South Australian
Certificate of Education

1

Chemistry
2021

Question booklet 1

- Questions 1 to 3 (60 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

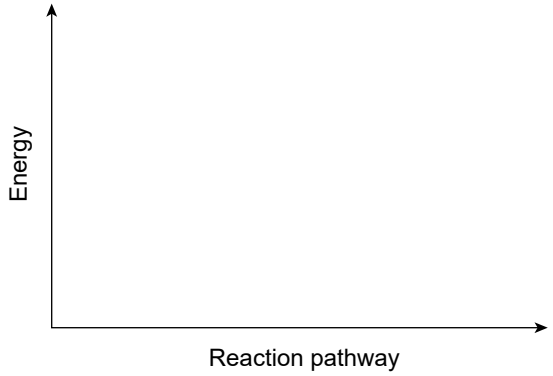
Government
of South Australia

1. Hydrogen gas is produced industrially to use in the manufacture of a wide variety of products.

(a) Currently, most hydrogen gas is produced industrially in a reaction using methane. The reaction occurs at high temperatures in the presence of a nickel catalyst. The equation for this reaction is shown below.

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons 3H_{2(g)} + CO_{(g)} \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

(i) *On the axes below*, draw an energy profile diagram for the forward reaction. Label the activation energy and the enthalpy change on your diagram.



(3 marks)

(ii) Write the K_c expression for this reaction.

(2 marks)

(iii) A mixture of 5.00 mol CH_4 and 5.00 mol H_2O was placed in an empty 50.0 L container and allowed to reach equilibrium at 1200 K. At equilibrium, 1.935 mol CH_4 remained.

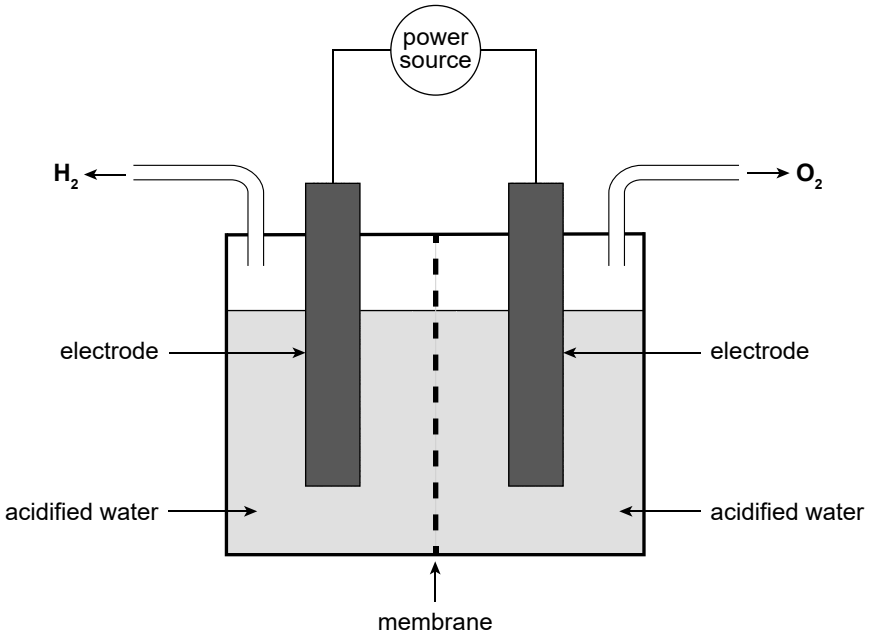
Use this information to determine the concentration of H_2 at equilibrium. Give your answer to the correct number of significant figures.

(4 marks)

(iv) Explain how a manufacturer of hydrogen gas would benefit from using a high temperature for this reaction.

(6 marks)

(b) Another method for producing hydrogen industrially is by electrolysis of acidified water, as shown in the diagram of an electrolytic cell below.



(i) (1) Write the half-equation for the reaction that produces hydrogen in this cell.

(2 marks)

(2) *On the diagram above*, draw the direction of electron flow through the external circuit.

(1 mark)

(ii) This electrolysis process uses a platinum catalyst.

(1) State why a catalyst is used in this process.

_____ (1 mark)

(2) Cobalt(II) phosphide is being investigated as an alternative catalyst to platinum for this process. Although cobalt(II) phosphide is cheaper, it is less effective than platinum in catalysing the process.

Suggest *one* benefit, other than cost, of using this alternative catalyst.

_____

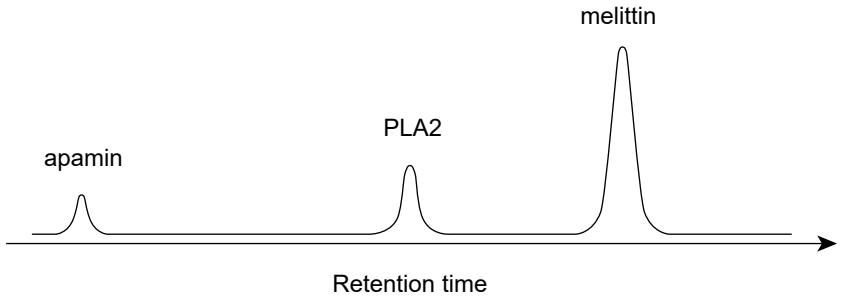
_____ (1 mark)

(3) Using subshell notation, write the electronic configuration of the cobalt(II) ion, Co^{2+}.

_____ (2 marks)

2. When threatened, honeybees may inject venom into other animals. The venom is a solution, with a pH of 4.5–5.5, containing a mixture of proteins and other chemicals that cause a range of effects in animals.

(a) Scientists used high-performance liquid chromatography to separate and identify three proteins in honeybee venom: apamin, PLA2, and melittin. A section of the chromatogram obtained, using a non-polar stationary phase, is shown below.



Identify and explain which *one* of the three proteins is the most polar.

_____

_____

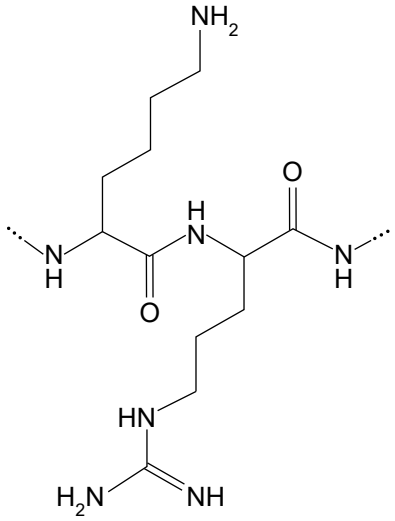
_____

_____

_____

_____ (3 marks)

(b) Melittin is the main protein in honeybee venom. The protein chain consists of linked amino acid units. The structural formula of a section of the melittin protein chain is shown below.



(i) Name the functional group that links amino acid units in this protein chain.

_____ (1 mark)

(ii) Draw the structural formula of *one* of the amino acids used to form this section of the melittin protein chain.

(2 marks)

(c) Hyaluronidase (HLA) is an enzyme in honeybee venom.

(i) Cation exchange chromatography can be used to separate HLA from other proteins in honeybee venom.

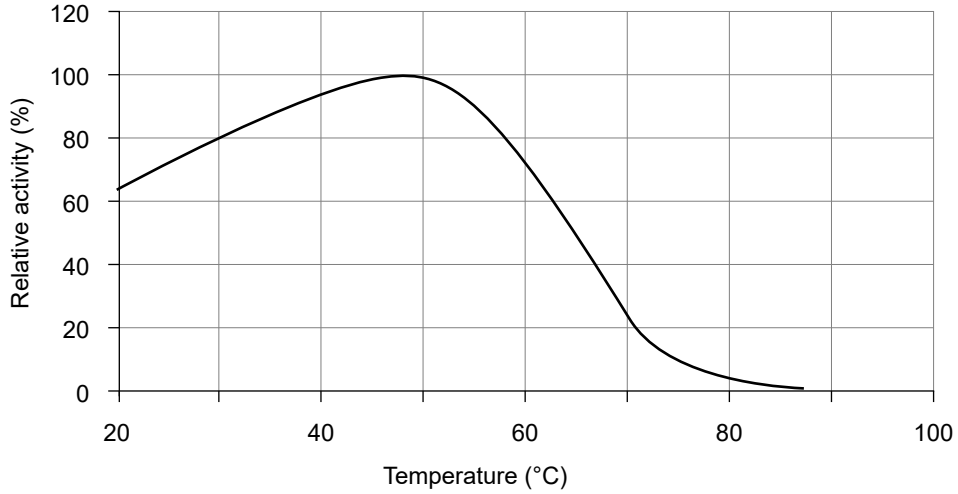
(1) State the charge on the resin in cation exchange chromatography.

_____ (1 mark)

(2) Explain why proteins that are attached to the surface of a cation exchange resin are removed when concentrated $NaCl_{(aq)}$ passes over the surface of the resin.

(2 marks)

(ii) An investigation to determine the effect of temperature on the activity of HLA was conducted at constant pH. The results are shown in the graph below.



(1) Determine the temperature at which the maximum activity of HLA occurred.

(1 mark)

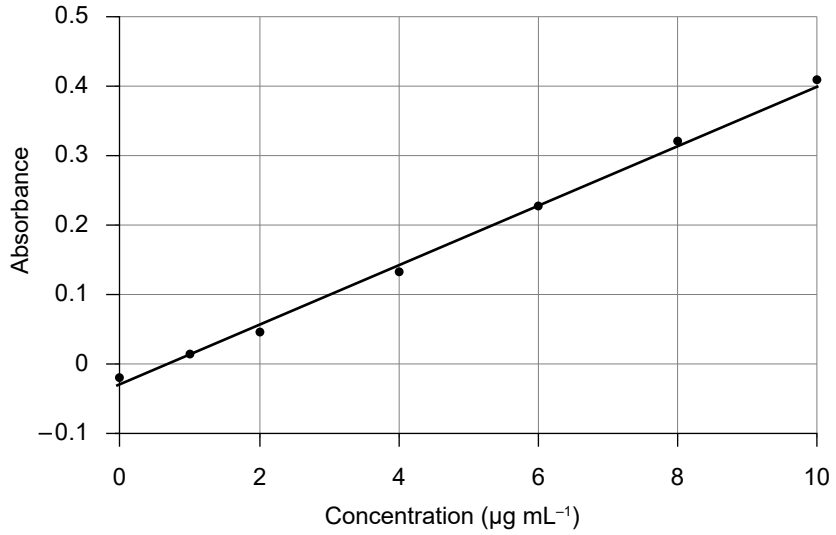
(2) State and explain the effect that increasing the temperature from 60°C to 80°C had on the activity of HLA.

(4 marks)

3. Iron is one of the most abundant elements on Earth. Iron ores contain various iron compounds and impurities such as aluminium oxide. Iron and its compounds have a broad range of uses.

(a) The percentage of iron in a sample of ore can be determined using AAS.

One spectrometer was calibrated using several solutions of known concentrations of iron. The calibration graph obtained is shown below.



(i) State the feature of the graph that indicates that random error has occurred.

_____ (1 mark)

(ii) A solution of a sample of one iron ore was analysed using AAS. The absorbance of this solution was 0.3.

(1) Use the graph to determine the concentration of iron, in μg mL^{-1}.

_____ (1 mark)

(2) Express this concentration of iron in ppm.

_____ (1 mark)

(3) Explain why the presence of aluminium oxide in the ore sample does not affect the value of the iron concentration determined by AAS.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) The most common iron compound in iron ores is haematite, Fe_2O_3. Iron metal is produced from Fe_2O_3 by chemical reduction with carbon monoxide, CO, in a reaction that also produces carbon dioxide.

(i) Write a balanced equation for this reaction.

(2 marks)

(ii) Suggest why iron metal can be produced using chemical reduction with carbon monoxide, whereas aluminium metal must be produced using electrolysis.

_____

_____

_____

_____

_____

_____ (3 marks)

(c) Liquid medications that contain Fe^{2+} can be taken to boost iron levels in the body.

(i) The concentration of Fe^{2+} in one brand of medication, **A**, was determined by titration, using a solution of 0.0311 mol L^{-1} potassium permanganate, $KMnO_4$. The equation for the reaction is shown below.

$$5Fe^{2+}_{(aq)} + MnO_4^-{}_{(aq)} + 8H^+_{(aq)} \longrightarrow 5Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}$$

The potassium permanganate solution was added from a burette to a conical flask containing a 25.0 mL sample of **A**. The titration data are shown in the table below.

Trial	1	2	3	4	5
Titre (mL)	26.65	26.10	26.40	26.20	26.15

The average titre value was calculated as 26.15 mL.

(1) Explain why more than three trials were necessary in order to calculate the average titre value.

_____

_____

_____

_____ (2 marks)

(2) Calculate the concentration of Fe^{2+}, in mol L^{-1}, in **A**.

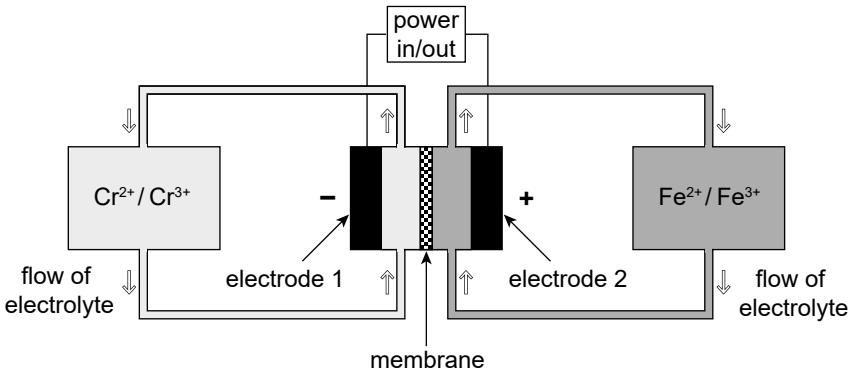
(4 marks)

(ii) The concentration of Fe^{2+} in another brand of medication, **B**, is 0.196 mol L^{-1}. The Fe^{2+} is present as $FeSO_4$.

Determine the concentration, in %w/v, of $FeSO_4$ in **B**.

(3 marks)

(d) In one type of flow cell, a solution of Fe^{2+} and Fe^{3+} is used as the electrolyte in one of the two electrode compartments. A diagram of this flow cell in operation is shown below.



When the flow cell is operating as shown in the diagram, the reactions at the two electrodes are represented by the half-equations shown below.

Electrode 1: $Cr^{2+} \longrightarrow Cr^{3+} + e^-$

Electrode 2: $Fe^{3+} + e^- \longrightarrow Fe^{2+}$

(i) Explain whether the flow cell, as shown in the diagram, is operating as a galvanic cell or as an electrolytic cell.

(2 marks)

(ii) Describe *one* major benefit of using a flow cell compared with other types of fuel cells.

(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. 3(c)(i)(2) continued).

South Australian
Certificate of Education

Chemistry
2021

Question booklet 2

- Questions 4 to 7 (60 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

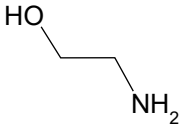
2

Copy the information from your SACE label here

SEQ	FIGURES	CHECK LETTER	BIN

Government
of South Australia

4. MEA is a chemical that has many uses, including the removal of CO_2 from air and the production of important industrial chemicals. The structural formula of MEA is shown below.



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

_____ (2 marks)

(ii) Name the *two* functional groups present in MEA.

_____ (2 marks)

(b) Carbon capture technology can be used to remove CO_2 from the gases released from factories, in order to decrease emissions of CO_2 into the atmosphere. In one carbon capture process, an aqueous solution of MEA is used to remove CO_2 from these gases.

(i) When CO_2 is added to an aqueous solution of MEA, the MEA molecule is converted into a positively charged ion.

Explain how the MEA molecule is converted into a positively charged ion.

_____

_____

_____

_____ (2 marks)

(ii)

> The concentration of carbon dioxide in the atmosphere is now at its highest level in human history. This has prompted businesses and governments to consider investing in carbon capture projects. Much scientific research has focused on improving carbon capture technology because it is energy intensive and expensive.

Referring to the information above, explain why society might *influence* businesses and governments to increase spending on carbon capture research and technology.

_____

_____

_____

_____

_____

_____

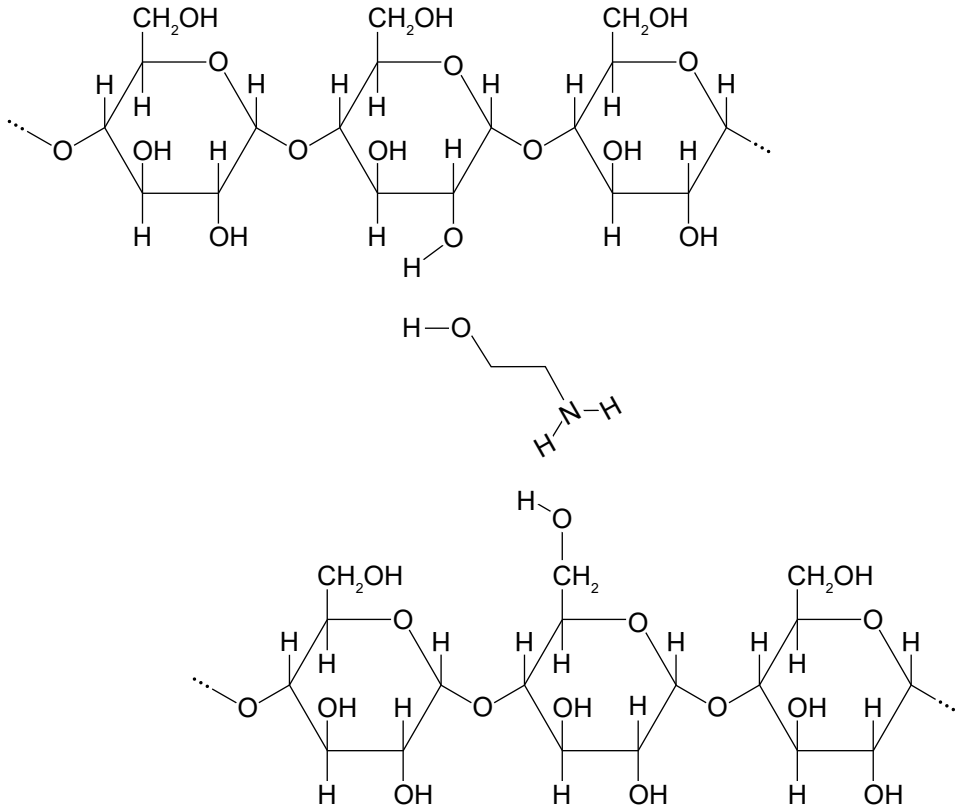
_____

_____

_____ (4 marks)

(c) In the mining industry, a mixture of MEA and starch can be used to thicken water-based drilling fluids. MEA molecules form interactions with starch polymer chains.

The structural formulae of sections of two starch polymer chains and one molecule of MEA are shown below.



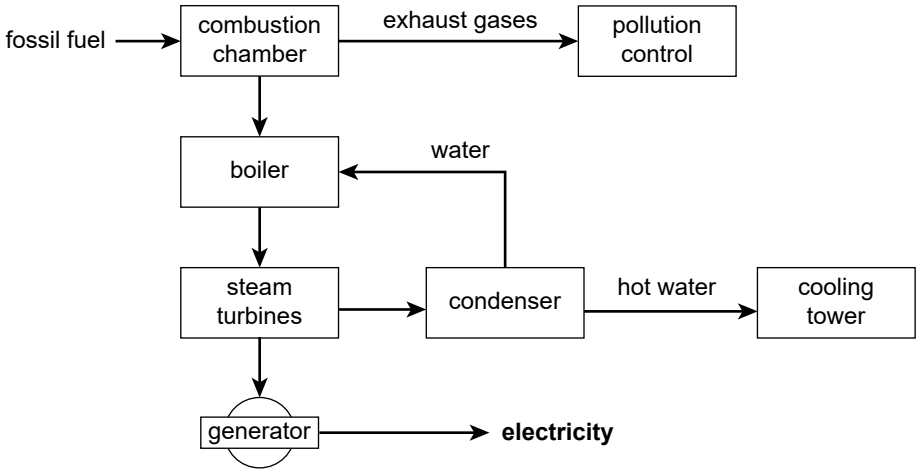
(i) Name the strongest type of interaction that forms between MEA molecules and starch polymer chains.

_____ (1 mark)

(ii) *On the diagram above*, draw *one* example of this type of interaction at *one* end of the MEA molecule. Use appropriate notation on your example.

(2 marks)

5. Electricity is commonly generated in power stations using steam turbines. A simplified flow chart for the generation of electricity using steam turbines is shown below.



(a) State *one* advantage of generating electricity as shown in the flow chart compared with generating electricity using photovoltaic cells.

_____

_____ (1 mark)

(b) Globally, coal is the main fuel used in the combustion chamber of a power station.

(i) Using the data below, calculate the mass of coal, in kg, required to increase the temperature of 1000 kg of water from 25°C to 100°C.

molar mass of coal = 3080 g mol^{-1}

enthalpy of combustion = 77 000 kJ mol^{-1}

specific heat of water = 4.18 J g^{-1} K^{-1}

(Assume complete combustion of coal and 100% efficiency of heat transfer to the water.)

(3 marks)

(ii) Name *one* other fossil fuel that could be used as the fuel in the combustion chamber.

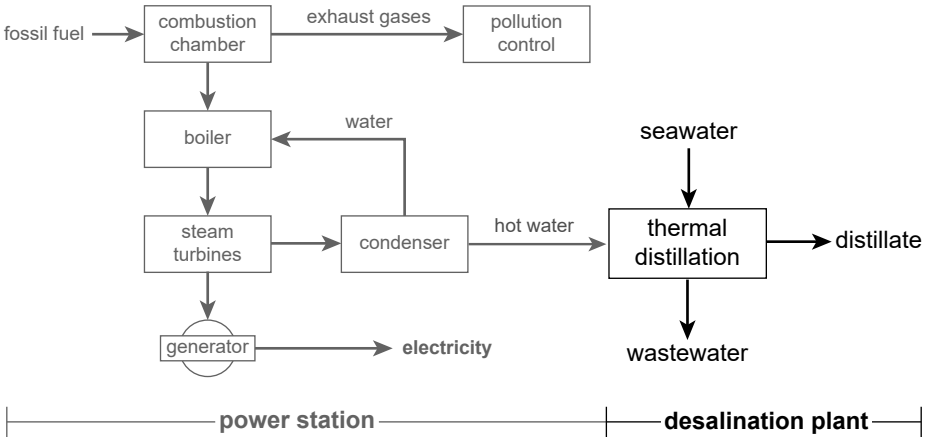
_____ (1 mark)

(iii) CO_2 is produced in the combustion chamber.

Identify *one* other substance produced from air in the combustion chamber that would need pollution control, as shown on the flow chart.

_____ (1 mark)

(c) A desalination plant can be connected to a power station that generates electricity from steam turbines, as shown in the flow chart below.



(i) Identify the distillate produced in the desalination plant.

_____ (1 mark)

(ii) Describe how connecting a desalination plant to a power station minimises costs.

_____

_____

_____

_____ (2 marks)

(iii) Another desalination method is reverse osmosis.

Explain why reverse osmosis has high energy requirements.

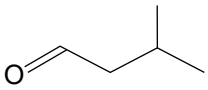
_____

_____

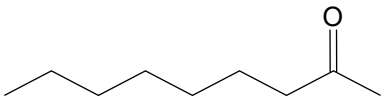
_____ (2 marks)

6. Pet dogs need to be washed regularly. Volatile compounds, produced by microbes living in dog hair, cause the distinctive smell of dogs when their hair is wet.

(a) The structural formulae of two volatile compounds found in dog hair, compound **X** and compound **Y**, are shown below.



compound **X**



compound **Y**

(i) Write the systematic name of compound **X**.

_____ (2 marks)

(ii) (1) Identify *one* reagent that could be used in a chemical test to distinguish between compound **X** and compound **Y**.

_____ (1 mark)

(2) State the expected observations during this test for both compound **X** and compound **Y**.

_____

_____

_____

_____ (2 marks)

(iii) Explain why compound **X** is more soluble in water than compound **Y**.

_____

_____

_____

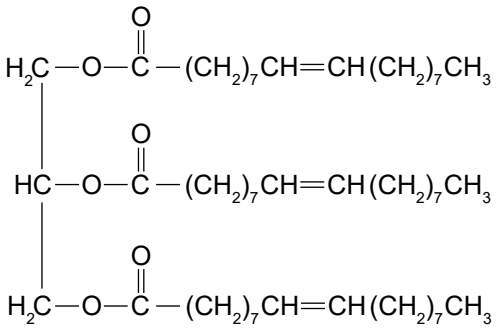
_____ (2 marks)

(iv) Compound **Y** is produced by oxidation of another compound present in dog hair, compound **Z**.

Draw the structural formula of compound **Z**.

(2 marks)

(b) Homemade soap for washing dogs can be made by heating an aqueous solution of potassium hydroxide with olive oil. Triglycerides in olive oil are hydrolysed to produce this soap, which contains a mixture of carboxylate ions and one other organic product. The structural formula of one triglyceride found in olive oil is shown below.



(i) Draw the structural formula of *one* carboxylate ion produced from the hydrolysis of the triglyceride shown in the diagram above.

(2 marks)

(ii) Identify the other organic product formed by the complete hydrolysis of this triglyceride.

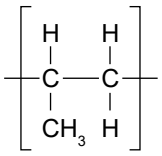
_____ (1 mark)

(iii) Explain how carboxylate ions in soap form micelles in aqueous solutions and then explain how these micelles would remove compound **Y** from dog hair. You may include a diagram in your answer.

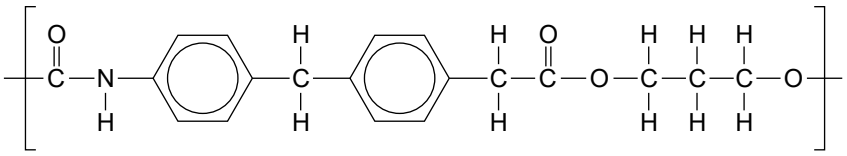
(6 marks)

7. Polymer materials may be non-biodegradable or biodegradable.

(a) Two commonly used non-biodegradable polymers are polypropene and polyurethane. The structural formulae of the repeating units for these two polymers are shown below.



polypropene



polyurethane

Explain why polypropene is easier to melt than polyurethane.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) PHB is a biodegradable polymer. PHB can be used as a substitute for polypropene in items such as shampoo bottles and food containers, because PHB and polypropene have similar physical properties.

(i) PHB can be produced by bacterial cells, which are a renewable resource.

Explain *one* advantage of producing polymers from renewable resources.

_____

_____

_____

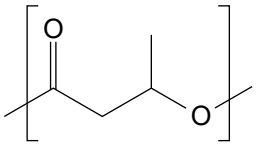
_____ (2 marks)

(ii) In the first step of PHB production, starch is hydrolysed to produce a glucose solution, used as a food source by the bacteria.

Write a chemical equation for the hydrolysis of starch, $(C_6H_{10}O_5)_n$.

(2 marks)

(iii) The structural formula of the repeating unit of the PHB polymer is shown below.



PHB

(1) State whether PHB is produced by addition polymerisation or by condensation polymerisation.

_____ (1 mark)

(2) Name the functional group present in the main chain of the PHB polymer.

_____ (1 mark)

(3) Explain why PHB is biodegradable and polypropene is not.

_____

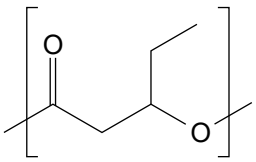
_____

_____

_____ (2 marks)

(iv) Researchers have designed new forms of PHB that have modified structures with altered physical properties.

(1) One modification to the chain structure has the monomer of the polymer PHV randomly inserted into the chain in multiple locations, to produce a modified form of PHB. The structural formula of the PHV repeating unit is shown below.



PHV

With reference to the structural formula of the PHV repeating unit, explain whether the melting point of the modified form of PHB would be higher or lower than the melting point of PHB.

_____

_____

_____

_____

_____ (3 marks)

(2)

PHB has had limited use because of its brittleness and its variable rates of biodegradation. Scientists at Cornell University in the United States have designed a PHB polymer material that incorporates particles of clay that are nanometres in diameter. This new form of PHB has increased strength and a faster rate of biodegradation than the original PHB. The scientists found that, after 7 weeks in a compost chamber, samples of the new form of PHB degraded almost completely, while samples of the original PHB showed almost no degradation. It was also found that the quantity of clay nanoparticles added affected the rate of biodegradation.

Source: based on Choi, CQ 2007, 'New plastic decomposes faster', Live Science, viewed 29 July 2021, https://livescience.com/4736-plastic-decomposes-faster.html

Explain *two* ways in which this research exemplifies science as a human endeavour.

(4 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. 7(iv)(1) continued).

Chemistry data sheet

Metal activity

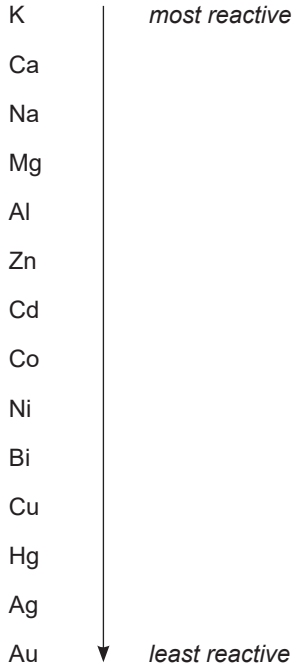


Table of SI prefixes

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)