Chemistry
2024

Question booklet 1

- Questions 1 to 3 (63 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. The types of food an individual eats can affect the growth of gut microorganisms living in their intestines, and hence, gut health.

(a) Triglycerides that are solid at room temperature can negatively affect the balance of gut microorganisms. The structural formulae of two triglycerides are shown below.
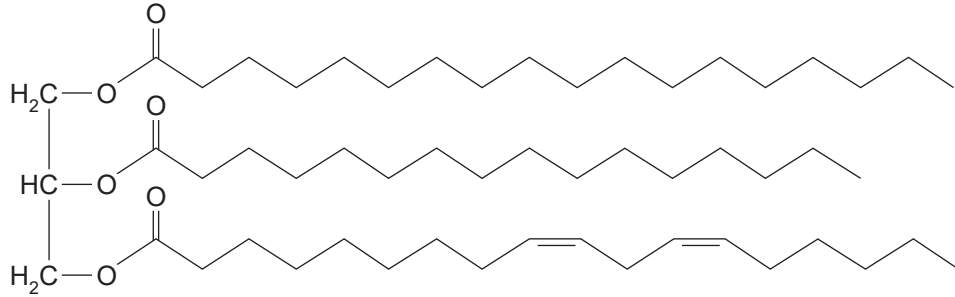
Triglyceride A
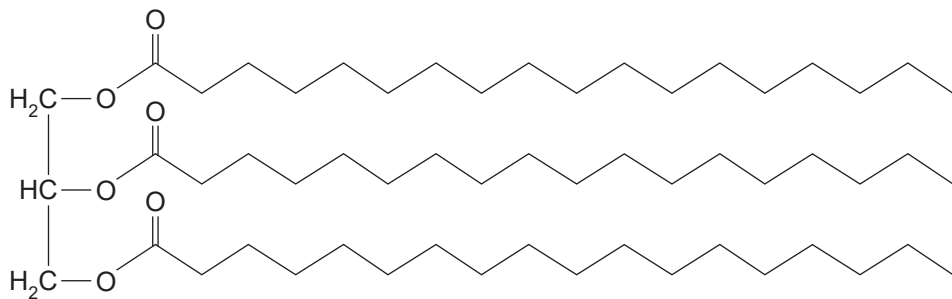
Triglyceride B

(i) Referring to the structures of these triglycerides, explain which of A or B is more likely to be found as a solid at room temperature.

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_____ (4 marks)

(ii) Triglycerides are broken down in the intestine by alkaline hydrolysis.

(1) Name the functional group in triglycerides that is hydrolysed.

_____ (1 mark)

(2) Draw the structural formula of *one* carboxylate ion formed during alkaline hydrolysis of triglyceride B.

(2 marks)

(b) Some food additives, such as polysorbate 80, can disrupt the function of gut microorganisms.

(i) Polysorbate 80 is made from sorbitol. The structural formula of sorbitol is shown below.
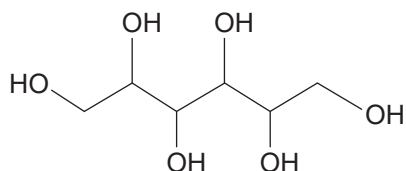
Sorbitol

(1) With reference to its structural formula, state why sorbitol should not be classified as a carbohydrate.

_____

_____ (1 mark)

(2) Sorbitol can be oxidised to form an aldehyde.

(A) *On the structural formula of sorbitol above,* circle *one* functional group that can be oxidised to form an aldehyde functional group.

(1 mark)

(B) State *one* laboratory test and the resulting observation that would confirm the presence of the new aldehyde group.

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_____ (2 marks)

(ii) The structural formula of polysorbate 80 is shown below.
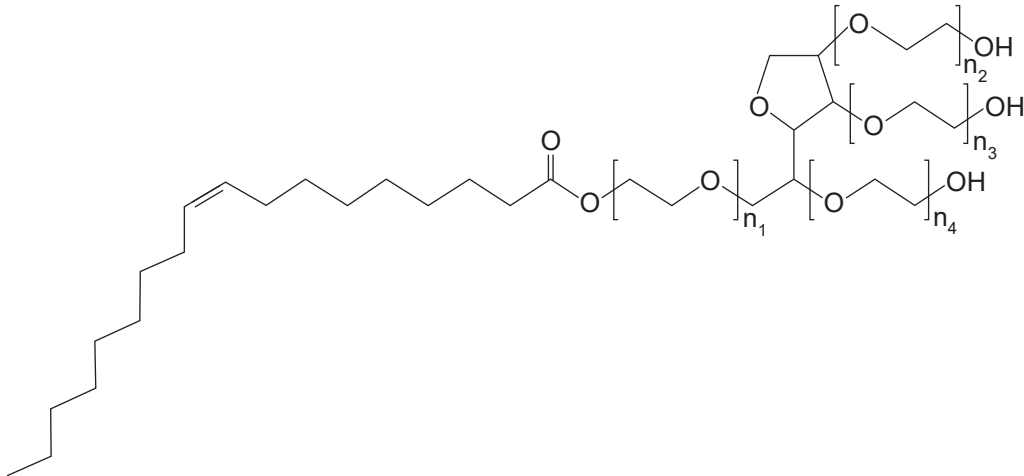
Polysorbate 80

Explain how the structure of polysorbate 80 enables it to interact with both water molecules and lipid molecules.

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_____ (3 marks)

(c) Glutamine is an amino acid that has an important role in maintaining the balance of gut microorganisms.

The structural formula of glutamine is shown below.
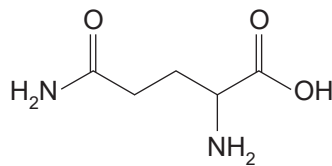
Glutamine

(i) *On the structural formula of glutamine above*, circle the amide functional group.

(1 mark)

(ii) Parts of the small intestine have a pH of 7. Glutamine exists in its self-ionised form at pH 7. Draw the structural formula of glutamine in its self-ionised form.

(2 marks)

(iii) Draw the structural formula of a section of a protein chain containing two glutamine units.

(2 marks)

(d) Studies have shown that vitamins, such as B2 and C, are beneficial to gut health. Many people consume vitamins in the form of dietary supplements.

HPLC is a technique used to separate and identify vitamins in dietary supplements. Vitamin C is more polar than vitamin B2.

The chromatogram obtained using HPLC to separate the components of one dietary supplement is shown below.
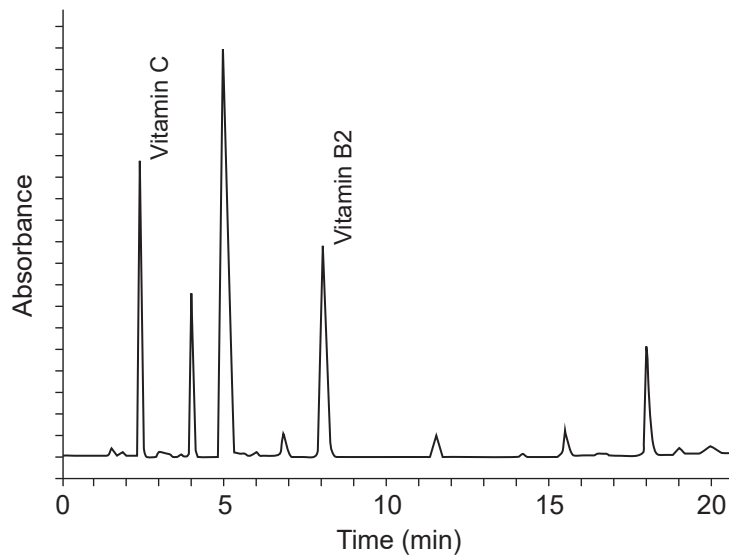
Using the principles of chromatography, explain how vitamin B2 was separated from vitamin C in the column.

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_____ (3 marks)

2. One common method of hydrogen production uses the 'water gas shift' reaction. CO required for this reaction is produced from fossil fuels. The equation for the water gas shift reaction is shown below.

$$H_2O_{(g)} + CO_{(g)} \rightleftharpoons H_{2(g)} + CO_{2(g)}$$
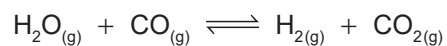
(a) A mixture of steam and carbon monoxide, both with an initial concentration of 0.50 mol L^{-1}, was introduced into an empty reaction vessel at 730°C. The vessel was closed and, after some time, the concentration of CO_2 was found to be 0.24 mol L^{-1}.

Determine whether the system has reached equilibrium, given that the K_c value at this temperature is 1.44. Use the blank space below to show your calculations.

(5 marks)

(b) The graph below shows the effect of temperature on the K_c value for the water gas shift reaction.
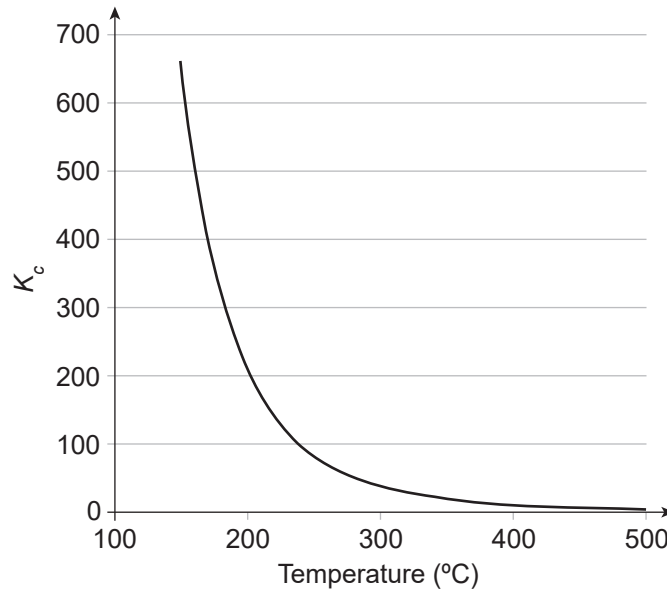
Water gas shift reaction

Using the information in the graph above, explain whether the water gas shift reaction is exothermic or endothermic.

_____

_____

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_____ (3 marks)

(c) (i) State *one disadvantage* to the manufacturer of using increased pressure for the water gas shift reaction.

_____

_____ (1 mark)

(ii) Explain *one advantage* to the manufacturer of using increased pressure for the water gas shift reaction.

_____

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_____ (3 marks)

(d) When CO_2 produced in the water gas shift reaction is released to the atmosphere, the concentration of atmospheric CO_2 increases.

Explain why increased atmospheric CO_2 concentrations cause average global temperatures to rise.

_____

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_____ (3 marks)

(e) Researchers have found a bacterium that uses the same water gas shift reaction to produce H_2 at room temperature and standard atmospheric pressure. The K_c for this reaction is 5×10^4. This biological system can be set up in a conventional closed reactor.

Explain *one* benefit of using this biological system to produce H_2 compared with the commonly used method.

_____

_____

_____

_____ (2 marks)

3. Motor vehicle manufacturers are looking for new methods of reducing the concentrations of CO and NO from the exhaust emissions of diesel engines.

(a) One common method of decreasing the concentration of NO in exhaust emissions is to use a catalytic converter.

(i) Explain why it is desirable to reduce the concentration of NO in exhaust emissions from diesel engines.

_____

_____

_____

_____

_____ (3 marks)

(ii) Write *one* equation for a reaction in a catalytic converter that decreases the concentration of NO in the exhaust emissions.

(2 marks)

(b) Fuel additives are compounds added to petrol to improve petrol properties. Researchers investigated the effects of several fuel additives on the performance of petrol-injected engines. They found that when a certain additive was present, it had the effect of decreasing the internal temperature of the engine, and decreasing the concentrations of CO and NO in engine emissions.

(i) Describe *one* undesirable consequence of the presence of CO in exhaust gases.

_____

_____

_____

_____ (2 marks)

(ii) Explain why the concentration of NO produced is decreased when the temperature inside the engine is lower.

_____

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_____ (3 marks)

(c) The CO emissions from engines using biodiesel are lower than those from engines using conventional diesel.

(i) Biodiesel production can be catalysed by sodium hydroxide.

Identify *two* main raw materials required for the formation of biodiesel.

_____

_____ (2 marks)

(ii) The table below contains information about *one* biodiesel, $C_{17}H_{34}O_{2\,(l)}$.

Molar mass (g mol^{-1})	Density (g mL^{-1})	Energy released (kJ mol^{-1})
270.46	0.852	9950

(1) Calculate the energy released, in kJ g^{-1}.

(1 mark)

(2) Calculate the energy released, in kJ L^{-1}.

(2 marks)

(iii) Write the thermochemical equation for the complete combustion of $C_{17}H_{34}O_{2\,(l)}$.

(4 marks)

(iv) A student conducted an experiment to determine the quantity of energy released by combustion of a sample of a different biodiesel. The experimental setup and data recorded are shown in the diagram below.

thermometer

100.0 g of water heated from 19.4°C to 32.9°C

Cotton wool soaked in biodiesel; 1.05 g of biodiesel burned
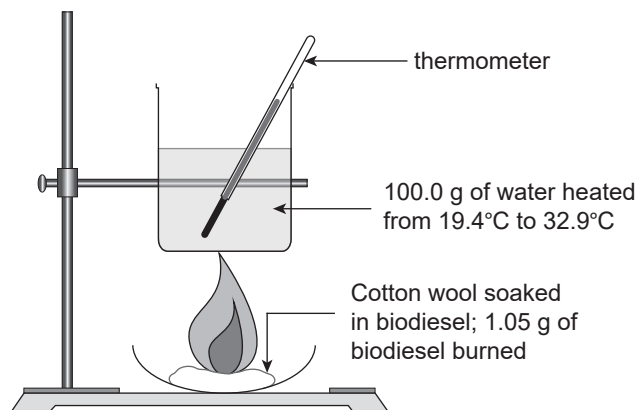
(1) Using data from the diagram above, calculate the quantity of heat, in kJ, absorbed by the water in this experiment.

(The specific heat capacity of water = 4.18 $J\ g^{-1}\ °C^{-1}$).

(3 marks)

(2) Explain *one* systematic error that results in the value calculated for the quantity of energy released by combustion of this biodiesel being significantly smaller than its true value.

_____

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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. 3(c)(ii)(2) continued).

Question booklet 2

- Questions 4 to 7 (57 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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4. Marine ecosystems are a vital resource for life on Earth.

(a) The blue mussel is a valuable shellfish in marine ecosystems. Researchers are concerned that increasing levels of dissolved carbon dioxide in sea water could negatively affect blue mussel populations in the oceans.

(i) When carbon dioxide dissolves in water, a series of reversible reactions occur.

Using equilibrium principles, explain how increased levels of dissolved carbon dioxide result in an increased concentration of H^+ ions in sea water. Include *at least one* equation in your answer.

_____

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_____ (3 marks)

(ii) The current average ocean pH is 8.1. Some researchers predict that ocean pH could change to 7.8 by the year 2100.

Calculate the concentration of H^+ ions at pH 7.8.

(2 marks)

(iii) One study investigated the effect of ocean pH on the shell strength of the blue mussel. The results are shown in the graph below.
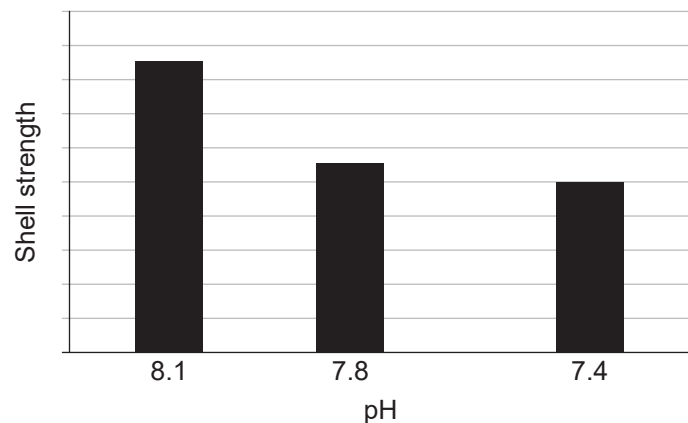
(1) State the relationship between pH and shell strength indicated by the graph above.

_____

_____ (1 mark)

(2) The main chemical component of the blue mussel shell is calcium carbonate.

Explain, with the aid of an equation, why shell strength is affected by a change in pH.

_____

_____

_____

_____ (2 marks)

(b) Kelp, a type of seaweed, is harvested from oceans as a source of alginate. Alginate is a polysaccharide that can be used in the form of a hydrogel to heal wounds.

The structural formula of a section of alginate is shown below.
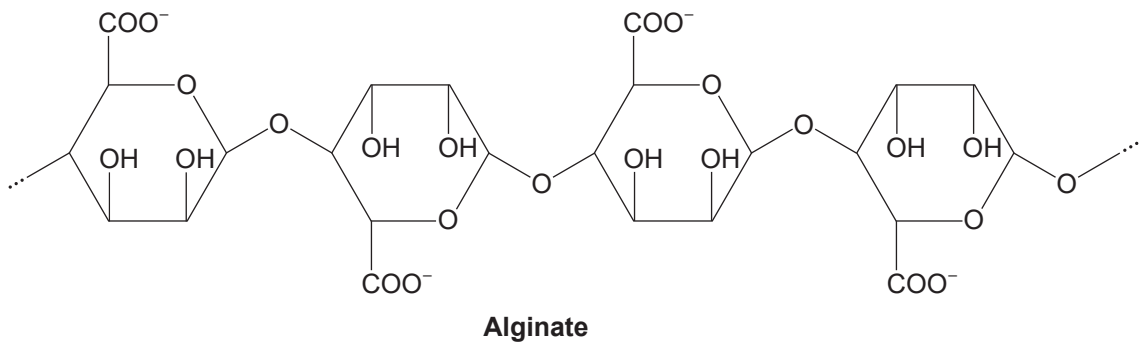
Alginate

(i) Identify the type of polymerisation that produced this polysaccharide from its monomers.

_____ (1 mark)

(ii) When Ca^{2+} ions are mixed with alginate, the polysaccharide chains become connected to form a hydrogel.

Explain how Ca^{2+} ions connect these polysaccharide chains.

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_____ (2 marks)

5. Polychloroprene is a polymer with excellent insulating properties. It is used to make wetsuits to keep divers and surfers warm in cold water.

    (a) The structural formula of a section of polychloroprene is shown below.

$$\cdots-CH_2-C=CH-CH_2-CH_2-C=CH-CH_2-CH_2-C=CH-CH_2-\cdots$$
$$\quad\quad\quad\ |\quad\quad\quad\quad\quad\quad\quad\quad\ |\quad\quad\quad\quad\quad\quad\quad\quad\ |$$
$$\quad\quad\quad\ Cl\quad\quad\quad\quad\quad\quad\quad\quad Cl\quad\quad\quad\quad\quad\quad\quad\quad Cl$$
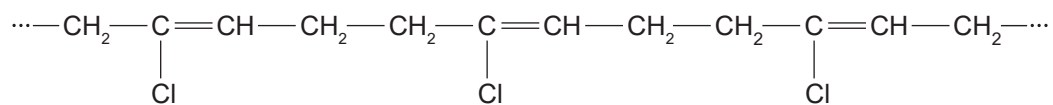
Polychloroprene

    (i) *On the structure above*, draw square brackets around one repeating unit of polychloroprene.

(1 mark)

    (ii) When making a wetsuit, polychloroprene undergoes the process of vulcanisation that forms crosslinks between the polymer chains.

        (1) Identify the structural feature of polychloroprene that enables crosslinking to occur.

_____ (1 mark)

        (2) Explain why vulcanised polychloroprene is difficult to recycle.

_____

_____

_____

_____ (2 marks)

(b) | Polychloroprene is typically produced from fossil fuels.

A Japanese company developed an alternative method for producing a polychloroprene material, using limestone to replace some of the fossil fuel feedstock. The polychloroprene material produced in this way became known as 'limestone neoprene'.

The production of limestone neoprene requires mining followed by chemical reactions at high temperatures.

Limestone neoprene contains more of the tiny air bubbles that give wetsuits their insulating properties, so a thinner wetsuit will provide the same insulation as a thicker conventional wetsuit. It also tends to last longer than conventional wetsuit material.

The manufacturers claim that limestone neoprene wetsuits have less impact on the environment.

(i) With reference to *one or more* relevant science as a human endeavour concepts, use information from the passage above to discuss the impact on the environment of using limestone neoprene to make wetsuits.

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_____ (4 marks)

Question 5 continues on page 6.

(ii) Limestone can be used as the feedstock for the production of $CaCN_2$, a fertiliser that provides water-soluble ions that contain nitrogen for plants.

(1) State *one* type of nitrogen-containing compound made by plants.

_____ (1 mark)

(2) When $CaCN_2$ hydrolyses, water-soluble ions containing nitrogen, such as ammonium ions, are formed in the soil water. Ammonium ions then bind to silicate minerals in the soil.

(A) The formula of one soil silicate is $Ca_2Al_3Si_3O_{12}(OH)$.

Write the formula of the anion in this *silicate mineral*.

_____

_____ (2 marks)

(B) Explain how ammonium ions that are bound to soil silicates become available to plants.

_____

_____

_____

_____

_____

_____ (3 marks)

6. Gallium, the element with atomic number 31, is a soft, silvery metal that is never found as a free element in nature. Its main uses are in electronic circuits and light-emitting diodes.

(a) Gallium can be produced by electrolysis of a solution containing gallium cations, usually gallium chloride.

(i) Using the periodic table, determine the most common charge on a gallium cation.

_____ (1 mark)

(ii) Using subshell notation, write the electron configuration for the gallium cation you identified in part (a)(i).

_____ (2 marks)

(iii) State whether the gallium is produced at the positive or negative electrode in the electrolysis.

_____ (1 mark)

(iv) Other cations often present in the electrolyte solution, such as sodium, magnesium, and aluminium, are not affected by this electrolysis.

(1) Using this information, suggest whether gallium is *above* or *below* aluminium in the metal activity series.

_____ (1 mark)

(2) Give the reason for your answer to part (a)(iv)(1).

_____

_____ (1 mark)

(v) Hydrogen gas is also produced during electrolysis. It may be collected, purified, and sold for use in other industries and processes.

(1) State *one commercial* use of hydrogen gas.

_____

_____ (1 mark)

(2) Explain why the hydrogen gas produced during the electrolysis of a solution containing gallium cations is classified as a by-product rather than a waste product.

_____

_____

_____

_____ (2 marks)

(b) The increasing use of gallium in the micro-electronics industry has led to concern about levels of gallium compounds in the wastewater.

Gallium concentrations in wastewater can be measured using AAS. Five standard solutions of gallium chloride were used to construct a calibration graph as shown below.
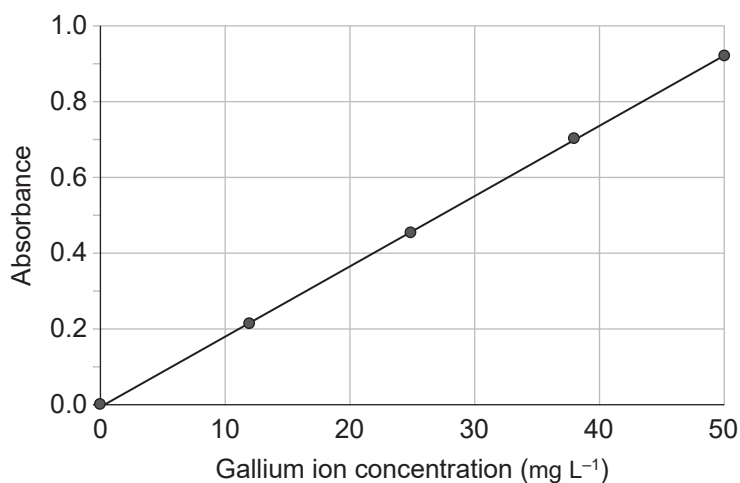
(i) State the term used to describe a set of data that has minimal scatter from the line of best fit, as shown in the graph above.

_____ (1 mark)

(ii) A particular sample of wastewater had an absorbance of 0.85. Using the graph above, determine the concentration of gallium ions, in mg L^{-1}, in this sample.

_____ (1 mark)

(iii) A lamp emitting light with a wavelength of 417 nm was used in this measurement.

Explain why specific wavelengths of light are absorbed by elements atomised by a flame.

_____

_____

_____

_____ (2 marks)

(iv) State why the measurement of gallium concentration using AAS is not affected by the presence of aluminium in the sample.

_____

_____ (1 mark)

(c) Wastewater from the micro-electronics industry may also contain Fe^{3+}.

A titration was used to determine the concentration of Fe^{3+} in a 20.00 mL sample of wastewater. The sample was transferred to a conical flask and acidified. Excess I^- were added. The equation for the reaction is shown below.

$$2Fe^{3+} + 2I^- \longrightarrow I_2 + 2Fe^{2+}$$
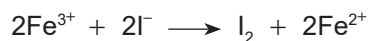
The resulting mixture was then titrated with a standardised solution containing 0.9930 mol L^{-1} of $S_2O_3^{2-}$ ions. The reaction with iodine is shown in the equation below.

$$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$$

The procedure was repeated three times, and the results are shown in the table below.

$S_2O_3^{2-}$ solution	Trial 1	Trial 2	Trial 3	Trial 4
Titre (mL)	3.50	3.75	3.53	3.51

(i) Calculate the appropriate average titre value, in mL.

(1 mark)

(ii) Hence, calculate the number of moles of $S_2O_3^{2-}$ in the average titre.

(2 marks)

(iii) Hence, calculate the number of moles of I_2 that reacted with $S_2O_3^{2-}$.

(1 mark)

(iv) Hence, determine the concentration of Fe^{3+}, in mol L^{-1}, in the wastewater. Express the answer to the appropriate number of significant figures.

(3 marks)

(v) Complete the half-equation for the conversion of $S_2O_3^{2-}$ to $S_4O_6^{2-}$.

$$S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$$

(2 marks)

PLEASE TURN OVER

7. Perfluoroalkyl substances (PFAS) have been widely used in consumer products for more than 50 years due to their non-stick, water-repelling, and flame-retardant properties. They are now found widely dispersed in the environment.

(a) Perfluorooctanoic acid, (PFOA), is a member of the PFAS group of synthetic chemicals. The structural formula of PFOA is shown below.
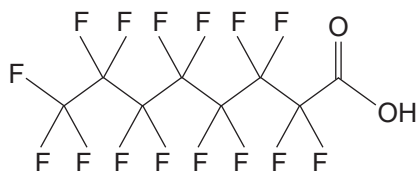
(i) When PFOA is released into water, it ionises to a small extent.

Explain why the anion formed by this ionisation is more water-soluble than the original PFOA molecule.

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_____ (3 marks)

(ii) In Australia, the maximum acceptable concentration of PFOA in drinking water is 560 ng L^{-1}.
One groundwater sample recorded a PFOA concentration of 45 ppb.
Calculate the concentration of this PFOA sample in ng L^{-1} and hence, determine whether it is under the maximum acceptable concentration for drinking water.

(2 marks)

(b) PFAS can be removed from the environment using different processes.

One method used to remove PFOA from water sources is to pass the polluted water through an ion exchange column.

(i) State the type of charge on the resin in the ion exchange column used to remove PFOA anions.

_____ (1 mark)

(ii) Adsorbed PFOA can be removed from the column by passing a solution of an ionic compound through it.

Explain which *one* of the following three ionic solutions would remove the adsorbed PFOA the most effectively:

2.0 mol L^{-1} NaCl   **OR** 2.0 mol L^{-1} CaCl$_2$ **OR** 2.0 mol L^{-1} FeCl$_3$

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_____

_____ (3 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(b)(ii) continued).

Chemistry data sheet

Metal activity

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

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

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

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

$$Q = mc\Delta T$$

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

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

Periodic table of the elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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	57¹ **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)	89² **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)

¹lanthanide series

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce cerium 140.1	**Pr** praseodymium 140.9	**Nd** neodymium 144.2	**Pm** promethium (145)	**Sm** samarium 150.4	**Eu** europium 152.0	**Gd** gadolinium 157.3	**Tb** terbium 158.9	**Dy** dysprosium 162.5	**Ho** holmium 164.9	**Er** erbium 167.3	**Tm** thulium 168.9	**Yb** ytterbium 173.0	**Lu** lutetium 175.0

²actinide series

90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th thorium 232.0	**Pa** protactinium 231.0	**U** uranium 238.0	**Np** neptunium (237)	**Pu** plutonium (244)	**Am** americium (243)	**Cm** curium (247)	**Bk** berkelium (247)	**Cf** californium (251)	**Es** einsteinium (252)	**Fm** fermium (257)	**Md** mendelevium (258)	**No** nobelium (259)	**Lr** lawrencium (262)