OCR ADVANCED SUBSIDIARY GCE
IN CHEMISTRY (SALTERS) (3887)

OCR ADVANCED GCE
IN CHEMISTRY (SALTERS) (7887)

Specimen Question Papers and Mark Schemes

These specimen assessment materials are intended to accompany the OCR Advanced Subsidiary GCE and Advanced GCE specifications in Chemistry (Salters) for teaching from September 2000.

Centres are permitted to copy material from this booklet for their own internal use.

The GCE awarding bodies have prepared new specifications to incorporate the range of features required by new GCE and subject criteria. The specimen assessment material accompanying the new specifications is provided to give centres a reasonable idea of the general shape and character of the planned question papers in advance of the first operational examination.

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Advanced Subsidiary GCE

A2

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

CHEMISTRY (SALTERS)
CHEMISTRY FOR LIFE **2850**

Specimen Paper

Candidates answer on the question paper.
Additional materials:
  Data Booklet for Chemistry (Salters)
  To be brought by candidate: electronic calculator

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

Write your name, Centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.

There should be ample space for your answers. If you need more space for answers or rough work you may use the blank spaces at the end of questions or any blank pages. Rough work that is not to be marked should be crossed out.

You will be awarded marks for the quality of your written communication where an answer requires a piece of extended writing.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

A copy of the Periodic Table and other tables of information are provided in a data booklet for use with this examination; other necessary data are given as required in the questions.

You may use an electronic calculator.

Answer **all** questions.

1. Bone consists of a complex mixture of calcium salts, such as calcium carbonate, and other material. If bone is strongly heated, the calcium salts turn into calcium oxide, CaO. This can be separated from the other material by dissolving it in dilute hydrochloric acid, to form calcium chloride, $CaCl_2$, solution.

(a) **(i)** Draw a flow diagram to show how calcium carbonate in bone is turned into calcium chloride. Show the formulae of the compounds connected by labelled arrows.

[3]

(ii) Complete and balance the chemical equation for the reaction between solid calcium oxide and dilute hydrochloric acid, showing state symbols.

$$CaO \quad + \quad HCl \quad \rightarrow$$

[2]

(b) An experiment showed that 14.4 g of calcium oxide were made from a sample of bone of mass 50.0 g. (A_r: Ca, 40; O, 16)

Calculate:

(i) the amount in moles of CaO in 14.4 g;

[2]

(ii) the amount in moles of Ca in the bone sample;

[1]

(iii) the % of calcium by mass in the bone.

[2]

(c) Strontium compounds are incorporated into bones because their chemistry is similar to that of calcium compounds. For example, both strontium and calcium form ions with the same charge. Explain, in terms of the Periodic Table, the electronic structures of the atoms and ionisation energies, why calcium and strontium (and their compounds) have similar chemical properties.

*(**Note:** In this question, 1 mark is available for the quality of written communication).*

....

....

....

....

....

....

.... **[6]**

(d) Strontium-90, ${}^{90}_{38}\mathrm{Sr}$, is a radioactive isotope of strontium that emits β^{-} particles (electrons). It was produced in nuclear fall-out and became incorporated in peoples' bones.

(i) For the strontium-90 nucleus, write down the number of

protons .... **[1]**

neutrons .... **[1]**

(ii) Write a nuclear equation for the process by which a strontium-90 nucleus emits a β^{-} particle, representing the β^{-} particle as ${}^{0}_{1}\mathrm{e}$.

[3]

(iii) A sample of naturally-occurring strontium was placed in a mass spectrometer and the following peaks were obtained:

Mass	**Intensity (%)**
84	0.56
86	9.86
87	7.02
88	82.56

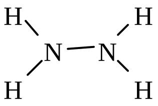
Calculate the relative atomic mass of the sample of strontium, giving your answer to three significant figures. Show your working.

[4]

Total 25 marks

2. The substance hydrazine, N_2H_4, is used as a rocket fuel because it reacts very exothermically with oxygen and it can be stored as a liquid at low temperatures.

(a) The full structural formula of hydrazine is shown below.



hydrazine

(i) Draw a dot-cross diagram for hydrazine, showing the outer electron shells only.

[3]

(ii) State, giving reasons, the value you would expect for the H–N–H bond angle in hydrazine.

Angle:.. **[1]**

Reasons:..

....

.... **[2]**

(b) Hydrazine reacts with oxygen according to the equation:

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(l)$$

Calculate a value for the enthalpy change of combustion of hydrazine, following the steps below.

Compound	$\Delta H^\ominus_{f,298}$ **/ kJ mol^{-1}**
$N_2H_4(l)$	+51
$H_2O(l)$	–286

(i) Draw a labelled enthalpy cycle to include the information about enthalpy changes of formation above and the enthalpy change of combustion of hydrazine.

[3]

(ii) Use the data on the previous page and your cycle to calculate a value for the enthalpy change of combustion of hydrazine.

[2]

(c) Use the equation in part **(b)** to calculate the volume of oxygen required to burn 1.0 kg of hydrazine. (A_r: N, 14; H, 1; 1.0 mol of molecules of a gas at room temperature and pressure occupies 24 dm^3)

[3]

(d) At the high temperature of the rocket engine, a reaction might take place between nitrogen gas and oxygen gas to produce nitrogen monoxide, NO.

(i) Write an equation for this reaction.

[1]

(ii) State **one** way in which nitrogen monoxide causes pollution in the atmosphere.

....

....

.... **[1]**

(e) Which has the greater entropy at room temperature, one mole of liquid hydrazine or one mole of gaseous hydrazine? Explain your answer.

....

....

.... **[2]**

Total 18 marks

3. Butane, C_4H_{10}, can be used as a fuel. Here are some data about butane:

Boiling point, 0 °C;

Standard enthalpy change of combustion, $\Delta H^{\ominus}_{c,298} = -2880 \text{ kJ mol}^{-1}$.

(a) To what homologous series does butane belong?

....**[1]**

(b) Butane has one structural isomer.

(i) Say what you understand by the term **structural isomer**.

....

....

.... **[2]**

(ii) Draw the full structural formula of the structural isomer of butane and name it.

Name ....……....... **[3]**

(c) All the H–C–H bonds in butane have the same angle in the three-dimensional molecule. State the value of this angle and, with the help of a labelled diagram, describe the shape of the butane molecule.

H–C–H bond angle.. **[1]**

Shape of butane molecule:

[3]

(d) "The standard enthalpy change of combustion of the isomer in part **(b)** will be very similar to that of butane itself as all the bonds are the same."

Say whether or not this statement is correct and explain why.

....

....

....

.... **[3]**

(e) Write a balanced equation (with state symbols) for the complete combustion of butane under standard conditions.

[3]

(f) The isomer will have a higher **octane number** than butane itself.

(i) What does the **octane number** of a petrol tell you about its performance in a high-compression engine?

....

....

.... **[3]**

(ii) What feature of the isomer would cause it to have a higher octane number than butane?

....

.... **[1]**

(g) Suggest **one** technical problem (apart from ones associated with octane number) that might arise in using butane as a fuel for cars.

....

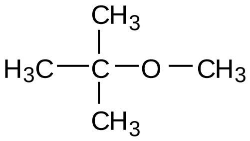
....

.... **[2]**

(h) The structures of two ‘oxygenates’ which can be added to petrol to improve the octane rating are given below.

$H_3C-CH_2-CH_2-OH$

Compound A



$$H_3C-\overset{\overset{\large CH_3}{|}}{\underset{\underset{\large CH_3}{|}}{C}}-O-CH_3$$

Compound B

(i) Name the **functional group** in Compound A.

.... **[1]**

(ii) Name **Compound A**.

.... **[1]**

(iii) Name the **functional group** in Compound B.

.... **[1]**

(i) A car running on butane would produce carbon monoxide as a polluting gas.

(i) How is carbon monoxide produced in car engines?

....

.... **[2]**

(ii) Explain why carbon monoxide is a polluting gas.

....

.... **[1]**

(j) A catalytic converter can convert carbon monoxide in the car’s exhaust to carbon dioxide.

(i) Explain why such a catalyst is called **heterogeneous**.

....

.... **[2]**

(ii) Complete the sequence to explain how such a catalyst works:

1. Reactants get adsorbed on to the catalyst surface.

2. .... **[1]**

3. New bonds form.

4. .... **[1]**

(iii) Lead-free petrol must be used with catalytic converters because lead 'poisons' the catalyst. Explain what this means.

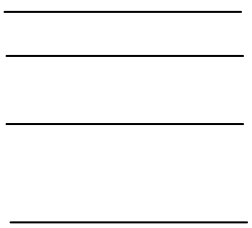
....

.... **[2]**

Total 34 marks

4. The presence of sodium in the Sun's photosphere is shown by a pair of dark lines in the Sun's absorption spectrum in the visible region. The element magnesium can be detected in the same way.

(a) The lines below represent some of the electron energy levels of a sodium atom. Draw labelled arrows on the diagram and explain why sodium absorbs only certain definite frequencies of visible light.



[4]

(b) Sodium and magnesium are adjacent in the same period of the Periodic Table. Say whether each of the following statements about ^{23}Na and ^{24}Mg atoms is true or false, briefly justifying your answer.

(i) They have mass numbers which differ by one.

....

.... **[1]**

(ii) They have atomic numbers which differ by one.

....

.... **[1]**

(iii) They have the same number of full electron shells.

....

.... **[1]**

(iv) Their reactions would be expected to be very similar.

....

....

.... **[2]**

(c) The sodium in the Universe was made by nuclear reactions such as

$$2\,^{12}\mathrm{C} \rightarrow \,^{23}\mathrm{Na} + \text{...........}$$

(i) Explain why this is called a **fusion** reaction.

....

....

.... **[2]**

(ii) Complete the nuclear equation above by adding atomic numbers and the symbol for the other nucleus formed.

[2]

Total 13 marks

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

CHEMISTRY (SALTERS)
CHEMISTRY FOR LIFE **2850**

Mark Scheme

1. **(a)** **(i)**

$$CaCO_3 \xrightarrow{\text{heat}} CaO \xrightarrow[\text{(or dilute hydrochloric acid)}]{HCl} CaCl_2$$

Correct formula for calcium carbonate	[1 mark]
Other formulae correct and in right places	[1 mark]
Correctly labelled arrows	[1 mark]
	[3 marks]

(ii) $CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$

Correctly balanced equation	[1 mark]
Correct state symbols	[1 mark]
	[2 marks]

(b) **(i)**

M_r CaO = 56	[1 mark]
$\frac{14.4}{56}$ = 0.257 moles CaO	[1 mark]
	[2 marks]

(ii) 0.257 moles Ca **[1 mark]**

(iii) $\frac{0.257 \times 40}{50.0} \times 100 = 20.6\%$

Working	[1 mark]
Answer	[1 mark]
(Correct answer based on 'something over 50.0 multipied by 100' scores 1 mark; correct answer with no working scores 2 marks.)	**[2 marks]**

(c) Calcium and strontium are:

both in same group of Periodic Table	[1 mark]
both have two electrons in outer shell	[1 mark]
sum of first two ionisation energies	[1 mark]
quite low	[1 mark]
two electrons lost to form ion	[1 mark]

Quality of written communication:

A minimum of two linked sentences making correct use of scientific terms such as *atom*, *ion*, *element*, *compound*, *ionisation*, *energy*. [1 mark]

[6 marks]

(d) (i) 38 protons [1 mark]

52 neutrons [1 mark]

[2 marks]

(ii) ${}^{90}_{38}\text{Sr} \rightarrow {}^{0}_{-1}\text{e} + {}^{90}_{39}\text{Y}$

${}_{39}\text{Y}$ [1 mark]

Mass number of 90 for new element formed [1 mark]

Rest of equation correct [1 mark]

[3 marks]

(iii) {(84 x 0.56) + (86 x 9.86) + (87 x 7.02) + (88 x 82.56)} / 100 = 87.7

Correct working [1 mark]

Answer in range 87 – 88 [1 mark]

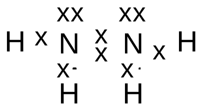
correct [1 mark]

Correct sf (on reasonable answer) [1 mark]

[4 marks]

Total 25 marks

2 (a) (i)



Lone pairs of electrons on nitrogens [1 mark]

Single bond between nitrogens correctly shown [1 mark]

Rest correct [1 mark]

[3 marks]

(ii) Angle: 109^{o} (±5) [1 mark]

Reasons: <u>Four</u> groups of electrons (or areas of electron density) [1 mark]

Repel each other [1 mark]

[3 marks]

(b)

(i)

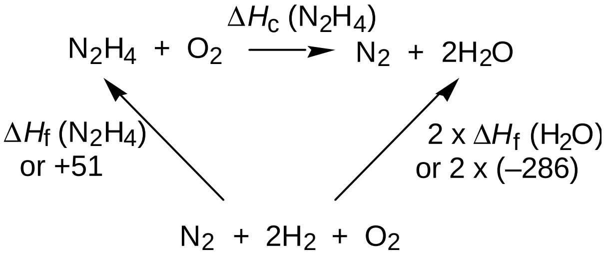


Diagram correct shape (elements, reactants, products) [1 mark]

$\Delta H^{\ominus}_{f}$ (H_2O) x 2) or –286 multiplied by 2 [1 mark]

Rest of detail correct [1 mark]

[3 marks]

(ii) $\Delta H^{\ominus}_{c}$ (N_2H_4) = 2 x (–286) – 51) [1 mark; *allow ecf from diagram*]

Correct answer with sign and units, –623 kJ mol^{-1}) [2 marks]

[2 marks]

(c) Amount in moles N_2H_4 = 1000/32 (= 31.25) [1 mark]

Amount in moles O_2 = Amount in moles N_2H_4) [1 mark]

Volume O_2 = (moles N_2H_4) x 24 = 750 dm^3

[1 mark; *includes correct answer (with ecf) and units*]

[3 marks]

(d) **(i)** $N_2 + O_2 \rightarrow 2NO$ **[1 mark]**

(ii) *Any one of the following:*

toxic; (reacts to give NO_2 which causes) acid rain; greenhouse gas; causes (photochemical) smog. **[1 mark]**

(e) **Gaseous hydrazine**

more random arrangement/ more ways of arrangement [1 mark]

of particles/molecules [1 mark]

[2 marks]

Total 18 marks

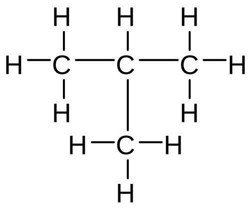
3. (a) Alkanes **[1 mark]**

(b) (i) Same molecular formula [1 mark]

Different arrangement [1 mark]

[2 marks]

(ii) Correct structure



[2 marks; *1 mark for an incorrect branched structure*]

Name: Methylpropane [1 mark]

[3 marks]

(c) H-C-H bond angle: 109° [1 mark]

Zig-zag carbon chain [1 mark]

Tetrahedral arrangement around a carbon atom [1 mark]

Rest of molecule correct [1 mark]

[4 marks]

(d) It is **correct**. [1 mark]

Bond enthalpies (or equivalent) are (approx) the same in different environments [1 mark]

Same bonds involved (or broken and made) in the combustion of both isomers [1 mark]

[3 marks]

(e) $C_4H_{10}(g) + 6.5O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$ (*or* doubled)

Formulae correct [1 mark]

Balancing correct [1 mark]

State symbols [1 mark]

[3 marks]

(f) (i) A measure [1 mark]

of the tendency of the petrol to pre-ignite / autoignite [1 mark]

Higher the number, the less tendency (owtte) [1 mark]

[3 marks]

	(ii)	It has a branched chain	**[1 mark]**
(g)		It is a gas	[1 mark]
		so a large tank is needed	[1 mark]
or			
		It must be compressed	[1 mark]
		which is difficult/expensive	[1 mark]
			[2 marks]
(h)	**(i)**	alcohol/hydroxy	**[1 mark]**
	(ii)	propan-1-ol	**[1 mark]**
	(iii)	ether	**[1 mark]**
(i)	**(i)**	Incomplete combustion	[1 mark]
		of the fuel/hydrocarbons/butane	[1 mark]
			[2 marks]
	(ii)	It is **toxic** *or* **poisonous** *or* **harmful** to humans	**[1 mark]**
(j)	**(i)**	Reactants in different state from catalyst	[1 mark]
		gas/solid	[1 mark]
			[2 marks]
	(ii)	*1.* Reactants get adsorbed on to the catalyst surface.	
		2. **Bonds break in reactants**	[1 mark]
		3. New bonds form.	
		4. **Product molecules released/diffuse away**	[1 mark]
			[2 marks]
	(iii)	Lead absorbed on surface	[1 mark]
		instead of reactants	[1 mark]
			[2 marks]
			Total 34 marks

4.	**(a)**		Arrow upwards labelled ‘electrons promoted’ (owtte)	[1 mark]
			Indication that only changes between energy levels allowed	[1 mark]
			Energy absorbed related to (visible) frequency	[1 mark]
			$E = h\nu$	[1 mark]
				[4 marks]
	(b)	**(i)**	True, 23 and 24	**[1 mark]**
		(ii)	True, 11 and 12/always true for two adjacent elements	**[1 mark]**
		(iii)	True, 2.8/two each	**[1 mark]**
		(iv)	False, different number of outer-shell electrons	[1 mark]
			Na 1 outer electron, Mg 2 outer electrons	[1 mark]
				[2 marks]
	(c)	**(i)**	two nuclei/atoms	[1 mark]
			merging/coming together	[1 mark]
				[2 marks]
		(ii)	$2\,{}^{12}_{6}\mathrm{C} \rightarrow \mathrm{Na} + {}^{1}_{1}\mathrm{H/p}$	
			Atomic numbers of C and Na correct	[1 mark]
			Hydrogen correct	[1 mark]
				[2 marks]
				Total 13 marks

Assessment Grid: Unit 2850

Question	Teaching module	Core coverage	AO1		AO2		Total marks
			Coverage	Marks	Coverage	Marks	
1 (a) (i)	EL2(u)	3.5.1			2b	3	3
(ii)	EL2(u)	3.5.1/3.12.2	1a	2			2
(b) (i)	EL2(f)	3.5.2			2c	2	2
(ii)	EL2(f)	3.5.2			2c	1	1
(iii)	EL2(f)	3.5.2			2c	2	2
(c)	EL2(n)(p)(q)(r)	3.12.1/3.12.2/3.12.3	1a, 1c	6			6
(d) (i)	EL2(b)	3.6.1	1a	2			2
(ii)	EL2(l)	–	1a	3			3
(iii)	EL2(e)	3.6.1			2c	4	4
2 (a) (i)	EL2(w)	3.7.2			2d	3	3
(ii)	EL2(y)	3.7.4	1a	3			3
(b) (i)	DF2(b)(e)	3.8.2	1a	3			3
(ii)	DF2(e)	3.8.2			2c	2	2
(c)	DF2(a)	3.5.2			2c	3	3
(d) (i)	DF2(t)	3.5.1	1a	1			1
(ii)	DF2(s)	–	1b	1			1
(e)	DF2(y)(z)	–	1a	2			2

Assessment Grid: Unit 2850 (Cont)

3 (a)	DF2(i)	3.13.1	1a	1			1
(b) (i)	DF2(l)(m)	3.13.1	1a	2			2
(ii)	DF2(m)(n)	3.13.1	1a	2			2
	DF2(k)	–	1a	1			1
(c)	EL2(v)(w)	3.7.4	1a	4			4
(d)	DF2(c)(g)	3.8.1			2a, 2e	3	3
(e)	DF2(p)	3.5.1/3.13.2	1a	3			3
(f) (i)	DF(r)	–	1b	3			3
(ii)	DF2(q)	–	1b	1			1
(g)	DF2(aa)	–			2d	2	2
(h) (i)	DF2(i)	3.13.2	1a	1			1
(ii)	DF2(k)	–	1a	1			1
(iii)	DF2(i)	–	1a	1			1
(i) (i)	DF2(s)	–	1b	2			2
(ii)	DF2(s)	–	1b	1			1
(j) (i)	DF2(v)	–	1a, 1b	2			2
(ii)	DF2(v)	(3.9.2)			2a	2	2
(iii)	DF2(u)	–	1b	2			2
4 (a)	EL2(h)	–			2a, 2d	4	4
(b) (i)	EL2(n)	3.6.1	1a	1			1
(ii)	EL2(n)	3.6.1/3.12.1	1a	1			1
(iii)	EL2(p)	3.6.2/3.12.1	1a	1			1
(iv)	EL2(n)	3.12.2	1a	2			2
(c) (i)	EL2(g)	–	1a, 1c	2			2
(ii)	EL2(l)	–	1a	2			2
Total				**59**		**31**	**90**

Quantitative questions:	18 marks	(20%)
Equations and structural formulae:	10 marks	(11%)
Extended writing:	9 marks	(10%)
Quality of written communication:	1 mark	(AO1)

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

CHEMISTRY (SALTERS)
MINERALS TO MEDICINES **2851**

Specimen Paper

Candidates answer on the question paper.
Additional materials:
Data Booklet for Chemistry (Salters)
To be brought by candidate: electronic calculator

TIME 2 hours

INSTRUCTIONS TO CANDIDATES

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You will be awarded marks for the quality of your written communication where an answer requires a piece of extended writing.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

A copy of the Periodic Table and other tables of information are provided on a data sheet for use with this examination; other necessary data are given as required in the questions.

You may use an electronic calculator.

1 In 1930 the American, Thomas Midgeley, inhaled a lungful of the CFC with formula CCl_2F_2 and used it to blow out a candle. He did this to demonstrate a new refrigerant which was both non-flammable and non-toxic.

(a) What does CFC stand for?

....**[1]**

(b) State **two** other uses (as well as refrigerants) to which CFCs have been put.

....

....**[2]**

(c) In the stratosphere, CFCs are broken down to give chlorine atoms. The following two reactions then occur:

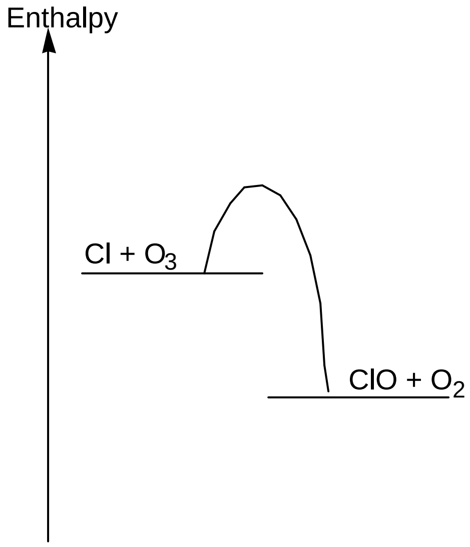
$Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$ **Equation 1.1**

$ClO^{\bullet} + O \rightarrow Cl^{\bullet} + O_2$ **Equation 1.2**

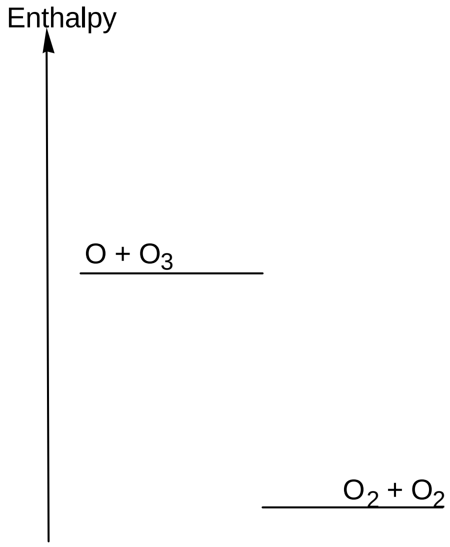
Equations 1.1 and 1.2 can be combined to give an overall equation for the reaction:

$O + O_3 \rightarrow 2O_2$ **Equation 1.3**

(i) Chlorine atoms act as **catalysts** for the reaction in **Equation 1.3**. Complete the diagram below to show the enthalpy profile of the reaction in **Equation 1.3** and mark on this diagram the **activation enthalpy** for the reaction.



Reaction in **Equation 1.1**



Reaction in **Equation 1.3**

[2]

(ii) Use **Equations 1.1-1.3** and the enthalpy diagrams in **(c) (i)** to explain how chlorine atoms act as catalysts for the reaction in **Equation 1.3**.

....

....

....

....**[4]**

(d) Chlorine atoms are sometimes described as radicals. Explain what the term **radical** means.

....

....**[1]**

(e) Suggest a reason why Midgeley was unaware of the drawbacks associated with CFCs.

....

....**[1]**

(f) Chemists are now looking for compounds to replace CFCs. Describe **two** properties which these compounds should have, as well as being non-toxic and non-flammable.

....

....**[2]**

(g) A variety of halogenoalkanes similar to Midgeley's original compound has been synthesised to see whether they might be useful. For example, CF_2I_2 has been synthesised.

(i) Give a reason why CF_2I_2 reacts faster than CCl_2F_2 with sodium hydroxide solution.

....

....**[1]**

(ii) When CF_2I_2 reacts with sodium hydroxide, iodide ions are formed in the alkaline solution. In order to test for the presence of these ions, dilute nitric acid has first to be added to neutralise the alkali. If you were doing this test, state:

the substance you would add to test for the iodide ions;

....

....**[1]**

the positive result of the test;

....

....**[1]**

and write an ionic equation (with state symbols) for the reaction.

....

....**[2]**

Total 18 marks

2 Many copper minerals are found in hydrothermal deposits where they were formed by crystallisation from very hot solutions which were trapped underground at high pressures.

(a) One such copper mineral is chalcopyrite, $CuFeS_2$, which contains both copper and iron in the +2 oxidation state. The mineral is smelted in modern works by heating with air:

$$CuFeS_2 + 10.5O_2 \rightarrow 4Cu + 2FeO + Fe_2O_3 + 8SO_2$$ **Equation 2.1**

(i) Write the electron configurations, in terms of *s*, *p* and *d* electrons for

a copper atom .... **[2]**

a Cu^{2+} ion .... **[1]**

(ii) Copper is reduced in this reaction. Complete the chart of oxidation states below to show two elements that are **oxidised** in the reaction.

Element		**from**	**to**
Copper	reduced	+2	0
....	oxidised	....	....
....	oxidised	....	....

[4]

(iii) Calculate the percentage of copper by mass in a sample of rock containing 0.50% by mass of chalcopyrite, assuming this is the only source of copper in the rock.

(A_r: Cu, 64; Fe, 56; S, 32)

[3]

(iv) Suggest an environmental problem which arises as a result of your answer to **(iii)**.

....

....

....**[2]**

(b) Water draining from the waste heaps around a copper mine is often blue due to the presence of hydrated copper(II) ions. If this water runs over iron metal (such as discarded tools or railings) a redox reaction occurs. The iron becomes coated with a brown layer of copper and hydrated iron(II) ions are released in to the water.

(i) Write **half-equations** for the oxidation and reduction processes in this redox reaction.

oxidation .... **[1]**

reduction .... **[1]**

(ii) Write an equation (with state symbols) for the overall reaction.

....**[2]**

(iii) The copper(II) ions in solution are said to be **hydrated**. Draw a labelled diagram of a hydrated copper(II) ion to show what this means.

[3]

(c) The rate of the reaction in **Equation 2.1** changes if the $CuFeS_2$ is ground up and if the temperature is raised. In each case, state whether the rate increases or decreases and explain your answer in terms of collisions of reactant particles and the activation enthalpy of the reaction.

(i) The effect of grinding up the $CuFeS_2$

....

....

....**[3]**

(ii) The effect of raising the temperature

....

....

....**[3]**

Total 25 marks

3 A manufacturer makes poly(propene) from propene monomer, $CH_3CH=CH_2$. The polymer produced has an average relative molecular mass of 1.0×10^6.

(a) Draw the full structural formula for propene.

[1]

(b) The reactions of alkenes, such as propene, with bromine can be used as a simple test for the alkene functional group.

(i) Describe how you would carry out this simple test on a liquid alkene and say what you would expect to see.

....

....

....**[2]**

(ii) Which structural feature of propene is responsible for its reaction with bromine? Explain how the structural feature is involved in the first stage of the reaction mechanism.

....

....

....

....

....**[4]**

(iii) Circle **two** words in the list below that describe the mechanism of the reaction between propene and bromine:

electrophilic radical nucleophilic addition substitution.

[2]

(c) **(i)** Draw a full structural formula which indicates clearly the structure of the repeating unit in poly(propene).

[2]

(ii) How many monomer units are joined together to give poly(propene) with a relative molecular mass of 1.0 x 10^6?

(A_r: C, 12; H, 1)

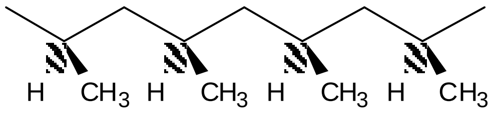
[2]

(d) Why is the mass referred to as an **average** relative molecular mass?

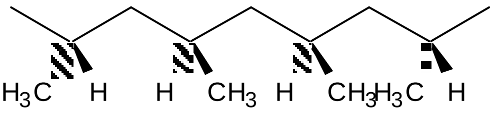
....

....**[1]**

(e) Poly(propene) can exist in two forms:



isotactic



atactic

(i) Explain with reasons which of the two forms of poly(propene) you would expect to be more crystalline.

....

....

....**[2]**

(ii) Explain why the more crystalline form can be used to make strong fibres for carpets.

....

....

....**[2]**

Total 18 marks

4 Some students were investigating butter which had been allowed to 'go off'. They were able to obtain an impure sample of the substance responsible for the unpleasant smell. When they distilled this sample, they obtained a colourless liquid that boiled at around 160 °C. Further investigations showed that this liquid was butanoic acid, C_3H_7COOH.

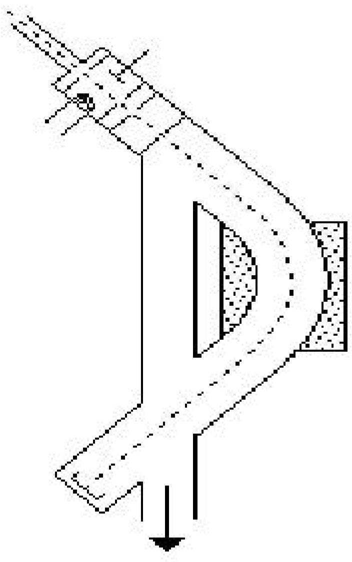
(a) In the space below, draw a labelled diagram of the apparatus you would use to carry out a distillation to purify the impure liquid initially obtained by the students and, at the same time, measure its boiling point accurately.

[4]

(b) Mass spectrometry of the pure liquid helped to confirm its structure.

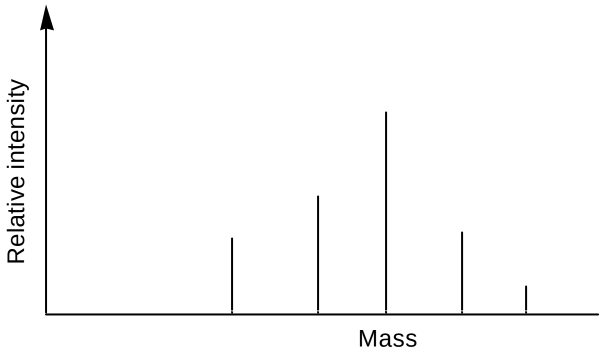
(i) Write the following labels (with appropriately drawn lines) on the diagram of a mass spectrometer shown below:

sample inserted here; ionisation occurs here; electric field; magnetic field.



[4]

(ii) The mass spectrum of butanoic acid is shown below. Indicate which line in the spectrum shows that the substance has an M_r of 88. Explain your choice.



Explanation...

....

.... **[2]**

(c) The infra-red spectrum provided further evidence for the structure of the pure liquid and is shown below in **Figure 1**.

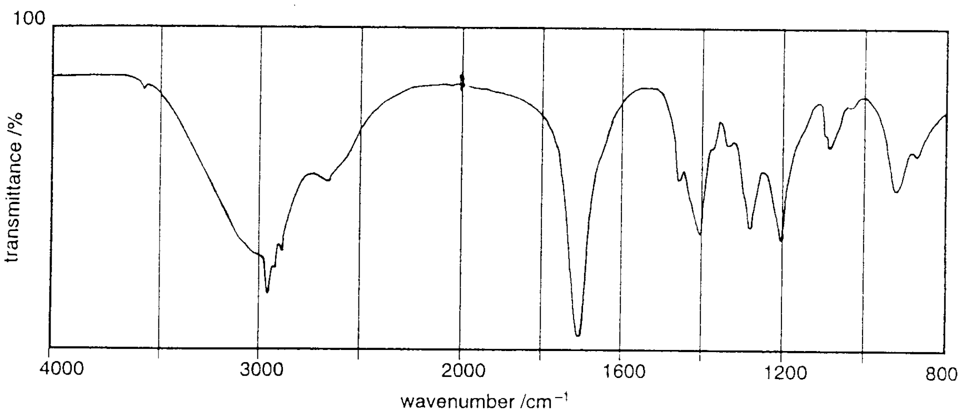
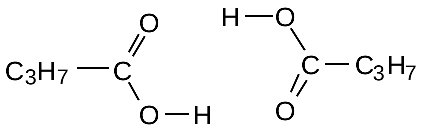


Figure 1 Infra-red spectrum of the pure liquid responsible for the unpleasant smell of butter

Butanoic acid contains C=O, O–H and C–H bonds. Label on **Figure 1** the absorptions characteristic for these groups. A table of characteristic infra-red absorptions is given on the Data Booklet accompanying this paper.

[3]

(d) In liquid butanoic acid, the molecules are found in pairs with hydrogen bonds between each pair. Indicate on the diagram below the positions of the hydrogen bonds that would form. Explain, with reference to the bonds you have drawn, the conditions necessary for hydrogen bonds to form.



[2]

Explanation...

....

.... **[2]**

Total 17 marks

5 When oxygen is in short supply, human muscle cells can break down glucose by a process which involves the following sequence of molecules, among others:

$C_6H_{12}O_6 \rightarrow CH_2OH\text{–}CHOH\text{–}CHO \rightarrow CH_3\text{–}CO\text{–}COOH \rightarrow CH_3\text{–}CHOH\text{–}COOH$

glucose **glyceraldehyde** **pyruvic acid** **lactic acid**

The lactic acid can cause pain in muscles ('a stitch').

(a) Circle a secondary alcohol group in one of the above formulae.

[1]

(b) Draw a full structural formula for **glyceraldehyde** .

[2]

(c) Eventually, lactic acid is transported to the liver where it is oxidised back to pyruvic acid.

(i) Give the reagents and conditions you would use to oxidise lactic acid to pyruvic acid in the laboratory.

....

.... **[3]**

(ii) State the colour change you would expect to see as this reaction proceeds.

From .... **to** .... **[2]**

(d) In the laboratory, the concentration of a solution of lactic acid can be found be titration with sodium hydroxide solution. The equation for the reaction is shown below:

$$CH_3\text{–}CHOH\text{–}COOH(aq) + NaOH(aq) \rightarrow CH_3\text{–}CHOH\text{–}COONa(aq) + H_2O(l).$$

25.0 cm^3 of a solution of lactic acid were titrated with a 0.0500 mol dm^{-3} solution of sodium hydroxide; 22.2 cm^3 of the sodium hydroxide solution were required. Calculate the concentration (in mol dm^{-3}) of the lactic acid solution.

[3]

(e) A student set out to show that a sample of lactic acid was pure using thin layer chromatography.

Draw a diagram and describe the steps taken. Show the expected result.

[5]

Total 16 marks

6 Carbon dioxide is used to add the 'fizz' to fizzy drinks. It is dissolved in water under pressure and when the pressure is released the 'fizz' appears.

(a) Carbon dioxide molecules contain covalent bonds. Explain carefully what you understand by the term **covalent bond**.

....

....

.... **[3]**

(b) **(i)** Use your knowledge of the bonding in carbon dioxide, the electronegativities of carbon and oxygen, and the shape of the molecule, to explain why carbon dioxide has no overall dipole. (Electronegativities: carbon, 2.5; oxygen, 3.5)

....

....

....

....

....

....

.... **[3]**

(ii) Name the type of bonding found **between molecules** in carbon dioxide.

.... **[1]**

(c) In a stoppered bottle of fizzy drink, the following chemical equilibrium exists:

$CO_2(g) \rightleftharpoons CO_2(aq)$ **Equation 6.1**

(i) Chemical equilibria are sometimes described as dynamic equilibria. Draw a labelled diagram of the surface of the solution in a stoppered bottle of fizzy drink and use it to illustrate what you understand by the term **dynamic equilibrium** for the reaction in **Equation 6.1**.

[4]

(ii) When the stopper is removed from a bottle of fizzy drink it goes ‘flat’ because much of the dissolved carbon dioxide comes out of solution. Use your understanding of chemical equilibrium to explain why this happens.

....

....

....

....

.... **[3]**

(d) The concentration of carbon dioxide in the atmosphere is gradually increasing. There are concerns that this will enhance the 'greenhouse effect' and contribute to global warming. In the space below, draw a labelled diagram to explain the **greenhouse effect** in the Earth's atmosphere and how it causes the atmosphere to warm up.

***Note:** In this question 1 mark is available for the quality of written communication.*

[6]

(e) Silicon is in the same group of the Periodic Table as carbon, yet its oxide, SiO_2 is a covalent network structure, with each silicon atom covalently bonded to four oxygen atoms and each oxygen atom covalently bonded to two silicon atoms.

(i) Draw a diagram to illustrate this structure which shows the 3-dimensional arrangement of bonds around the silicon atom.

[1]

(ii) Use your answer to part **(i)** for SiO_2 and your answers to **(b)** for CO_2 to explain why CO_2 is a gas a room temperature whereas SiO_2 is a high-melting solid.

***Note**: In this question 1 mark is available for the quality of written communication.*

....

....

....

....

....

.... **[5]**

Total 26 marks

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

CHEMISTRY (SALTERS)
MINERALS TO MEDICINES **2851**

Mark Scheme

1 **(a)** Chorofluorocarbon **[1 mark]**

(b) *Two marks for two from*:

(aerosol) propellants

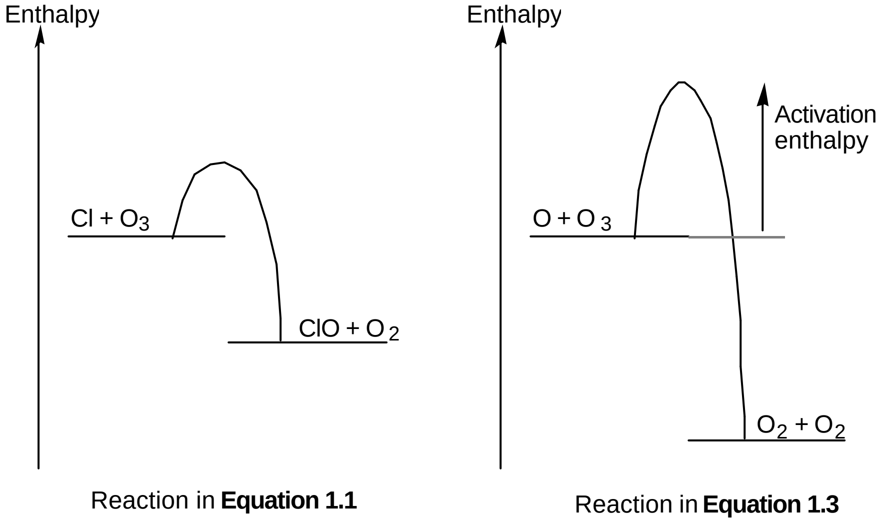
blowing plastics

degreasing solvent. **[2 marks]**

(c) **(i)** Enthalpy profile line drawn correctly with higher maximum than for reaction in **Equation 1.1** [1 mark]

Activation enthalpy correctly labelled [1 mark]

[2 marks]



(ii) Chlorine atoms regenerated (*or* unchanged*)* at the end of the reactions in **Equations 1.1 and 1.2** [1 mark]

Activation enthalpy of catalysed route lower [1 mark]

More collisions with enough energy to react [1 mark]

Thus, route involving chlorine atoms is faster [1 mark]

[4 marks]

(d) A radical has an unpaired electron **[1 mark]**

(e) He was unaware of the reactions in the stratosphere (*or* similar/related point) **[1 mark]**

(f) *Two marks for two from:*

inexpensive
low ODP
suitable volatility
unreactive in use;
reactive in troposphere
low Greenhouse factor. **[2 marks]**

(g) **(i)** C–I bond weaker than C–Cl bond **[1 mark]**

(ii) Silver nitrate solution [1 mark]
yellow precipitate [1 mark]
$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$ [equation, 1 mark]
[state symbols (if equation correct), 1 mark]
[4 marks]

OR

Chlorine water [1 mark]
solution goes from colourless to brown [1 mark]
$Cl_2(aq) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$ [equation, 1 mark]
[state symbols (if equation correct), 1 mark]
[4 marks]

Total 18 marks

2 **(a)** **(i)** **A copper atom:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$ [2 marks]
[ending $3d^9 4s^2$ scores 1 mark]
a Cu^{2+} ion $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$ [1 mark]
[3 marks]

(ii)

Element		**from**	**to**
Copper	reduced	+2	0
Fe	oxidised	**+2**	**+3**
S	oxidised	**– 2**	**+4**

One mark for each element

One mark for both oxidation states of each element **[4 marks]**

(iii) $M_r(CuFeS_2) = 184$ [1 mark]

$\frac{0.50}{100} \times \frac{64}{184} \times 100$ [1 mark]

= 0.17% [1 mark, allow max 3 sig. fig.]

[3 marks]

(iv) Large amounts of waste [1 mark]

which cause an eyesore *or* need a lot of energy for disposal *or* cause a large hole to be dug *or* destroy habitats [1 mark]

[2 marks]

(b) (i) **Oxidation:** $Fe \rightarrow Fe^{2+} + 2e^-$ **[1 mark]**

Reduction: $Cu^{2+} + 2e^- \rightarrow Cu$ **[1 mark]**

(ii) $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$ [equation, 1 mark]

[state symbols (if equation correct), 1 mark]

[2 marks]

(iii) Copper surrounded by several water molecules [1 mark]

Oxygen atoms of water molecules point towards copper [1 mark]

Correct charge (2+) shown on copper ion and δ– on oxygen [1 mark]

[3 marks]

(c) (i) Smaller surface area [1 mark]

More collisions per second [1 mark]

Faster reaction [1 mark]

[3 marks]

(iii) More collisions with energy [1 mark]

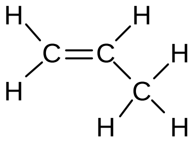
greater than activation enthalpy [1 mark]

Faster reaction [1 mark]

[3 marks]

Total 25 marks

3 **(a)** *One mark for correct structure:*



[1 mark]

(b) **(i)** Shake alkene with bromine water [1 mark]

Mixture goes colourless [1 mark]

[2 marks]

(ii) (Carbon-carbon) double bond [1 mark]

has high electron density [1 mark]

Description of mechanism in words or through a diagram:

Approaching bromine molecule becomes polarised so that the end that is positively charged is attracted towards the double bond [1 mark]

Br^+ reacts with the double bond [1 mark]

[4 marks]

(iii) Electrophilic [1 mark]

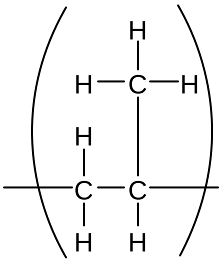
addition [1 mark]

[2 marks]

(c) **(i)** *Two marks for correct structure:*

idea of repeating unit (bracket not essential) [1 mark]

detail correct [1 mark]



[2 marks]

(ii) $\frac{1.0 \times 10^6}{42}$ [1 mark]

$= 2.4 \times 10^4$ [1 mark]

(two marks for correct answer with no working; allow 1 or 2 sf) **[2 marks]**

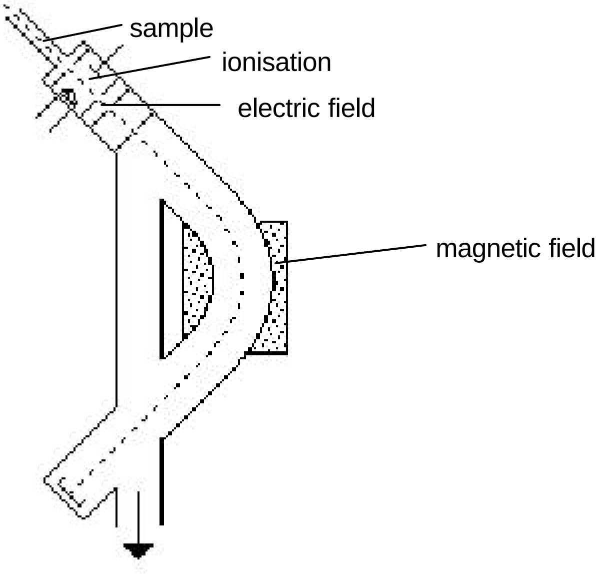
(d) Chains not all the same length **[1 mark]**

(e)	**(i)**	Isotactic - chains more regular	[1 mark]
		Chains pack together better	[1 mark]
			[2 marks]
	(ii)	Strong attractive forces between chains	[1 mark]
		Chains do not move past each other easily so fibre strong	[1 mark]
			[2 marks]

Total 18 marks

4	**(a)**	Distilling flask, joined without leaks to next part, heat source and liquid shown or labelled	[1 mark]
		Thermometer shown with bulb opposite outlet to condenser	[1 mark]
		Condenser with correct water connections	[1 mark]
		Collection of liquid (not in sealed apparatus)	[1 mark]
			[4 marks]

(b) **(i)** One mark for each correct label:



[4 marks]

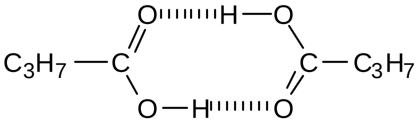
(ii)	Right-hand peak indicated	[1 mark]
	Explanation: this is the peak with the highest mass (*or* highest mass/charge ratio) *or* it represents the molecular ion (*or* the unfragmented molecule)	[1 mark]
		[2 marks]

(c) One mark for each correctly identified peak:

C=O	absorption at 1700 cm^{-1}	[1 mark]
O–H	broad absorption 2500 - 3500 cm^{-1}	[1 mark]
C–H	absorption at 2800 - 3000 cm^{-1}	[1 mark]

[3 marks]

(d) *One mark for each hydrogen bond*



[2 marks]

A hydrogen atom attached to an electron-withdrawing oxygen atom [1 mark]

is bonded to a small electronegative atom, oxygen [1 mark]

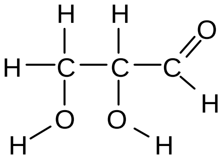
[4 marks]

Total 17 marks

5 **(a)** Central OH (*or* CHOH) of glyceraldehyde *or* lactic acid [1 mark]

(b) Aldehyde group [1 mark]

Rest of structure



[1 mark]

[2 marks]

(c) **(i)** Dilute sulphuric acid [1 mark]

Potassium (*or* sodium) dichromate solution [1 mark]

Reflux/heat [1 mark]

[3 marks]

(ii) From **Orange** to **Green** [1 mark for each]

[2 marks]

(d) Sodium hydroxide solution contains $\frac{0.0500 \times 22.2}{1000}$ moles NaOH [1 mark]

= 1.11 x 10^{-3} moles NaOH

Reacts with 1.11 x 10^{-3} moles lactic acid [1 mark]

Concentration lactic acid solution = 1.11 x 10^{-3} x 40 = 0.044(4) mol dm^{-3}

[1 mark*; allow 2 or 3 sf]*

[3 marks]

(e) Diagram (or words) describing:

initial spot on chromatogram	[1 mark]
solvent in container (level below spot)	[1 mark]
container covered	[1 mark]
location by u.v. *or* iodine	[1 mark]
single spot obtained	[1 mark]

[5 marks]

Total 16 marks

6 (a) Covalent Bond:

Atoms share [1 mark]
a pair of electrons [1 mark]
which holds them together [1 mark]
[3 marks]

(b) (i) Carbon–oxygen bond is polarised, with partial negative charge on oxygen [1 mark]

Carbon dioxide is a linear molecule, O=C=O [1 mark]

The dipoles cancel [1 mark]

[3 marks]

(ii) Instantaneous dipole – induced dipole

accept alternatives, such as *Van der Waals* **[1 mark]**

(c) (i) Diagram showing:

surface with gas and water labelled [1 mark]

carbon dioxide molecules moving in [1 mark]

and out of solution [1 mark]

clear indication that, at equilibrium, rate of entry to solution equals rate of loss from solution [1 mark]

[4 marks]

(ii) Molecules can now escape from bottle and concentration of CO_2(g) above liquid surface falls (*or* pressure falls) [1 mark]

Rate of molecules entering solution is less than rate of molecules leaving (*or* position of equilibrium moves to left to counteract change) [1 mark]

Concentration of CO_2(aq) falls [1 mark]

[3 marks]

(d) Diagram to show:

Radiation coming into Earth and going out form the Earth [1 mark]

Correct change of frequency/wavelength (*or* u.v./visible in, i.r. out) [1 mark]

Atmospheric gases absorb outgoing radiation [1 mark]

Vibrational energy transfered to thermal energy [1 mark]

Process shown as taking place in the troposphere [1 mark]

Quality of written communication: a clear diagram with appropriate labels making correct use of scientific terms such as troposphere, radiation, relection, absorption, wavelength/frequency [1 mark]

[6 marks]

(e) **(i)** Diagram to show:

Atoms bonded as stated in question with tetrahedral arrangement of bonds around silicon **[1 mark]**

(ii) Weak intermolecular forces in CO_2 [1 mark]

broken easily (to form gas) [1 mark]

Strong covalent bonds in SiO_2 [1 mark]

must break (to form liquid), not enough energy to do this at room temperature (so solid) [1 mark]

Quality of written communication: a minimum of 2 linked sentences, presenting a logical argument in which scientific terms such as, covalent bond, intermolecular force, molecular structure, gient/network structure, are used correctly [1 mark]

[5 marks]

Total 26 marks

Assessment Grid: Unit 2851

Question	Teaching module	Core coverage	AO1		AO2		Total marks
			Coverage	Marks	Coverage	Marks	
1 (a)	A2(z)	-	1b	1	-	-	1
(b)	A2(z)	-	1b	2	-	-	2
(c) (i)	A2(j)	3.9.1	-	-	2d	2	2
(ii)	A2(l)	3.9.2	1b, 1c	4	-	-	4
(d)	A2(n)	3.13.2	1a	1	-	-	1
(e)	A2(z)	-	-	-	2d	1	1
(f)	A2(cc)	-	1b	2	-	-	2
(g) (i)	A2(y)	3.13.3	-	-	2a	1	1
(ii)	M2(l)(p)	3.12.2	1a	4	-	-	4
2 (a) (i)	M2(d)	3.6.2	1a	3	-	-	3
(ii)	M2(f)(g)	3.11.1	1a	4	-	-	4
(iii)	EL2(f); M2(s)	3.5.2	-	-	2c	3	3
(iv)	M2(s)	–	1b	2	-	-	2
(b) (i)	M2(h)	3.11.2	-	-	2d	2	2
(ii)	M2(h)	3.11.2	-	-	2d	2	2
(iii)	M2(q)	–	-	-	2d	3	3
(c) (i)	A2(i)	3.9.1	-	-	2d	3	3
(ii)	A2(k)	3.9.1	-	-	2d	3	3

Assessment Grid: Unit 2851 (Cont)

Question	Teaching module	Core coverage	AO1		AO2		Total marks
			Coverage	Marks	Coverage	Marks	
3 (a)	DF2(i); PR2(e)	-	1a	1	-	-	1
(b) (i)	PR2(h)	3.13.2	1a	2	-	-	2
(ii)	PR2(j)	3.13.2/3	1a	4	-	-	4
(iii)	A2(n)(s);PR2(i)	3.13.2	1a	2	-	-	2
(c) (i)	PR2(d)	-	-	-	2d	2	2
(ii)	EL2(f); PR2(q)	3.5.2	-	-	2c	2	2
(d)	PR2(q)	-	1b	1	-	-	1
(e) (i)	PR2(p)	-	1b, 1c	2	-	-	2
(ii)	PR2(q)	-	1b, 1c	2	-	-	2
4 (a)	A2(u)	-	1a	4	-	-	4
(b) (i)	WM2(i)	3.6.1	1a	4	-	-	4
(ii)	WM2(j)	3.14.1	-	-	2b	2	2
(c)	WM2(k)	3.14.1	-	-	2b	3	3
(d)	PR2(l)	3.7.3	-	-	2d	2	2
		3.7.3	1a	2	-	-	2

Assessment Grid: Unit 2851 (Cont)

Question	**Teaching module**	**Core coverage**	**AO1**		**AO2**		**Total marks**
			Coverage	**Marks**	**Coverage**	**Marks**	
5 (a)	WM2(a)	3.13.2	1a	1	-	-	1
(b)	WM2(b)	-	-	-	2b	2	2
(c) (i)	WM2(d)	3.13.2	1a	3	-	-	3
(ii)	WM2(d)	3.13.2	1a	2	-	-	2
(d)	M2(a)	3.5.2	-	-	2c	3	3
(e)	WM2(h)	-	1a	5	-	-	5
6 (a)	EL2(w);M2(aa)	3.7.2	1a	3	-	-	3
(b) (i)	A2(x); PR2(k)	3.7.3	1a	3	-	-	3
(ii)	PR2(l)	3.7.3	1a	1	-	-	1
(c) (i)	A2(ff)	3.10.1	-	-	2a	4	4
(ii)	A2(gg)	3.10.1	1c	3	-	-	3
(d)	A2(dd)	-	1b, 1c	6	-	-	6
(e) (i)	M2(z)	3.7.2	1a,1c	1	-	-	1
(ii)	M2(aa)	3.7.2	1a, 1c	5	-	-	5
Total				**80**		**40**	**120**

Quantitative questions:	8 marks	(7%)
Equations and structural formulae:	16 marks	(13%)
Extended writing:	14 marks	(11.7%)
Quality of written communication:	2 marks	(AO1)

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

CHEMISTRY (SALTERS)
OPEN THE -BOOK PAPER **2852/01**

Specimen Paper

ANALYSIS

The open-book paper is part of Unit 2852 for the Advanced Subsidiary GCE specification.

Candidates are required to use their knowledge, understanding and skills from Units 2850 and 2851 to interpret and evaluate scientific information and data, to research the topic of the articles, and to write a 1000 word report and a 50 word abstract.

All of the objectives in **AO2** are assessed on this paper.

In addition, the quality of written communication is assessed in the context of the candidate's knowledge and understanding of chemistry and ability to communicate this clearly in a piece of extended writing.

The paper consists of **three** articles about the use of micro-organisms to extract metals from their ores.

1. Using between 800 and 1000 words, write a report in which you

- describe the processes used to extract copper and gold from their ores using bacterial leaching. In each case, explain how the micro-organisms liberate the metal from its ore and describe how the metal is then extracted from the mixture **[14]**

- discuss the advantages and disadvantages of using bacterial leaching rather than traditional extraction methods and suggest why bacterial leaching is used only as a secondary extraction process for copper but as a primary extraction process for gold **[10]**

- summarise the development stages that a new mining process (such as bacterial leaching) must pass through before it can operate commercially **[2]**

Notes:

The numbers in brackets show the approximate division of marks between the three sections. The remaining 19 marks are awarded for research and referencing (5 marks), and for the quality of written communication in the summary and the report (14 marks).

Credit will be given for good use of equations and structural formulae, appropriate use of illustrations such as pictures, diagrams etc., the clear use of English and the correct use of technical and scientific terms.

2. When you have finished writing your report, summarise the main points of your report using up to 50 words on the Summary Sheet sheet provided.

Before you start, read carefully the 'Notes for Guidance' on the next page.

Notes for guidance

1 Your report should be between 800 and 1000 words. Reports which are in excess of 1000 words will indicate poor structure and unselective choice of material, so that full credit will not be available. You should indicate the number of words in the margin at approximately 200 word intervals.

2 Your report should demonstrate an understanding of the **chemical issues** involved. It should be aimed at an audience with an understanding of chemistry to Advanced Subsidiary GCE level. It should have a clear and helpful structure and should show evidence of planning.

3 To help you understand the articles in this paper, you are encouraged to use books and other written sources of information, but **your report should be based closely on the information given in the question paper**.

4 Your report should be illustrated by pictures, diagrams, tables, flow charts, graphs, etc., as appropriate. Remember that these can often be used to replace words in the text. Illustrations should be relevant, concisely labelled and positioned appropriately with links to the text. The inclusion of large blocks of text in such illustrations is discouraged; any such text will be included in the word count.

5 You should take care to use technical and scientific terms correctly and to write in clear and correct English.

6 You may hand-write or word-process your report. Remember that if subscripts, superscripts, arrows in equations, dots on radicals, etc. are not available on your word-processor, these must be drawn in correctly and clearly by hand.

7 At the end of your report, you should list clearly any sources you have used. Your list should contain at least **two relevant sources** as well as the articles supplied. The list of references is not included in the word count.

8 You should refer to these references in your report where appropriate. Where you have incorporated material into your report which is copied directly from the articles in the question paper or from elsewhere, the **text must be annotated** and the source properly acknowledged. However, extensive copying from the articles or from other sources will not gain credit.

9 Your report should be written on unheaded A4 paper with a hole in the top left hand corner. Pages should be numbered and should have a **clear margin on the right hand side**. You should **write on one side of the paper only** and each separate sheet should be marked with your name or candidate number.

10 Your summary should be written on the special sheet provided.

11 When you have finished, tie the sheets together **loosely** or use a treasury tag, so that they turn over freely, with your Summary Sheet on the top. Do not use staples or paper clips and do not put your report in a plastic folder.

Article 1

MINING WITH MICROBES

Extracting metals from low-grade ores is usually a tricky business, but some bacteria have no problems with it. The metal industry is using these tiny helpers to make their mines both green and profitable.

The Rio Tinto mine, in the province of Huelva in the south-western corner of Spain, has been a source of copper for some 2000 years (see Figure 1). In 1752, engineers investigating the possibility of reopening the Roman workings noticed streams of blue-green liquid running from the mountains of excavated rock that surround the site. When this fluid ran across old iron implements, it left a brown film. When the engineers scraped it off, they realised that the film was pure copper.

At first, people thought that the copper ions were being leached from tailings dumps - the waste left over from ore-crushing - as a result of inorganic chemical reactions, like those used to extract metals from ores. But, in 1947, US microbiologists discovered that the transformation was in fact the work of micro-organisms.

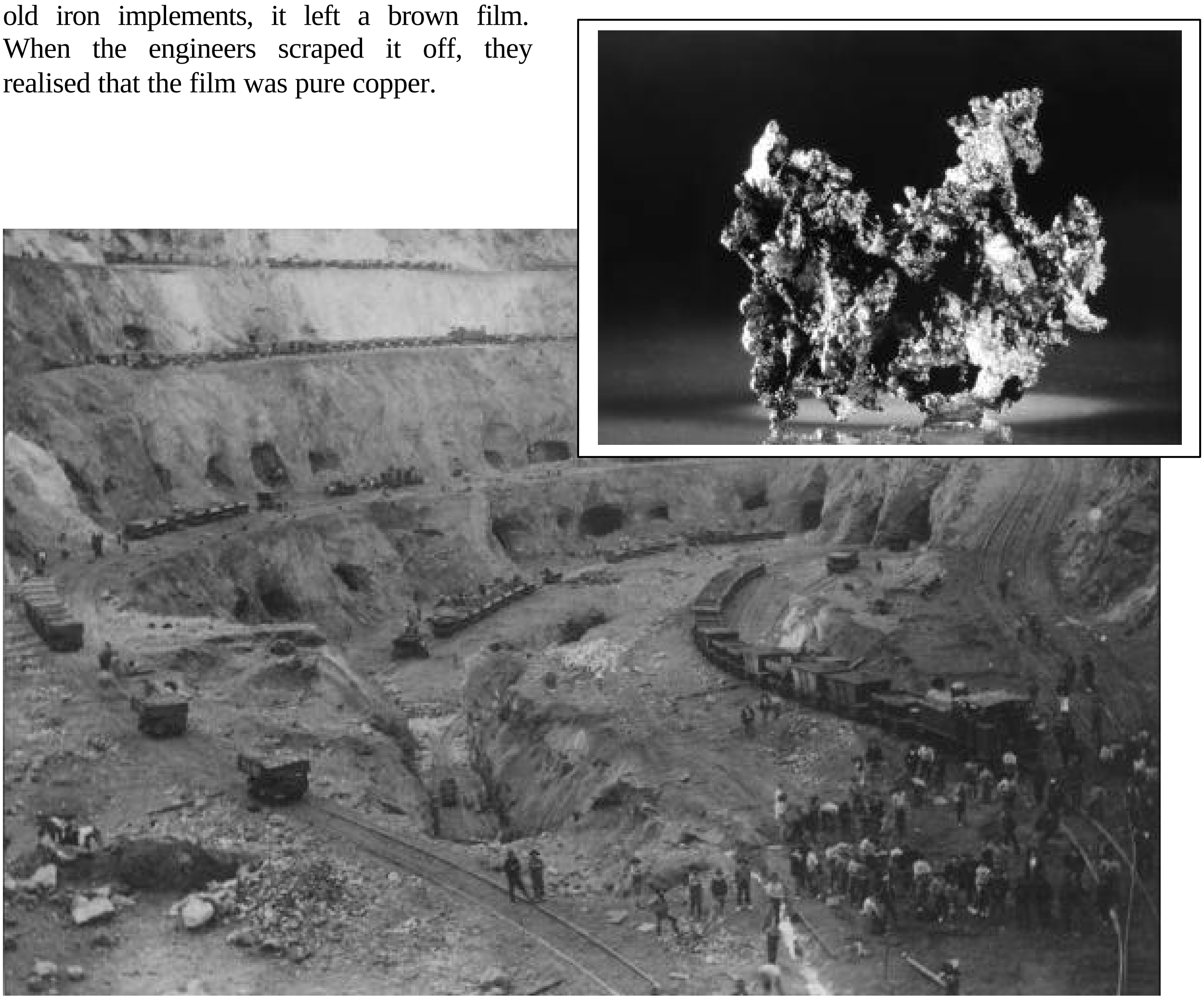


Figure 1: The Rio Tinto copper mine in Spain. *The inset shows a sample of native copper, but ores in the form of copper oxides and sulphides are more common than the metal.*

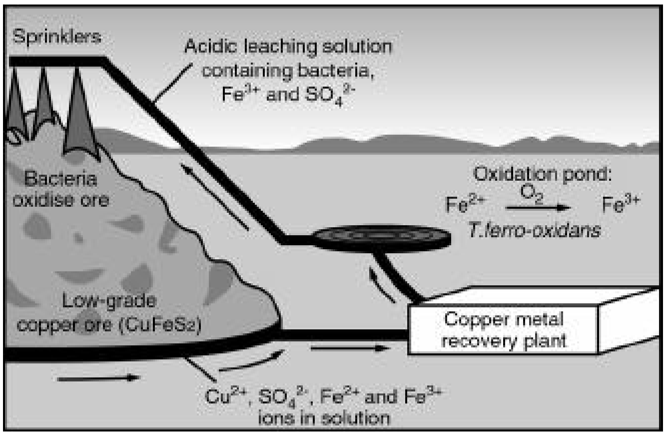


Figure 2: Mining with bacteria*: copper can be extracted from the solution that drains off a pile of low-grade ore or tailings, sprayed with an acidic leaching solution containing bacteria.*

Bacteria such as *Thiobacillus ferro-oxidans* and *Thiobacillus thio-oxidans* obtain the energy they need to live by oxidising Fe^{2+} ions and S^{2-} ions, respectively. The S^{2-} ions are present in insoluble minerals of copper, zinc and lead. The oxidation of the S^{2-} ions by bacteria releases these valuable metal ions into solution (from where the metallic elements can be extracted).

Humans can achieve the same result only by smelting ores at high temperatures, a far more polluting and energy-intensive approach. As we learn more about these biological processes, it is becoming clear that they can be used to process ores - a technology that in the future could transform the metal industries and bring enormous environmental benefits.

Research laboratories around the world are witnessing a marriage between biotechnology and metallurgy, creating a new discipline known as **biohydro-metallurgy**.

By the mid-1980s, the copper industry in the US was on its last legs. Sources of high-grade ores were becoming exhausted, so the industry was having to move, crush and smelt more and more lower-grade rock to end up with the same amount of copper. Coupled with this, the international price of a kilo of copper had dropped from \$3.20 in 1980 to \$1.30 in 1985. Also, regulatory agencies were beginning to restrict emissions of sulphur dioxide, a major cause of acid rain, adding to the cost of metal production. To stay in business, firms began to look to technologies that were more cost-effective and less polluting. These proved to be biological and now 30% of the copper produced in the US is extracted in this way.

Smelting copper ore by traditional methods had cost between \$130 and \$200 per tonne. The introduction of biohydro-metallurgy cut the cost to less than \$70 per tonne. Production of one tonne of copper by smelting typically results in two tonnes of sulphur dioxide being pumped into the atmosphere. Biological extraction avoids this.

Biohydrometallurgy is straightforward when applied to copper production. First, the low-grade ore - and tailings left from any earlier conventional mining - are piled up in an area where the ground has been made impermeable. It is then sprayed with an acidic leaching solution containing *T. ferro-oxidans* and *T. thio-oxidans* (see Figure 2). These bacteria thrive in an acidic environment. They do not need any organic material on which to feed. They require only a supply of Fe^{2+} ions, or S^{2-} ions, oxygen and carbon dioxide (plus bacterial nutrients containing nitrogen and phosphorus).

The overall result is that the bacteria convert the insoluble sulphide minerals into a solution containing Cu^{2+}, Fe^{2+}, Fe^{3+} and SO_4^{2-} ions. Because the piles sit on an impermeable base layer, it is easy to drain off the solution carrying the copper ions. The copper ions are then removed from it with another solvent (see Article 2). The remaining leaching solution flows into an open pond, where *T. ferro-oxidans* catalyses oxidation of the remaining Fe^{2+} ions to Fe^{3+} ions. This recharges the leaching solution, which is pumped back to the top of the pile for the cycle to begin again.

The copper, meanwhile, is extracted as sheets through an ‘electro-winning’ process, in which an electric current is passed through the copper ion solution. The metal collects on the negative electrodes. This part of the process is still costly in energy, but research is under way to develop ‘bioabsorption filters’ such as algae to collect the copper. The whole process would then be entirely biological.

Biohydrometallurgy may provide a method of underground mining, without the environmental damage associated with conventional techniques. There is now a mine in San Manuel in Arizona, consisting of five holes drilled into an ore deposit, which was fractured by detonating an explosive charge underground. Instead of standard mining practice, an acidic leaching solution containing bacteria is pumped down the central hole where the bacteria do their work. The resulting solution, rich in valuable copper ions, is pumped from the other four holes and processed. The leaching solution is recycled.

Despite the potential of these methods, the mining industry is reluctant to use them. So far, they have been applied only as a last resort to recover copper from low-grade ores from sites where traditional methods are not profitable. The problem lies in the slowness of the biological process: the bacteria have not yet come to appreciate the importance of rate of return on capital. According to Keith Debus from the Centre for Interfacial Microbial Engineering at Montana State University, “conventional processes can recover most metal from an ore deposit in a matter of months or years, depending on the size of the deposit and the level of resources applied to production, but biological metal recovery may take decades. Where both techniques have been evaluated, biological approaches have often been found to be cheaper, but delay in cash flow from slower production has hindered adoption”.

Political pressure on the metal industries could force the pace of change. If miners can extract metals from ores of lower grade than is possible with conventional techniques, they can transform old tailings sites from polluting nuisances into valuable sources of raw materials. But research on biological techniques of metal extraction remains rare. Debus sees stricter environmental regulation as the key to encouraging research. “If we were to have left environmental regulations in the US as they were 50 years ago, we would see little use for these biological techniques. In essence, it is an economic issue: the industry has been spilling its waste on the rest of society which imposes a cost on us all. What’s happening is that the cost is now being put back on the mining industry”.

As might be expected, the mining industry rejects this suggestion. It argues that it has always been pushing the research barriers aside in the search for new techniques. Industry has funded much of the research in biohydrometallurgy, which is now beginning to pay back the investment. If society wants to make mining protect the environment, industry’s demand for profit will mean that we may have to accept higher prices. Increasing environmental concern, coupled with the cost-effective techniques of biohydro-metallurgy, could change the face of the mining industry for good.

John Merson is a Senior Lecturer in the School of Science and Technology at the University of New South Wales and a member of the Australian Broadcasting Corporation Science Unit.

Article 2

EXTRACTING COPPER IONS FROM LEACHING SOLUTIONS

Water running out of copper mines and their waste heaps contains dissolved copper ions that have been leached from copper minerals by bacterial action. The dissolved copper ions pose an environmental threat and also represent a loss of revenue for the mining company. Indeed, some mines make use of bacterial leaching solutions to extract copper from low-grade ores and tailings dumps (see Article 1).

Copper ions, Cu^{2+}, can be selectively removed from bacterial leaching solutions by the process of **ligand exchange solvent extraction**. Other metal ions, such as Fe^{2+} and Fe^{3+} ions, are left behind in the aqueous solution.

A **ligand** is a compound with a lone pair of electrons that binds to metal ions. A **complex** is formed in which the central metal ion is surrounded by a number of ligands.

A compound which is a good ligand for copper ions is dissolved in an organic solvent, such as kerosene, that is immiscible with water. When this solution is shaken with the water containing the copper ions, the following reaction takes place.

$Cu^{2+}(aq) + 2LH(organic) \rightleftharpoons CuL_2(organic) + 2H^{+}(aq)$ **Equation 1**

where L represents the ligand.

The effect of the process is to remove the copper ions from the water (where they are at low concentration) and to transfer them to the organic solvent where their concentation is much higher.

The process in **Equation 1** can be reversed by mixing the organic solution with a small volume of concentrated acid. This pushes Cu^{2+} ions back into the aqueous solution containing the acid and a further increase in concentration of Cu^{2+} ions is achieved. The two processes, the extraction of Cu^{2+} ions into the organic solvent and then back into the aqueous phase, both depend on pH (i.e. depend on the concentration of H^{+} ions in solution).

Article 3

A GOLDEN OPPORTUNITY

***Jack Barrett** and **Martin Hughes** describe how the reorganisation of London University led to a new full-scale commercial process for extracting gold.*

‘There’s gold in them thar hills’ - and plenty of volunteers to help dig for it! Few people strike it lucky, however; more fortunes were lost than were ever won in the famous 19th century gold rushes of California, Ballarat and the Klondike.

Gold mining today may not be quite so frenetic but it is still a risky business. Even after finding reliable deposits, extracting the gold from them is no mean feat. Between 15% and 30% of the world’s gold reserves occur as refractory minerals - microscopic particles of gold encapsulated in a mineral matrix. Well known examples of such gold-containing minerals include arsenopyrite (FeAsS), iron pyrites (FeS_2) and chalcopyrite ($FeCuS_2$).

The first stage in obtaining the gold is usually to use froth flotation to separate these refractory minerals from any unwanted oxide ores and non-metallic minerals present. This produces a sulphide concentrate, which is then roasted to liberate the gold. The gold is extracted by treating the resulting mixture with an aerated solution of sodium cyanide, a process called **cyanidation**.

Gold extraction is not without its problems; roasting converts any sulphur in the refractory minerals to sulphur dioxide and any arsenic to arsenic(III) oxide, both of which have undesirable environmental and economic implications. In some cases, roasting traps the gold in fused silicate minerals and fails to liberate all the metal. Cyanidation is also difficult. The mineral matrix acts as an impervious physical barrier and shields most of the gold particles from attack by cyanide ions. Despite being used for over 100 years, cyanidation of refractory ores yields only a fraction of the contained gold.

And so it might have continued, if it had not been for a chance coincidence that resulted in the coming together of the authors in 1984, as part of the reorganisation of the University of London, in which, among other changes, King’s College, Chelsea College and Queen Elizabeth College were merged. At the time, a team of Chelsea undergraduates was carrying out a final-year project on the refractory sulphide concentrate produced from a gold deposit at the Clogau St David’s mine in North Wales. The group quickly hit upon a problem. Since roasting the concentrate to liberate the gold was not permitted on the National Park property where the mine was located, they were only able to extract 10% of the gold by cyanidation. As an alternative to roasting, the undergraduates investigated various ways of converting the gold in the concentrate into soluble compounds, using acidic solutions of thiourea and different oxidants. They showed this could be achieved but not to an extent that would be economic.

Striking it lucky

Instead, the answer to the problem arose from existing interests at Queen Elizabeth College on metal-microbe interactions. For the Chelsea researchers, this work suggested a possible solution and the two groups soon combined forces. The researchers treated the refractory sulphide concentrate with the thermophilic bacterium *Sulpholobus acidocalderius*. These bacteria catalyse the oxidation of the encapsulating sulphide minerals by dioxygen under aqueaous conditions at 70 °C. Cyanidation of the resulting extract led to a remarkable - and quite un-expected - increase in gold recovery from 10% to 100%!

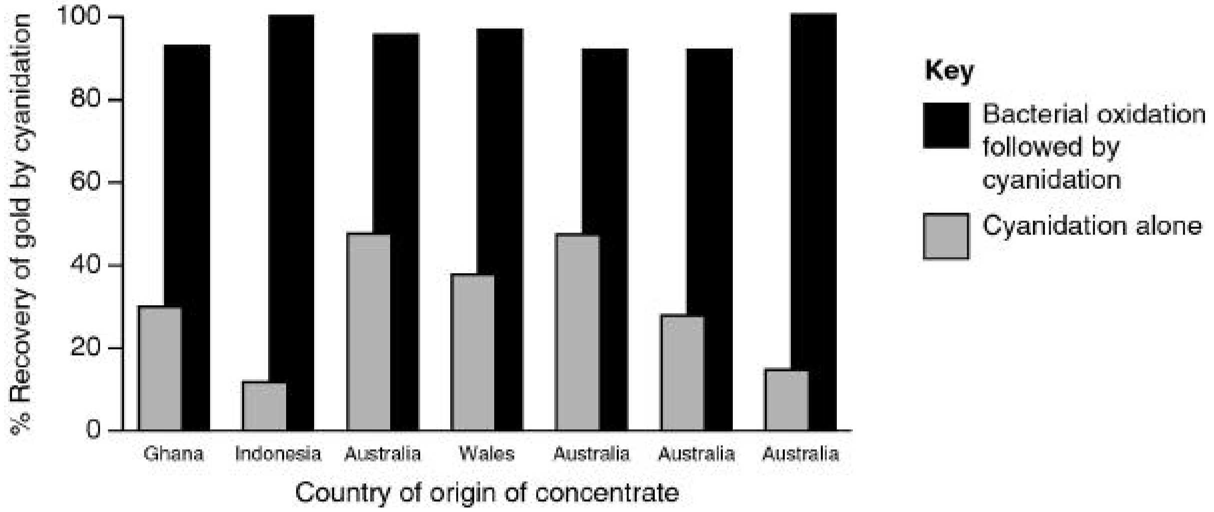


Figure 1: Examples of the enhancement of gold recovery from a range of refractory sulphide concentrates by the use of bacterial oxidation.

Despite these results, the team was unable to obtain any UK funding to pursue their work. By a lucky coincidence, however, Jack Barrett happened to bump into a former student, Richard Ratcliffe, at about the this time. Ratcliffe, who was then working in Australia where he had set up his own mineral export business, was immediately impressed on hearing of the work and returned to Australia with the aim of raising funds.

Golden opportunism

He was soon successful. Besides attracting support for the continuance of the research here in the UK, various Australian businesses were sufficiently interested to provide money to set up a company to exploit the process in Australia. We and Richard retained a modest shareholding in the company, now called BacTech (Australia).

Back in the UK, meanwhile, the Australian funds allowed us to extend our studies of bacterial oxidation to a variety of gold-bearing mineral concentrates, using different bacterial cultures. These studies in turn led to a further bit of good luck - the isolation, by PhD student Ali Nobar, of a mixed culture of moderately thermophilic bacteria from samples sent from Australia. This robust and adaptable culture was effective over a wide range of temperature (30 °C to 55 °C), pH, water salinity and arsenic concentration. The bacteria worked best at a temperature of 46 °C and in solutions with pH between 0.5 and 1.5, greatly enhancing the percentages of gold extracted. Some typical results are shown in Figure 1.

At King's College, London (as the merged institution was now called), our team went on to work out the basic overall mechanism of the bacterial oxidation (see Box 1). Frustratingly, however, we were unable to get beyond the 1 dm^3 reaction vessel stage before the technology was sold to BacTech in 1988.

Research at BacTech quickly progressed to a 450 dm^3 laboratory plant and then to a 32 m^3 transportable pilot plant. The pilot plant was used for test runs in Australia, Ghana and Bulgaria, and is now in Kazakhstan. It gave excellent results under very varied conditions, ranging from a three-day period in Australia where temperatures of 55 °C were recorded, to several weeks in Bulgaria where the temperature was as low as –22 °C.

Box 1 Microbes at work

Taking arsenopyrite (idealised formula FeAsS) as the example, the overall oxidation process is represented by the following equation.

$$2FeAsS + 7O_2 + 4H^+ + 2H_2O \longrightarrow 2Fe^{3+} + 2H_3AsO_4 + 2HSO_4^-$$

The formal oxidation states of iron, arsenic and sulphur in arsenopyrite are +2, –1 and –1, respectively. The resulting iron(III) is present in complexes such as $[Fe(H_2AsO_4)]^{2+}$, $[Fe(HAsO_4)]^+$ and $[FeAsO_4]$ (omitting any water molecules from these formulae), that contain arsenic in its +5 oxidation state.

Bacterial oxidation occurs in two stages. The first stage involves reactions at the inter-face between the surface of the bacterial cell and the arsenopyrite. Bacteria catalyse the formation of soluble compounds of iron(II), arsenic(III) and sulphur(VI).

$$FeAsS \xrightarrow[\text{bacteria}]{\text{dioxygen/Fe(III)}} Fe(II) + As(III) + S(VI)$$

The second stage consists of separate reactions in which iron(II) and arsenic(III) are oxidised.

$$Fe(II) \xrightarrow[\text{bacteria}]{\text{dioxygen}} Fe(III)$$

$$As(III) \xrightarrow[\text{bacteria}]{\text{Fe(III)/pyrite}} As(V)$$

No gases are produced during the bacterial oxidation of arsenopyrite. The main products are iron(III), arsenic(V) and sulphuric(VI) acid, all of which are water soluble.

Waste water from the process is usually treated with hydrated calcium hydroxide or crushed limestone in the form of a slurry with water. This neutralises the sulphuric(VI) acid and caused the precipitation of a gelatinous mixture of iron(III) arsenates and iron oxohydroxide (FeO(OH)), together with gypsum ($CaSO_4.2H_2O$).

The stable arsenic compound arising from the mixture is iron(III) arsenate(V) dihydrate. It is possible that acidic rain or river water may react slowly with precipitated material and dissove arsenic(V), but the highest concentration of arsenic in such waters does not reach the US Environmental Protection Agency limit of 2 ppm.

In September 1994, 11 years after our work on bacterial oxidation began, the first full-scale plant using the patented BacTech process was commissioned and is now producing the first bacterially liberated gold at the Youanmi Mine, 500 km north-east of Perth in Australia. The mine operated as an open-cut until November 1992, when the accessible oxide layers became uneconomic. The deeper sulphide layers were only accessible by underground mining, which began in November 1993.

The first sulphide ore, produced in June 1994, was tested at the BacTech laboratory pilot plant in Perth. The gold particles in the Youanmi deposit are mainly associated with arsenopyrite, and 90% oxidation of the arsenic together with 25% oxidation of the sulphur liberates at least 92% of the gold. The unrefined ore contains about 12 g of gold per tonne. A typical concentrate contains 40 g to 65 g of gold per tonne, 2.5% to 3% arsenic and 28% to 32% sulphur.

Good company

Figure 2 shows the various stages of extraction at the Youanmi plant. In 1995, the plant produced over 1 tonne of gold and estimates suggest that there is enough gold in the region to sustain production for at least seven years.

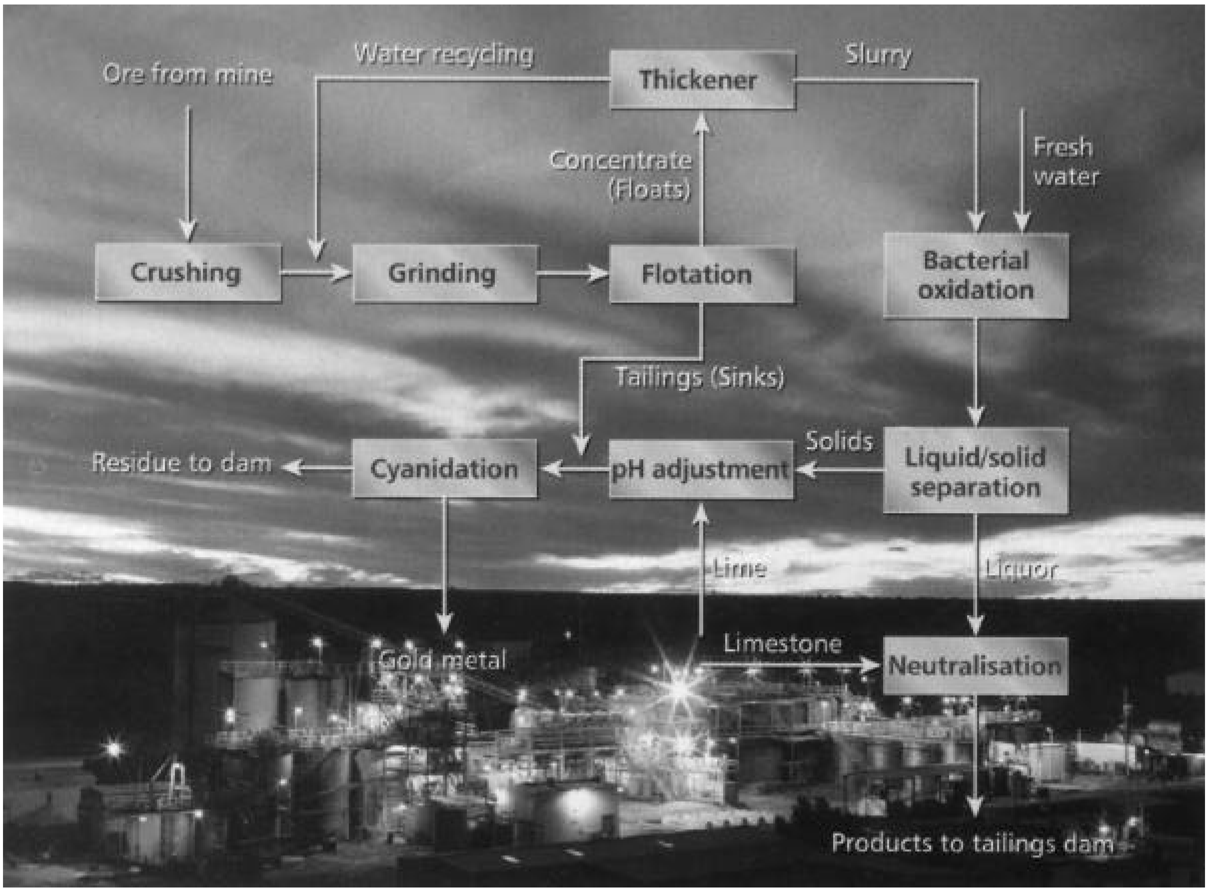


Figure 2: Various stages of gold extraction at the Youanmi mine

The cost of running the plant is surprisingly low - roughly $30 per tonne of concentrate, including power, chemicals, maintenance and labour (only one person is needed per shift). One reason for this is the use of locally quarried calcrete (a form of limestone found in cemented superficial gravel) to neutralise the effluent and the bacterially oxidised concentrate. The other reagents are bacterial nutrients containing nitrogen and phosphorus, mainly in the form of ammonium phosphate.

The recovery of base metals during gold extraction is also high.

Researchers at BacTech have recovered not less than 89% of copper, nickel, cobalt and zinc, all of which contributes to the profitability of plant operations. In fact, recent work has shown that bacterial recovery of the base metals alone, whether or not gold is present in the concentrate, is feasible and economically competitive with conventional processes..

Jack Barrett has now retired from King’s College, London and acts as a consultant to the gold industry. Martin Hughes is Professor of Chemistry in the Department of Chemistry at King’s College, London.

Acknowledgements: Thanks to Richard Winby, Julia Budden and Mike Rhodes for supplying information and photographs used in this article; and to BacTech (Australia) and Gold Mines of Australia, for permission to use this information.

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

CHEMISTRY (SALTERS)
OPEN-BOOK PAPER **2852**

Mark Scheme

BREAKDOWN OF MARKS

Understanding of basic chemical content of paper **[14 marks]**

Chemistry of the processes used to extract copper and gold from their ores using bacterial leaching - how the micro-organisms liberate the metal from its ore and how the metal is then extracted from the mixture.

Evaluation of chemical content in context of question **[12 marks]**

Outline of the processes used to extract copper and gold from their ores using bacterial leaching; advantages and disadvantages of using bacterial leaching rather than traditional extraction methods and why bacterial leaching is used only as a secondary extraction process for copper but as a primary extraction process for gold; development stages for a new mining process.

Research skill in using and acknowledging sources of information **[5 marks]**

Quality of Written Communication

Quality summary	**[4 marks]**
Quality communication in main report	**[10 marks]**

[Total marks: 45]

CHEMISTRY (SALTERS)

OPEN-BOOK PAPER (AS Unit 2852, Component 01)

Additional Marking Instructions for Examiners

Before you begin, you should read Points 1-4 in the *Marking Instructions for Examiners* for Chemistry (Salters). Points 5-10 in these instructions do not apply to the Open-Book Paper because there are many more marking points than marks available.

The Open-Book Paper is marked with the help of a marking grid. The following instructions describe how to mark the Open-Book Paper and use the marking grid. An exemplar grid shows how the marks should be entered.

1 Use red pen to mark the scripts and to fill in the marking grids. Use HB pencil for the computer printed mark sheets.

2 Place a tick on the script next to each marking point that has been scored and place a number '1' on the grid in the appropriate box. The points in the mark scheme and on the marking grid are coded with numbers for easy reference. Write these code numbers in the margin of the script as the point is scored.

3 On the script, underline errors and mark omissions. Indicate any irrelevant material with a wavy line. (See the general marking instructions for a complete list of marking codes.) It also helps to indicate spelling mistakes in the margin (sp).

4 Please ensure that each page of the script shows evidence that it has been considered. If there are no other red marks, place a small cross in the bottom right-hand corner of the page (including blank pages) to show that it has been seen and read.

5 If the point is partly covered and you feel deserves some credit, put a question mark (?) and the reference number in the margin of the script and a question mark on the grid for that point. If there are several such incompletely covered points in a section, you will need to take this into consideration when arriving at the overall mark for that section. We will discuss this further at the Standardisation Meeting.

6 The grid is to help you arrive at a mark for each section. These section marks are written in the shaded boxes on the marking grid and then transferred to the box provided on the cover sheet of the script. Write the marks for each section in the order shown below:

	FOR EXAMINER'S USE
Understanding of basic chemical content	14
Evaluation of chemical content in context of question	12
Research and referencing	5
Communication in abstract	4
Communication in main report	10
Total	45

7 Circle the total out of 45.

8 Make sure your name and the appropriate centre number is on each marking grid.

Do not use the same grid for more than one centre.

9 Store scripts in their original envelopes throughout together with the completed grids.

Checking

Please ensure that the following checks are made:

1 Marking grids: check that the section sub-totals (in the grey bands) add up to the total mark for the paper at the bottom.

2 Check that the section sub-totals and the total mark have been transferred correctly onto the cover sheet of the script in the boxes provided.

3 Check that all pages have been seen and marked and that the candidate declaration on the cover sheet has been signed.

4 Check that the total mark for the paper has been transferred correctly to the mark sheet (check both candidate name and number) and that the lozenges have been filled in correctly.

5 The checker should then place a small pencil tick by each candidate's name and sign the mark sheet in the space provided.

At the end of your marking

Please send to your team leader:

- your Assistant Examiner's Report Form (including your suggestions on what you feel should be minimum marks for Grade A, Grade B and Grade E *on this component*).

Please send to OCR:

- mark sheets (first class post), as directed
- scripts and your completed marking grids (parcel post)
- reports to centres
- marking expenses claim forms.

Please contact your team leader during the marking period if you have queries or problems.

The following marking points are listed by number and key words on the marking grid. For the two sections, *'Understanding of basic chemical content of the paper'* and *'Evaluation of chemical content in the context of the question'* there are more marking points than the maximum marks available. For *'Understanding of basic chemical content of the paper'* there are 20 possible marking points for a maximum of 14 marks. For *'Evaluation of chemical content in the context of the question'* there are 21 possible marking points for a maximum of 12 marks. In both these sections, partial credit for incomplete coverage of a marking point may be awarded where indicated in the mark scheme. This is shown by a question mark (?) on the marking grid.

General rule : 3 (?) = 1 mark within the chemistry section and within the evaluation section

MARK SCHEME

Understanding of basic chemical content of paper

The extraction of copper from its ore using bacterial leaching:

1 **a** Copper extracted from sulphide minerals (with example, such as chalcopyrite $FeCuS_2$) [1 mark]

(? if no example given; example scores full mark)

b Bacteria oxidise Fe^{2+} and S^{2-} ions in mineral, and release Cu^{2+} ions/or copper ions [1 mark]

(not copper or metals ions) (*? for one point only)*

c Half equation for oxidation of either Fe^{2+} or S^{2-} *(or in words mentioning removal* e^-*)* [1 mark]

(No ?)

2 Bacteria obtain energy to live from oxidation of Fe^{2+} and/or S^{2-} ions / electrons are transported into cells and used to reduce O_2 to water / do not need organic compounds to live / need only Fe^{2+}*and/or* S^{2-} ions , O_2, CO_2 and nutrients [1 mark]

(any one point; could be made in context of gold extraction) *(No ?)*

3 **a** Bacterial leaching solution is acidic solution, containing *Thiobacillus ferro-oxidans and/or Thiobacillus thio-oxidans,* Fe^{3+} ions and SO_4^{2-} ions, 20-35 °C [1 mark]

(2 points out of 4) *(No ?)*

b Solution draining away/leachate contains (bacteria), Cu^{2+}, (Fe^{2+}) Fe^{3+} and SO_4^{2-} ions [1 mark]

(could be in diagram, Figure 2 Article 1) *(No ?)*

Extraction of copper from leach solution:

4 By a displacement reaction with iron/more reactive metal *(equation or in words)* [1 mark]

(No ?)

5 By ligand exchange solvent extraction:

a (good) ligand for copper dissolved in (organic) solvent *(or kerosene)* that is immiscible with water [1 mark]

(No ?)

b other metal ions/Fe^{2+} and Fe^{3+} left in (aqueous) solution/or complex dissolves in organic solvent *(idea of separation)* *(No ?)* [1 mark]

c extraction back into water at low pH; discussion of equilibrium [1 mark]

(? for first point)

6 Copper metal obtained from solution of Cu^{2+} ions by electrolysis (not electrowinning); brief description *(e.g. Cu^{+} discharged)* or ionic equation for discharge [1 mark]

(? if electrolysis only; second point gains full mark; no marks if describe electrorefining)

The extraction of gold from its ore using bacterial leaching:

7 **a** Gold extracted from (refractory) minerals (with example, such as FeAsS, FeS_2, $FeCuS_2$); in which (microscopic particles) of gold are encapsulated [1 mark]

(refractory or an example in first point scores ?; second point alone scores ?)

b Bacteria oxidise iron or arsenic or sulphur in mineral; and release gold [1 mark]

(? for one point)

c Increase in oxidation state of iron or arsenic or sulphur *(in words or equations e.g. in Box 1, Article 2, not overall equation)* [1 mark]

(No ?)

8 **a** Bacterial leaching solution contains *Sulpholobus acidocalderius*/ mixed culture/ thermophilic bacteria, O_2, conditions of temperature or pH [1 mark]

(No ?)

b Main products are sulphuric acid *(or SO_4^{2-} or HSO_4^-)* and iron(III) arsenate *(or component ions; or formula of complexes in Box 1, Article 2)* [1 mark]

(No ?)

9 **a** Gold extracted from resulting mixture by treatment with aerated solution of sodium cyanide (cyanidation) *(no marks for cyanidation only)* [1 mark]

(No ?)

b Gold forms (soluble) complex with cyanide ions *(or formula of complex $[Au(CN)_2]^-$ or $[Au(CN)_4]^-$* [1 mark]

(No ?)

10 **Other chemical points (Max 2 marks)** [1 mark each]

For example:

Explanation of froth flotation

Comment on fate of Fe^{3+} ions in bacterial leaching process for copper

Calculations involving scale of process and quantity of waste produced

Discussion of role of lone pair on ligand in forming complex with Cu^{2+} ion

[Max 14 marks]

Evaluation of chemical content in context of question

Outline of the processes used to extract copper and gold from their ores using bacterial leaching:

11 **Extraction of copper**

a Carried out on low-grade ores and/or tailings from (conventional) mining [1 mark]

(No ?)

b Piled in heap on impermeable area and sprayed with bacterial leaching solution [1 mark]

(No ?)

c Leaching solution recycled [1 mark]

(No ?)

(11a, b and c cannot be scored by copying Figure 2 in Article 1)

12 (Underground mining) - holes drilled into ore deposit and bacterial leaching solution pumped through [1 mark]

(No ?)

13 **Extraction of gold**

a Refractory *(or gold-containing)* minerals separated from unwanted minerals by froth flotation [1 mark]

(No ?)

b Waste water neutralised with lime *(or limestone)* *(cannot be scored by copying Figure 2 in Article 2)* [1 mark]

(No ?)

Advantages and disadvantages of using bacterial leaching rather than traditional extraction methods and why bacterial leaching is used only as a secondary extraction process for copper but as a primary extraction process for gold:

14 **Comparison of bacterial leaching with traditional extraction methods**

Marks may be gained by stating just the advantage (or disadvantage) of one process

a Ores heated at high temperatures/large energy input in traditional methods; high energy costs [1 mark]

(? for 1 point)

(or high temperatures not needed for bacterial leaching, so cheaper)

b Sulphur dioxide released during roasting - toxic *or* causes acid rain [1 mark]

(? for first point)

(not produced during bacterial leaching)

c Expensive to remove sulphur dioxide from emissions; with generalised reason, such as expense of installing filters or adding absorption materials /or needed because of legislation [1 mark]

(? for first point)

d Bacterial leaching process is quieter [1 mark]

(No ?)

15 Why secondary extraction process for copper:

a Only used to recover copper where traditional methods are not profitable *(No ?)* [1 mark]

b Slow; causing delay in cash flow *(? for first point)* [1 mark]

16 Why primary extraction process for gold:

a In traditional process, arsenic released as (volatile) arsenic(III) oxide [1 mark]

(or formula As_2O_3*)* ; which is toxic *(? for first point)*

b Arsenic product from bacterial leaching is (stable and) non-toxic [1 mark]

No ?

c Roasting can trap gold in fused (silicate) minerals (so it cannot be extracted) [1 mark]

No ?

d Percentage of gold that can be extracted by bacterial leaching is very much greater [1 mark]

(or quote numbers from Article 2)

No ?

(or reverse for copper)

Development stages for a new mining process:

17 Research (to find best bacterial culture and conditions) [1 mark]

No ?

18 Funding to develop pilot stages [1 mark]

No ?

19 Scale up from laboratory plant to (transportable) pilot to full scale [1 mark]

No ?

20 Other evaluation points (Max 2 marks) [1 each]

For example Research to develop bioabsorption filters such as algae to collect the copperso that the process is entirely biological;

Recovery of base metals from leach solution in gold extraction increases profitability;

Bacterial processes need fewer people to operate;

Operating temperature specific to bacteria and may not match temperature of mine;

Alternative method of extraction to replace cyanidation with reason why improvement [Max 12 marks]

Research skill in using and acknowledging sources of information

21 **List of sources used** which should include the articles in the question paper and at least two additional and *relevant* references [2 marks]
(1 mark if only Salters references quoted; 1 mark if articles in the question paper are not listed or acknowledged in the report, or if only one relevant reference given in addition to the articles)

22 **Appropriate material** selected from the question paper and elsewhere to produce a report within the required word limit. [1 mark]

23 **Text annotation**
Text annotated where appropriate to acknowledge use of information from the sources listed *(2 marks for 4 or more relevant annotations; 1 mark for 3 or 2 relevant annotations)* [2 marks]

Quality of Written Communication

24 **Summary** Four relevant chemical points which summarise the content of their own response, for example: [4 marks]

> *Bacteria that live by oxidising iron, sulphur and arsenic are used to liberate copper and gold from minerals containing these elements. Bacterial leaching is less polluting than traditional methods and, for gold, more metal is extracted. For copper, the process is too slow to be profitable on a large scale.*
>
> (Possible marking points (1 mark for each): bacteria oxidise ions in the mineral; this breaks down the mineral so that valuable metals such as copper and gold are released; copper obtained by ligand exchange solvent extraction/gold obtained by cyanidation; bacterial leaching is less polluting than traditional methods; less energy used; for gold more metal is extracted; for copper process too slow to be profitable on a large scale; a new mining process must go through an extended development and trialling process to make sure it is viable on a large scale.)

MAIN REPORT

25 Structure of report

a Well-structured report in which relevant information is organised clearly and coherently without undue repetition [1 mark]

b Balanced coverage of the required points [1 mark]

26 Clear and correct use of language

a Legible text, appropriate form and style of writing, grammar, punctuation and spelling accurate so that meaning is clear [2 marks]

Up to two different spelling mistakes allowed: 1 mark if grammar, punctuation and spelling mostly accurate but there are some lapses; no marks if the text is illegible or the report is not written in continuous prose or if there are frequent errors in grammar, punctuation and spelling.

b Correct use of scientific and technical terms where appropriate [2 marks]

2 marks where scientific and technical terms are used correctly throughout the report; 1 mark where scientific and technical terms are mostly used correctly but there are 1 or 2 lapses

27 Good use of equations and structural formulae [2 marks]

2 marks for 4 relevant and correct equations or structural formulae;

1 mark for 3 or 2 relevant and correct equations or structural formulae

28 Good use of appropriate illustrations (pictures, diagrams, tables, flow charts, graphs, etc) [2 marks]

2 marks for 2 relevant illustrations, well-positioned and labelled or well-linked into text; these may be from the articles in the question paper; 1 mark for 1 such diagram;

1 mark only if 2 relevant diagrams from articles simply photocopied and pasted in without further annotation or link from the text.

[max:14 marks]

List of possible equations and structural formulae

Redox reactions for bacterial oxidation of copper-containing minerals; overall reaction

Redox reactions for bacterial oxidation of gold-containing minerals; overall reaction

Displacement reaction of Cu by Fe

Ligand exchange solvent extraction

Formula of iron(III) arsenate (and complexes)

Formula of gold complex with cyanide ions

List of possible illustrations

Diagram to show bacterial leaching of copper (from Article 1)

Bar chart to show enhancement of gold recovery (from Article 3)

Stages in gold extraction (from Article 3)

Flow diagrams showing chemistry of copper and gold extraction

Table comparing the advantages and disadvantages traditional and bacterial methods

	Candidate number														

Chemistry

1	Extraction of copper	1+1+1													
2	Bacterial energy source	1													
3	Bacterial leaching of copper	1+1													
4	Extraction of Cu by displacement	1													
5	Ligand exchange solvent extraction	1+1+1													
6	Copper by electrolysis	1													
7	Extraction of gold	1+1+1													
8	Bacterial leaching of gold	1+1													
9	Cyanidation	1+1													
10	Other chemical points	1 each													
	Chemistry	**Max 14**													

Evaluation

11	Extraction of copper	1+1+1													
12	Underground mining	1													
13	Extraction of gold	1+1													
14	Comparison of methods	1+1+1+1													
15	Secondary process for Cu	1+1													
16	Primary process for Au	1+1+1+1													
17	Laboratory research	1													
18	Funding for development	1													
19	Scale-up stages	1													
20	Other evaluation points	1 each													
	Evaluation	**Max 12**													

Research

21	List of sources used	2													
22	Appropriate material selected	1													
23	Text annotation	2													
	Research	**Max 5**													

Communication

24	**Summary**	**Max 4**													
25	Structure of report	1+1													
26	Use of language	2+2													
27	Equations and structural formulae	2													
28	Illustrations	2													
	Main report	**Max 10**													

	TOTAL	**/45**													

Oxford Cambridge and RSA Examinations

Advanced GCE

CHEMISTRY (SALTERS)
POLYMERS, PROTEINS AND STEEL 2853

Specimen Paper

Candidates answer on the question paper.

Additional materials:
Data Booklet for Chemistry (Salters)
To be brought by candidate: electronic calculator

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

Write your name, Centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.

There should be ample space for your answers. If you need more space for answers or rough work you may use the blank spaces at the end of questions or any blank pages. Rough work that is not to be marked should be crossed out.

You will be awarded marks for the quality of your written communication where an answer requires a piece of extended writing.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

A copy of the Periodic Table and other tables of information are provided on a data sheet for use with this examination; other necessary data are given as required in the questions.

You may use an electronic calculator.

1. Stainless steel contains chromium which reduces corrosion, mainly by forming a very thin layer of chromium(III) oxide on the surface. Stainless steel is made by adding chromium in the last stage of steelmaking.

(a) Steel is usually made from blast furnace iron by the BOS process. Oxygen is blown through the molten iron and basic oxides (for example, calcium oxide) are added. Carbon escapes as carbon monoxide. Other elements (for example, silicon) form oxides which react with the basic oxides present. Thus they can be removed as slag.

(i) Write equations that show how silicon is removed by the BOS process.

....

.... **[2]**

(ii) Suggest why the chromium is added **after** the oxygen blow rather than before it.

....

.... **[1]**

(b) One way in which the steel may be analysed to find its chromium content is to dissolve out the chromium as the complex $[Cr(NH_3)_6]^{3+}$ ion which is green.

(i) What is the oxidation state of chromium in the complex ion?

.... **[1]**

(ii) Draw a diagram to show the shape of the $[Cr(NH_3)_6]^{3+}$ ion, labelling the metal ion and a ligand molecule. Show clearly which part of the ligand molecule forms a bond with the metal ion.

[2]

(c) Describe **in outline** how you would use a colorimeter to find the concentration of the green complex ion in solution, given a sample of the pure green solid.

....

....

....

....

....

....

.... **[5]**

(d) In a separate experiment to find the iron content of a sample of steel, 1.40 g of the metal were dissolved by boiling with acid. The iron in the solution was then all converted into the +2 oxidation state and the solution was made up to 100.0 cm^3 using dilute sulphuric acid. 10.0 cm^3 of this solution were titrated against a 0.0200 mol dm^{-3} solution of potassium manganate(VII). 24.2 cm^3 of the potassium manganate(VII) solution were required to reach the end-point of the titration. The reaction occurring in the titration is:

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

(i) Calculate the mass of iron in the sample of steel. (A_r: Fe, 56.0)

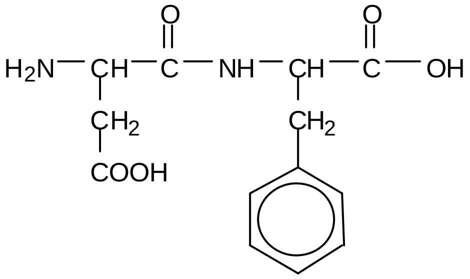
[3]

(ii) Calculate the percentage by mass of iron in the steel.

[1]

Total 15 marks

2 **Aspartame** is an artificial sweetener which is about 200-times sweeter than sucrose. It is a methyl ester of a dipeptide formed from two α–amino acids: aspartic acid and phenylalanine.



the aspartame dipeptide

(a) Explain the meaning of the term **dipeptide**.

....

....**[2]**

(b) Draw a skeletal formula for the aspartame dipeptide.

[2]

(c) One way to show the composition of aspartame is to hydrolyse it and then separate and identify the substances formed.

(i) Briefly describe the procedure which is used to hydrolyse a protein or a dipeptide.

....

....

.... **[2]**

(ii) Three compounds are formed when aspartame is hydrolysed. Name these **three** compounds and explain what further information you would need to establish the structure of aspartame.

Products of hydrolysis :..

.... **[2]**

Further information needed:...

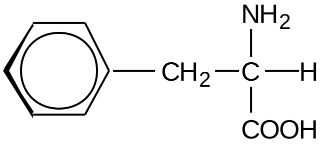
....

....

.... **[2]**

(d) Both aspartic acid and phenylalanine exist in two optical isomer forms, labelled the L form and the D form. Only the L amino acids occur naturally in proteins. Many of the chemical reactions of L and D amino acids are identical, but in the body they can behave differently. For example, D-phenylalanine tastes sweet, but L-phenylalanine is bitter.

(i) On the diagram of the structure of phenylalanine which follows, place an asterisk (*) next to the atom which indicates to you that there are two optical isomers.



[1]

(ii) In the space below, draw diagrams to illustrate the two optical isomers of phenylalanine.

mirror

[2]

(e) A solution of phenylalanine in water will contain few molecules like the one shown in **(d)(i)**. Draw a structure for the form of phenylalanine most likely to be present in an aqueous solution.

[2]

(f) A disadvantage of using aspartame as a sweetener is that it breaks down much faster than sucrose. In soft drinks stored in cans or bottles, about 10% of the aspartame is destroyed each month. Suggest a reason why aspartame breaks down in this way.

....

.... **[1]**

Total 16 marks

3 Sea squirts (*Ascidia*) have an extensive biochemistry based on vanadium, and some of them have blood containing vanadium compounds. Vanadium can be present in three oxidation states in sea squirts. The effectiveness of a biochemistry based on vanadium compounds is thought to arise, in part, from the ease with which these three oxidation states can be interconverted.

Electrode potential values are given below for the reduction of oxygen to water and for half-reactions which involve V^{3+}, VO^{2+} and VO_2^{+}.

These three ions are commonly found in aqueous solutions of vanadium compounds.

These electrode potential values were obtained under standard conditions, except that pH = 7.

Electrode potentials:			**$E^{\ominus}$/V**
$VO^{2+}(aq) + 2H^+(aq) + e^-$	$\rightarrow$	$V^{3+}(aq) + H_2O(l)$	–0.50
$VO_2^{+}(aq) + 2H^+(aq) + e^-$	$\rightarrow$	$VO^{2+}(aq) + H_2O(l)$	+0.16
$O_2(g) + 4H^+(aq) + 4e^-$	$\rightarrow$	$2H_2O(l)$	+0.98

(a) In the space below, draw a labelled diagram of the apparatus which could be used to measure the standard electrode potential of a half-reaction involving ions in solution.

[5]

(b) **(i)** Predict, using the electrode potentials given above, the oxidation state of vanadium that would be stable in aqueous solution at pH = 7 in the presence of air.

.... **[1]**

(ii) Explain how the electrode potential data allow this prediction to be made.

....

....

....

.... **[2]**

(c) In reactions in living cells, transition metal ions are often present in the form of biochemical complexes. State why the electrode potential data given above do not allow a reliable prediction to be made of the oxidation state of vanadium that would be stable in the presence of oxygen in such reactions.

....

.... **[1]**

(d) Vanadium has an atomic (proton) number of 23. Complete the space below to show the electron configuration of a vanadium atom.

$1s^2 2s^2 2p^6 3s^2 3p^6$ .... **[2]**

Ionisation enthalpy changes for vanadium and calcium are given in the table below.

	Ionisation enthalpy changes/kJ mol^{-1}					
	1st	2nd	3rd	4th	5th	6th
calcium	590	1145	4912	6474	8144	10 496
vanadium	650	1414	2828	4507	6294	12 362

(e) Write the chemical equation for the third ionisation of vanadium.

.... **[2]**

(f) Explain, using the ionisation enthalpy data in the table, why vanadium can form high oxidation states in its compounds whereas calcium does not form oxidation states greater than +2 in its compounds.

....

....

....

.... **[2]**

Total 15 marks

4 A large proportion of the nylon manufactured in the UK is nylon-6,6 made from 1,6-diaminohexane and hexanedioic acid. In the industrial process currently in use, both 1,6-diaminohexane and hexanedioic acid are made from benzene.

(a) Draw the full structural formula of 1,6-diaminohexane.

[2]

(b) 1,6-diaminohexane is not very soluble in water but dissolves readily in dilute hydrochloric acid. Write a balanced equation for this reaction. (You do not need to draw again the full structural formula for 1,6-diaminohexane, but your formula should show the functional groups clearly.)

[2]

(c) The repeating unit in nylon-6,6 is shown below:

$–HN–(CH_2)_6–NH–CO–(CH_2)_4–CO–$ **repeating unit**

(i) Suggest why nylon made in this way is called nylon-6,6.

....

.... **[1]**

(ii) Explain, in terms of interactions between polymer chains, why nylon-6,6 is a strong polymer material at room temperature, but becomes less strong as the temperature is raised.

***Note**: In this question 1 mark is available for the quality of written communication.*

....

....

....

....

....

....

....

.... **[7]**

(d) Chemists have recently developed a new process for making hexanedioic acid from glucose. Enzymes in some organisms can convert glucose into muconic acid. The chemists modified the bacterium E. coli by genetic engineering to produce these enzymes. The modified bacteria are then fed glucose and produce muconic acid. This is collected and converted into hexanedioic acid.

HOOC–CH=CH–CH=CH–COOH **muconic acid**

(i) Briefly explain, in outline, how a bacterium such as *E. coli* can be modified by genetic engineering. (It is not necessary to give practical details.)

....

....

....

....

.... **[3]**

(ii) The nuclear magnetic spectrum of muconic acid contains two signals. Suggest, giving a reason, a chemical shift for each signal.

....

....

.... **[2]**

Total 17 marks

5 The water which runs from waste heaps associated with copper mines contains low concentrations of dissolved copper ions. Companies have begun removing Cu^{2+} ions from the water by the process of **ligand exchange solvent extraction**.

A compound which is a good ligand for copper ions is dissolved in an organic solvent that is immiscible with water. When this solution is shaken with the water containing the copper ions, the following reaction takes place:

$$Cu^{2+}(aq) + 2LH(organic) \rightleftharpoons CuL_2(organic) + 2H^+(aq) \qquad \textbf{Equation 5.1}$$

(where L represents the ligand).

(a) Explain why the process represented in **Equation 5.1** is classed as a **ligand exchange** reaction.

....

....

.... **[2]**

(b) The effect of the process is to remove a low concentration of copper ions from water and to transfer them, at much higher concentration, to the organic solvent. The process can be reversed by then shaking the organic solution with moderately concentrated acid. This pushes Cu^{2+} ions back into aqueous solution and, again, an increase in concentration can be achieved.

(i) Use **Equation 5.1** to explain why extraction of Cu^{2+} ions into the organic solvent and then their reversal back ito the aqueous phase is pH dependent (i.e. depends on the concentration of H^+ ions in solution).

....

....

....

....

.... **[2]**

(ii) Suggest how an increase in concentration of copper ions is achieved at each stage of the extraction.

....

.... **[1]**

(c) Research chemists have carried out experiments to find equilibrium constant, K_c, values for reactions like the one in **Equation 5.1**. Aqueous solutions of Cu^{2+} ions were shaken with solutions of a ligand in an organic solvent and allowed to reach equilibrium. In one experiment, which was maintained at pH = 2 (i.e. $[H^+] = 1.0 \times 10^{-2}$ mol dm^{-3}) and 298 K throughout, the equilibrium mixture was analysed and found to correspond to the following concentrations:

$[Cu^{2+}(aq)]$ = 0.0020 mol dm^{-3}
$[CuL_2(organic)]$ = 0.045 mol dm^{-3}
$[LH(organic)]$ = 0.10 mol dm^{-3}

(i) Write an expression, in terms of concentrations, for K_c for the reaction in **Equation 5.1**.

[2]

(ii) Calculate the ratio of the concentration of Cu^{2+} in the organic phase to the concentration of Cu^{2+} in the aqueous phase, and hence the percentage of copper extracted in the experiment.

[3]

(iii) Calculate a value for K_c at 298 K from the results of this experiment.

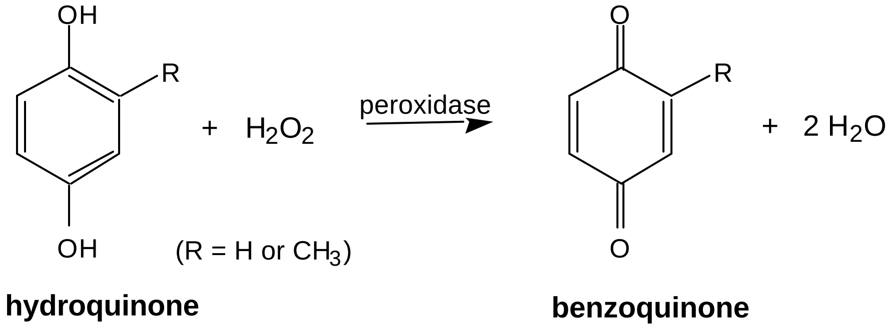
[2]

Total 12 marks

6 The South American bombadier beetle has an unusual way of dealing with predators. When threatened, it releases an explosive spray of boiling hot corrosive liquid, aimed with precision from a gland on the tip of its abdomen.

The gland has two separate chambers; one containing a solution of hydroquinones and excess hydrogen peroxide, the other containing a mixture of two enzymes, catalase and peroxidase. When the beetle is attacked, the mixture of hydroquinones and hydrogen peroxide is released into the reaction chamber containing the enzymes. As the chemicals mix, a hot spray is released explosively from the gland.

The enzyme peroxidase catalyses the reaction of hydroquinones with hydrogen peroxide. The reaction is exothermic:



Equation 6.1

At the same time the decomposition of hydrogen peroxide is catalysed by the enzyme catalase in a second exothermic reaction:

$$2H_2O_2 \xrightarrow{\text{catalase}} 2H_2O + O_2$$ **Equation 6.2**

(a) Explain (in terms of the reactions shown in **Equations 6.1** and **6.2**) why the spray released from the gland of the bombadier beetle is:

(i) **hot**

....

.... **[1]**

(ii) **released explosively**

....

.... **[2]**

(b) Name the functional group which is present in:

(i) **hydroquinone** .... **[1]**

(ii) **benzoquinone** .... **[1]**

(c) The effect of the concentration of hydrogen peroxide on the rate of the decomposition reaction in **Equation 6.2** was investigated in the laboratory. This was done by adding solid catalase to hydrogen peroxide solution and measuring the rate at which oxygen was given off.

(i) Draw a labelled diagram of the apparatus you would use for this, showing how you would start the reaction and how you would collect the gas.

[4]

(ii) The table below shows the results of a series of experiments in which the initial rate of the reaction was found for different starting concentrations of hydrogen peroxide. The concentration of catalase and the temperature were the same in each experiment.

Hydrogen peroxide concentration / mol dm^{-3}	**Initial rate / (cm^3 of O_2) s^{-1}**
0.05	0.13
0.10	0.27
0.20	0.53
0.35	0.94

Plot this data on the grid below.

[2]

(iii) What is the order of the reaction with respect to hydrogen peroxide? Explain your reasoning.

....

....

.... **[2]**

(iv) Using the decomposition of hydrogen peroxide as an example, explain the meaning of the term **rate constant**.

....

....

....

.... **[2]**

Total 15 marks

Oxford Cambridge and RSA Examinations

Advanced GCE

CHEMISTRY (SALTERS)
POLYMERS, PROTEINS AND STEEL **2853**

Mark Scheme

1 **(a)** **(i)** $Si + O_2 \rightarrow SiO_2$ [1 mark]

$SiO_2 + CaO \rightarrow CaSiO_3$ [1 mark]

[2 marks]

(ii) Otherwise it would be removed as an oxide **[1 mark]**

(b) **(i)** +3 **[1 mark]**

(ii) Octahedral shape indicated (must be three-dimensional) [1 mark]

NH_3 ligand labelled and bonded via N atom to metal ion [1 mark]

[2 marks]

(c) *Five marks for five of the following points:*

Select a suitable filter

Use a blank/reference cell

Make up solutions of known concentration

Measure the absorptions of the solutions

Plot a calibration curve

Measure absorption of the green solution of unknown concentration

Read off its concentration from calibration curve **[5 marks]**

(d) **(i)** Amount of MnO_4^- used in the titration $= \dfrac{0.0200 \times 24.2}{1000}$ [1 mark]

(= 4.84×10^{-4} moles)

Mass of iron in steel sample $= 5 \times 4.84 \times 10^{-4}$ [1 mark]

$\times 10 \times 56.0 = 1.36$ g [1 mark]

[3 marks]

(ii) Percentage by mass of iron in steel $= \dfrac{1.36 \times 100}{1.40} = 96.8\%$ [1 mark]

allow 2 or 3 significant figures

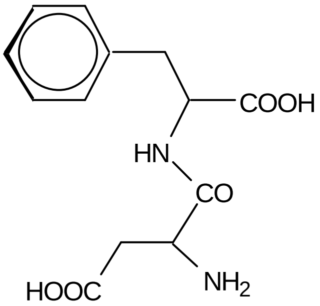
Total 15 marks

2 **(a)** Two amino acids [1 mark]

Joined together by a peptide/amide/ –CONH– link [1 mark]

[2 marks]

(b) *The structure below is one possible answer:*



Formula drawn omitting skeletal C atoms and C–H bonds and

C–C bonds represented by lines with bends at bond junctions [1 mark]

Accuracy [1 mark]

[2 marks]

(c) **(i)** Heat under reflux [1 mark]

with moderately concentrated acid [1 mark]

(e.g. 4 mol dm^{-3} HCl)

[2 marks]

(ii) **Products of hydrolysis:** aspartic acid and phenylalanine [1 mark]

and methanol [1 mark]

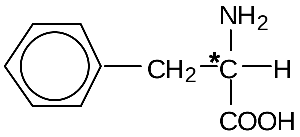
Further information needed:

which way round the two amino acids are linked [1 mark]

and which acid group is esterified [1 mark]

[4 marks]

(d) **(i)** *The a C atom of the amino acid should be starred:*

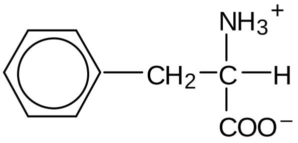


[1 mark]

(ii) The two diagrams should be **mirror images**. They should be clear and use the wedge and dashed-bond convention

(1 mark where this convention is not used but there is an attempt to show the correct stereochemistry) **[2 marks]**

(e) *The zwitterion structure is the most likely:*



NH_3^+ or COO^- [1 mark]

Or for

complete structure [2 marks]

[2 marks]

(f) The peptide linkage is being hydrolysed **[1 mark]**

Total 16 marks

3 **(a)** High resistance voltmeter (*or* potentiometer) [1 mark]

Salt bridge [1 mark]

Hydrogen half-cell (*or* other reference cell; allow copper ions/copper) [1 mark]

Vanadium ions half-cell (or general ion/ion half-cell) [1 mark]

Standard conditions [1 mark]

[5 marks]

(b) **(i)** Stable oxidation state would be expected to be **+5** **[1 mark]**

(ii) Electrons flow from more negative to more positive half-cell [1 mark]

Both vanadium half-cells are more negative than oxygen half-cell [1 mark]

or V(+4) to V(+5) is still sufficiently negative to supply electrons to oxygen half-cell)

[2 marks]

(c) Electrode potential values depend on the ligands present in a complex **[1 mark]**

(d) $4s^2 3d^3$ (or $3d^3 4s^2$) (1 mark for each sub-shell correctly stated)

[2 marks]

(e) $V^{2+}(g) \rightarrow V^{3+}(g) + e^-$ *(1 mark for change from +2 to +3)*

(1 mark for gaseous state)

[2 marks]

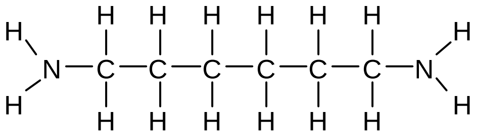
(f) Comment to the effect that: after the loss of 2 electrons from calcium, further ionisation requires a large energy input [1 mark]

Comment to the effect that: vanadium can lose a greater number of electrons before a large energy input is required [1 mark]

[2 marks]

Total 15 marks

4 (a)



six carbon atoms in a chain [1 mark]

–NH_2 groups at both ends and fully correct [1 mark]

[2 marks]

(b) $H_2N–(CH_2)_6–NH_2 + 2HCl \rightarrow Cl^- \; {}^+H_3N–(CH_2)_6–NH_3^+ \; Cl^-$

At least one –NH_2 group converted to –NH_3^+ group [1 mark]

Completely correct [1 mark]

[2 marks]

(c) (i) There are 6 carbon atoms in each monomer **[1 mark]**

or in each of the two reagents

(ii) *Six marks for six of the following points:*

Nylon has hydrogen bonding

between the C=O and –NH– groups

This is relatively strong intermolecular bonding

and prevents polymer chains sliding over one another

As temperature is raised, molecules have more energy

Can overcome the intermolecular forces

and chains can slide over one another

Link movement of chains to strength of polymer [6 marks]

Quality of written communication:

a minimum of 2 linked sentences, presenting a logical argument which distinguishes between covalent bonds within the molecules and hydrogen bonds with correct use of scientific terms such as, molecule, polymer chain, temperature, energy in this context [1 mark]

[7 marks]

(d) **(i)** Genes that code for the particular enzyme [1 mark]
are inserted [1 mark]
into the DNA of the bacterium [1 mark]
[3 marks]

(ii) Chemical shifts at:
6.1 (C**H**=C**H**) [1 mark]
11.0 (COO**H**) [1 mark]
[2 marks]

Total 17 marks

5 **(a)** Water ligands around the copper ions [1 mark]

are replaced by new ligands (L) [1 mark]

[2 marks]

(b) **(i)** Awareness of Le Chatelier's Principle or reversibility of process [1 mark]

Correct discussion of effect of [H+] on position of equilibrium [1 mark]

[2 marks]

(ii) Small volume of extracting solvent used **[1 mark]**

(c) **(i)** $K_c = \dfrac{[\text{CuL}_2(\text{org})][\text{H}^+(\text{aq})]^2}{[\text{Cu}^{2+}(\text{aq})][\text{LH}(\text{org})]^2}$

Top correct [1 mark]

Bottom correct [1 mark]

[2 marks]

(ii) Ratio is 22.5 : 1 [1 mark]

Hence percentage extracted $= \dfrac{22.5 \text{ x } 100}{23.5}$ [1 mark]

= 96% [1 mark]

[3 marks]

(iii) Correct insertion of data into equilibrium constant expression [1 mark]

K_c = 0.23 (*or* 0.223) [1 mark]

candidates who omit the $[H^+]^2$ *term in* ***(c)(i)*** *and who give the answer as 2250* $dm^6\ mol^{-2}$ *gain both marks* **[2 marks]**

Total 12 marks

6 **(a)** **(i)** Reactions are exothermic *or* heat/energy given out by reactions **[1 mark]**

(ii) Oxygen *(not just gas)* (*or* steam) is produced (as well) [1 mark]

so pressure builds up in gland (*or* forced out) [1 mark]

[2 marks]

(b) **(i)** Phenol (*or* hydroxyl) **[1 mark]**

(ii) Ketone (*or* carbonyl) **[1 mark]**

(c) **(i)** Flask or tube containing labelled reaction mixture connected to next stage without leaks [1 mark]

Some indication of how reaction started [1 mark]

(allow 'add catalase quickly and restopper' or funnel method)

Collection of gas in syringe or over water [1 mark]

(reasonable sized ; no leaks)

Calibration shown or labelled [1 mark]

(extra pieces of apparatus (e.g. reflux condensers) lose 1 mark if 3 otherwise scored) **[4marks]**

(ii) *Labelled axes* [1 mark]

correctly plotted data and straight line [1 mark]

[2 marks]

(iii) Initial rate of reaction is proportional to starting concentration of H_2O_2 [1 mark]

so reaction is first order with respect to hydrogen peroxide [1 mark]

[2 marks]

(iv) It is the constant in the rate equation that relates rate [1 mark]

to concentrations [1 mark]

or by writing the rate equation:
rate of reaction $= k\,[H_2O_2]\,[\text{catalase}]^n$ and identifying k **[2 marks]**

Total 15 marks

Assessment Grid: Unit 2853

Question	Teaching module	Core coverage	AO1		AO2		Total marks
			Coverage	Marks	Coverage	Marks	
1 (a) (i)	SS2(c)	3.5.1	1a, 1c	2	-	-	2
(ii)	SS2(c)	-	-	-	2d	1	1
(b) (i)	SS2(h)	3.12.5(a)	1a	1	-	-	1
(ii)	SS2(o)	3.12.5(c)	1a, 1c	2	-	-	2
(c)	SS2(e)	-	1a, 1c	5	-	-	5
(d) (i)	SS2(f)	3.11.3	-	-	2c	3	3
(ii)	SS2(f)	3.11.3	-	-	2c	1	1
2 (a)	EP2(d)	3.13.5	1a	2	-	-	2
(b)	DF2(n); EP2(d)	-	-	-	2b	2	2
(c) (i)	EP2(d)	3.13.2/3.13.5	1a	2	-	-	2
(ii)	DP2(e);EP2(d)	3.13.7	-	-	2d	4	4
(d) (i)	EP2(f)	3.13.6	1a	1	-	-	1
(ii)	EP2(h)	3.13.6	-	-	2a, 2b	2	2
(e)	EP2(c)	3.13.5	1a	2	-	-	2
(f)	EP2(d)	-	-	-	2d	1	1
3 (a)	SS2(r)(t)	-	1a	5	-	-	5
(b) (i)	SS2(x)	-	-	-	2b	1	1
(ii)	SS2(x)	-	-	-	2d	2	2
(c)	SS2(x)	-	-	-	2d	1	1
(d)	M2(d); SS2(h)	3.6.2	1a	2	-	-	2
(e)	SS2(j)	3.12.5	1a	2	-	-	2
(f)	SS2(j)	3.12.5	-	-	2a, 2b	2	2
4 (a)	DP2(f)	-	-	-	2b	2	2
(b)	DP2(h)	3.13.5	-	-	2d	2	2
(c) (i)	DP2(a)	-	1b	1	-	-	1
(ii)	DP2(l)(m)	3.7.3	-	-	2a	7	7
(d) (i)	EP2(aa)	-	1a, 1c	3	-	-	3
(ii)	EP2(j)	3.14.1	-	-	2d	2	2

Assessment Grid: Unit 2853 (Cont)

Question	Teaching module	Core coverage	AO1		AO2		Total marks
			Coverage	Marks	Coverage	Marks	
5 (a)	SS2(l)	3.12.5(c)	1a	2	-	-	2
(b) (i)	A2(hh); EP2(m)	3.10.1	-	-	2a, 2d	2	2
(ii)	A2(hh); EP2(m)	3.10.1	-	-	2a, 2d	1	1
(c) (i)	EP2(k)	3.10.2	1a	2	-	-	2
(ii)	EP2(m)	3.10.2	-	-	2c	3	3
(iii)	EP2(m)	3.10.2	-	-	2c	2	2
6 (a) (i)	DF2(b)	-	-	-	2d	1	1
(ii)	DF2(a)	-	-	-	2d	2	2
(b) (i)	WM2(b)	-	1a	1	-	-	1
(ii)	WM2(b)	-	1a	1	-	-	1
(c) (i)	EP2(u)	3.9.3	1a	4	-	-	4
(ii)	EP2(v)	3.9.3	-	-	2b	2	2
(iii)	EP2(v)	3.9.3	-	-	2b, 2c	2	2
(iv)	EP2(t)	3.9.3	1a, 1c	2	-	-	2
Total				**44**		**46**	**90**

Quantitative questions:	11 marks	(12%)
Equations and structural formulae:	17 marks	(19%)
Extended writing:	12 marks	(13%)
Quality of written communication:	1 mark	(AO2)

Oxford Cambridge and RSA Examinations

Advanced GCE

CHEMISTRY (SALTERS)
CHEMISTRY BY DESIGN **2854**

Specimen Paper

Candidates answer on the question paper.
Additional materials:
Data Booklet for Chemistry (Salters)
To be brought by candidate: electronic calculator

TIME 2 hours

INSTRUCTIONS TO CANDIDATES

Write your name, Centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.

There should be ample space for your answers. If you need more space for answers or rough work you may use the blank spaces at the end of questions or any blank pages. Rough work that is not to be marked should be crossed out.

This question paper is synoptic in nature. You are required to show your knowledge and understanding of different areas of chemistry and apply these, and the chemical skills you have learned, to the situations in the questions.

You will be awarded marks for the quality of your written communication where an answer requires a piece of extended writing.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

A copy of the Periodic Table and other tables of information are provided on a data sheet for use with this examination; other necessary data are given as required in the questions.

You may use an electronic calculator.

1 Two Australian chemists have developed a method for measuring the ethanol content of alcoholic drinks which is based on the oxidation of ethanol by acidified dichromate(VI) ions.

In this method of analysis, the intensity of colour of a solution of dichromate(VI) ions, to which alcoholic drink has been added, is compared with that of a solution of dichromate(VI) ions alone.

This comparison is made using a colorimeter. Because solutions of dichromate(VI) ions have an intense orange colour, light with a wavelength of 440 nm is chosen for use in the colorimeter. The difference in absorbance at this wavelength between the two solutions is measured. Under the conditions used in the analysis, this change in absorbance is directly proportional to the amount (in moles) of dichromate(VI) ions which has reacted. It is also, therefore, directly proportional to the amount (in moles) of ethanol which was added in the form of alcoholic drink.

(a) **Fig. 1.1** summarises the wavelength ranges of the colour of visible light.

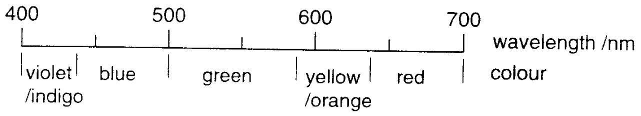


Fig. 1.1: Wavelengths and colours of visible light

Using the information in **Fig. 1.1**, explain why light with a wavelength of 440 nm is used for measuring the concentration of the orange solution of dichromate(VI) ions.

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.... **[3]**

(b) Briefly describe how absorption of light by an atom, molecule or ion can be explained in terms of the effect of the light on the electrons present.

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.... **[3]**

The method used to analyse the contents of a bottle of white wine is given below.

- 25.0 cm^3 of a solution containing dichromate(VI) ions were pipetted into a 50.0 cm^3 volumetric flask.
- 50.0 μl of white wine were added to the volumetric flask from a micropipette. (1 μl = 1×10^{-6} dm^3 = 1×10^{-3} cm^3.)
- Dilute sulphuric acid was added to the volumetric flask to bring the volume of the contents up to 50.0 cm^3.
- The absorbance of a sample of this mixture was recorded. The absorbance of a 'blank' solution made up in the same way but without the addition of any ethanol was also recorded.
- The change in absorbance between the blank solution and the sample was compared with the calibration graph shown in **Fig. 1.2**.
- The amount of ethanol (in mol), which was added to the solution of dichromate(VI) ions in the 50.0 μl of the white wine, was read off from the calibration graph. The ethanol concentration in the white wine was calculated from this.

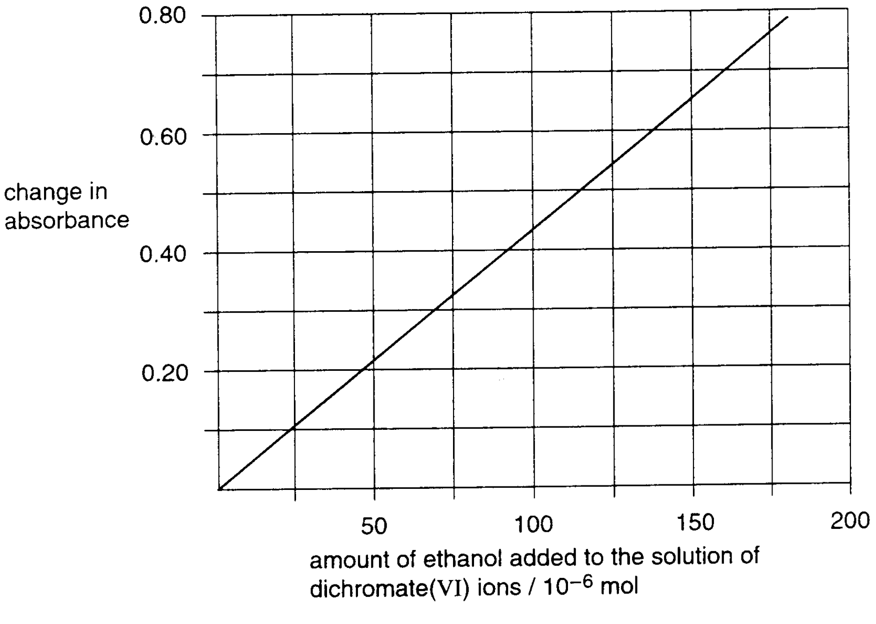

Fig. 1.2: Calibration graph for the absorbance, at 440 nm, of solutions of dichromate(VI) ions to which ethanol has been added.

(c) Describe what **measurements** you would make in order to plot a calibration graph such as the one in **Fig. 1.2**.

....

....

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.... **[2]**

(d) The bottle of white wine which was analysed was stated on the label to contain 12% by volume of ethanol. The change in absorbance recorded in the analysis of this wine was 0.45. Calculate, showing the steps clearly, the concentration of ethanol in the wine (in cm^3 per dm^3), and confirm that the value quoted on the label is correct.

(Density of ethanol = 0.789 g cm^{-3}; M_r(ethanol) = 46)

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.... **[4]**

(e) This method of analysis for ethanol concentration uses the same chemistry as that of a 'breathalyser' which measures the ethanol content of breath. The suspect blows through a tube containing potassium dichromate(VI) crystals. If alcohol is present in the breath, the crystals turn green as the orange $Cr_2O_7^{2-}$ ions are oxidised to Cr^{3+} ions.

The half equation for the oxidation of ethanol is shown below:

Oxidation of ethanol:

$$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$$

Complete the equation below for the reduction of dichromate(VI) ions and write a balanced **overall** equation for the process that takes place in a breathalyser tube.

Reduction of dichromate(VI) ions:

$Cr_2O_7^{2-}$ + ... + ... → .... + ...

Overall equation:

....

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.... **[5]**

Total 17 marks

2 It has recently been reported that an incident occurred at the Dounreay fast-reactor nuclear plant in Scotland in May 1977 in which about 2 kg of sodium were dumped down a shaft which had earlier been used for the disposal of radioactive waste. (Liquid sodium is used as a coolant in this type of reactor.) The shaft was partially flooded with seawater, and the violent reaction between sodium and water led to an explosion which scattered radioactive material over the nearby area.

(a) A number of highly exothermic reactions occur when sodium comes into contact with water. The principal reaction is

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$ **Equation 2.1**

(i) Suggest why the reaction of sodium with water, in the restricted situation of the old mine shaft, gave rise to an explosion.

....

....

....

.... **[3]**

(ii) Calculate the standard enthalpy change for the reaction in **Equation 2.1** using the standard enthalpy change of formation values which follow.

$\Delta H_f^{\ominus}$ /kJ mol^{-1}: $H_2O(l)$ = –286, NaOH(aq) = –470

....

....

.... **[2]**

(b) Sodium and magnesium are neighbours in the Periodic Table. Sodium hydroxide is considerably more soluble in water than magnesium hydroxide, $Mg(OH)_2$. In part, solubility is controlled by the enthalpy change of solution (ΔH_{soln}). This is itself determined by other enthalpy changes: for example, the enthalpies of hydration (ΔH_{hyd}) of the cations and anions. Some data for the cations, Na^+ and Mg^{2+}, are given in **Table 2.1**.

	Na^+	**Mg^{2+}**
Ionic radius/nm	0.102	0.072
Enthalpy of hydration /kJ mol^{-1}	–390	–1891
Extent of hydration / average number of attached water molecules	5	15

Table 2.1: Some data for sodium and magnesium cations

(i) Explain why water molecules are able to interact with both cations and anions.

....

....

....

.... **[2]**

(ii) Explain, in terms of the three quantities: charge, ionic radius and extent of hydration, why ΔH_{hyd} for Mg^{2+} is more negative than ΔH_{hyd} for Na^+.

Note: *In this question 1 mark is available for the quality of written communication.*

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.... **[6]**

(iii) Name another enthalpy change which contributes to the enthalpy change of solution.

.... **[1]**

(c) Solubility is also controlled by the entropy change (ΔS) which accompanies solution.

(i) In terms of the number of ions per mole of each compound, explain why this entropy change would be expected to be more positive for $Mg(OH)_2$ than for NaOH.

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.... **[3]**

(ii) In terms of the arrangement of water molecules, explain why this entropy change would be expected to be more negative for $Mg(OH)_2$ than for NaOH.

....

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.... **[2]**

(iii) Name another entropy change which contributes to the total entropy change accompanying solution, and explain how it arises.

....

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.... **[2]**

Total 21 marks

3 New Zealand has no oilfields of its own and until recently relied completely on imported oil to meet its need for liquid fuels. The country does, however, have large reserves of natural gas (which is largely methane) and, since 1985, much of the petrol needed in New Zealand has been produced by chemical conversion of methane into liquid, hydrocarbon fuel.

The first stage in this process involves production of methanol from methane using the reactions in **Equations 3.1** and **3.2**. Data about these reactions are shown in **Table 3.1.**

$CH_4(g) + H_2O(l) \rightleftharpoons CO(g) + 3H_2(g)$ **Equation 3.1**

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ **Equation 3.2**

	Reaction 3.1	**Reaction 3.2**
Conditions:		
Temperature /K	1100	550
Pressure /atm	5	100
Catalyst	Nickel	Copper/zinc
$\Delta H_{reaction}$ /kJ mol^{-1}	+206	–128

Table 3.1

(a) Catalysts play a key role in increasing the rates of **Reactions 3.1 and 3.2**.

(i) State **two** other ways in which the conditions above are chosen to increase the rates of **Reactions 3.1 and 3.2**.

....

....

.... **[2]**

(ii) For **each** answer to **(a) (i)** explain why this choice of conditions leads to increased reaction rate.

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.... **[4]**

(b) The conditions used for **Reactions 3.1 and 3.2** are chosen to give optimum yields at equilibrium from these reactions. For each reaction, explain why the conditions of temperature and pressure chosen give an optimum yield of products.

***Note**: In this question 1 mark is available for the quality of written communication.*

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.... **[8]**

(c) In the second stage of the process, methanol is converted into a mixture of hydrocarbons by **Reactions 3.3 and 3.4**. (In **Equation 3.4**, the mixture of hydrocarbons (petrol) is represented by octene, C_8H_{16}.) The reactions take place at 600 K in the presence of a zeolite catalyst.

$2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g)$ **Equation 3.3**

$4CH_3OCH_3(g) \rightleftharpoons C_8H_{16}(g) + 4H_2O(g)$ **Equation 3.4**

(i) In the space below. write an expression for K_p for the equilibrium in **Equation 3.3** in terms of the partial pressures of the gases involved.

[2]

(ii) Under the conditions used in the industrial process, **Reaction 3.3** reaches equilibrium. Calculate the equilibrium partial pressure of methoxymethane (CH_3OCH_3) when the partial pressure of methanol at equilibrium is 0.142 atm.

(K_p = 9.00)

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.... **[3]**

(d) Zeolites are crystalline aluminosilicate materials with structures containing a network of linked channels through which molecules can pass. The channels restrict the size of the hydrocarbon molecules produced and their passage out of the zeolite.

In the zeolite used as a catalyst for **Reactions 3.3 and 3.4**, only molecules with up to 12 carbons atoms can be formed and pass through the channels. Despite this, up to 200 hydrocarbon compounds are present in the reaction product. This large number is due to the fact that, for most hydrocarbons, there are several ways in which the carbon and hydrogen atoms can be arranged for any given formula.

(i) Give **three** ways in which the arrangement of carbon and hydrogen atoms can give rise to different molecules of the same formula.

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.... **[3]**

(ii) Describe another industrial use for zeolites.

....

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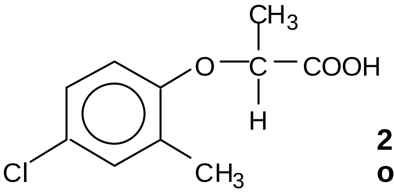
.... **[2]**

Total 24 marks

4 The compound *Mecoprop* is used as a herbicide. It is structurally similar to a number of other compounds which are also used as herbicides. One structural feature which these molecules share with *Mecoprop* is the presence of a chlorinated benzene ring.



2-(4-chloro-2-methylphenoxy)propanoic acid or *Mecoprop*

(a) **(i)** State the reagent(s) and conditions which can be used to substitute a chlorine atom into a benzene ring.

Reagent(s)..

....

Conditions..

....

.... **[3]**

(ii) It is usually necessary to use a catalyst in order to substitute a chlorine atom into a benzene ring. Explain the function of the catalyst in this process.

....

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.... **[3]**

Mecoprop and related herbicides are solids with very low solubilities in water. They are considerably more soluble in organic solvents such as ethyl ethanoate. However, drinking water in certain areas of the UK, has been found to be contaminated with traces of *Mecoprop* and other herbicides. The identities of the herbicides in a sample of water can be found by first extracting them into a solvent such as ethyl ethanoate, concentrating the solution formed and then analysing this solution.

(b) Describe, in outline, how you could take a sample of water containing dissolved herbicides and extract the herbicides into a solvent such as ethyl ethanoate (which is immiscible with, and less dense than water), and then concentrate the resulting solution.

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.... **[5]**

(c) One way to analyse the resulting solution is by gas-liquid chromatography (g.l.c.). Before a sample of this solution is injected into the column, it is treated with diazomethane to convert any carboxylic acid groups present into methyl esters.

(i) Suggest why the sample is treated in this way.

....

.... **[2]**

(ii) Draw out the full structural formula of the methyl ester produced from *Mecoprop*.

[2]

Total 15 marks

5 Is there life on Mars? The following experiment was designed to detect the presence of micro-organisms in Martian soil.

A solution of compounds, known to be nutrients for micro-organisms on Earth, was added to a sample of Martian soil. The compounds were labelled with ^{14}C, a radioactive isotope of carbon. If micro-organisms were present in the soil sample, they might metabolise the labelled compounds and break them down into small molecules, some of which would contain labelled carbon atoms.

(a) One of the compounds used was sodium 2-hydroxypropanoate (sodium lactate). This was made from a sample of 2-hydroxypropanoic acid in which each molecule contained a ^{14}C atom.

Molecules of this kind were not already available and had to be prepared from a source of ^{14}C by appropriate chemical reactions. One such source is ^{14}C-labelled cyanide ions, $^{14}CN^-$. A list of potentially useful reaction is given below (R represents an alkyl group).

$$RBr \xrightarrow{NH_3} RNH_2$$

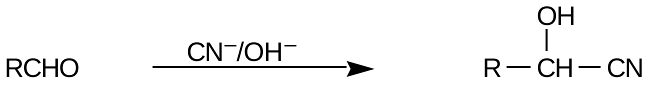
$$RBr \xrightarrow{OH^-} ROH$$

$$RBr \xrightarrow{CN^-} RCN$$

$$RNH_2 \xrightarrow{H^+/NO_2^-} ROH$$

$$RCN \xrightarrow{H_2/\text{Pt catalyst}} RCH_2NH_2$$

$$RCN \xrightarrow{H^+/H_2O} RCOOH$$



$$RCHO \xrightarrow{CN^-/OH^-} R-\overset{\overset{OH}{|}}{CH}-CN$$

$$RCHO \xrightarrow{H^+/Cr_2O_7^{2-}} RCOOH$$

$$RCH_2OH \xrightarrow{H^+/Cr_2O_7^{2-}} RCHO$$

(i) Choose reactions from this list to suggest a two-step route which could be used to prepare 2-hydroxypropanoic acid. Record your chosen route by completing the sequence below, writing reagents over the arrows as above. Label the carbon atoms which will be radioactive with an asterisk.

$$\xrightarrow[\textbf{Step 1}]{} \qquad\qquad \xrightarrow[\textbf{Step 2}]{} R-\overset{\overset{OH}{|}}{CH}-COOH$$

[4]

(ii) State the **type** of reaction mechanism for **Step 1** of your reaction sequence.

....

.... **[2]**

(b) The infra-red spectrum of the product of the reaction sequence was recorded to find out if a pure sample of 2-hydroxypropanoic acid had been successfully prepared. This spectrum is shown below in **Fig. 5.1**. (Data about characteristic infra-red absorptions are given in the Data Booklet which accompanies this paper.)

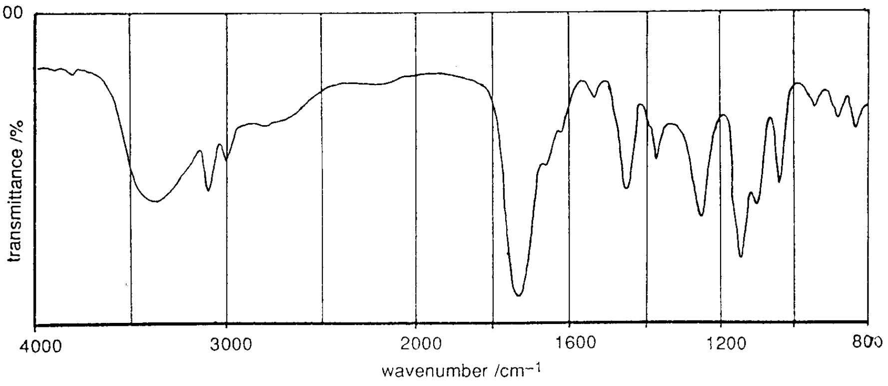


Fig. 5.1: Infra-red spectrum of the product of the reaction sequence

(i) Explain how the infra-red spectrum in **Fig. 5.1** shows that 2-hydroxypropanoic acid has been obtained.

....

....

.... **[2]**

(ii) Explain why the infra-red spectrum in **Fig. 5.1** cannot be used to show that the 2-hydroxypropanoic acid is free from traces of the organic compound used as the starting material in your synthesis sequence in **(a) (i)**.

....

....

....

....

.... **[3]**

(c) The proton n.m.r. spectrum of the product of the reaction sequence was recorded and is shown in **Fig. 5.2**.

(Data about proton n.m.r. chemical shifts are given in the Data Booklet which accompanies this paper.)

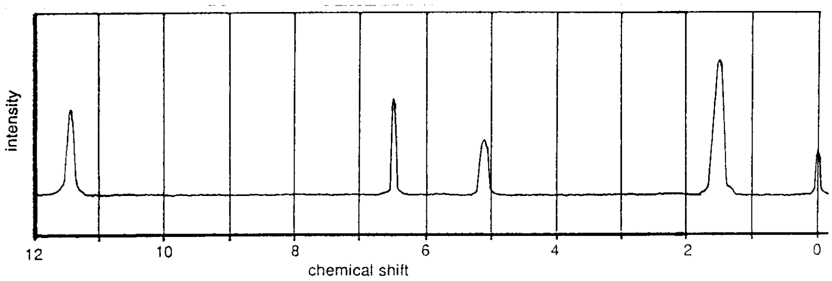


Fig. 5.2: Proton n.m.r. spectrum of the product of the reaction sequence

(i) As well as showing that 2-hydroxypropanoic acid has been obtained, the n.m.r. spectrum also shows that the reaction product is free from traces of starting material. Give a value for the chemical shift of one signal which is absent from this spectrum but which would be seen if traces of starting material were present. State the type of proton which would give rise to the signal you have chosen.

Chemical shift..

Type of proton.. **[2]**

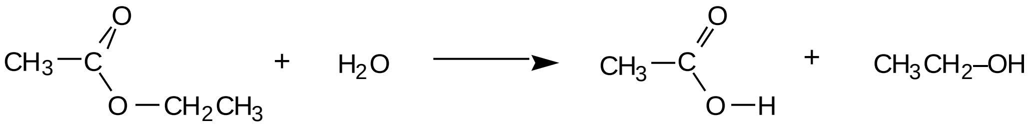
(ii) State why the signal at a chemical shift of 1.5 is larger than the other peaks in the spectrum.

....

.... **[2]**

(d) Isotopically labelled atoms are sometimes used as tracers to help work out the mechanism of a reaction. In one example of this technique, ^{18}O atoms have been used to decide which carbon-oxygen bond breaks when an ester is hydrolysed.

For the hydrolysis of ethyl ethanoate, shown below, indicate which atom in the ester molecule would be labelled with ^{18}O, and suggest what the researchers looked for in the products in order for them to make a decision.



$CH_3COOCH_2CH_3 + H_2O \longrightarrow CH_3COOH + CH_3CH_2\text{–}OH$

....

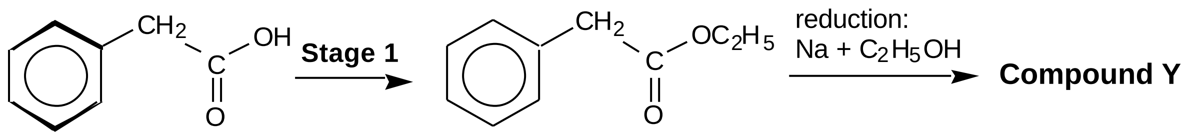
....

....

.... **[3]**

Total 18 marks

6 This question is about one of the compounds that contributes to the smell of roses, carnations, hyacinths and many other flowers. It is widely used in perfumery, and it is the basis of all rose-smelling perfumes. The substance, called **Compound Y** in this question, can be synthesised from phenylethanoic acid by the sequence of reactions shown below.



phenylethanoic acid **ethyl phenylethanoate**

(a) High resolution mass spectrometry shows that the accurate relative molecular mass of **Compound Y** is 122.08. Three possible molecular formulae for **Compound Y**, with masses close to this value, are $C_7H_6O_2$, $C_8H_{10}O$ and C_9H_{14}.

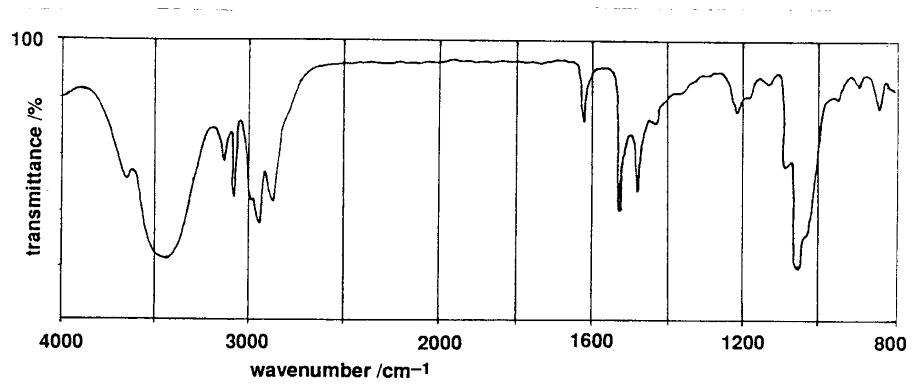
Accurate relative masses for the most abundant isotopes of carbon, hydrogen and oxygen are:

$$H = 1.008,\ C = 12.000,\ O = 15.995.$$

In the space which follows, show how these isotope masses can be used to determine which of the three possibilities is the molecular formula of **Compound Y**.

[2]

(b) The infra-red spectrum of **Compound Y** is shown below. (A table of characteristic infra-red absorptions is given in the Data Booklet which accompanies this paper.)



Use information about infra-red absorptions in the Data Booklet, together with your answer in **(a)** to identify **Compound Y**. Write down the name and structural formula of **Compound Y** in the space below and explain your reasoning.

Name: ....

Structural formula:

Reasoning:

....

....

....

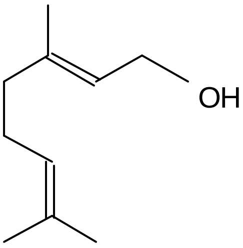
.... **[4]**

(c) State the reagents and conditions needed to carry out **Stage 1** of the reaction sequence.

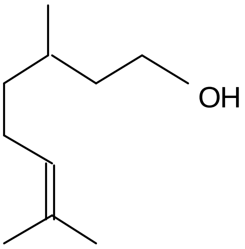
Reagents :..

Conditions :.. **[2]**

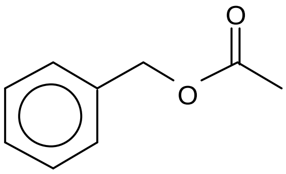
(d) It is thought that the sensation of smell is triggered by molecules which fit into smell receptors in the nose. There are probably several types of smell receptor, each type having a particular shape and containing particular chemical groups. The structures of three compounds, which have floral smells similar to **Compound Y**, are shown below.



geraniol:
geranium, roses



citronellol:
lillies



benzyl ethanoate:
jasmine

In the space below, use words and/or structures to suggest which common features, possessed by the molecules of these three compounds and **Compound Y**, could be responsible for their similar smells.

[2]

(e) Compare the structure of ethyl phenylethanoate with the structures of the compounds in **(d)**, and decide whether or not you would expect ethyl phenylethanoate also to have a floral smell. Explain your decision.

....

....

....**[2]**

Total 12 marks

7 The pH of blood is maintained in healthy individuals by various buffering systems. One of the most important systems contains carbon dioxide, CO_2, and hydrogencarbonate ions, HCO_3^-, linked by the reaction:

$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ **Equation 7.1**

K_a for this reaction has the value of 4.5×10^{-7} mol dm^{-3} at the temperature in the body.

(a) **(i)** Give the mathematical definition of pH.

[1]

(ii) Write the expression for K_a for the equilibrium shown in **Equation 7.1** in terms of the concentrations of $CO_2(aq)$, $H^+(aq)$ and $HCO_3^-(aq)$.

[2]

(b) In the blood of a healthy person:

$[HCO_3^-(aq)] = 2.5 \times 10^{-2}$ mol dm^{-3}

*(This comes from other processes as well as **Equation 7.1**)*

$[CO_2(aq)] = 1.25 \times 10^{-3}$ mol dm^{-3}

(i) Use this data, your answer to **(a) (ii)** and the value of K_a to calculate the concentration of H^+ ions in the blood of a healthy person.

[2]

(ii) Calculate the pH of the blood of a healthy person.

[1]

(c) Use **Equation 7.1** and the information in **(b)** to explain how blood acts as a buffer solution.

$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ **Equation 7.1**

***Note**: In this question 1 mark is available for the quality of written communication.*

....

....

....

....

....

....

.... **[5]**

(d) The equilibrium reaction in **Equation 7.1** plays a dual role in controlling the acidity of the oceans and controlling the concentration of carbon dioxide in the atmosphere.

Write two further equations, with state symbols, to show how dissolved carbon dioxide in the oceans can be converted to calcium carbonate in sea shells.

....

.... **[2]**

Total 13 marks

Oxford Cambridge and RSA Examinations

Advanced GCE

CHEMISTRY (SALTERS)
CHEMISTRY BY DESIGN **2854**

Mark Scheme

1 **(a)** Solution of dichromate(VI) ions reflects orange light/ ~600 nm [1 mark]

and absorbs blue/blue-violet light /~440 nm [1 mark]

Answer must make clear that by using this wavelength the measurement is more accurate, only the light which is changing in intensity is being detected [1 mark]

[3 marks]

(b) Electrons can only occupy definite energy levels [1 mark]

Energy equal to the difference between energy levels is transferred to electrons from light [1 mark]

The energy transferred is proportional to the frequency of the light absorbed [1 mark]

[3 marks]

(c) Measure the absorbances of a number of solutions of dichromate(VI)ions [1 mark]

to which different amounts of ethanol have been added [1 mark]

[2 marks]

(d) An absorbance change of 0.45 corresponds to 103×10^{-6} mol of ethanol added [1 mark]

103×10^{-6} mol in 50×10^{-6} dm^3 is equivalent to a concentration of 2.06 mol dm^{-3} [1 mark]

2.06 mol dm^{-3} = 94.8 g dm^{-3} [1 mark]

94.8 g dm^{-3} corresponds to 120 cm^3 dm^{-3} [1 mark]

Therefore, wine is 12% ethanol **[4 marks]**

(e) Reduction of dichromate(VI) ions:

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

$2Cr^{3+} + 7H_2O$ [1 mark]

$H^+ + e^-$ on RHS equation [1 mark]

Correct balanced equation [1 mark]

Overall equation:

$$3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

Attempt to combine the two half-equations and with no electrons in the overall equation [1 mark]

Correct equation [1 mark]

[5 marks]

Total 17 marks

2 **(a)** **(i)** Answer must mention the explosive combustion of hydrogen [1 mark]

the role of the very hot material in starting combustion [1 mark]

and the fact that hydrogen could not escape [1 mark]

[3 marks]

(ii) $\Delta H^\ominus = 2\Delta H_f^\ominus \text{ (NaOH)} - 2\Delta H_f^\ominus \text{ (}H_2O\text{)}$ [1 mark]

$= -368 \text{ kJ}$ [1 mark]

[2 marks]

(b) **(i)** Diagram to show correct polarity of water molecule [1 mark]

Correctly assigned interaction with cation and anion [1 mark]

[2 marks]

(ii) More negative value means stronger bonding between cations and water molecules [1 mark]

Stronger bonding arises with higher ionic charge [1 mark]

and smaller ionic radius [1 mark]

Correct comparison of Mg^{2+} and Na^+ in terms of charge and size [1 mark]

Reference to greater number of water molecules bonded to Mg^{2+} than to Na^+ [1 mark]

Quality of written communication: a minimum of 2 linked sentences, presenting a logical argument in which scientific terms such as, *ion, charge, ionic radius* and *hydration*, are used correctly [1 mark]

[6 marks]

(iii) Lattice enthalpy **[1 mark]**

(c) **(i)** 1 mol of $Mg(OH)_2$ produces 3 mol of ions compared with 2 mol of ions from NaOH [1 mark]

More disorder is associated with 3 mol of dissolved ions than with 2 mol

Or there are more ways of arranging 3 mol of ions than 2 mol [1 mark]

Entropy increases with disorder (*or* with number of arrangements) [1 mark]

[3 marks]

(ii) More water molecules become attached to Mg^{2+} than to Na^{+} [1 mark]

resulting in fewer free water molecules (or causing a greater loss of disorder or smaller increase in disorder) [1 mark]

[2 marks]

(iii) Entropy change in the surroundings [1 mark]

Resulting from heating or cooling by the reaction [1 mark]

[2 marks]

Total 21 marks

3 **(a)** **(i)** High pressure [1 mark]

High temperature [1 mark]

[2 marks]

(ii) Higher pressure pushes the molecules closer together [1 mark]

leading to more frequent collisions [1 mark]

Higher temperature gives a larger percentage of collisions/molecules [1 mark]

with energy in excess of the activation enthalpy for the reaction [1 mark]

[4 marks]

(b) *7 marks for 7 of the following eight points:*

For **Reaction 3.1**, equal numbers of molecules on each side of equation, so pressure has no effect on the yield at equilibrium [1 mark]

Reaction is endothermic, so increase in temperature causes position of equilibrium to move to right to oppose temperature increase [1 mark]

so high temperature used to increase yield of products [1 mark]

High temperatures are expensive, so optimum temperature chosen [1 mark]

Reaction 3.2 leads to a reduction in the number of molecules [1 mark]

so high pressure causes position of equilibrium to move to right to oppose the pressure increase [1 mark]

Reaction is exothermic, so increase in temperature causes postion of equilibrium to move to left to oppose temperature increase [1 mark]

and optimum temperature chosen to give reasonable rate [1 mark]

Quality of written communication: a series of more than 2 linked sentences, presenting a clear and logical argument in which scientific terms such as, yield, rate, equilibrium, temperature and pressure, are used correctly [1 mark]

[8 marks]

(c) **(i)** $K_p = \frac{p_{CH_3OCH_3} \times p_{H_2O}}{(p_{CH_3OH})^2}$

correct partial pressures including squared quantity [1 mark]

correct way up [1 mark]

[2 marks]

(ii) At equilibrium, partial pressure of CH_3OCH_3 equals that of H_2O [1 mark]

(Partial pressure of $CH_3OCH_3)^2$ = 9.00 x $(0.142)^2$ [1 mark]

Partial pressure of CH_3OCH_3 = 0.426 atm [1 mark]

[3 marks]

(d) **(i)** *Three marks for 3 of the following five points:*

Atoms can be arranged in chains or rings
Molecules can contain double bonds or benzene rings
Chain isomerism can occur
Geometric / *cis-trans* isomerism can occur
Optical isomers can exist **[3 marks]**

(ii) Name *or* description of process [1 mark]

description of use [1 mark]

(for example, cracking of hydrocarbons; acts as a catalyst and/or as a molecular sieve)

[2 marks]

Total 24 marks

4 **(a)** **(i)** **Reagent:** chlorine [1 mark]

Conditions: aluminium chloride (*or* $FeCl_3$ or ICl_3) [1 mark]

Anhydrous *(must be stated as condition or in name of substance)* [1 mark]

(Allow aluminium chloride as reagent or catalyst; allow formula) **[3 marks]**

(ii) Catalyst polarises [1 mark]

chlorine molecules to produce positively charged Cl

(either δ+ on molecule or whole + ion) [1 mark]

which are attacked by electrons [1 mark]

of benzene ring.

(Allow 'react with' or 'act as electrophile', but not 'attract' in place of 'attack') **[3 marks]**

(b) Shake the water sample containing the herbicides with ethyl ethanoate (*or* other extracting solvent) [1 mark]

Use large volume of water to small volume of organic solvent [1 mark]

Retain upper layer [1 mark]

Use of separating funnel [1 mark]

Evaporate organic layer to concentrate [1 mark]

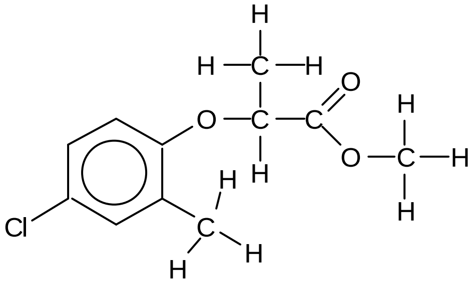
[5 marks]

(c) **(i)** Ester will have lower boiling point/be more volatile than the acid [1 mark]

and so will have a shorter retention time on the column (*or* produce a sharper peak) [1 mark]

[2 marks]

(ii)



correct stucture of methyl ester [1 mark]

rest of molecule [1 mark]

[2 marks]

Total 15 marks

5 **(a)** **(i)** Step 1: R-CHO with CN^-/OH^- [1 mark]

Step 2: RCN with H^+/H_2O [1 mark]

In this case, R = CH_3 [1 mark]

(If no conditions given over arrows, allow one out of two marks for steps 1 and 2; allow 1 mark if step 2 correctly gives final product but step 1 is wrong)

Asterisk on –*CN and –*COOH groups [1 mark]

[4 marks]

(ii) Nucleophilic [1 mark]

addition (*allow ecf)* [1 mark]

[2 marks]

(b) **(i)** Correct wave number of peak chosen (even if second mark lost) [1 mark]

Bond chosen that gives a peak which would indicate that 2-hydroxypropanaoic acid had formed (so, –OH must be chosen if starting material contains –C=O) [1 mark]

(Mark consequentially, so if starting material is R–Br, a mark could be gained by chosing –C=O) **[2 marks]**

(ii) Two marks for indicating the general point that both compounds [1 mark]

will have similar spectra *(or equivalent; for example,* starting material has same peaks as product) [1 mark]

specifying a peak for which there would be overlap [1 mark]

(Mark consequentially. Therefore, for the correct reaction sequence, the mark is gained for the –C=O peak ; if the sequence starts with an –OH compound, the mark would be gained by the –OH peak, etc.) **[3 marks]**

(c) **(i)** Chemical shift: 9.5 [1 mark]

Type of proton: H in –CHO [1 mark]

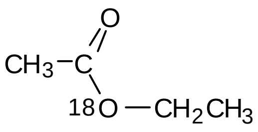
(or chemical shift of 2.3 from $CH_3C=O$) **[2 marks]**

(ii) Arises from 3 protons [1 mark]

whereas other peaks from single protons [1 mark]

[2 marks]

(d)



[1 mark]

If label in acid product, the O–CH_2 bond must have broken [1 mark]

If label in alcohol product, the C–O bond must have broken [1 mark]

[3 marks]

Total 18 marks

6 **(a)** Molecular mass of correct compound must be calculated with **at least** one other to provide check [1 mark]

(Values are $C_8H_{10}O$ = 122.075, $C_7H_6O_2$ = 122.038, C_9H_{14} = 122.112)

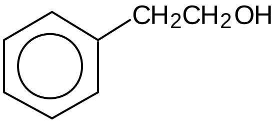
Comment that $C_8H_{10}O$ is Compound Y because its mass is closest to mass spectrum value [1 mark]

[2 marks]

(b) **Name:** 2-phenylethanol *(or satisfactory alternative containing number 2)* [1 mark]

(Score 1 mark for correct name of incorrect structure)

Structure:



[1 mark]

(Score 1 mark if incorrect structure fits the molecular formula $C_8H_{10}O$ and is a stable compound)

Reasoning:

The i.r. spectrum shows no C=O absorption around 1700 cm^{-1} [1 mark]

but shows strong –OH absorption, broad peak at about 3450 cm^{-1} [1 mark]

[4 marks]

(c) **Reagents:** Ethanol (*or* formula)

Conditions: Heat (under reflux) [1 mark]

with conc sulphuric acid [1 mark]

[2 marks]

(d) There needs to be a large hydrocarbon unit capable of adopting a shape like a hexagonal ring [1 mark]

Also, a short side-chain containing an electronegative atom such as oxygen (or a $-CH_2O-$ side-chain) [1 mark]

[2 marks]

(e) *Either:*

It would have a floral smell because a hexagonal ring plus a short side-chain and electronegative atom are present

or

It would not have a floral smell because there is no $–CH_2O–$ side-chain

(i.e. pointing out a structural difference and making a decision about smell from it) **[2 marks]**

Total 12 marks

7 **(a)** **(i)** $pH = –\log_{10}[H^+]$ [1 mark]

($\log_{10}$ may be replaced by lg or log; $[H^+]$ my be replaced by $[H_3O^+]$) **[1 mark]**

(ii)
$$\frac{[H^+(aq)] \times [HCO_3^-(aq)]}{[CO_2(aq)]}$$

top line correct [1 mark]

whole expression [1 mark]

[2 marks]

(**b**) **(i)** $[H^+] = (1.25\text{x}10^{-3}\text{ mol dm}^{-3}) \text{ x } (4.5\text{x}10^{-7}\text{ mol dm}^{-3}) / 2.5\text{x}10^{-2}\text{ mol dm}^{-3}$ [1 mark]

$= 2.3 \text{ x } 10^{-8}\text{ mol dm}^{-3}$ [1 mark]

[2 marks]

(ii) pH = 7.6 **[1 mark]**

(c) On addition of small amounts of H^+ ions, react with HCO_3^- ions to form CO_2 and H_2O [1 mark]

Large excess of HCO_3^- ions [1 mark]

On addition of small amounts OH^- ions, react with H^+ ions to form H_2O [1 mark]

More CO_2 and H_2O react to replace H^+ ions removed [1 mark]

Quality of written communication: a minimum of 2 linked sentences, presenting a logical explanation based on Equation 7.1 which shows that the meaning of the term ‘buffer’ is understood [1 mark]

[5 marks]

(d) $HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$ [1 mark]

$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s)$ [1 mark]

[2 marks]

Total 13 marks

Assessment Grid: Unit 2854

Question	**Teaching module**				**Core coverage**	**AO1**		**AO4**		**Total marks**
	Unit 2850	**Unit 2851**	**Unit 2853**	**Unit 2854**		**Coverage**	**Marks**	**Coverage**	**Marks**	
1 (a)	-	-	SS2(d)(e)	-	3.14.1	1a	3	-	-	3
(b)	EL2(h)	A2(c)(d)	-	CD2(a)	3.14.1	1a, 1c	3	-	-	3
(c)	-	-	SS2(e)	-	3.14.1	-	-	4b	2	2
(d)	-	M2(a)	SS2(e)	-	3.5.2	-	-	4b	4	4
(e)	-	M2(p)	SS2(q)	-	3.11.2	-	-	4b	5	5
2 (a) (i)	DF2(b)	A2(i)	-	AA2(n);VCI 2(c)	3.12.4	-	-	4a	3	3
(ii)	DF2(e)	-	-	-	3.8.2	-	-	4b	2	2
(b) (i)	-	M2(q);PR2(m)	-	-	-	1a, 1c	2	-	-	2
(ii)	DF(f)(h)	-	-	AA2(h);O2(e)	-	-	-	4a	6*	6
(iii)	-	-	-	O2(c)	3.8.3	1a	1	-	-	1
(c) (i)	DF2(y)	-	-	O2(h)	-	-	-	4a	3	3
(ii)	DF2(y)	-	-	O2(h)	-	-	-	4a	2	2
(iii)	-	-	-	O2(h)(i)	-	1a	2	-	-	2
3 (a) (i)	-	A2(i)	-	-	3.9.1	-	-	4a	2	2
(ii)	-	A2(i)(j)(k)	-	-	3.9.1	1b, 1c	4	-	-	4
(b)	-	A2(hh)	-	AA2(k);VCI 2(c)	3.10.1	-	-	4a	8*	8
(c) (i)	-	-	-	AA2(l)	3.10.2	1a	2	-	-	2
(ii)	-	-	-	AA2(m)	3.10.2	-	-	4b	3	3
(d) (i)	DF2(i)(l)	PR2(f)	EP2(f)	-	3.13.1	-	-	4a	3	3
(ii)	DF2(x)	-	-	VCI 2(b)	-	-	-	4a	2	2
					-	-	-	-	-	-

Question	**Teaching module**				**Core coverage**	**AO1**		**AO4**		**Total marks**
	Unit 2850	**Unit 2851**	**Unit 2853**	**Unit 2854**		**Coverage**	**Marks**	**Coverage**	**Marks**	
4 (a) (i)	-	-	-	CD2(l)	3.13.7	1a	3	-	-	3
(ii)	-	-	-	CD2(l)	3.13.5	1c	3	-	-	3
(b)	-	A2(t)	-	AA2(q)	-	-	-	4a	5*	5
(c) (i)	-	WM2(d)	DP2(d)	CD2(e)(f)	-	-	-	4a	2	2
(ii)	-	WM2(d)	DP2(d)	-	-	-	-	4b	2	2
5 (a) (i)	-	A2(v);WM2(d)	-	MD2(j)	3.13.7	-	-	4a	4	4
(ii)	-	-	-	MD2(c)	3.13.5	1a	2	-	-	2
(b) (i)	-	WM2(k)	-	-	3.14.1	-	-	4a	2	2
(ii)	-	WM2(k)	-	-	3.14.1	-	-	4a	3	3
(c) (i)	-	-	EP2(j)	-	3.14.1	-	-	4a	2	2
(ii)	-	-	EP2(j)	-	3.14.1	-	-	4a	2	2
(d)	EL2(c)(m)		DP2(e)	-	-	-	-	4a	3	3
6 (a)	-	WM2(j)	-	-	3.5.1	-	-	4b	2	2
(b)	DF2(n)	WM2(j)(k)	-	MD2(m)	3.14.1	-	-	4a/b	4	4
(c)	-	-	DP2(d)	MD2(j)	3.13.7	1a	2	-	-	2
(d)	DF2(i)(n)(o)	WM2(b)	-	MD2(e)(f)	-	-	-	4a/b	2	2
(e)	-	-	-	MD2(e)	-	-	-	4a	2	2
7 (a) (i)	-	-	-	O2(m)	3.10.3	1a	1	-	-	1
(ii)	-	-	-	O2(p)	3.10.4	1a	2	-	-	2
(b) (i)	-	A2(gg)	-	O2(q)	3.10.4	-	-	4b	2	2
(ii)	-	A2(gg)	-	O2(q)(t)	3.10.4	-	-	4b	1	1
(c)	-	A2(gg)	-	O2(r)	3.10.4	-	-	4a	5*	5
(d)	-	M2(p)	-	O2(x)	-	-	-	4a	2	2
Total							**30**		**90**	**120**

Breakdown of marks

Quantitative questions:	14 marks	(12%)
Equations:	7 marks	(6%)
Structures and structural formulae:	11 marks	(9%)
Techniques:	7 marks	(6%)
Spectroscopy:	11 marks	(9%)
Organic synthesis:	9 marks	(7.5%)
Organic reactions mechanisms:	8 marks	(7%)
*Extended writing:	24 marks	(20%)
Quality of written communication:	3 marks	(AO4)