International Baccalaureate®
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CHEMISTRY
STANDARD LEVEL
PAPER 1

SPECIMEN PAPER

45 minutes

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is *[30 marks]*.

The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01				Atomic number **Element** Relative atomic mass													2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.90
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
6	55 **Cs** 132.91	56 **Ba** 137.33	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (269)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (281)	112 **Cn** (285)	113 **Unt** (286)	114 **Uug** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. What is the total number of atoms in 0.50 mol of 1,4-diaminobenzene, $H_2NC_6H_4NH_2$? (Avogadro's constant (L or N_A) = 6.0×10^{23} mol^{-1}.)

A. 16.0×10^{23}

B. 48.0×10^{23}

C. 96.0×10^{23}

D. 192.0×10^{23}

2. What is the sum of the coefficients when the equation for the combustion of ammonia is balanced using the smallest possible whole numbers?

$$\_\_\_\ NH_3(g) + \_\_\_\ O_2(g) \rightarrow \_\_\_\ N_2(g) + \_\_\_\ H_2O(g)$$

A. 6

B. 12

C. 14

D. 15

3. Which changes of state are endothermic processes?

I. Condensing

II. Melting

III. Subliming

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

4. 5.00 g of calcium carbonate, when heated, produced 2.40 g of calcium oxide. Which is the correct expression for the percentage yield of calcium oxide? ($M_r(CaCO_3) = 100; M_r(CaO) = 56$.)

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

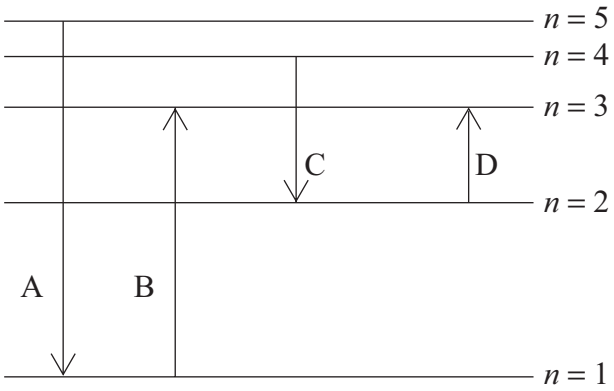
A. $\dfrac{56 \times 5.00 \times 100}{2.40}$

B. $\dfrac{2.40 \times 100 \times 100}{56 \times 5.00}$

C. $\dfrac{56 \times 5.00 \times 100}{2.40 \times 100}$

D. $\dfrac{2.40 \times 100}{56 \times 5.00}$

5. Which electronic transition would absorb the radiation of the shortest wavelength?



6. What are the numbers of protons, neutrons and electrons in the ion $^{238}_{92}X^{2+}$?

	Protons	Neutrons	Electrons
A.	146	92	144
B.	92	146	90
C.	92	146	94
D.	92	238	90

7. Which element is in the f-block of the periodic table?

A. Be

B. Ce

C. Ge

D. Re

8. Which property increases down group 1 of the periodic table?

A. Melting point

B. First ionization energy

C. Atomic radius

D. Electronegativity

9. Which is the best description of ionic bonding?

A. Electrostatic attraction between oppositely charged ions

B. Electrostatic attraction between positive ions and electrons

C. Electrostatic attraction of nuclei towards shared electrons in the bond between the nuclei

D. Electrostatic attraction between nuclei

10. Which has bonds with the greatest covalent character?

A. $SrCl_2$

B. $SiCl_4$

C. $SnCl_2$

D. Sn

11. Which bond is the **least** polar?

A. C=O in CO_2

B. C–H in CH_4

C. C–Cl in CCl_4

D. N–H in CH_3NH_2

12. Which substance has a high melting point and does not conduct electricity in any state?

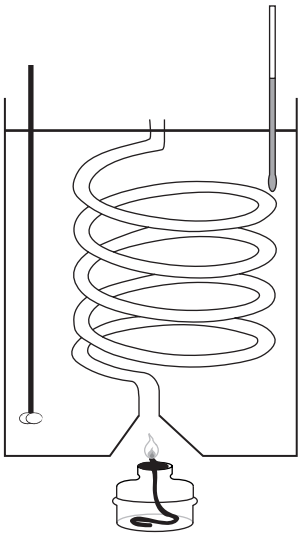
A. $PbBr_2$

B. Fe

C. NaCl

D. SiO_2

13. When 0.46 g of ethanol is burned under a water-filled calorimeter, the temperature of 500 g of water is raised by 3.0 K. (Molar mass of ethanol = 46 g mol^{-1}; specific heat capacity of water = 4.18 J g^{-1} K^{-1}; $q = mc\Delta T$.)



What is the expression for the enthalpy of combustion, ΔH_c, in kJ mol^{-1}?

A. $-\dfrac{500\times4.18\times3.0\times46}{0.46}$

B. $-\dfrac{500\times4.18\times(273+3.0)\times46}{0.46\times1000}$

C. $-\dfrac{500\times4.18\times3.0\times46}{0.46\times1000}$

D. $-\dfrac{0.46\times1000}{500\times4.18\times3.0\times46}$

14. Which reaction represents the average bond enthalpy of the C–H bond?

A. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + \frac{1}{2}H_2(g)$

B. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}CH_2(g) + \frac{1}{4}H_2(g)$

C. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + H(g)$

D. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(s) + H(g)$

15. Given the following information, what is the standard enthalpy of formation, $\Delta H^{\ominus}_{f}$, of methane?

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = E \text{ kJ}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H = F \text{ kJ}$$
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = G \text{ kJ}$$

A. E + F + G

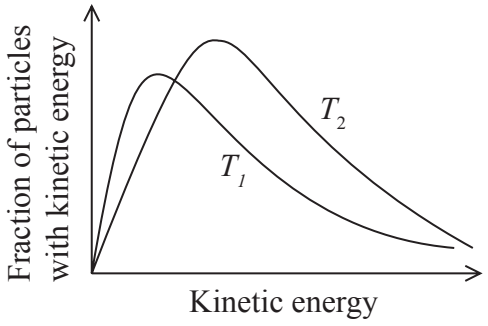
B. E + F – G

C. E + 2F + G

D. E + 2F – G

16. Which graph shows the Maxwell-Boltzmann energy distribution of a same amount of a gas at two temperatures, where T_2 is greater than T_1?

A.



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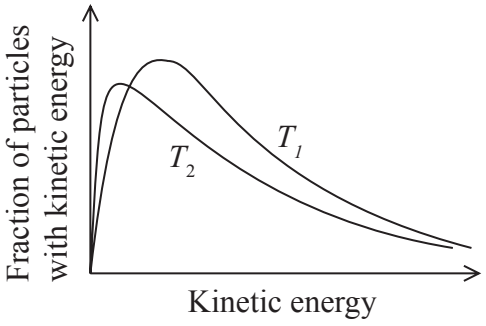

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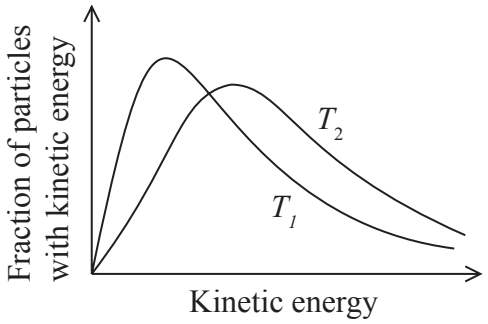
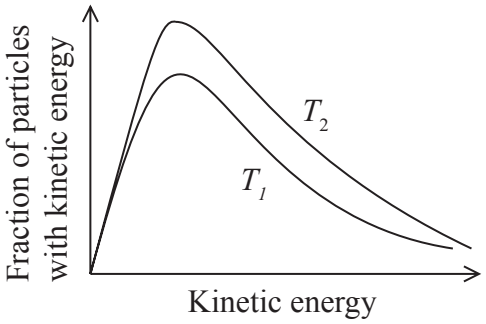


D.



17. Which changes increase the rate of this reaction, other conditions remaining constant?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

I. Using larger lumps of calcium carbonate

II. Increasing the temperature of the reaction mixture

III. Increasing the concentration of hydrochloric acid

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

18. Which conditions give the greatest equilibrium yield of methanal, $H_2CO(g)$?

$$CO(g) + H_2(g) \rightleftharpoons H_2CO(g) \qquad \Delta H = -1.8\,kJ$$

	Pressure	Temperature
A.	high	low
B.	high	high
C.	low	high
D.	low	low

19. Which of the following is **not** amphiprotic?

A. H_2O

B. HPO_4^{2-}

C. $H_2PO_4^-$

D. H_3O^+

20. Which compound will react with dilute hydrochloric acid, $HCl(aq)$, to give off a gas?

A. $Cu_2O(s)$

B. $Cu(OH)_2(s)$

C. $CuCO_3(s)$

D. $CuO(s)$

21. The equations below represent reactions involved in the Winkler method for determining the concentration of dissolved oxygen in water:

$$2Mn(OH)_2(s) + O_2(aq) \rightarrow 2MnO(OH)_2(s)$$
$$MnO(OH)_2(s) + 2H_2SO_4(aq) \rightarrow Mn(SO_4)_2(s) + 3H_2O(l)$$
$$Mn(SO_4)_2(s) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2SO_4{}^{2-}(aq)$$
$$2S_2O_3{}^{2-}(aq) + I_2(aq) \rightarrow S_4O_6{}^{2-}(aq) + 2I^-(aq)$$

What is the amount, in mol, of thiosulfate ions, $S_2O_3{}^{2-}(aq)$, needed to react with the iodine, $I_2(aq)$, formed by 1.00 mol of dissolved oxygen?

A. 2.00

B. 3.00

C. 4.00

D. 6.00

22. What are the products when molten sodium chloride is electrolysed?

	Cathode	**Anode**
A.	hydrogen	chlorine
B.	sodium	chloride
C.	sodium	chlorine
D.	chlorine	sodium

23. Which is propyl propanoate?

A. $CH_3CH_2CH_2OOCCH_2CH_3$

B. $CH_3CH_2CH_2COOCH_2CH_3$

C. $CH_3CH_2CH_2COCH_2CH_3$

D. $CH_3CH_2CH_2OCH_2CH_2CH_3$

24. Which are consecutive members of a homologous series?

A. CH_4, CH_3Cl, CH_2Cl_2

B. HCOOH, CH_3COOH, C_2H_5COOH

C. C_2H_2, C_2H_4, C_2H_6

D. HCOOH, HCHO, CH_3OH

25. Which could form an addition polymer?

A. $H_2NCH_2CHCHCH_2NH_2$

B. $H_2N(CH_2)_6CO_2H$

C. $HO(CH_2)_2CO_2H$

D. $H_2N(CH_2)_6NH_2$

26. A compound decolorizes bromine water in the dark. Which statement is correct?

A. It contains C=C and is an alkene.

B. It contains C–C and is an alkene.

C. It contains C=C and is an alkane.

D. It contains C–C and is an alkane.

27. How can a systematic error be minimized?

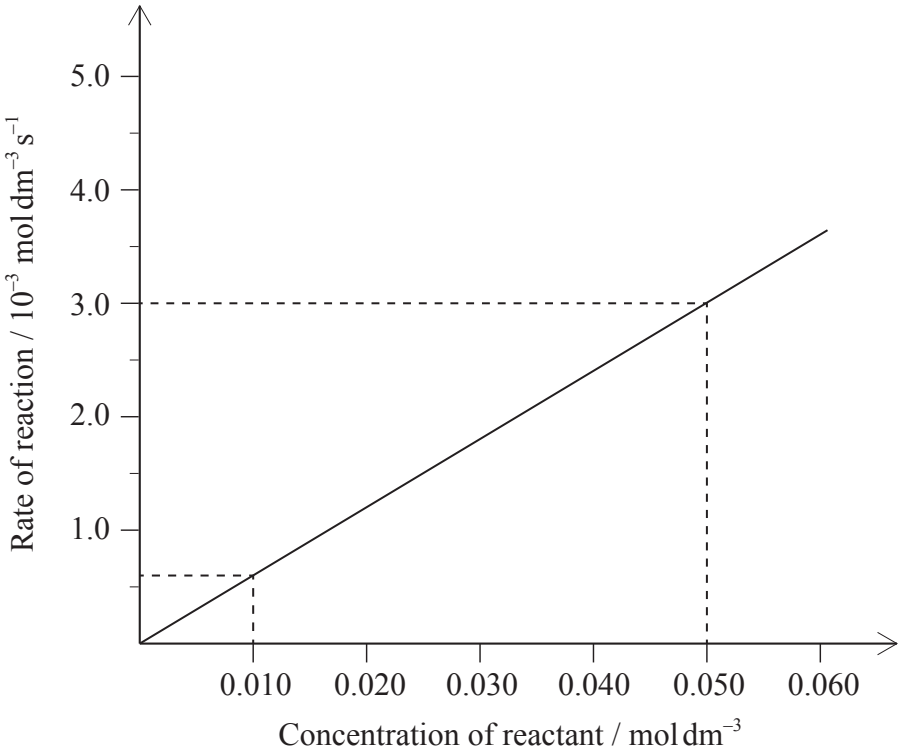
A. By taking the reading many times

B. By repeating the experiment many times

C. By using a more accurate measuring device

D. By evaluating and modifying the method

28. Which combination in the table correctly states the value and units of the gradient?



	Value	Units
A.	$\frac{3.0\times10^{-3}-0.6\times10^{-3}}{0.050-0.010}$	s^{-1}
B.	$\frac{3.0\times10^{-3}-0.6\times10^{-3}}{0.050-0.010}$	s
C.	$\frac{0.050-0.010}{3.0\times10^{-3}-0.6\times10^{-3}}$	s^{-1}
D.	$\frac{0.050-0.010}{3.0\times10^{-3}-0.6\times10^{-3}}$	s

29. Which part of the electromagnetic spectrum is used by ^{1}H NMR spectroscopy?

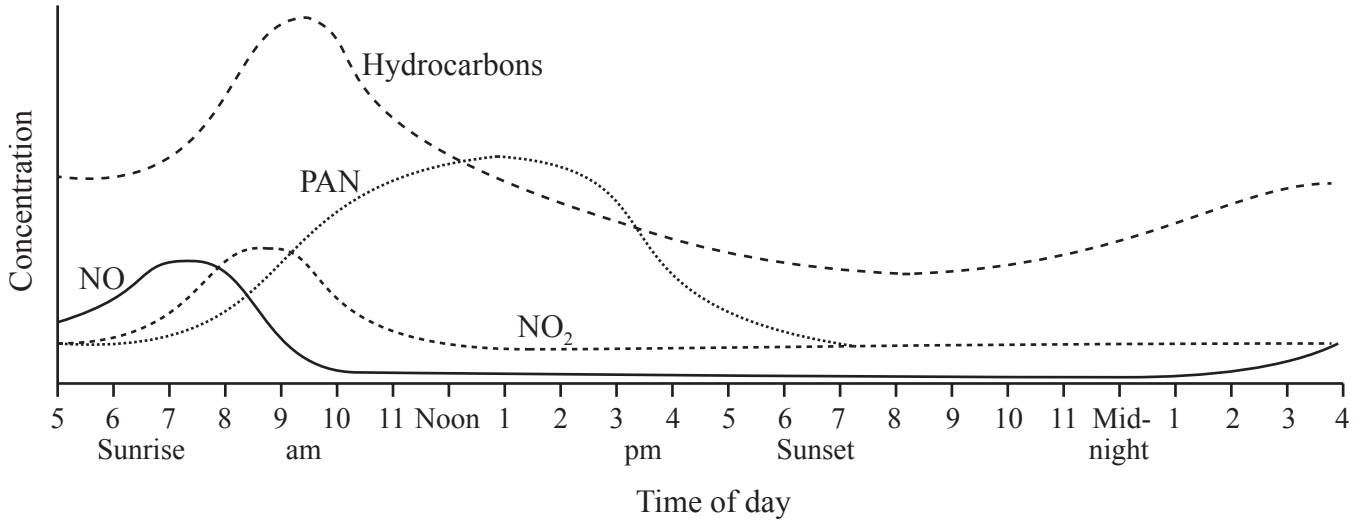
A. γ rays

B. X-rays

C. Microwaves

D. Radio waves

30. The graph shows the concentration of some pollutants in a city over a 24-hour period.



Which of the following could **not** be inferred from the graph?

A. Hydrocarbons cause less harm to health than PAN.

B. An increase in hydrocarbons is caused by the morning rush hour.

C. PAN concentration increases as the intensity of sunlight increases.

D. NO_2 production follows the production of NO.

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MARKSCHEME

SPECIMEN PAPER

CHEMISTRY

Standard Level

Paper 1

2 pages

1.	B	16.	C	31.	–	46.	–
2.	D	17.	C	32.	–	47.	–
3.	C	18.	A	33.	–	48.	–
4.	B	19.	D	34.	–	49.	–
5.	B	20.	C	35.	–	50.	–
6.	B	21.	C	36.	–	51.	–
7.	B	22.	C	37.	–	52.	–
8.	C	23.	A	38.	–	53.	–
9.	A	24.	B	39.	–	54.	–
10.	B	25.	A	40.	–	55.	–
11.	B	26.	A	41.	–	56.	–
12.	D	27.	D	42.	–	57.	–
13.	C	28.	A	43.	–	58.	–
14.	C	29.	D	44.	–	59.	–
15.	D	30.	A	45.	–	60.	–

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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

SPECIMEN PAPER

Examination code

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the *Chemistry data booklet* is required for this paper.
- The maximum mark for this examination paper is *[50 marks]*.

*Answer **all** questions. Write your answers in the boxes provided.*

1. Two IB students carried out a project on the chemistry of bleach.

(a) The bleach contained a solution of sodium hypochlorite, NaClO(aq). The students determined experimentally the concentration of hypochlorite ions, ClO^-, in the bleach.

Experimental procedure:

- The bleach solution was first diluted by adding 25.00 cm^3 of the bleach to a 250 cm^3 volumetric flask. The solution was filled to the graduation mark with deionized water.

- 25.00 cm^3 of this solution was then reacted with excess iodide in acid.

$$ClO^-(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow Cl^-(aq) + I_2(aq) + H_2O(l)$$

- The iodine formed was titrated with 0.100 mol dm^{-3} sodium thiosulfate solution, $Na_2S_2O_3(aq)$, using starch indicator.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The following data were recorded for the titration:

	First titre	**Second titre**	**Third titre**
Final burette reading of 0.100 mol dm^{-3} $Na_2S_2O_3(aq)$ (in $cm^3 \pm 0.05$)	23.95	46.00	22.15
Initial burette reading of 0.100 mol dm^{-3} $Na_2S_2O_3(aq)$ (in $cm^3 \pm 0.05$)	0.00	23.95	0.00

(i) Calculate the volume, in cm^3, of 0.100 mol dm^{-3} $Na_2S_2O_3(aq)$ required to react with the iodine to reach the end point. *[1]*

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(ii) Calculate the amount, in mol, of $Na_2S_2O_3(aq)$ that reacts with the iodine. *[1]*

. . . . . .
. . . . . .

(iii) Calculate the concentration, in $mol\,dm^{-3}$, of hypochlorite ions in the **diluted** bleach solution. *[1]*

. . . . . .
. . . . . .
. . . . . .

(iv) Calculate the concentration, in $mol\,dm^{-3}$, of hypochlorite ions in the **undiluted** bleach solution. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question 1 continued)

(b) Some of the group 17 elements, the halogens, show variable valency.

(i) Deduce the oxidation states of chlorine and iodine in the following species. *[1]*

NaClO:

. . . . . .

I_2:

. . . . . .

(ii) Deduce, with a reason, the oxidizing agent in the reaction of hypochlorite ions with iodide ions in part (a). *[1]*

. . . . . .

. . . . . .

. . . . . .

(iii) From a health and safety perspective, suggest why it is not a good idea to use hydrochloric acid when acidifying the bleach. *[1]*

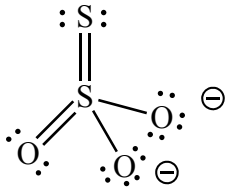
. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(iv) The thiosulfate ion, $S_2O_3^{2-}$, is an interesting example of oxidation states. The sulfur atoms can be considered to have an oxidation state of +6 on one atom and –2 on the other atom. Discuss this statement in terms of your understanding of oxidation state. *[2]*



Lewis (electron dot) structure of thiosulfate

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 1 continued)

(c) The various changes that have been made to the definitions of oxidation and reduction show how scientists often broaden similarities to general principles.

Combustion is also a redox type of reaction.

With reference to the combustion reaction of methane, explore **two** different definitions of oxidation, choosing one which is valid and one which may be considered not valid.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$ *[2]*

Valid:

. . . . . .
. . . . . .
. . . . . .

Not valid:

. . . . . .
. . . . . .
. . . . . .

(d) (i) State the **condensed** electron configuration of sulfur. *[1]*

. . . . . .

(ii) Deduce the orbital diagram of sulfur, showing all the orbitals present in the diagram. *[1]*

2. One of the main constituents of acid deposition is sulfuric acid, H_2SO_4. This acid is formed from the sulfur dioxide pollutant, SO_2.

A mechanism proposed for its formation is:

$$HO\bullet(g) + SO_2(g) \rightarrow HOSO_2(g)$$
$$HOSO_2(g) + O_2(g) \rightarrow HOO\bullet(g) + SO_3(g)$$
$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

(a) (i) State what the symbol (•) represents in the species shown in this mechanism. *[1]*

. . . . . .
. . . . . .

(ii) Draw one valid Lewis (electron dot) structure for each molecule below. *[2]*

Molecule	**Lewis (electron dot) structure**
SO_2	
H_2O	

(This question continues on the following page)

(Question 2 continued)

(iii) Deduce the name of the electron domain geometry and the molecular geometry for each molecule. *[2]*

	Electron domain geometry	**Molecular geometry**
SO_2	. . . . .	. . . . .
H_2O	. . . . .	. . . . .

(iv) Deduce the bond angles in SO_2 and H_2O. *[1]*

SO_2:

. . . . . .

H_2O:

. . . . . .

(This question continues on the following page)

(Question 2 continued)

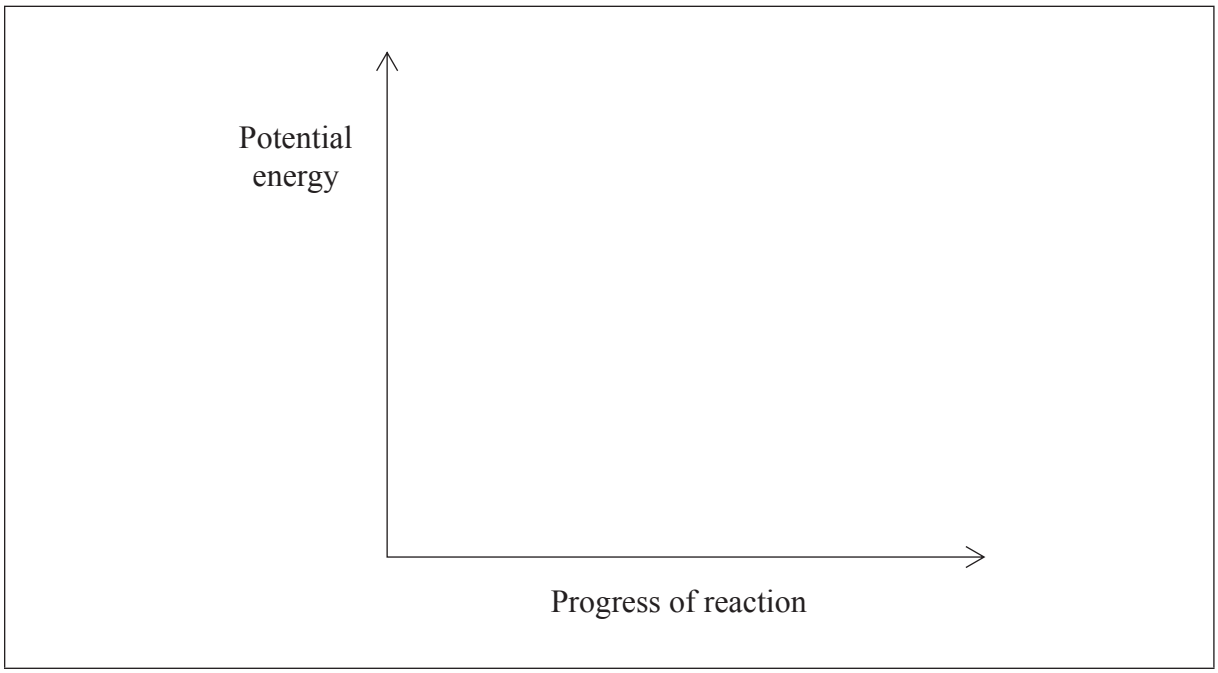
(v) Consider the following equilibrium between the two oxides of sulfur, sulfur dioxide and sulfur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -198\,kJ$$

Predict, with a reason, in which direction the position of equilibrium will shift for each of the changes listed below. *[3]*

Change	Shift	Reason
Increase in temperature	. . . . .	. . . . .
Increase in pressure	. . . . .	. . . . .
Addition of a catalyst to the mixture	. . . . .	. . . . .

(vi) Sketch the potential energy profile for the forward reaction in part (v) to show the effect of a catalyst on the activation energy, E_{act}. *[2]*



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(Question 2 continued)

(vii) Sulfuric acid, H_2SO_4, can be described as a Brønsted–Lowry acid. State what you understand by this description. *[1]*

. . . . . .

(viii) The hydrogen sulfate anion, HSO_4^-, is amphiprotic, so can act as an acid or a base. In the reaction of HSO_4^- with the hydronium cation, H_3O^+, identify the two species acting as bases.

$$HSO_4^-(aq) + H_3O^+(aq) \rightleftharpoons H_2SO_4(aq) + H_2O(l)$$ *[1]*

. . . . . .

(ix) Other compounds present in acid rain are formed from nitrogen dioxide, NO_2. Formulate an equation for the reaction of nitrogen dioxide with water. *[1]*

. . . . . .

3. Many automobile manufacturers are developing vehicles that use hydrogen as a fuel.

(a) Suggest why such vehicles are considered to cause less harm to the environment than those with internal combustion engines. *[1]*

. . . . . .
. . . . . .

(b) Hydrogen can be produced from the reaction of coke with steam:

$$C(s) + 2H_2O(g) \rightarrow 2H_2(g) + CO_2(g)$$

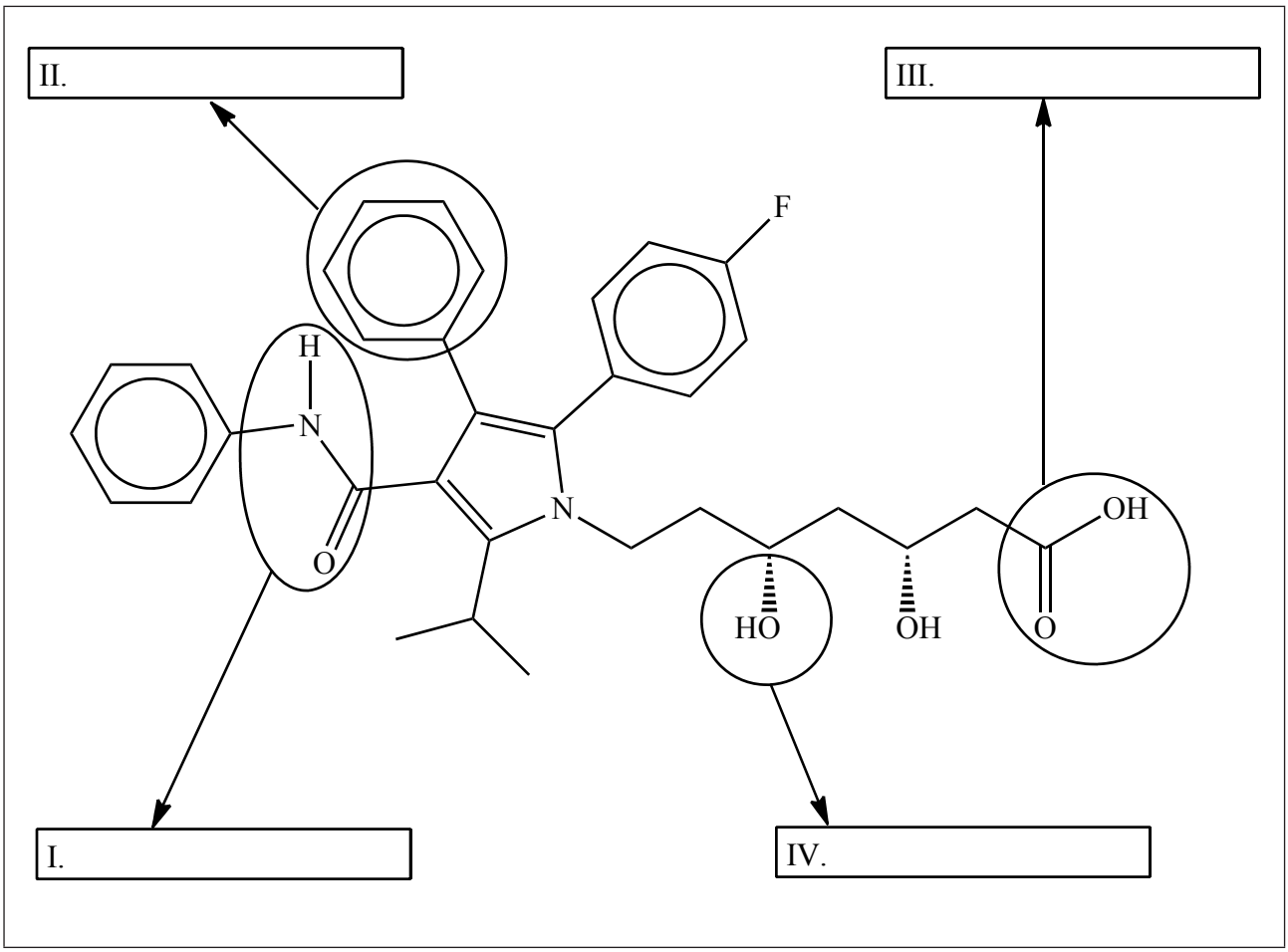
Using information from section 12 of the data booklet, calculate the change in enthalpy, ΔH, in $kJ\,mol^{-1}$, for this reaction. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

4. The biopharmaceutical industry is now a global contributor to the world economy.

(a) Atorvastatin, a drug used to lower cholesterol, recently gained attention from the global media.

Atorvastatin has the structure shown below.



Identify the **four** functional groups, I, II, III and IV. *[2]*

(This question continues on the following page)

(Question 4 continued)

(b) Bute, a painkiller used on horses, has caused widespread concern recently because analytical tests showed that it entered the food chain through horse meat labelled as beef. The drug is suspected of causing cancer.

(i) Analysis of a sample of bute carried out in a food safety laboratory gave the following elemental percentage compositions by mass:

Element	Percentage
C	73.99
H	6.55
N	9.09
O	Remainder

Calculate the empirical formula of bute, showing your working. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) The molar mass, M, of bute, is 308.37 g mol^{-1}. Calculate the molecular formula. *[1]*

. . . . . .
. . . . . .
. . . . . .

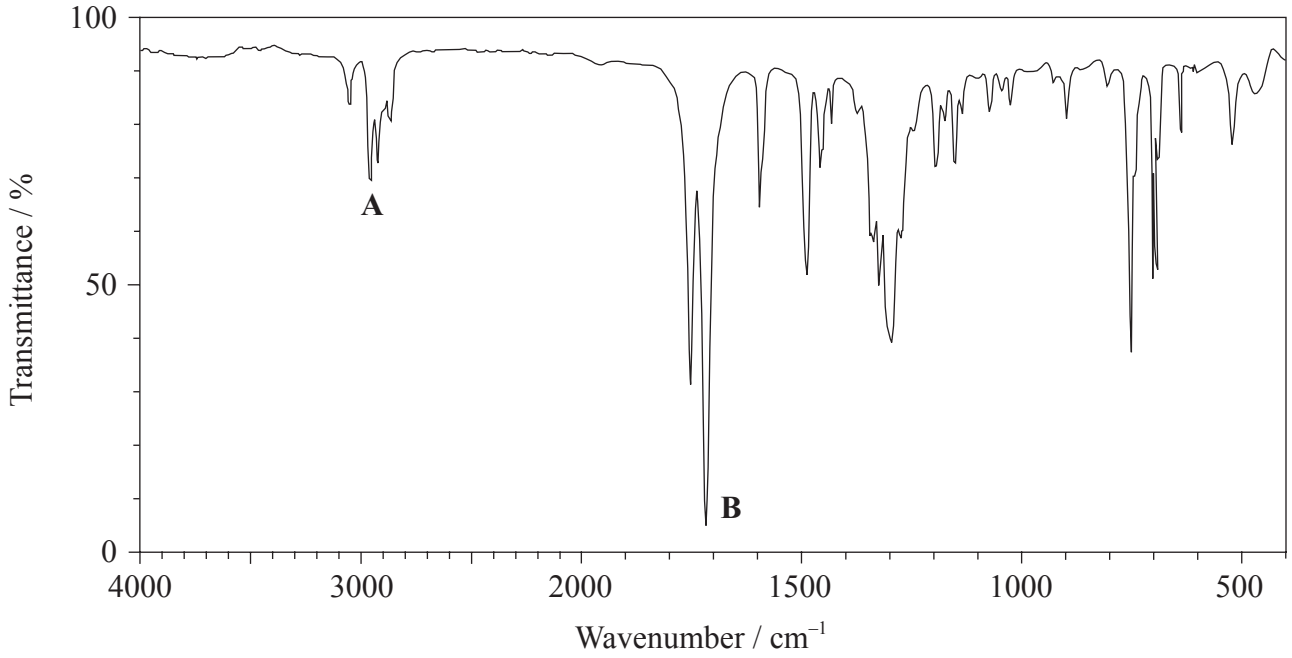
(This question continues on the following page)

(Question 4 continued)

(iii) Deduce the degree of unsaturation (index of hydrogen deficiency – IHD) of bute. *[1]*

. . . . . .
. . . . . .
. . . . . .

(iv) The infrared (IR) spectrum of bute is shown below.



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

Using information from section 26 of the data booklet, identify the bonds corresponding to **A** and **B**. *[1]*

A: . . . . . .

B: . . . . . .

(This question continues on the following page)

(Question 4 continued)

(v) Based on analysis of the IR spectrum, predict, with an explanation, one bond containing oxygen and one bond containing nitrogen that could **not** be present in the structure. *[2]*

Bond containing oxygen not present in structure:

. . . . . .

Bond containing nitrogen not present in structure:

. . . . . .

Explanation:

. . . . . .

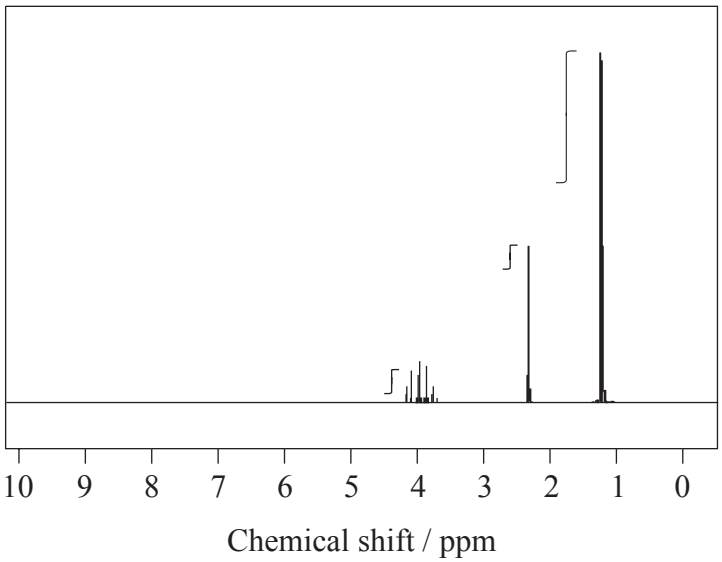
. . . . . .

. . . . . .

(This question continues on the following page)

(Question 4 continued)

(c) An alcohol, **X**, of molecular formula C_3H_8O, used as a disinfectant in hospitals, has the following ^{1}H NMR spectrum.



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

The three peaks in the ^{1}H NMR spectrum of **X** have chemical shift values centred at $\delta =$ 4.0, 2.3 and 1.2 ppm.

(i) From the integration trace, estimate the ratio of hydrogen atoms in different chemical environments. *[1]*

. . . . . .

. . . . . .

(ii) Deduce the full structural formula of **X**. *[1]*

(This question continues on the following page)

(Question 4 continued)

(iii) **Y** is an isomer of **X** containing a different functional group. State the condensed structural formula of **Y**. *[1]*

. . . . . .
. . . . . .

(iv) Compare and contrast the expected mass spectra of **X** and **Y** using section 28 of the data booklet. *[2]*

One similarity:

. . . . . .
. . . . . .
. . . . . .

One difference:

. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 4 continued)

(v) Both **X** and **Y** are soluble in water. Deduce whether or not both **X** and **Y** show hydrogen bonding with water molecules, representing any hydrogen bonding present by means of a diagram. *[2]*

. . . . . .

. . . . . .

(vi) **X** reacts with acidified potassium dichromate(VI) solution to form **Q** and with ethanoic acid to form **W**. Deduce the condensed structural formula of **Q** and **W**. *[2]*

Q:

. . . . . .

W:

. . . . . .

(This question continues on the following page)

(Question 4 continued)

(vii) Apply IUPAC rules to state the name of compound **Q**. *[1]*

. . . . . .

Please **do not** write on this page.

Answers written on this page
will not be marked.

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MARKSCHEME

SPECIMEN

CHEMISTRY

Standard Level

Paper 2

10 pages

Subject Details: Chemistry SL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions. Maximum total = **[50 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "***OR***" on the line between the alternatives. Either answer can be accepted.

7. Words in angled brackets ‹ › in the "Answers" column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

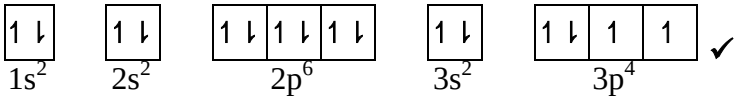
13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

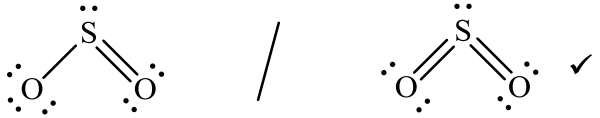
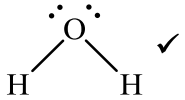
14. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column, similarly, if the formula is specifically asked for, unless directed otherwise in the "Notes" column do not award a mark for a correct name.

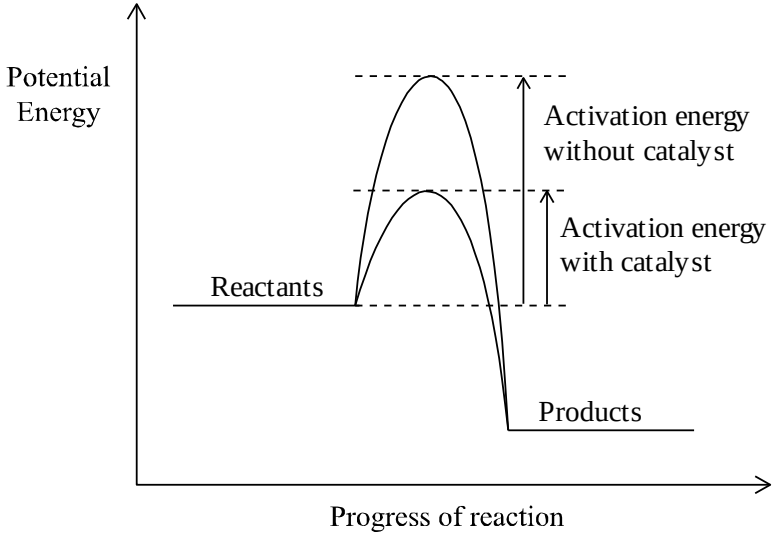
15. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

16. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Question			Answers	Notes	Total
1.	a	i	⟨$(22.05+22.15)(0.5)=$⟩22.10⟨cm^3⟩ ✓		1
	a	ii	$\left\langle \frac{22.10\times 0.100}{1000} = \right\rangle 2.21\times10^{-3} / 0.00221$⟨mol⟩ ✓		1
	a	iii	$\left\langle \frac{0.5\times 2.21\times10^{-3}\times1000}{25.00} = \right\rangle 4.42\times10^{-2} / 0.0442$⟨$\text{mol dm}^{-3}$⟩ ✓		1
	a	iv	⟨$4.42\times10^{-2}\times10=$⟩$4.42\times10^{-1} / 0.442$⟨$\text{mol dm}^{-3}$⟩ ✓		1
	b	i	*NaClO*: +1 ⟨for chlorine⟩ **and** I_2: 0 ⟨for iodine⟩ ✓		1
	b	ii	ClO^- since chlorine reduced/gains electrons ***OR*** ClO^- since oxidation state of chlorine changes from +1 to –1/decreases ***OR*** ClO^- since it loses oxygen / causes iodide to be oxidized ✓		1
	b	iii	produces chlorine ⟨gas⟩/Cl_2 ⟨on reaction with ClO^-⟩ which is toxic ✓	*OWTTE*	1
	b	iv	oxidation states are not real ***OR*** oxidation states are just used for electron book-keeping purposes ✓ average oxidation state of sulfur calculated to be +2 ✓ but the two sulfurs are bonded differently/in different environments in thiosulfate so have different oxidation states ✓	*OWTTE*	2 max

Question			Answers	Notes	Total
	c		*Valid:* addition of oxygen signifies an oxidation reaction so C is oxidized ***OR*** loss of hydrogen signifies an oxidation reaction so C is oxidized ***OR*** oxidation state of C changes from –4 to +4/increases ✓ *Not valid:* loss of electrons might suggest formation of ionic product but not valid since CO_2 is covalent ***OR*** loss of electrons might suggest formation of ionic product but not valid since reaction only involves neutral molecules ✓	*OWTTE*	**2**
	d	**i**	$[Ne]3s^2 3p^4$ ✓	*Electrons must be given as superscript.*	**1**
	d	**ii**	 ✓		**1**

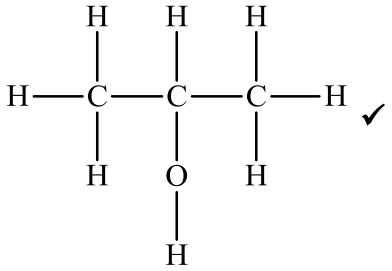
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>2.</td><td>a</td><td>i</td><td>radical / unpaired electron ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>ii</td><td>
<table>
<tr><th>Molecule</th><th>Lewis (electron dot) structure</th></tr>
<tr><td>SO_2</td><td>  / ✓</td></tr>
<tr><td>H_2O</td><td>  ✓</td></tr>
</table>
</td><td>Lines, x’s or dots may be used to represent electron pairs.</td><td>2</td></tr>
<tr><td></td><td>a</td><td>iii</td><td>
<table>
<tr><th></th><th>Electron domain geometry</th><th>Molecular geometry</th></tr>
<tr><td>SO_2</td><td>trigonal/triangular planar</td><td>bent/v-shaped/angular ✓</td></tr>
<tr><td>H_2O</td><td>tetrahedral</td><td>bent/v-shaped/angular ✓</td></tr>
</table>
</td><td>Award [1 max] for either both electron domain geometries correct OR for either both molecular geometries correct.</td><td>2</td></tr>
<tr><td></td><td>a</td><td>iv</td><td>SO_2: Accept any angle in the range greater than 115° but less than 120°.
and
H_2O: 104.5° ✓</td><td>Experimental value is 119°</td><td>1</td></tr>
</table>

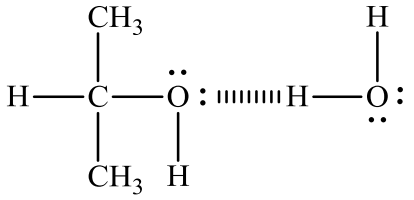
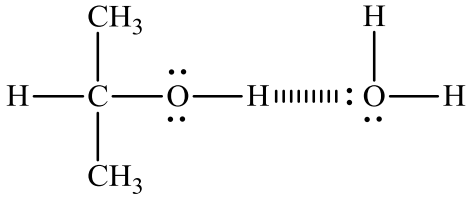
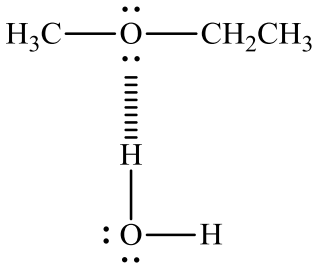
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>2</td><td>a</td><td>v</td><td>
<table>
<tr><th>Change</th><th>Shift</th><th>Reason</th></tr>
<tr><td>Increase in temperature</td><td>LHS</td><td>since ‹forward› exothermic reaction/ $\Delta H < 0$ ✓</td></tr>
<tr><td>Increase in pressure</td><td>RHS</td><td>since fewer ‹gaseous› molecules on RHS ✓</td></tr>
<tr><td>Addition of a catalyst to the mixture</td><td>No change</td><td>since affects rate of forward and reverse reactions equally ✓</td></tr>
</table>
</td><td></td><td>3</td></tr>
<tr><td></td><td>a</td><td>vi</td><td> 

correct positions of reactants and products ✓
correct profile with labels showing activation energy with and without a catalyst ✓</td><td></td><td>2</td></tr>
<tr><td></td><td>a</td><td>vii</td><td>proton/H^+ donor ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>viii</td><td>$HSO_4^-(aq)$ and $H_2O(l)$ ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>ix</td><td>$2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$ ✓</td><td>Ignore state symbols.</td><td>1</td></tr>
</table>

Question			Answers	Notes	Total
3.	**a**		<u>only</u> water/H_2O produced ‹so non-polluting› ✓		**1**
	b		$\Delta H = [(-393.5)] - [(2)(-241.8)]$ ✓ +90.1‹kJ› ✓	*Award **[2]** for correct final answer.*	**2**

4.	**a**		*I:* carboxamide ✓ *II:* phenyl ✓ *III:* carboxyl / carboxy ✓ *IV:* hydroxyl ✓	*Award **[2]** for all four correct, **[1]** for two or three correct.* *Do not allow benzene.* *Do not allow carboxylic/alkanoic acid.* *Do not allow alcohol or hydroxide.*	**2 max**
	b	**i**	$n_C : \left\langle \frac{73.99}{12.01} \right\rangle = 6.161\,(\text{mol})$ **and** $n_H : \left\langle \frac{6.55}{1.01} \right\rangle = 6.49\,(\text{mol})$ **and** $n_N : \left\langle \frac{9.09}{14.01} \right\rangle = 0.649\,(\text{mol})$ **and** $n_O : \left\langle \frac{10.37}{16.00} \right\rangle = 0.6481\,(\text{mol})$ ✓ $n_C : n_H : n_N : n_O = 9.5 : 10 : 1 : 1$ ✓ *Empirical formula*: $C_{19}H_{20}N_2O_2$ ✓	*Award **[2 max]** for correct final answer without working.*	**3**
	b	**ii**	$C_{19}H_{20}N_2O_2$ ✓		**1**
	b	**iii**	$\langle (0.5)(40-20-2) = \rangle 9$ ✓		**1**
	b	**iv**	*A:* C–H **and** *B:* C=O		**1**
	b	**v**	O–H **and** N–H ✓ frequencies/stretches due to O–H and N–H occur above 3200 ‹cm^{-1}› which are not present in IR of *bute* ✓		**2**
	c	**i**	1:1:6 ✓		**1**

Question			Answers	Notes	Total
	c	ii	 ✓		1
	c	iii	$CH_3OCH_2CH_3$ ✓		1
	c	iv	*Similarity:* both have fragment corresponding to $(M_r - 15)^+$ / both have $m/z = 45$ ✓ *Difference:* **X** has fragment corresponding to $(M_r - 17)^+$ / **X** has $m/z = 43$ ***OR*** **X** has fragment corresponding to $(M_r - 43)^+$ / **X** has $m/z = 17$ ***OR*** **Y** has fragment corresponding to $(M_r - 31)^+$ / **Y** has $m/z = 29$ ***OR*** **Y** has fragment corresponding to $(M_r - 29)^+$ / **Y** has $m/z = 31$ ✓	*Allow "both have same molecular ion peak/M^+ / both have m/z = 60". However in practice the molecular ion peak is of low abundance and difficult to observe for propan-2-ol.*	2

Question			Answers	Notes	Total
4.	**c**	**v**	both **X** and **Y** will exhibit hydrogen bonding with water molecules ✓ diagrams showing hydrogen bonding ✓ X:  **OR**  Y: 		**2**
	c	**vi**	*I:* CH_3COCH_3 ✓ *II:* $CH_3COOCH(CH_3)_2$ ✓		**2**
	c	**vii**	propanone ✓		**1**

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CHEMISTRY
STANDARD LEVEL
PAPER 3

Candidate session number

SPECIMEN PAPER

Examination code

1 hour

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the *Chemistry data booklet* is required for this paper.
- The maximum mark for this examination paper is *[35 marks]*.

Option	Questions
Option A — Materials	3 – 6
Option B — Biochemistry	7 – 9
Option C — Energy	10 – 12
Option D — Medicinal chemistry	13 – 15

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. Compounds used to generate cooling in refrigerators and air-conditioning systems are known as refrigerants. A refrigerant undergoes a reversible change of state involving vaporization and condensation. The search for suitable refrigerants has occupied chemists for approximately 200 years.

Previously, the most popular refrigerants were chlorofluorocarbons (CFCs), but these have been replaced, first by hydrochlorofluorocarbons (HCFCs) and more recently by hydrofluorocarbons (HFCs).

Some data on examples of these three classes of refrigerants are shown below.

Class	Compound	ODP[1]	GWP[2] over 100 years	ΔH_{vap}[3] / kJ mol^{-1}	Atmospheric lifetime / years
CFC	CCl_3F	1.0	4000	24.8	45
CFC	CCl_2F_2	1.0	8500	20.0	102
HCFC	$CHCl_2CF_3$	0.02	90	26.0	1
HCFC	$CHClF_2$	0.05	1810	20.2	12
HFC	CH_2FCF_3	0	1100	–	–
HFC	CHF_2CF_3	0	3500	30.0	32

[1] ODP: The ozone depletion potential (ODP) is a relative measure of the amount of degradation to the ozone layer caused by the compound. It is compared with the same mass of CCl_3F, which has an ODP of 1.0.

[2] GWP: The global warming potential (GWP) is a relative measure of the total contribution of the compound to global warming over the specified time period. It is compared with the same mass of CO_2, which has a GWP of 1.0.

[3] ΔH_{vap}: Defined as the energy required to change one mole of the compound from a liquid to a gas.

(a) (i) Explain why the values for ODP and GWP have no units. *[1]*

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 1 continued)

(ii) By making reference to the chemical formulas and ODP values of the compounds, comment on the hypothesis that chlorine is responsible for ozone depletion. *[1]*

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. . . . . .
. . . . . .

(b) Use data from the table to interpret the relationship between the atmospheric lifetime of a gas and its GWP. *[2]*

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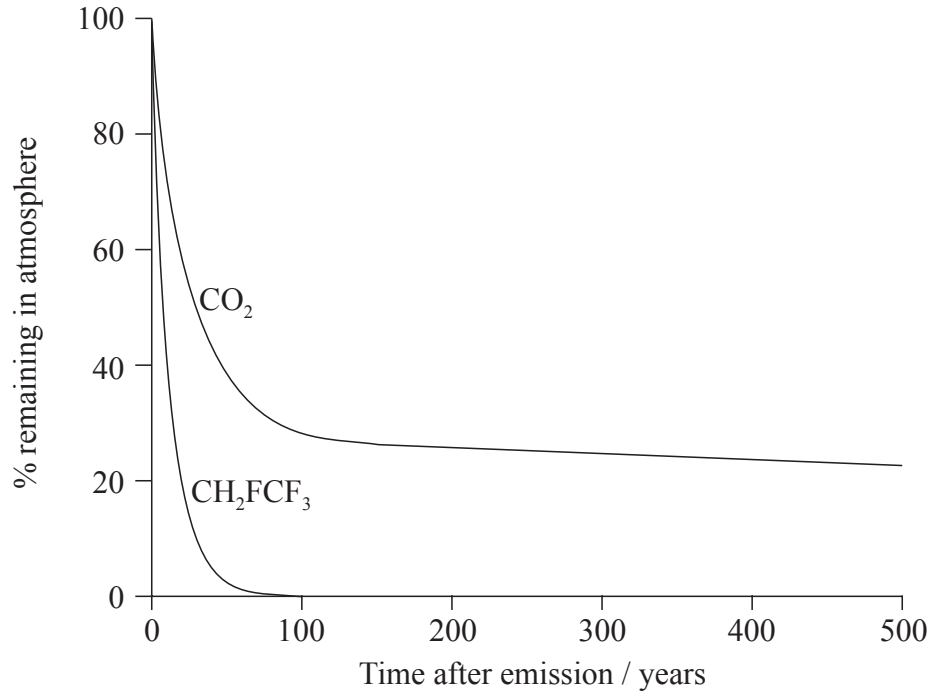
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 1 continued)

(c) The graph shows the change in levels with time of equal masses of CO_2 and CH_2FCF_3 introduced into the atmosphere.



(i) Apply IUPAC rules to state the name of CH_2FCF_3. *[1]*

. . . . . .

(ii) The $\Delta H_{vaporization}$ for CH_2FCF_3 is $217\,kJ\,kg^{-1}$. Calculate the value of the enthalpy change for the condensation of one mole of CH_2FCF_3. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(iii) With reference to the graph on page 4, comment on the atmospheric lifetime of CO_2 relative to CH_2FCF_3, and on the likely influence of this on climate change. *[2]*

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. . . . . .

2. Thomas wants to determine the empirical formula of red-brown copper oxide. The method he chooses is to convert a known amount of copper(II) sulfate into this oxide. The steps of his procedure are:

- Make 100 cm^3 of a 1 mol dm^{-3} solution using hydrated copper(II) sulfate crystals.
- React a known volume of this solution with alkaline glucose in order to convert it to red-brown copper oxide.
- Separate the precipitated oxide and find its mass.

(a) Thomas calculates that he needs $0.1 \times [1 \times 63.55 + 1 \times 32.07 + 4 \times 16.00] = 15.962 \pm 0.001$ g of the copper(II) sulfate to make the solution. Outline the major error in his calculation. *[1]*

. . . . . .
. . . . . .

(b) He now adds $100 \pm 1\,cm^3$ of water from a measuring/graduated cylinder and dissolves the copper(II) sulfate crystals. A friend tells him that for making standard solutions it is better to use a volumetric flask rather than adding water from a measuring cylinder. Suggest **two** reasons why a volumetric flask is better. *[2]*

. . . . . .
. . . . . .
. . . . . .

(c) Thomas now heats 25 cm^3 of the solution with excess alkaline glucose to convert it to a suspension of red-brown copper oxide. Describe how he can obtain the pure, dry solid product. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 2 continued)

(d) Using the same chemical reactions, suggest how Thomas' method to determine the mass of red-brown copper oxide that could be obtained from a known mass of copper(II) sulfate crystals might be simplified to produce more precise results. *[1]*

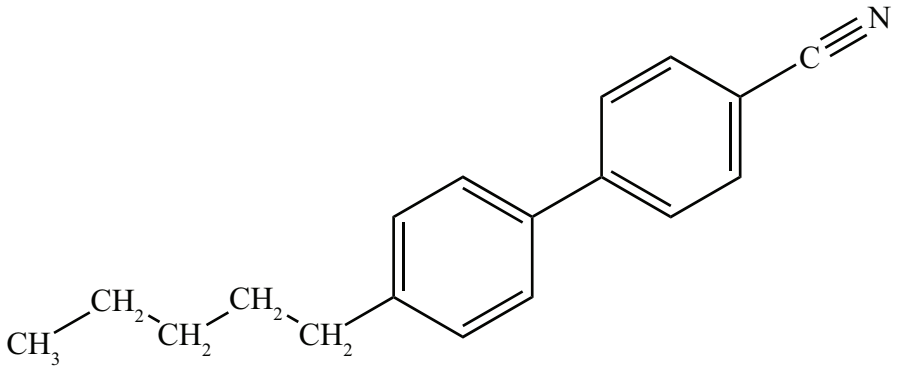
. . . . . .
. . . . . .
. . . . . .
. . . . . .

SECTION B

*Answer **all** of the questions from **one** of the options. Write your answers in the boxes provided.*

Option A — Materials

3. (a) The molecule shown below is frequently used in liquid-crystal displays (LCDs).



Identify a physical characteristic of this molecule that allows it to exist in a liquid-crystal state. *[1]*

. . . . . .

(b) (i) Describe the chemical vapour deposition (CVD) method for the production of carbon nanotubes. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) Many modern catalysts use carbon nanotubes as a support for the active material. State the major advantage of using carbon nanotubes. *[1]*

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(Option A continues on the following page)

(Option A continued)

4. Different metal oxides are widely used in the production of ceramic materials and their function is closely linked to the type of bonding present in the compound.

(a) Both magnesium oxide and cobalt(II) oxide are incorporated into ceramics. Use section 8 of the data booklet to calculate values to complete the table below. *[2]*

Compound	Magnesium oxide	Cobalt(II) oxide
Electronegativity difference	. . . . .	. . . . .
Average electronegativity	. . . . .	. . . . .

(b) Predict the bond type and percentage covalent character of each oxide, using section 29 of the data booklet. *[2]*

Compound	Magnesium oxide	Cobalt(II) oxide
Bond type	. . . . .	. . . . .
% covalent character	. . . . .	. . . . .

(Option A continues on the following page)

(Option A continued)

5. Magnesium is an essential component of chlorophyll and traces of it can be found in various fluids from plants. Its concentration may be estimated using inductively coupled plasma optical emission spectroscopy (ICP-OES).

(a) Outline what the specific plasma state involved in ICP spectroscopy comprises. *[1]*

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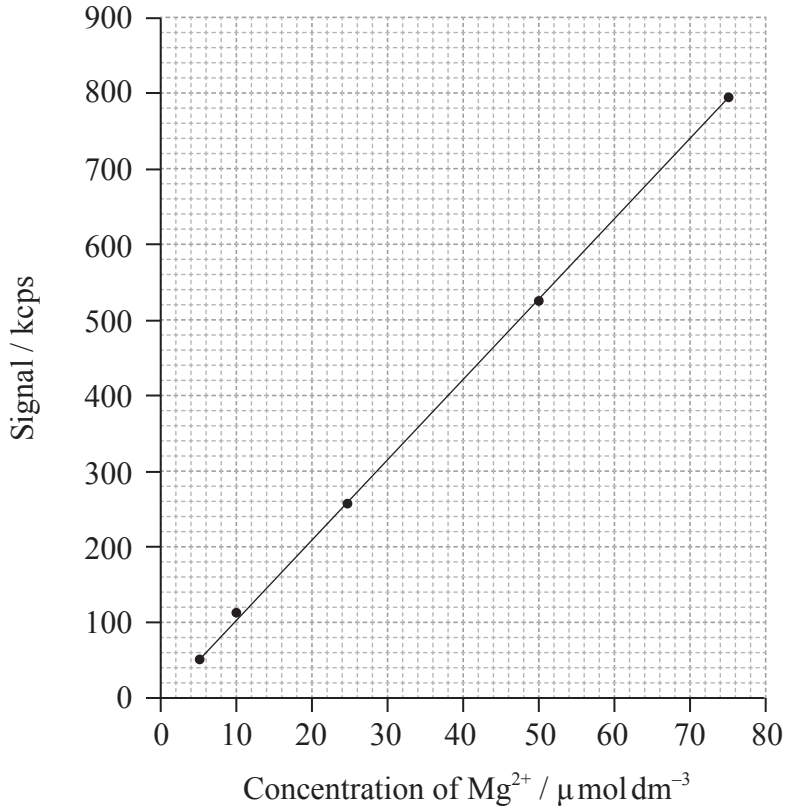
(b) An ICP-OES calibration curve for magnesium is shown in the graph below.



(Option A continues on the following page)

(Option A, question 5 continued)

(i) Determine the mass of magnesium ions present in 250 cm^3 of a solution with a concentration of 10 μmol dm^{-3}. *[2]*

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(ii) Taking into account your answer to part (b)(i), discuss how the solutions for this calibration curve could be produced. *[2]*

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(iii) Two solutions gave count rates of 627 kcps and 12 kcps respectively. Justify which solution could be more satisfactorily analysed using this calibration graph. *[1]*

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(Option A continues on the following page)

(Option A continued)

6. Plastics, such as PVC and melamine, are widely used in modern society.

(a) PVC is thermoplastic, whereas melamine is thermosetting. State one other way in which scientists have tried to classify plastics, and outline why the classification you have chosen is useful. *[2]*

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(b) It was almost a century after the discovery of PVC before Waldo Semon turned it into a useful plastic by adding plasticizers. State and explain the effect plasticizers have on the properties of PVC. *[2]*

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(c) Justify why, in terms of atom economy, the polymerization of PVC could be considered "green chemistry". *[1]*

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(Option A continues on the following page)

(Option A, question 6 continued)

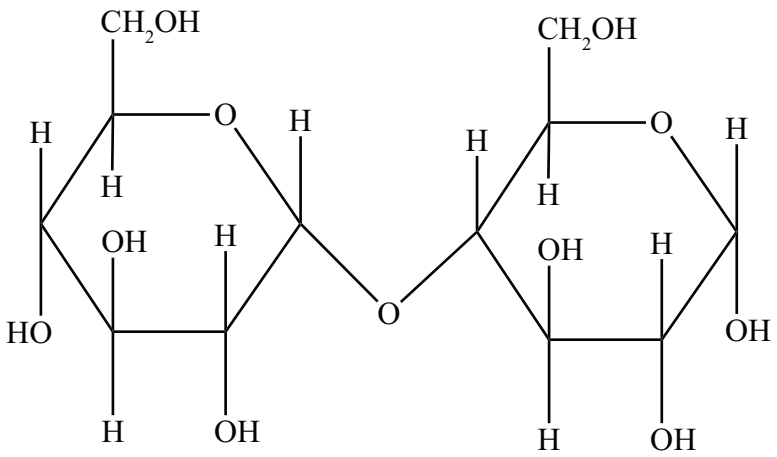
(d) In spite of the conclusion in part (c), many consider that PVC is harmful to the environment. Identify **one** specific toxic chemical released by the combustion of PVC. *[1]*

. . . . . .

End of Option A

Option B — Biochemistry

7. The diagram below shows the structure of a disaccharide called maltose.



(a) Identify on the diagram one primary alcohol group by marking I on the oxygen, **and** one secondary alcohol group by marking II on the oxygen. *[1]*

(b) (i) Formulate an equation, using molecular formulas, to show the conversion of this molecule into its monomers. *[1]*

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(ii) Identify the type of metabolic process shown in part (b)(i). *[1]*

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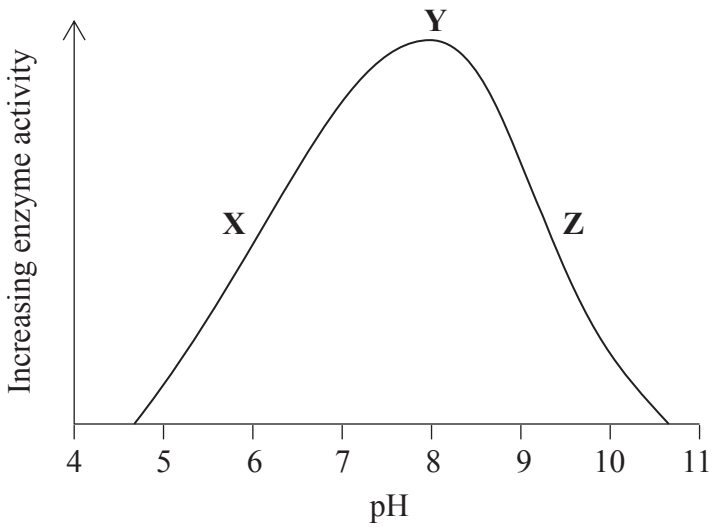
(Option B continues on the following page)

(Option B, question 7 continued)

(c) The reaction in part (b) is catalysed by the enzyme maltase. Experiments were carried out to investigate the rate of breakdown of maltose in the presence of maltase over a range of pH values from 4 to 11. The results are shown below.



Describe how the activity of the enzyme changes with pH, including in your answer specific reference to how the pH is affecting the enzyme at **X**, **Y** and **Z**. *[3]*

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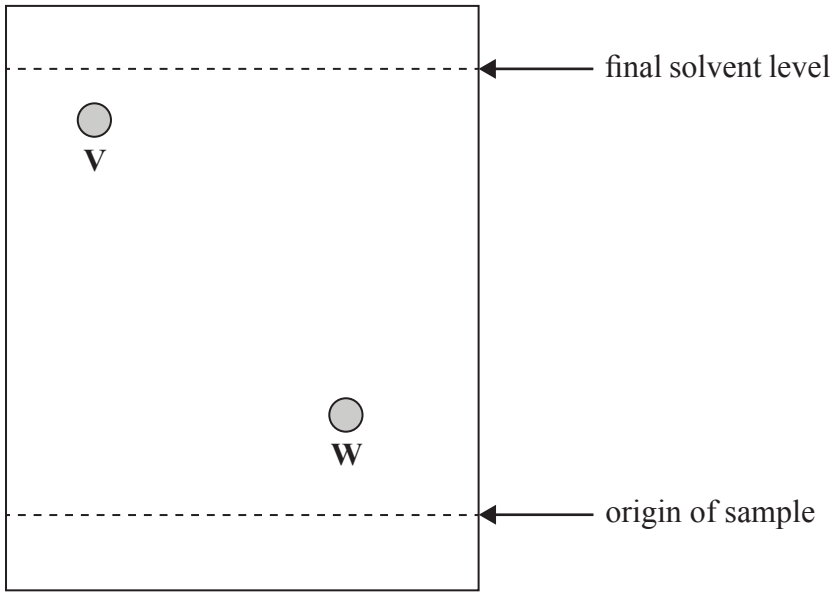
(Option B continues on the following page)

(Option B, question 7 continued)

(d) A separate experiment was done to determine the amino acid composition of maltase. A sample of the enzyme was hydrolysed into a mixture of its component amino acids. Paper chromatography and a locating agent were then used to try to identify the amino acids present in the mixture. The diagram below shows part of the chromatogram in which the positions of two amino acids, **V** and **W**, can be seen.



Amino acid	R_f
Lysine	0.14
Glutamine	0.26
Proline	0.41
Methionine	0.56
Leucine	0.73

Use the chromatogram and the data table to deduce the identity of **V** and **W** if possible. *[2]*

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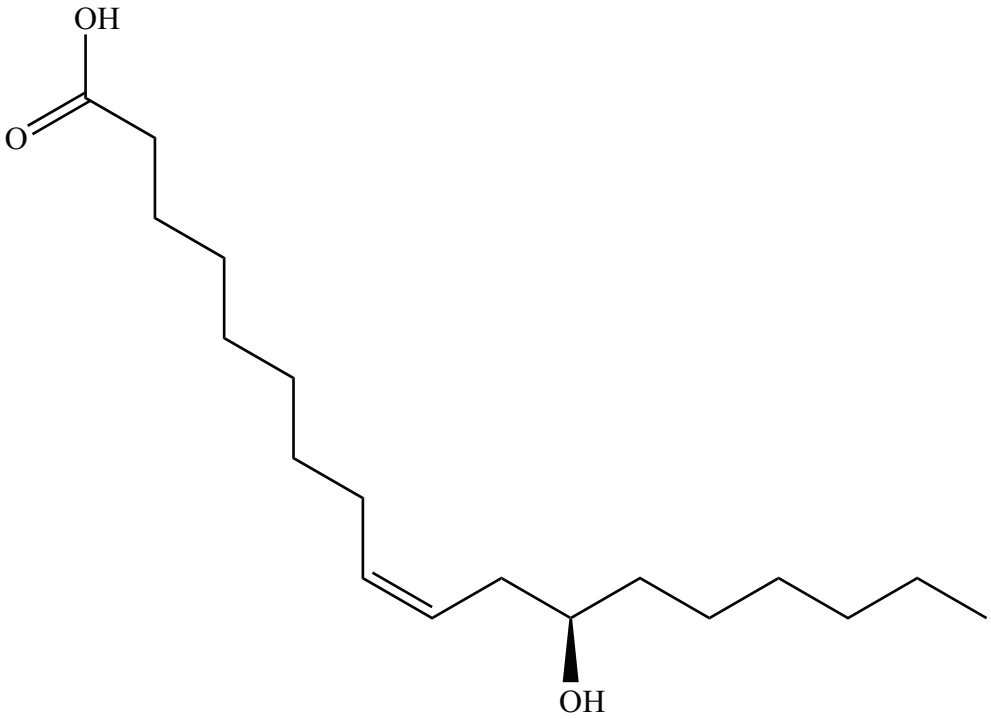
(Option B continues on the following page)

(Option B continued)

8. The castor plant is grown as a crop for its oil. Castor oil is mostly a triglyceride of the relatively rare fatty acid ricinoleic acid, whose structure is given below.



(a) State the molecular formula of ricinoleic acid. *[1]*

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(b) (i) Compare and contrast the structure of ricinoleic acid with stearic acid, whose structure is given in section 34 of the data booklet. *[3]*

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(Option B continues on the following page)

(Option B, question 8 continued)

(ii) State and explain how you would expect ricinoleic acid triglyceride to differ from stearic acid triglyceride in its tendency to undergo oxidative rancidity. *[2]*

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(c) The castor seed contains ricin, a toxic protein which is fatal in small doses. During the oil extraction process, the toxin is inactivated by heating.

(i) Outline why ricin loses its toxic effects on being heated. *[1]*

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(ii) Examine why many countries no longer harvest the castor plant but rely instead on imports of castor oil from other countries. *[2]*

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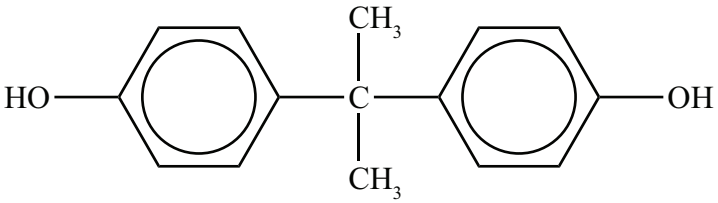
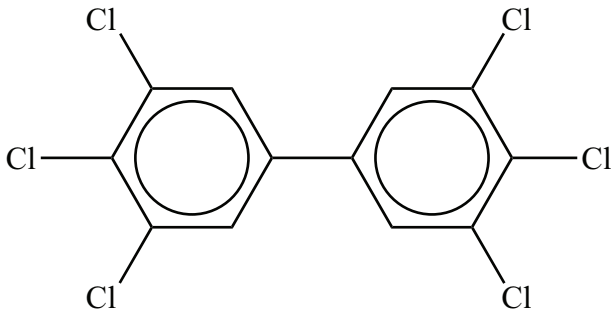
(Option B continues on the following page)

(Option B continued)

9. The figure below shows two examples of molecules known as xenoestrogens, a type of xenobiotic. They have effects on living organisms similar to those of the female hormone estrogen. These compounds are found in the environment and can be taken up by living organisms, where they may be stored in certain tissues.





(a) State what is meant by the term xenobiotic. *[1]*

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(b) With reference to their structures, outline why these xenobiotics are stored easily in animal fat. *[1]*

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(Option B continues on the following page)

(Option B, question 9 continued)

(c) One way to decrease the concentration of a xenobiotic in the environment is to develop a specific molecule, a "host", that can bind to it. The binding between the host and the xenobiotic forms a supramolecule.

State **three** types of association that may occur within the supramolecule between the host and the xenobiotic. *[1]*

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End of Option B

Please **do not** write on this page.

Answers written on this page
will not be marked.

Option C — Energy

10. Plants convert solar energy into chemical energy. It would therefore be very convenient to use plant products, such as vegetable oils, directly as fuels for internal combustion engines.

(a) (i) Identify the major problem involved in using vegetable oils directly as a fuel in a conventional internal combustion engine. *[1]*

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. . . . . .

(ii) Transesterification of the oil overcomes this problem. State the reagents required for this process. *[1]*

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(b) Plant products can also be converted to ethanol, which can be mixed with alkanes, such as octane, to produce a fuel. The table below gives some properties of these compounds.

Compound	**Molar mass / g mol^{-1}**	**Density / g dm^{-3}**	**ΔH_c / kJ mol^{-1}**	**Equation for combustion**
Ethanol	46.08	789	–1367	$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
Octane	114.26	703	–5470	$C_8H_{18}(l) + 12\frac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$

(i) State the name of the process by which ethanol can be produced from sugars. *[1]*

. . . . . .

(Option C continues on the following page)

(Option C, question 10 continued)

(ii) The energy density of ethanol is $23\,400\,kJ\,dm^{-3}$. Use data from the table to determine the energy density of octane. *[1]*

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(iii) Use these results to outline why octane is the better fuel in vehicles. *[1]*

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(iv) Use data from the table to demonstrate that ethanol and octane give rise to similar carbon footprints. *[1]*

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(v) Outline why, even though they have similar carbon footprints, using ethanol has less impact on levels of atmospheric carbon dioxide. *[1]*

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(Option C continues on the following page)

(Option C continued)

11. Nuclear power is an energy source that does not involve fossil fuels. Current nuclear technology is dependent on fission reactions.

(a) Commercial nuclear power technology developed very rapidly between 1940 and 1970. Outline why this occurred. *[1]*

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(b) The equation for a typical nuclear fission reaction is:

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} (\rightarrow {}^{236}_{92}\mathrm{U}) \rightarrow {}^{90}_{38}\mathrm{Sr} + {}^{136}_{54}\mathrm{Xe} + 10\,{}^{1}_{0}\mathrm{n}$$

The masses of the particles involved in this fission reaction are shown below.

Mass of neutron	=	1.00867 amu
Mass of U-235 nucleus	=	234.99333 amu
Mass of Xe-136 nucleus	=	135.90722 amu
Mass of Sr-90 nucleus	=	89.90774 amu

Using these data and information from sections 1 and 2 of the data booklet, determine the energy released when one uranium nucleus undergoes fission. *[3]*

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(Option C continues on the following page)

(Option C, question 11 continued)

(c) The half-lives of components of spent nuclear fuels range from a few years to more than 10,000 years. This means that while the radioactivity of nuclear waste initially decreases rapidly, some radioactivity remains for a very long time. Outline the storage of spent nuclear fuels in both the short and long term. *[2]*

Short term:

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. . . . . .

Long term:

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(Option C continues on the following page)

(Option C continued)

12. Energy production presents many threats to the environment. One issue that has caused much controversy over recent years is the emission of greenhouse gases, which most scientists believe is a major cause of global warming.

(a) Explain how greenhouse gases affect the temperature of the Earth's surface. *[3]*

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(b) Explain the molecular changes that must occur in order for a molecule to absorb infrared light. *[2]*

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(Option C continues on the following page)

(Option C, question 12 continued)

(c) (i) Carbon dioxide and water vapour are the most abundant greenhouse gases. Identify **one** other greenhouse gas and a natural source of this compound. *[1]*

Greenhouse gas:

. . . . . .

. . . . . .

Natural source:

. . . . . .

. . . . . .

(ii) Even though water vapour is the more potent greenhouse gas, there is greater concern about the impact of carbon dioxide. Suggest why this is the case. *[1]*

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End of Option C

Please **do not** write on this page.

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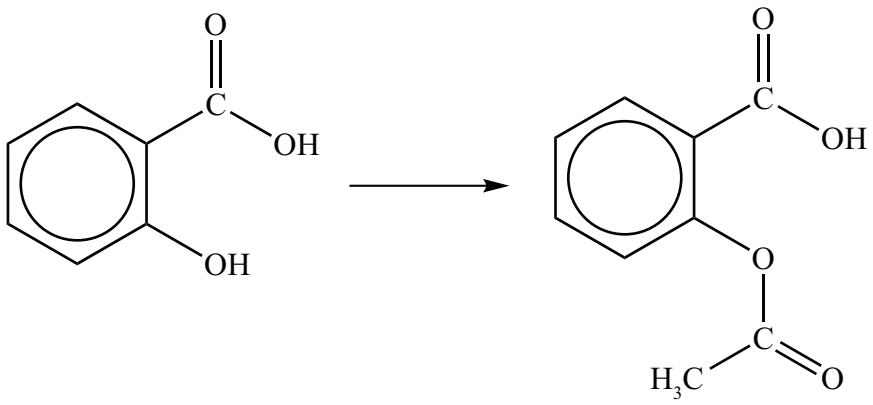
will not be marked.

Option D — Medicinal chemistry

13. Salicylic acid has been used to relieve pain and reduce fevers for centuries, although it can be irritating to the stomach. In the 1800s it was discovered that converting it into acetylsalicylic acid reduces the stomach irritation while still allowing it to be effective.



Salicylic acid Acetylsalicylic acid (aspirin)

(a) Identify the type of reaction used to convert salicylic acid to acetylsalicylic acid. *[1]*

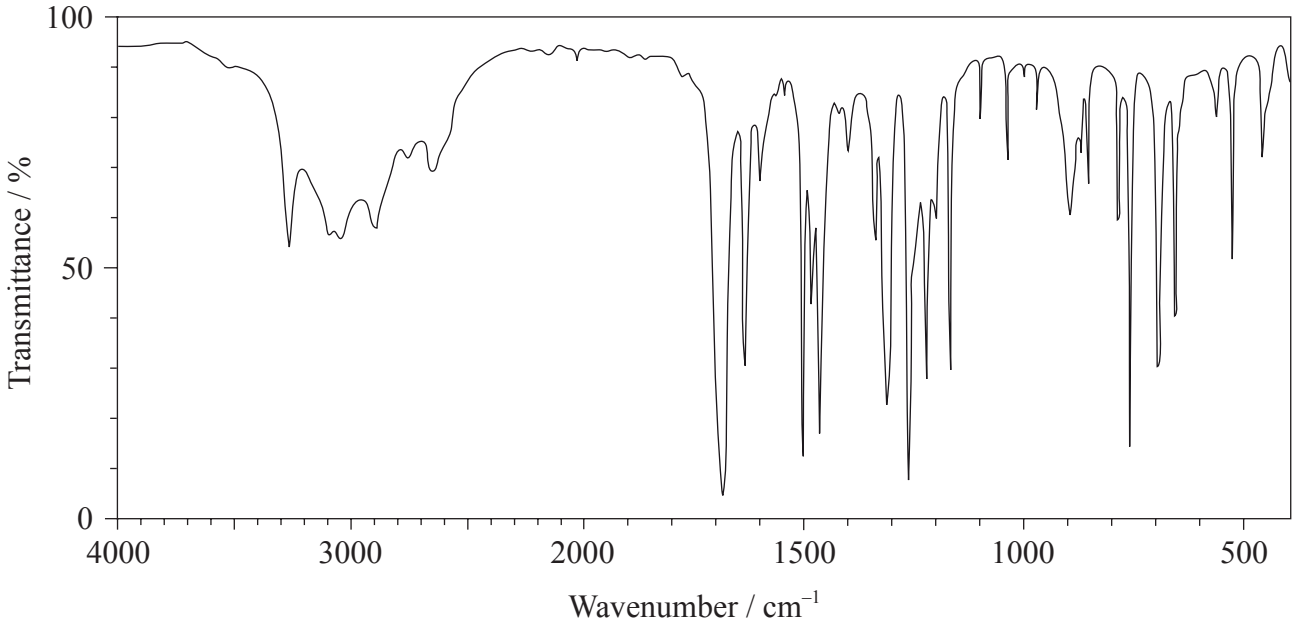
. . . . . .

(Option D continues on the following page)

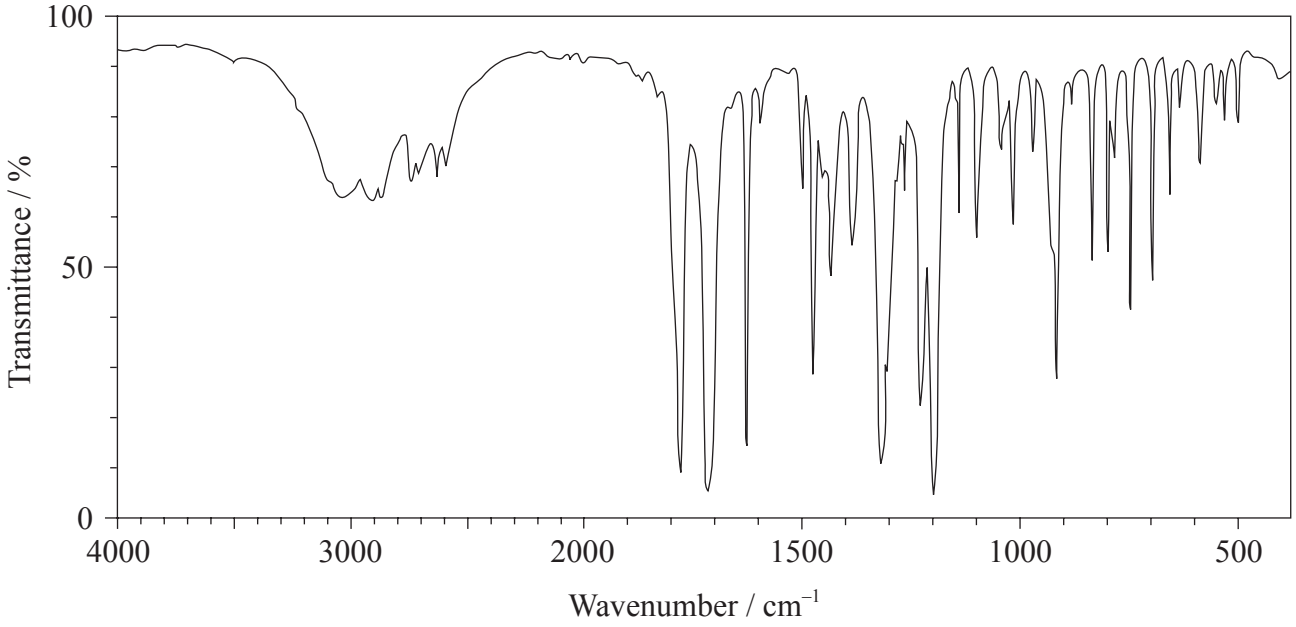
(Option D, question 13 continued)

(b) The infrared (IR) spectra for salicylic acid and acetylsalicylic acid are shown below.

Salicylic acid



Acetylsalicylic acid



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

(Option D continues on the following page)

(Option D, question 13 continued)

Using information from section 26 of the data booklet, compare and contrast the two spectra with respect to the bonds present. *[3]*

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(c) A modified version of aspirin is sometimes made by reacting it with a strong base, such as sodium hydroxide. Explain why this process can increase the bioavailability of the drug. *[3]*

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(Option D continues on the following page)

(Option D continued)

14. Recent advances in research into the viruses that cause flu have led to the production of two antiviral drugs, oseltamivir (Tamiflu®) and zanamivir (Relenza®).

(a) Outline why viruses are generally more difficult to target with drugs than bacteria. *[1]*

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. . . . . .

(b) By reference to their molecular structures given in section 37 of the data booklet, state the formulas of **three** functional groups that are present in both oseltamivir and zanamivir and the formulas of **two** functional groups that are present in zanamivir only. *[3]*

Present in both:

. . . . . .
. . . . . .
. . . . . .

Present in zanamivir only:

. . . . . .
. . . . . .

(c) Comment on how the widespread use of these drugs may lead to the spread of drug-resistant viruses. *[2]*

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(Option D continues on the following page)

(Option D, question 14 continued)

(d) Outline the general processes that should be followed to promote "green chemistry" in the manufacture of drugs such as oseltamivir and zanamivir. *[3]*

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(Option D continues on the following page)

(Option D continued)

15. Antacids help to neutralize excess hydrochloric acid produced by the stomach. The neutralizing power of an antacid can be defined as the amount in moles of hydrochloric acid that can be neutralized per gram of antacid.

(a) Formulate an equation to show the action of the antacid magnesium hydroxide. *[1]*

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. . . . . .

(b) An antacid tablet with a mass of 0.200 g was added to 25.00 cm^3 of 0.125 mol dm^{-3} hydrochloric acid. After the reaction was complete, the excess acid required 5.00 cm^3 of 0.200 mol dm^{-3} sodium hydroxide to be neutralized. Determine the neutralizing power of the tablet. *[3]*

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End of Option D

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MARKSCHEME

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CHEMISTRY

Standard Level

Paper 3

17 pages

Subject Details: Chemistry SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[15 marks]** and all questions from **ONE** option in Section B **[20 marks]**.
Maximum total = **[35 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max"** written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by '***OR***' on the line between the alternatives. Either answer can be accepted.

7. Words in angled brackets ‹ › in the "Answers" column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

14. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column, similarly, if the formula is specifically asked for, unless directed otherwise in the "Notes" column do not award a mark for a correct name.

15. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

16. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

SECTION A

Question			Answers	Notes	Total
1.	**a**	**i**	relative values ***OR*** compared with a standard ***OR*** not absolute measure ✓		**1**
	a	**ii**	high ODP for compounds with high Cl ***OR*** low ODP for compounds with less Cl ***OR*** zero ODP for compounds with no Cl ✓		**1**
	b		increasing atmospheric lifetime correlates with increasing GWP ✓ total contribution to global warming depends on length of time in atmosphere ***OR*** GWP depends on efficiency as greenhouse gas and atmospheric lifetime ✓	*Accept alternate answers based on sound scientific reasoning.*	**2**
	c	**i**	1,1,1,2-tetrafluoroethane ✓	*Allow without commas or dashes.*	**1**
	c	**ii**	$M(CH_2FCF_3) = (12.01\times 2) + (1.01\times 2) + (19.00\times 4) = 102.04 \langle g\,mol^{-1}\rangle$ ✓ ΔH (condensation CH_2FCF_3) $= -[0.217 \langle kJ\,g^{-1}\rangle \times 102.04 \langle g\,mol^{-1}\rangle] = -22.1 \langle kJ\,mol^{-1}\rangle$ ✓	*Award **[1 max]** for* $\Delta H = 22.1 kJ$	**2**
	c	**iii**	atmospheric lifetime CO_2 much longer than CH_2FCF_3 ***OR*** after 100 years approx 30 % CO_2 still present whereas CH_2FCF_3 removed ✓ CO_2 from current emissions will continue to effect climate change/global warming far into the future ✓	*OWTTE*	**2**

Question			Answers	Notes	Total
2.	**a**		forgot to take account of water of crystallisation ***OR*** should have used 24.972 g ✓	*OWTTE*	**1**
	b		less uncertainty in the volume ***OR*** more precise ✓ takes into account volume change on dissolving ***OR*** concentration is for a given volume of solution not volume of solvent ✓		**2**
	c		filter ***OR*** centrifuge ✓ rinse (the solid) with water ✓ heat in an oven ***OR*** rinse with propanone/ethanol/volatile organic solvent and leave to evaporate ✓	*Award **[2]** for all 3, **[1]** for any 2.*	**2**
	d		taking a known mass of the solid to react directly with glucose ***OR*** not making the standard solution ✓	*OWTTE* *Accept any other valid answer based on sound scientific reasoning.*	**1**

SECTION B

Option A — Materials

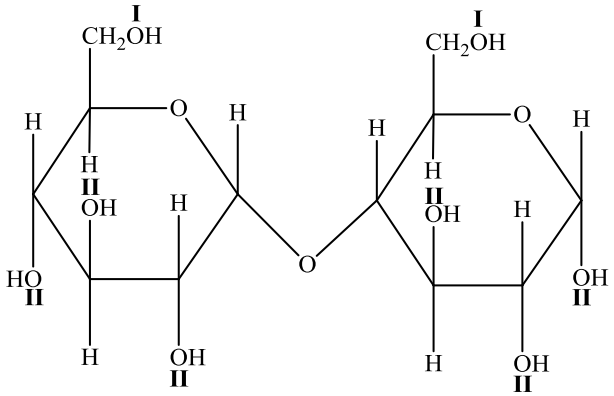
Question			Answers	Notes	Total
3.	**a**		rigid ***OR*** rod-shaped/long thin molecule ✓		**1**
	b	**i**	mixture of carbon containing compound and inert dilutant in gas/vapour phase ✓ passed over a heated metal catalyst ✓		**2**
	b	**ii**	(very) large surface area ✓		**1**

4.	**a**		<table><tr><th>Compound</th><th>Magnesium oxide</th><th>Cobalt(II) oxide</th></tr><tr><td>Electronegativity difference</td><td>2.1</td><td>1.5</td></tr><tr><td>Average electronegativity</td><td>2.35</td><td>2.65</td></tr></table> ✓ ✓	*Award **[1]** per correct row or column.*	**2**
	b		<table><tr><th>Compound</th><th>Magnesium oxide</th><th>Cobalt(II) oxide</th></tr><tr><td>Bond type</td><td>Ionic</td><td>Polar covalent</td></tr><tr><td>% covalent character</td><td>30 – 35</td><td>53 – 58</td></tr></table> ✓ ✓	*Award **[1]** per correct row or column.*	**2**

Question			Answers	Notes	Total
5.	**a**		positive argon ions and (free) electrons ✓		**1**
	b	**i**	mol $Mg^{2+} = \langle 0.25 \times 10 \times 10^{-6} \Rightarrow 2.5 \times 10^{-6} \langle mol \rangle$ ✓ mass $Mg^{2+} = \langle 24.31 \times 2.5 \times 10^{-6} \Rightarrow 6.08 \times 10^{-5}$ g ✓		**2**
	b	**ii**	mass of solid too small to weigh accurately ✓ successive dilution of solution ***OR*** dilution of concentrated solution ✓	*OWTTE*	**2**
	b	**iii**	627 kcps **and** it lies inside of the calibrated region ***OR*** 627 kcps **and** 12 kcps lies outside of calibrated region ✓	*Accept other correct suggestions, for example "low values such as 12 kcps would have very high uncertainty".*	**1**

Question			Answers	Notes	Total
6.	**a**		resin identification codes ✓ ensures uniformity for recycling ✓ ***OR*** addition/condensation ✓ classification into similar reaction types ✓ ***OR*** flexible ✓ direct towards appropriate uses ✓ ***OR*** brittle ✓ direct towards appropriate uses ✓	*OWTTE* *Accept "predict possible monomers". OWTTE* *Accept any other valid scientific classification with a justifiable scientific reason for **[2]**.*	**2**
	b		softens the polymer ✓ separates the polymer chains ***OR*** reduces intermolecular forces ✓		**2**
	c		all of the reagents end up in useful product ***OR*** atom economy is 100% ***OR*** there is no chemical waste ✓		**1**
	d		hydrogen chloride/HCl ***OR*** dioxin ✓		**1**

Option B — Biochemistry

Question			Answers	Notes	Total
7.	**a**		 ✓	*Award mark for a correctly placed **I** **and** a correctly placed **II**.* *Allow **II** placed on hemiacetal.*	**1**
	b	**i**	$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$ ✓		**1**
	b	**ii**	catabolism ✓	*Accept hydrolysis.*	**1**
	c		at X (low pH) enzyme/protein protonated/positively charged/cationic (so unable to bind effectively) ✓ at Y (optimum pH) enzyme maximally able to bind to substrate/maltose ✓ at Z (high pH) enzyme/protein deprotonated/negatively charged/anionic (so unable to bind effectively) ✓	*Award **[1 max]** for reference to denaturation/change in shape of active site without explanation in terms of changes in ionization.*	**3**
	d		R_f value $V = \frac{5.4}{5.9} = 0.91$ **and** R_f value $W = \frac{1.5}{5.9} = 0.25$ ✓ so W is glutamine (V cannot be identified) ✓		**2**

Question			Answers	Notes	Total
8.	**a**		$C_{18}H_{34}O_3$ ✓		**1**
	b	**i**	both have 18 carbon atoms ✓ both have COOH/carboxylic acid group ***OR*** both are fatty acids ✓ ricinoleic acid has a carbon-carbon double bond/C=C/‹mono›unsaturated whereas stearic acid has all single C–C bonds/saturated ✓ ricinoleic acid has an OH/hydroxyl group ‹in the chain› whereas stearic acid does not ✓	*Do not accept just acids in M2* *Any 3 for **[3 max]**.*	**3 max**
	b	**ii**	ricinoleic acid more likely to undergo oxidative rancidity ‹than stearic acid› ✓ carbon-carbon double bond/C=C can be oxidised ✓	*OWTTE*	**2**
	c	**i**	‹heating causes› denaturation ***OR*** ‹heating causes› loss of conformation ***OR*** ‹heating causes› change of shape ***OR*** ‹heating causes› inability to bind substrates ✓	*Do not accept inactivated.*	**1**
	c	**ii**	castor seeds contain toxins/ricin ***OR*** ingesting raw seeds can be fatal ✓ different health/safety standards in different countries ***OR*** richer countries exploit workers in less-developed/poorer countries ✓	*Accept alternate valid answers, such as economic considerations.*	**2**

Question			Answers	Notes	Total
9.	**a**		substance/chemical/compound found in organism not normally present ***OR*** compound foreign to living organism ✓	*Accept artificially synthesised/man-made compound in the environment/biosphere.*	**1**
	b		non-polar ***OR*** lipophilic ***OR*** structure based on phenyl/hydrocarbon ***OR*** hydrophobic interactions ***OR*** similar (non)polarity to fat ✓		**1**
	c		ionic bonds ✓ hydrogen bonds ✓ van der Waals' forces ✓ hydrophobic interactions ✓	*Award **[1]** for any 3 correct answers.* *Accept alternate valid answers other than covalent bonding.*	**1 max**

Option C — Energy

Question			Answers	Notes	Total
10.	**a**	**i**	viscosity too high ✓		**1**
	a	**ii**	alcohol **and** (strong) acid ***OR*** base ✓	*Accept any specific alcohol (eg ethanol).*	**1**
	b	**i**	fermentation ✓		**1**
	b	**ii**	$\left(\frac{703\times5470}{114.26}\right) = 33700\,(\text{kJ dm}^{-3})$ ✓		**1**
	b	**iii**	more energy from a given volume of fuel ✓	*Accept greater energy density.*	**1**
	b	**iv**	ethanol: $\frac{1367}{2} = 683.5\,\text{kJ mol}^{-1}$ **and** octane: $\frac{5470}{8} = 683.8\,\text{kJ mol}^{-1}$ ***OR*** mass of CO_2 produced in the release of 1000 kJ ethanol: $\frac{2\times44.01\times1000}{1367} = 64.4\,\text{g}$ **and** octane: $\frac{8\times44.01\times1000}{1367} = 64.4\,\text{g}$ ✓	*Accept other methods that show the amount carbon dioxide produced for the same heat energy output is the same for both fuels.*	**1**
	b	**v**	ethanol is a biofuel/produced from plant material ***OR*** growing plants absorbs carbon dioxide ✓		**1**

Question			Answers	Notes	Total
11.	**a**		nuclear power benefitted from the race to develop nuclear weapons ✓	*OWTTE* *Accept other valid explanations.*	**1**
	b		$\Delta m = \langle 234.99333 - 135.90722 - 89.907738 - [9 \times 1.00867] \rangle = 0.100342 \langle \text{amu} \rangle$ ✓ $= \langle 0.100342 \times 1.66 \times 10^{-27} \langle \text{kg} \rangle = 1.67 \times 10^{-28} \langle \text{kg} \rangle$ ✓ $E = \langle mc^2 = 1.67 \times 10^{-28} \times (3 \times 10^8)^2 = 1.50 \times 10^{-11} \langle \text{J} \rangle$ ✓	*Award **[3]** for correct final answer.*	**3**
	c		*Short term:* in cooling ponds ✓ *Long term:* vitrification ***OR*** underground in stable geological formations ✓		**2**

Question			Answers	Notes	Total
12.	**a**		incoming solar radiation is short wavelength ***OR*** incoming solar radiation is high frequency ***OR*** incoming solar radiation is high energy radiation ***OR*** incoming solar radiation is (UV radiation) ✓ radiation emitted (by the Earth's surface) is long wavelength ***OR*** radiation emitted (by the Earth's surface) is low frequency ***OR*** radiation emitted (by the Earth's surface) is low energy ***OR*** radiation emitted (by the Earth's surface) is IR radiation ✓ this energy is absorbed in the bonds of greenhouse gases ***OR*** the molecules vibrate when IR radiation is absorbed ✓ this energy is then re-radiated ‹some of it towards the surface of the Earth› ✓		**3 max**
	b		stretching ***OR*** bending ✓ causing a change in polarity/dipole moment ✓		**2**
	c	**i**	methane **and** anaerobic decomposition of organic matter ***OR*** digestion in animals ✓	*Accept other examples of greenhouse gases with correct <u>natural</u> sources.*	**1**
	c	**ii**	major sources of water vapour are natural rather than anthropogenic/due to humans ***OR*** levels of water vapour have remained almost constant whereas those of CO_2 have increased significantly in recent times ✓		**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
13.	**a**		esterification ***OR*** condensation ✓		**1**
	b		*Difference*: only spectrum for salicylic acid has ‹strong broad› peak from 3200–3600 cm^{-1} for OH ‹in alcohol/phenol› ✓ *Similarities*: both have ‹strong› peaks from 1050–1410 cm^{-1} for C–O ‹in alcohol/phenol› ✓ both have ‹strong› peaks from1700–1750 cm^{-1} for C=O ‹in carboxylic acid› ✓ both have ‹broad› peaks from 2500–3000 cm^{-1} for OH ‹in carboxylic acid› ✓ both have peaks from 2850–3090 cm^{-1} for C–H ✓	*Accept "acetylsalicylic acid has two peaks in the 1700–1800 cm^{-1} range due to 2 different C=O".* *Award **[2 max]** for two of the following similarities.*	**3 max**
	c		reaction with NaOH produces ‹ionic› salt ***OR*** $C_6H_4(OH)(COOH) + NaOH \rightarrow C_6H_4(OH)(COONa) + H_2O$ ✓ increases ‹aqueous› solubility ‹for transport/uptake› ✓ higher proportion of drug/dosage reaches target region/cells ✓		**3**

Question			Answers	Notes	Total
14.	**a**		lack cell structure ***OR*** exist within host cell ***OR*** mutate easily and frequently ✓		**1**
	b		*Present in both*: NH_2 ✓ CONH ✓ C=C ✓ COC ✓ *Present in zanamivir only*: COOH **and** OH ✓	*For similarities award **[2 max]** for any three correct, **[1 max]** for two correct, **[0]** for one correct.* *Accept C=N.*	**3 max**
	c		exposure of viruses to the drug favours resistant strains ✓ resistant strains difficult to treat ***OR*** drugs should be used only when required ‹not as prophylactic› ✓	*OWTTE*	**2**

(Question 14 continued)

Question			Answers	Notes	Total
	d		design chemicals to be less hazardous to health and environment ✓ use solvents/reagents that are less hazardous to the environment ✓ design ‹synthetic› processes that use less energy/materials ***OR*** design ‹synthetic› processes with high atom economy ✓ use renewable resources ***OR*** reuse/recycle materials ✓ treat waste to make less hazardous ✓ proper disposal of hazardous waste ✓		**3 max**

15.	**a**		$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$ ✓		**1**
	b		n(HCl added) $= \langle 0.02500 \times 0.125 \Rightarrow 0.00313 \langle$mol$\rangle$ ✓ n(HCl unreacted with tablet) $= n$(NaOH) $= 0.00500 \times 0.200 = 0.00100 \langle$mol HCl excess$\rangle$ n(HCl reacted with antacid) $= \langle 0.00313 - 0.00100 \Rightarrow 0.00213 \langle$mol$\rangle$ ✓ neutralizing power $\langle$mol g$^{-1}\rangle$ $= \langle \frac{0.00213}{0.200} \Rightarrow 0.011 \langle$ mol HCl neutralized per g antacid$\rangle$ ✓		**3**