Stage 2 Chemistry

Skills and Applications Task

SACE ID ______________________________

Time 90 minutes

- Questions 1 to 6, 86 marks
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on the space provided on the last page if you need more space

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

[2]Actinide 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
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)

Metal activity

K	↓	*most reactive*
Ca		
Na		
Mg		
Al		
Zn		
Cd		
Co		
Ni		
Bi		
Cu		
Hg		
Ag		
Au		*least reactive*

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

Magnitude of physical constants

Avogadro's number	6.02×10^{23} mol^{-1}
heat capacity of water	4.18 J g^{-1} K^{-1}

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}

Mathematical relationships

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

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

$$Q = mC\Delta T$$

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

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

Question 1 (11 marks)

Cleaning agents often have packaging labels that provide information about the chemical composition of the ingredients and optimum washing conditions for using the cleaning agent.

(a) The label on one package of detergent lists an enzyme as one ingredient and recommends warm water for optimum washing results.

Explain the effect of hot water on enzyme function.

(3 marks)

(b) The label on a package of another cleaning agent lists OCl^- as an ingredient.

(i) State the function of OCl^- in cleaning agents.

(1 mark)

(ii) OCl^- reacts with water to form HOCl and one other product. Complete the equation below for this reaction.

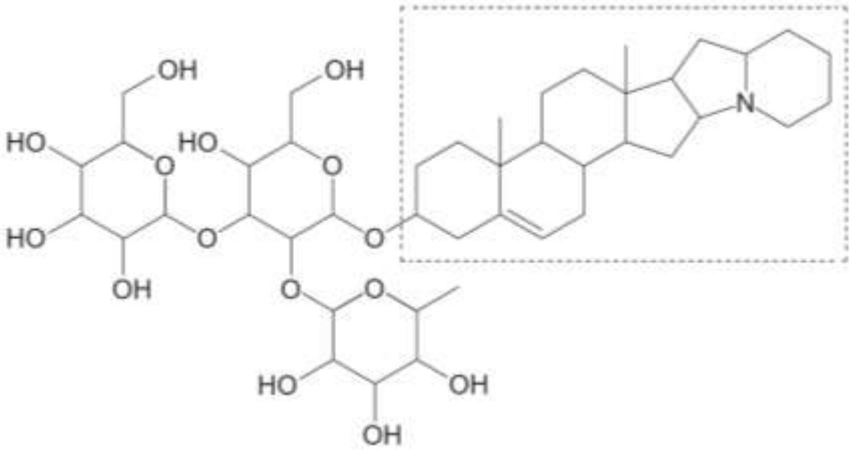
$$OCl^- + H_2O \underset{2}{\rightleftharpoons} HOCl +$$

(1 mark)

(iii) State whether the reaction of OCl^- with water would form a solution that has a pH greater than, equal to, or less than 7.

(1 mark)

(c) Soap nuts, which are a plant product, are an alternative to synthetic detergent. Soap nuts contain natural soaps called saponins. The structural formula of one saponin is shown below.



(i) State whether the section of the saponin molecule within the rectangle is hydrophobic or hydrophilic.

____

(1 mark)

(ii) Describe how saponins remove grease from clothing.

____

____

____

____

____

____

____

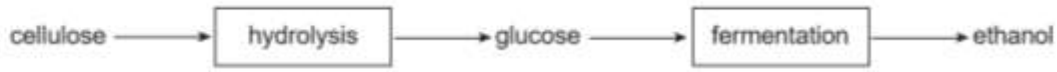
____

(4 marks)

Question 2 (18 marks)

Scientists are investigating the potential of converting waste from the citrus fruit industry into biofuels such as ethanol, methane, and limonene.

(a) The diagram below shows how cellulose, a polysaccharide present in citrus fruit waste, is converted into ethanol.



(i) Write an equation for the hydrolysis of cellulose to produce glucose.

(2 marks)

(ii) Describe the role of yeast in the fermentation of glucose to produce ethanol.

____

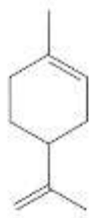
____

____

____

(2 marks)

(b) Limonene is one component of the oil that is present in citrus fruit peel. The structural formula of limonene is shown below.



Write the molecular formula of limonene.

____

(2 marks)

(c) Chemical data for ethanol and limonene, as provided by one laboratory, are shown in the table below.

Biofuel	*ΔH combustion (kJ mol^{-1})*	*Density (g mL^{-1})*	*Energy density (kJ L^{-1})*
Ethanol	–1370	0.789	
limonene	–6170	0.841	38 090

(i) Write a thermochemical equation for the complete combustion of ethanol.

(4 marks)

(ii) (1) Calculate the heat produced, in kJ g^{-1}, from the complete combustion of ethanol ($M = 46.068$ g mol^{-1}).

(1 mark)

(2) Hence calculate the energy density, in kJ L^{-1}, of ethanol.

(2 marks)

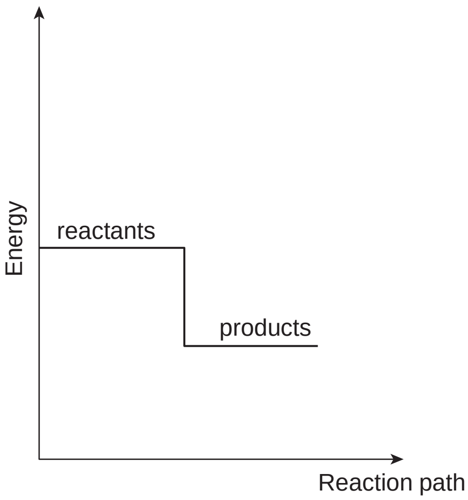
(iii) Limonene may be used as a fuel to heat water.

Calculate the temperature increase when 50.0 g of limonene ($M = 136.228 \text{ g mol}^{-1}$) is burned to heat 20 L of water. Assume that the combustion of limonene is complete.

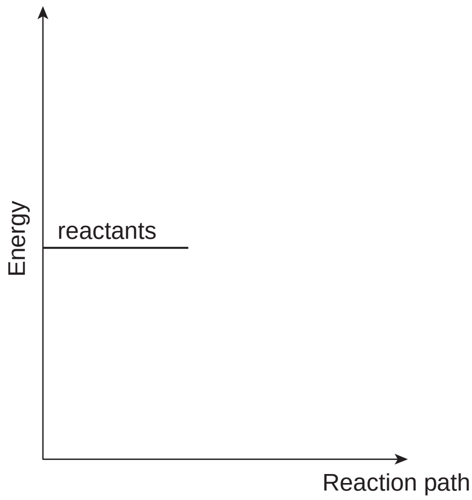
The specific heat capacity of water is 4.18 $Jg^{-1}K^{-1}$.

(4 marks)

(iv) Refer to the two energy diagrams below, which have been drawn using the same scale. One diagram represents the complete combustion of limonene and one diagram represents the incomplete combustion of limonene.



complete combustion



incomplete combustion

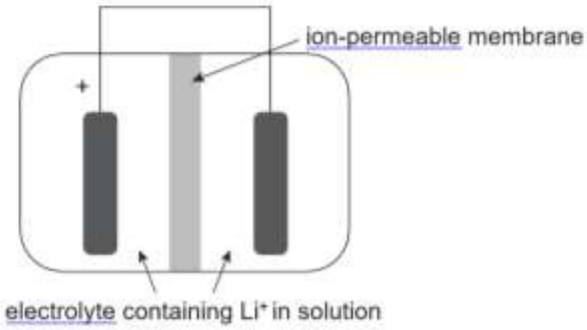
On the incomplete combustion diagram above, draw the continuation of the line to show the energy of the products when limonene has undergone incomplete combustion.

(1 mark)

Question 3 (10 marks)

Lithium-ion cell technology has led to the development of faster-charging and longer-lasting cells for use in home electronic appliances.

(a) A lithium–cobalt cell is represented in the diagram below.



(i) State whether Li^+ migrates to the positive electrode or to the negative electrode during charging.

(1 mark)

(ii) State whether the negative electrode acts as the anode or as the cathode during charging.

(1 mark)

(iii) On the diagram above, draw an arrow to indicate the direction of electron flow during charging.

(1 mark)

(iv) When the cell is discharging, cobalt (IV) oxide, CoO_2, reacts to form $LiCoO_2$.

The half-equation for this reaction is shown below.

$$CoO + Li^+ + e^- \longrightarrow LiCoO_2$$

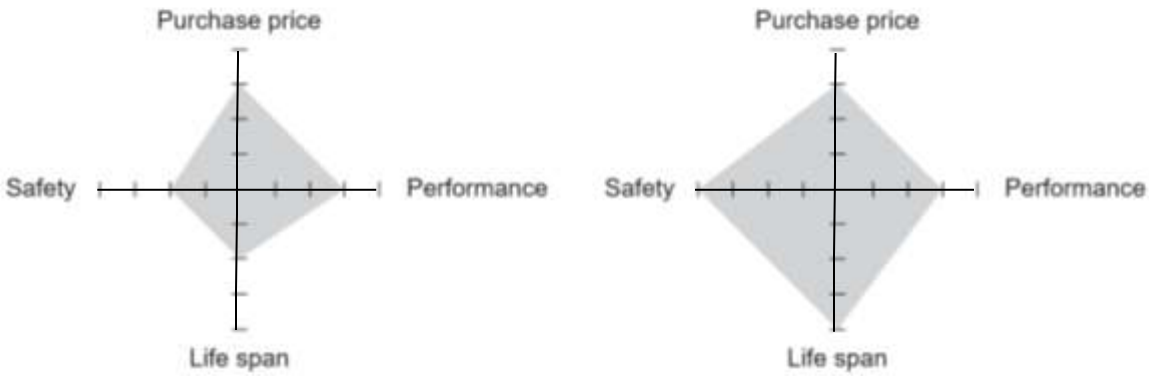
State and explain whether this reaction represents oxidation or reduction.

(2 marks)

(v) Identify the energy conversion that occurs in the cell when it is discharging.

(2 marks)

(b) A comparison of some features of two types of lithium-ion cell is shown in the diagrams below. For example, cell A is less safe than cell B.



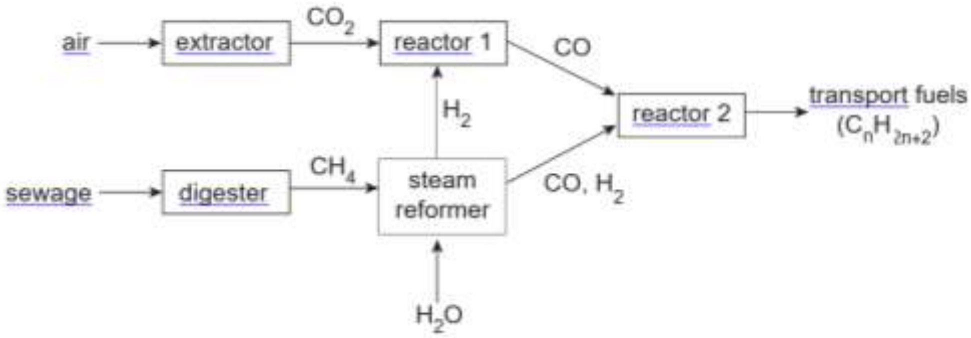
cell A **cell B**

Explain which of these two cells a consumer would prefer to use in their laptop computer, based on the purchase price and life span of each cell.

(3 marks)

Question 4 (14 marks)

The flow chart below represents a process for producing alkanes that could be used as transport fuels.



(a) (i) Identify *two* raw materials used for this process.

(2 marks)

(ii) State *one* advantage of producing transport fuels from sewage rather than from fossil fuels.

(1 mark)

(b) Sealed containers were used to conduct small-scale trials in order to investigate the reaction that occurs in the steam reformer. The equation for this reaction is shown below.

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3H_{2(g)}$$

(i) In one trial, $CH_{4(g)}$ and $H_2O_{(g)}$ were added in a 1.0 : 1.2 molar ratio.

Explain why an excess of $H_2O_{(g)}$ was used.

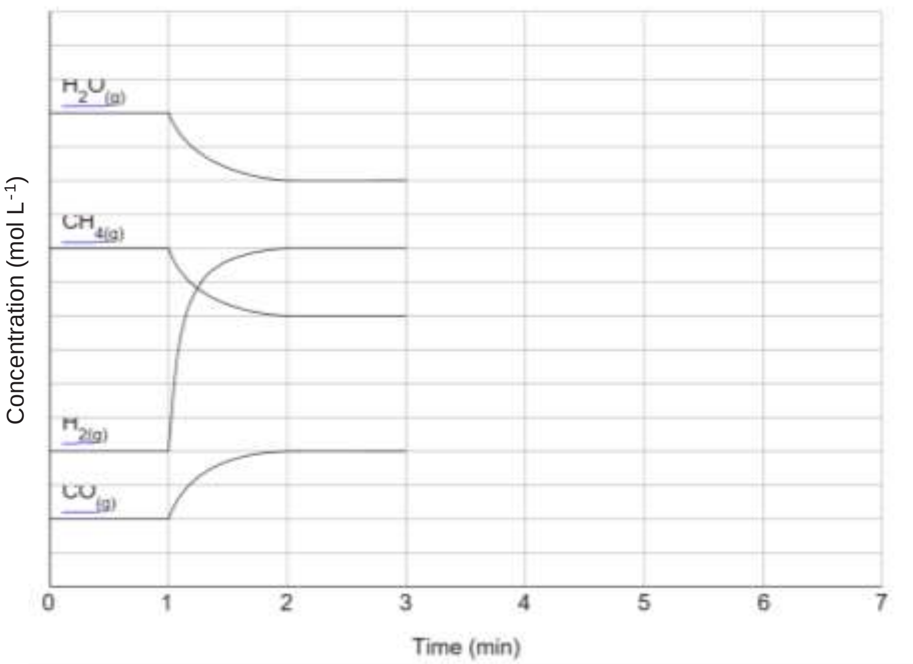
(2 marks)

(ii) In a second trial, a mixture of $CH_{4(g)}$ and $H_2O_{(g)}$ was placed in a 2 L container, heated to 850°C, and allowed to reach equilibrium. The equilibrium mixture contained 0.7 mol $CO_{(g)}$.

Calculate the concentration, in mol L^{-1}, of $H_{2(g)}$ present at equilibrium.

(2 marks)

(iii) In a third trial, another equilibrium mixture of the four gases was set up. A change in temperature was made to the system at 1 minute, as shown in the graph below.



(1) (A) The forward reaction is endothermic.

State whether the temperature was increased or decreased at 1 minute.

___

(1 mark)

(B) State the time at which equilibrium was re-established.

___

(1 mark)

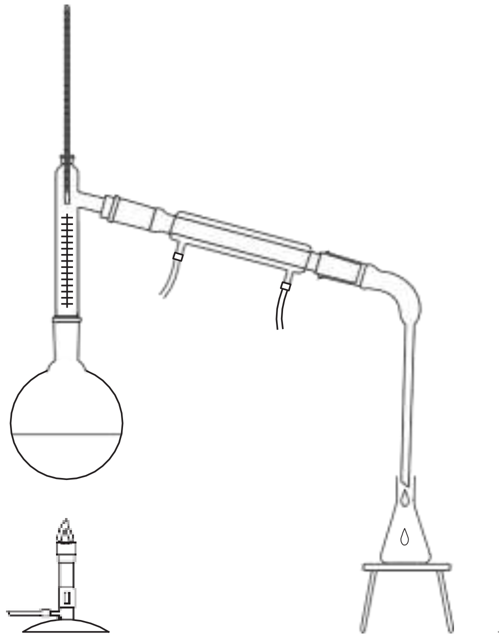
(2) At 3 minutes, the pressure on the system was increased. Equilibrium was re-established at 4 minutes.

Complete the graph above to show the change in concentration of $H_{2(g)}$ between 3 minutes and 5 minutes. (3 marks)

(c) The reaction in reactor 2 produces a mixture of hydrocarbons of varying size, each of which contains between 10 and 20 carbon atoms per molecule. The equation for this reaction is shown below.

$$nCO + (2n+1)H_2 \rightleftharpoons C_nH_{2n+2} + nH_2O$$

Laboratory equipment that can be used to separate these hydrocarbons by distillation is shown in the diagram below.



(i) Write the formula of the first hydrocarbon that will be collected using this process.

(1 mark)

(ii) On the diagram above, draw an arrow to indicate the direction of water flow as it enters the condenser.

(1 mark)

Question 5 (16 marks)

Mercury is extracted directly from its crushed ore, HgS, by roasting HgS in air. Mercury vapour is formed, and then collected by condensation. The other product of this reaction is SO_2.

(a) Write a balanced equation for the roasting of HgS in air.

(2 marks)

(b) Explain why mercury can be produced by roasting HgS in air, and does not require electrolysis or reduction using carbon.

____

____

____

____

(2 marks)

(c) The SO_2 formed from roasting HgS may be captured and converted into sulfur trioxide. The equation for this reaction is shown below.

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \quad \Delta H = -196\ \text{kJ}\,\text{mol}^{-1}.$$

(i) Write the K_c expression for this reaction.

(1 mark)

(ii) Using the terms ‘increase’, ‘decrease’, or ‘no change’, state how the addition of a catalyst affects each of the following aspects of this reaction:

Aspect	*Effect*
Rate of forward reaction	
Yield of sulfur trioxide	
Value of equilibrium constant	

(3 marks)

Credit will be given for answers to part (d) that are coherent and contain only relevant information.

(2 marks)

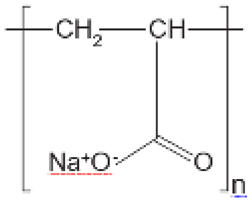
(d) The roasting of HgS releases nitrogen oxides to the air.

Explain how high concentrations of nitrogen oxides in the air lead to the formation of photochemical smog, and discuss the environmental benefits of reducing the formation of photochemical smog.

(6 marks)

Question 6 (17 marks)

The presence of sodium polyacrylate in disposable nappies (diapers) results in extremely high water absorbency. The structural formula of sodium polyacrylate is shown below.



(a) Draw the structural formula of the monomer used to make sodium polyacrylate.

(2 marks)

(b) Name *two* types of force that hold the polymer chains together in dry sodium polyacrylate.

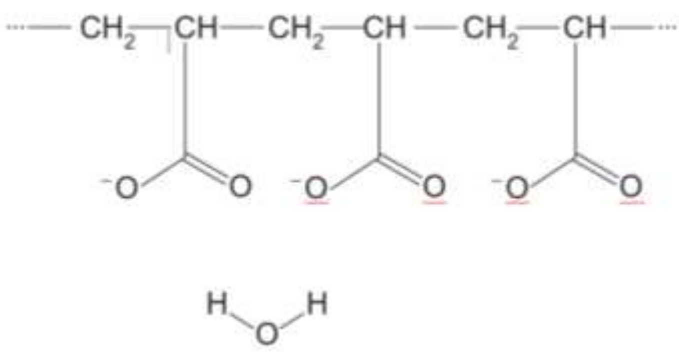
____

____

(2 marks)

(c) When distilled water is added to dry sodium polyacrylate, sodium ions dissociate from the polymer chains and then many water molecules move in between the polymer chains.

The diagram below represents a segment of one polymer chain after dissociation, and one water molecule.



(i) (1) On the diagram above, use appropriate symbols to indicate the polarity of the O–H bonds in the water molecule. (1 mark)

(2) On the diagram above, draw and label the *two* strongest types of interaction between the water molecule and the polymer chain.

(2 marks)

(3) The water added to dry sodium polyacrylate causes it to swell as it absorbs up to 800 times its weight in water.

State *two* reasons why such large volumes of water can be held between the polymer chains.

(2 marks)

(ii) (1) Explain how the volume of water absorbed would be affected if hard water, rather than distilled water, was added to dry sodium polyacrylate.

(3 marks)

(2) Explain why sodium polyacrylate could be useful in detergent formulations that are used in hard water.

(2 marks)

(d) Sodium polyacrylate is also used in other consumer products.

(i) Suggest *one* benefit of adding sodium polyacrylate to soil used for potted plants.

(1 mark)

(ii) One type of cross-linked sodium polyacrylate is used to make ‘instant snow’. Explain the effect that cross-linking has on one property of this polymer.

(2 marks)

You may write on this page if you need more space to finish your answers. Make sure to label each answer carefully (e.g. 4(b)(iii)(2)(B) continued).