy cities may absorb acidic gases from the atmosphere, resulting in acidic water falling onto the beach.

(i) Calculate the concentration of H^+ in water that has a pH of 4.1.

(2 marks)

(ii) Beach material that contains crushed shell is able to decrease the concentration of H^+ in acidic water that has fallen onto the beach.

Explain the process by which shell decreases the concentration of H^+ in acidic water. Include a balanced equation in your answer.

Equation:

Explanation: _____

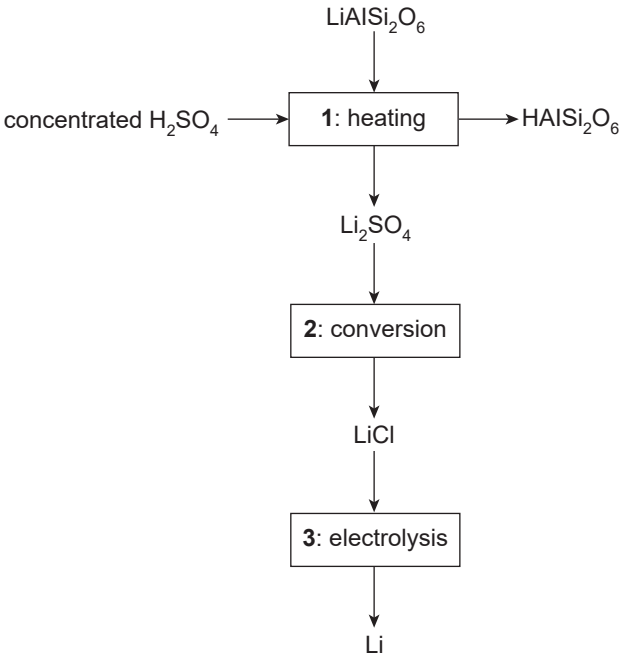
_____

_____ (3 marks)

8. Australia produces materials for local and international use.

(a) Australia produces more lithium from the mining of lithium ores than any other country. The increased usage of lithium–ion batteries has contributed to an increased global demand for lithium.

The mineral spodumene, $LiAlSi_2O_6$, is extracted from its ore and is then converted to lithium, Li, using processes **1**–**3** shown in the flow chart below.



(i) Using the information in the flow chart, write an equation for the reaction that occurs in process **1**.

(2 marks)

(ii) State why concentrated H_2SO_4 is classified as a raw material in process **1**.

_____

_____ (1 mark)

(iii) In process **3**, lithium metal is produced from the electrolysis of molten lithium chloride.

(1) Explain why molten lithium chloride, rather than aqueous lithium chloride, is used as the electrolyte in process **3**.

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_____

_____

_____ (2 marks)

(2) Describe *one* issue that arises for manufacturers when using a molten electrolyte.

_____

_____

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_____ (2 marks)

(iv) Currently, it is much cheaper to obtain lithium from spodumene than from the recycling of lithium–ion batteries.

State why it is desirable to recycle lithium.

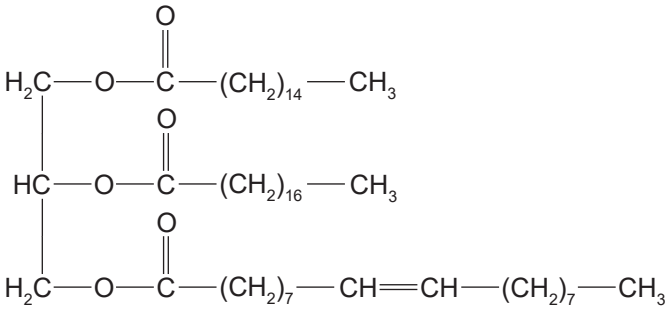
_____

_____ (1 mark)

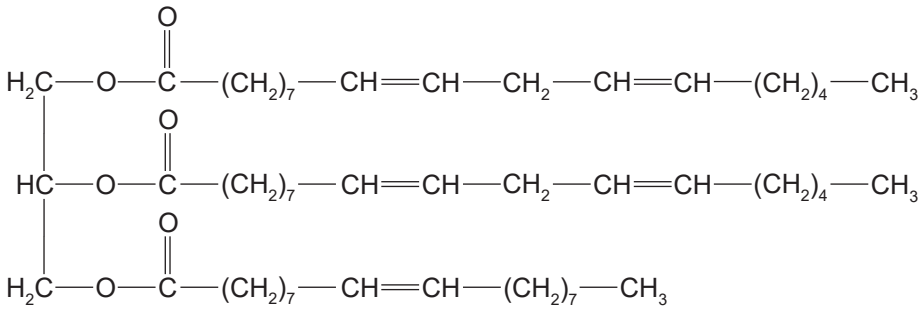
Question 8 continues on page 10.

(b) Many businesses in Tasmania use biodiesel that is made from locally produced poppy-seed oil.

The structural formulae of two triglycerides, **A** and **B**, that are found in poppy-seed oil are shown below.



A



B

(i) With reference to their structural formulae, explain which triglyceride — **A** or **B** — has the lower melting point.

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_____ (4 marks)

(ii) Explain how a test that uses a solution of bromine could distinguish between samples of triglyceride **A** and triglyceride **B**, and state the results of this test.

(4 marks)

(iii) The equation for the production of biodiesel from triglyceride **A** is shown below.

$$\text{triglyceride } \mathbf{A} + \text{reactant X} \xrightarrow{OH^-} \text{glycerol} + \text{biodiesel}$$

(1) Identify *one* chemical that could be reactant X.

(1 mark)

(2) Draw the structural formula of *one* biodiesel molecule that could be produced from triglyceride **A**.

(2 marks)

(3) Some data about one biodiesel fuel are shown in the table below.

Major component	*Energy content* ($kJ\,g^{-1}$)	*Density* ($g\,mL^{-1}$)	*Energy density* ($kJ\,L^{-1}$)
$C_{13}H_{26}O_2$	38	0.870	

Calculate the energy density of this biodiesel fuel, in $kJ\,L^{-1}$.

(2 marks)

You may write on this page if you need more space to finish your answers to any of the questions in this question booklet. Make sure to label each answer carefully (e.g. 6(c)(iii)(2) continued).

Chemistry data sheet

Metal activity

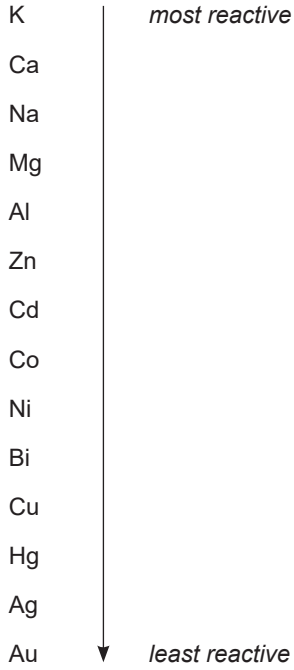

Table of SI prefixes

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}

Symbols of common quantities

amount of substance	n
mass	m
molar concentration	c
change in enthalpy	ΔH
molar mass	M
volume	V
heat energy	Q
specific heat capacity	c
temperature	T

Mathematical relationships

$$n = \frac{m}{M}$$

$$c = \frac{n}{V}$$

$$Q = mc\Delta T$$

$$\Delta H = \frac{Q}{n}$$

$$\text{pH} = -\log\left[\text{H}^{+}\right]$$

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)	113 Nh nihonium (284)	114 Fl flerovium (289)	115 Mc moscovium (288)	116 Lv livermorium (293)	117 Ts tennessine (294)	118 Og oganesson (294)

[1]lanthanide series	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
[2]actinide series	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)