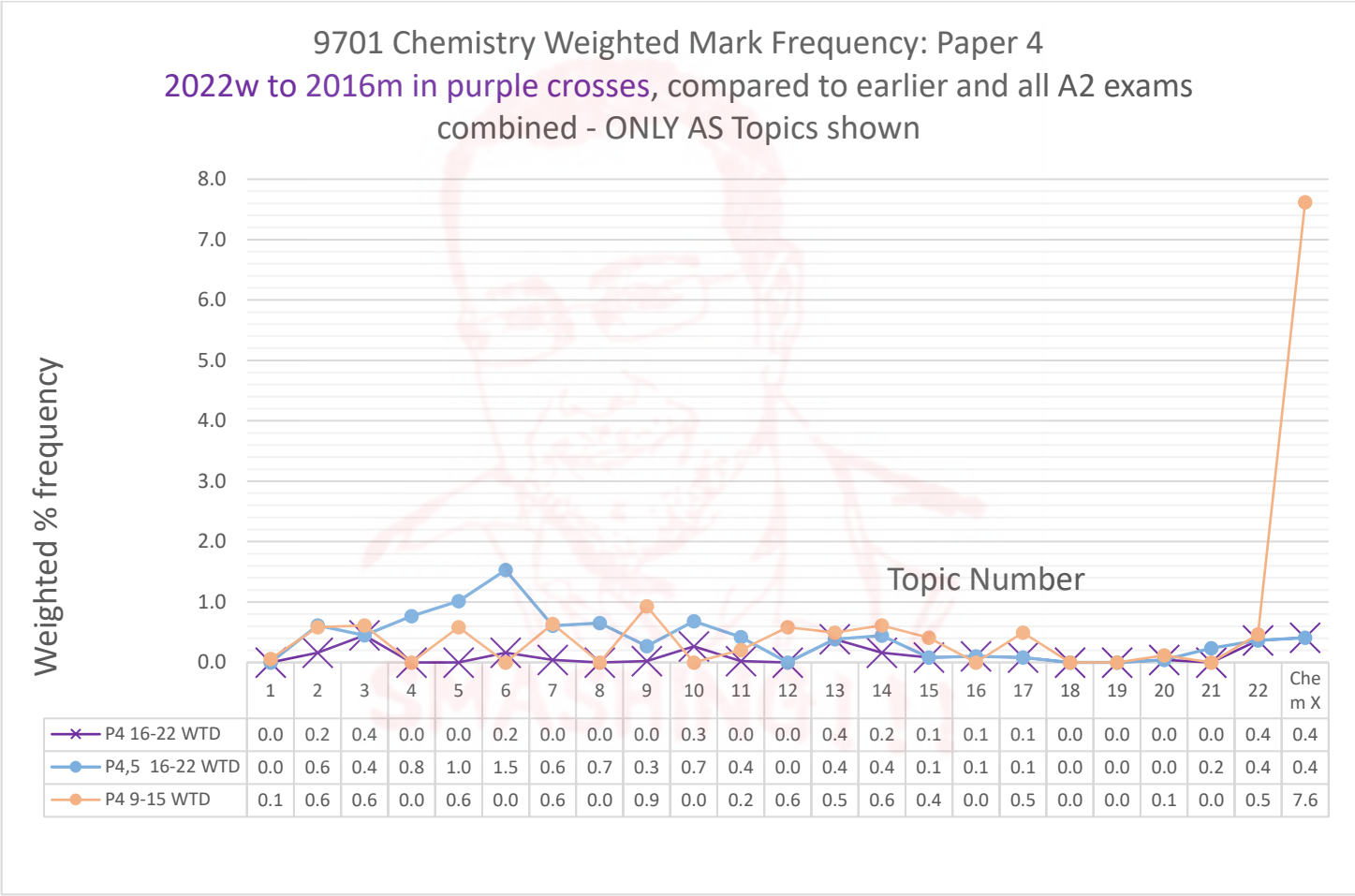
Name: Class: Date:

ALvl Chem 1 to 22 P4 22m to 09w AS Material in Paper 4 348marks 74Pages

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next.

Paper 4 Topic Checklist – Tick each task off as you go along	RANK:	P4 Noob	P4 Novice	P4 Bronze	P4 Silver	P4 Gold	P4 Winner[1]	P4 Hero	P4 Legend
	Marks	1 Q Started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topics 1 to 22/marks	348		5	35	87	139	174	261	348
Time (72seconds per mark)/min	418	3	7	42	104	167	209	313	418



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Chem X
P4 16-22 WTD	0.0	0.2	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.4	0.4
P4,5 16-22 WTD	0.0	0.6	0.4	0.8	1.0	1.5	0.6	0.7	0.3	0.7	0.4	0.0	0.4	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.2	0.4	0.4
P4 9-15 WTD	0.1	0.6	0.6	0.0	0.6	0.0	0.6	0.0	0.9	0.0	0.2	0.6	0.5	0.6	0.4	0.0	0.5	0.0	0.0	0.1	0.0	0.5	7.6

- Most of the marks covering content for the AS topics that was in Paper 4 has been reassigned into Paper 5, so most of these AS marks in this booklet come from papers before 2016, where they represented 16.4% of all of the marks, instead of 5.1% of the marks in the most recent period.
- But there is a remarkable consistency in the kinds of questions (e.g. parts of subtopics) that has appeared in recent Paper 4 exams. When combined and ranked against other topics, AS content for the 2016 to 2022 period becomes the 10th most common topic mark, behind Topic 27 (Group 2), and ahead of Topic 33 (Carboxylic acids and their derivatives).

[1] Before you concentrate on these higher levels of completion, make sure you have at achieved at least a silver (25% complete) in Paper 5 questions for these AS topics; most of the more recent AS marks in A2 exams are found in Paper 5.

Topic **Chem 1** Q# 1/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 **(a)** Calcium has atomic number 20.

Complete the electronic structures for a

calcium atom, $1s^2 2s^2 2p^6$.....

calcium ion in the +2 oxidation state. $1s^2 2s^2 2p^6$.....

[1]

Topic **Chem 1** Q# 2/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

Section A

Answer **all** the questions in the spaces provided.

1 **(a)** Complete the electronic configurations of the following atoms.

oxygen: $1s^2$.....

fluorine: $1s^2$.....

[1]

Topic **Chem 2** Q# 3/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

(ii) Most naturally occurring samples of iron(II) oxide are found as the mineral wüstite.

Wüstite has formula $Fe_{20}O_x$. It contains both Fe^{2+} and Fe^{3+} ions.

90% of the iron is present as Fe^{2+} and 10% is present as Fe^{3+}.

Deduce the value of x.

x = ... [1]

Topic **Chem 2** Q# 4/ ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

(b) Aluminium is extracted from Al_2O_3 by electrolysis. Al_2O_3 is dissolved in cryolite in this process.

(iii) Cryolite can be made from SiF_4.

The first step in this conversion is the reaction of SiF_4 with H_2O, forming H_2SiF_6 and SiO_2.

Write an equation for this reaction.

..... [1]

[Total: 11]

Topic **Chem 2** Q# 5/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Sodium oxide, Na_2O, is a white crystalline solid with a high melting point.

(a) Write an equation for the reaction of sodium with oxygen, forming sodium oxide. Include state symbols.

..... [2]

Topic **Chem 2** Q# 6/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) Explain why sodium oxide has a high melting point.

.....

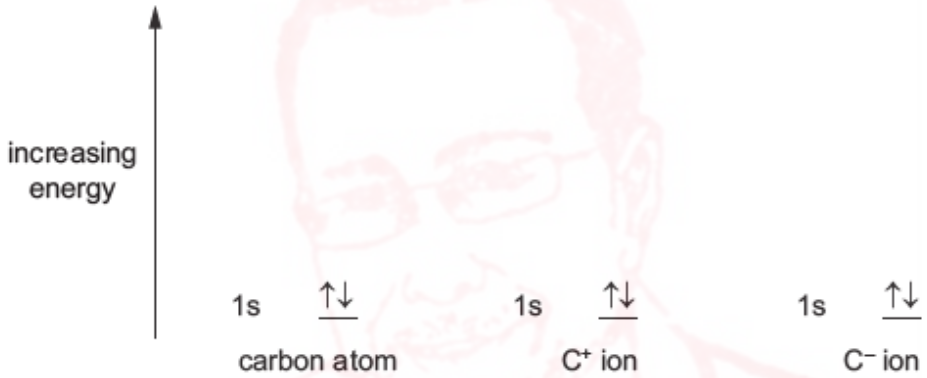
.....

.....

..... [2]

Topic **Chem 2** Q# 7/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 **(a)** Complete the diagrams to show the energies of the electrons in a carbon atom, a C^+ ion and a C^- ion.



[2]

Topic **Chem 2** Q# 8/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 Boron forms many useful compounds.

(a) The compound diborane, B_2H_6, can be used as a rocket fuel.
It can be prepared by the reaction of boron trifluoride, BF_3, with sodium borohydride, $NaBH_4$.

Balance this equation.

$$.....BF_3 + ...NaBH_4 \rightarrow .....B_2H_6 + ...NaBF_4$$

[1]

Topic **Chem 2** Q# 9/ ALvl Chemistry/2013/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(c) Alloys of aluminium, titanium and vanadium are used in aerospace and marine equipment, and in medicine.

When a powdered sample of one such alloy is heated with an excess of aqueous NaOH, only the aluminium reacts, according to the following equation.

$$2Al(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 2[Al(OH)_4]^-(aq) + 3H_2(g)$$

Reacting 100 g of alloy in this way produced 8.0 dm^3 of hydrogen, measured under room conditions.

Calculate the percentage by mass of aluminium in the alloy.

percentage = ... %
[3]

[Total: 14]

Topic **Chem 2** Q# 10/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 The most typical oxides of tin and lead are SnO, SnO_2, PbO and PbO_2.

The following two generalisations can be made about the oxides of the elements in Group IV.

- As the metallic character of the elements increases down the Group, the oxides become more basic.
- The oxides of the elements in their higher oxidation states are more acidic than the oxides of the elements in their lower oxidation states.

(b) 'Red lead' is used as a pigment, and as a metal primer paint to prevent the corrosion of steel. It is an oxide of lead that contains 9.30% oxygen by mass.

Calculate to **3 significant figures** the number of moles of oxygen and lead contained in a 100.0 g sample of red lead. Hence calculate its empirical formula.

empirical formula: ..... [2]

Topic **Chem 2** Q# 11/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(c) **(i)** Describe what you would observe when a solid sample of anhydrous $Cu(NO_3)_2$ is strongly heated.

.....

.....

(ii) Write an equation for this reaction.

.....

[2] **actually [3]**

(b) White phosphorus, P_4, is produced commercially by heating calcium phosphate(V) rock with a mixture of silica, SiO_2, and coke in an electric furnace at 1400 °C. Calcium silicate, $CaSiO_3$, and carbon monoxide are the other products.

(i) Balance the following equation which represents the overall process.

$$\_\_\_ Ca_3(PO_4)_2 + \_\_\_ SiO_2 + \_\_\_ C \rightarrow \_\_\_ P_4 + \_\_\_ CaSiO_3 + \_\_\_ CO$$

[2]

(b) White phosphorus, P_4, is produced commercially by heating calcium phosphate(V) rock with a mixture of silica, SiO_2, and coke in an electric furnace at 1400 °C. Calcium silicate, $CaSiO_3$, and carbon monoxide are the other products.

When heated to 400 °C in the absence of air, white phosphorus is changed into the red form of the element. The following table lists some of the properties of the two forms, which are known as allotropes.

allotrope	electrical conductivity	melting point / °C	solubility in water	solubility in benzene
white	none	44	insoluble	soluble
red	none	500	insoluble	insoluble

(ii) Suggest the type of structure and bonding in each allotrope.

allotrope	type of structure	type of bonding
white		
red		

[4]

(iii) In both allotropes, phosphorus has a valency of 3. Suggest by means of diagrams how the phosphorus atoms might be joined together in each allotrope.

white phosphorus

red phosphorus

[2]

(d) When a solution of $CaCl_2$ is added to a solution of the dicarboxylic acid, malonic acid, the salt calcium malonate is precipitated as a white solid. The solid has the following composition by mass: Ca, 28.2%; C, 25.2%; H, 1.4%; O, 45.2%.

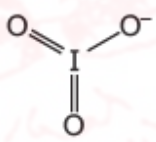
(i) Calculate the empirical formula of calcium malonate from these data.

(ii) Suggest the structural formula of malonic acid.

[3]

3 Iodates are compounds that contain the IO_3^- anion.

(a) The IO_3^- anion is shown.



Explain, with reference to the qualitative model of electron-pair repulsion, why the IO_3^- anion has a pyramidal shape.

.....

.....

..... [1]

2 When $ClNO_2$ reacts with NO an equilibrium is established.

$$ClNO_2(g) + NO(g) \rightleftharpoons NO_2(g) + ClNO(g)$$

In each $ClNO_2$ molecule the nitrogen atom is bonded to the chlorine atom and bonded to each of the oxygen atoms separately.

(a) Draw a 'dot-and-cross' diagram for the $ClNO_2$ molecule.

[2]

(c) The variation in the thermal stability of Group 2 amides is similar to that of Group 2 nitrates.

(d) $Ba(NH_2)_2$ contains the NH_2^- ion.

Predict the bond angle of NH_2^-. Explain your answer using the qualitative model of electron-pair repulsion.

bond angle .....

explanation .....

.....

.....

[3]

[Total: 9]

3 **(a)** Hydrogen cyanide, HCN, is a weak acid in aqueous solution.

$$HCN(aq) \rightleftharpoons H^+(aq) + CN^-(aq) \qquad K_a = 6.2 \times 10^{-10}\,mol\,dm^{-3}$$

(ii) Draw a 'dot-and-cross' diagram to represent the bonding in the hydrogen cyanide molecule. Show the outer shell electrons only.

[1]

(iii) State the hybridisation of the carbon and nitrogen atoms in hydrogen cyanide, and give the H–C–N bond angle.

hybridisation of C .....

hybridisation of N .....

H–C–N bond angle .....

[2]

1 The compound nitrosyl bromide, NOBr, can be formed by the reaction shown.

$$2NO + Br_2 \rightleftharpoons 2NOBr$$

(b) Nitrosyl bromide contains a trivalent nitrogen atom.

Draw the 'dot-and-cross' diagram for NOBr. Show outer electrons only.

[2]

2 **(a)** One atom of each of the four elements H, C, N and O can bond together in different ways. Two examples are molecules of cyanic acid, HOCN, and isocyanic acid, HNCO. The atoms are bonded in the order they are written.

(i) Draw 'dot-and-cross' diagrams of these two acids, showing outer shell electrons only.

HOCN, cyanic acid

HNCO, isocyanic acid

[3]

(ii) Suggest the values of the bond angles HNC and NCO in **isocyanic acid**.

HNC ..... NCO ..... [1]

(iii) Suggest which acid, cyanic or isocyanic, will have the **shorter** C–N bond length. Explain your answer.

.....

..... [1]

(iii) Draw a three-dimensional diagram showing the shape of the chloride. Give the C*l*–Si–C*l* bond angle.

[2]

(iv) Silicon reacts with oxygen to form a high melting point oxide.

- Suggest the formula of the oxide. .....
- Suggest, in terms of structure, why the oxide has a high melting point whereas the chloride has a low boiling point.

.....

.....

.....

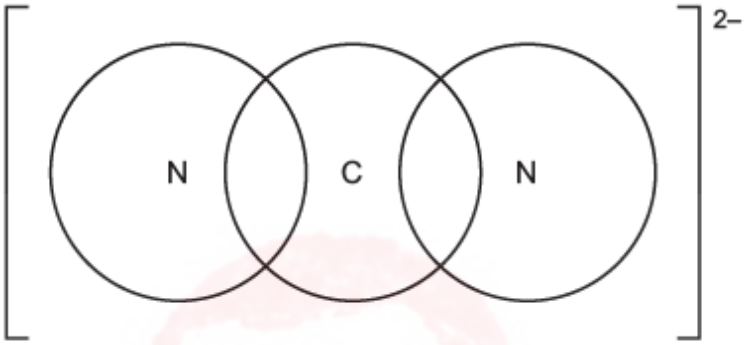
[2]

(c) Calcium cyanamide, $CaCN_2$, can be used as a fertiliser.

(i) Complete the 'dot-and-cross' diagram for the cyanamide ion, CN_2^{2-}.

Use the following key for the electrons.

- • electrons from carbon
- × electrons from nitrogen
- □ added electron(s) responsible for the overall negative charge



[2]

(b) A compound of fluorine and oxygen contains three atoms in each molecule.

(i) Predict its formula.

..... [1]

(ii) Draw a 'dot-and-cross' diagram to show its bonding.

[1]

(iii) Suggest the shape of this molecule.

..... [1]

(b) Phosphorus reacts with chlorine to form a variety of chlorides.
PCl_5 is an example of a compound that exists as two structures depending on the conditions.

$$2PCl_5(g) \rightleftharpoons [PCl_4]^+[PCl_6]^-(s)$$

(i) Draw a 'dot-and-cross' diagram to show the bonding in PCl_5. Show the outer electrons only.

(ii) Draw diagrams to suggest the shapes of $[PCl_4]^+$ and $[PCl_6]^-$.

$[PCl_4]^+$ $[PCl_6]^-$

[3]

(c) (i) Phosphorus(III) oxide, P_4O_6, contains no P–P or O–O bonds.
In the P_4O_6 molecule, all oxygen atoms are divalent and all phosphorus atoms are trivalent.

Sketch a structure for P_4O_6.

[1]

Topic **Chem 3** Q# 25/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) Gaseous ammonia reacts with gaseous hydrogen chloride to form solid ammonium chloride.

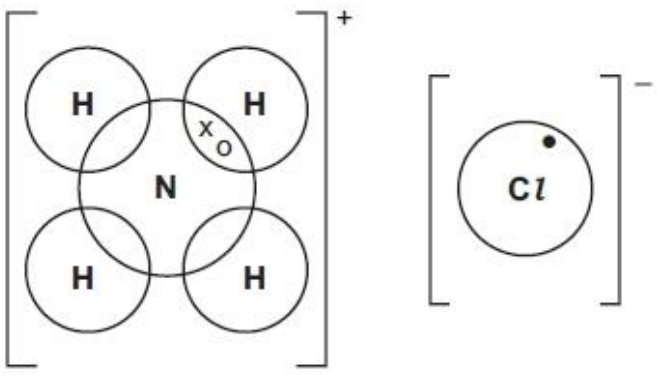
$$NH_3 + HCl \rightarrow NH_4Cl$$

The bonding in ammonium chloride includes ionic, covalent and co-ordinate (dative covalent) bonds.

Complete the following 'dot-and-cross' diagram of the bonding in ammonium chloride. For **each** of the six atoms show **all** the electrons in its outer shell. Three electrons have already been included.

Use the following code for your electrons.

- • electrons from chlorine
- x electrons from hydrogen
- o electrons from nitrogen



[3]

Topic **Chem 3** Q# 26/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 **(a)** **(i)** Describe and explain the trend in the volatilities of the Group IV chlorides CCl_4, $GeCl_4$ and $PbCl_4$.

.....

.....

.....

.....

.....

..... [3]

Topic **Chem 3** Q# 27/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Nitrogen monoxide, NO, is formed in a reversible reaction when air is heated to the temperature of a car engine.

(a) **(i)** Suggest a 'dot-and-cross' electronic structure for nitrogen monoxide.

[1]

Topic **Chem 3** Q# 28/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

Section A

Answer **all** questions in the spaces provided.

1 Taken together, nitrogen and oxygen make up 99% of the air. Oxygen is by far the more reactive of the two gases, and most of the substances that react with air combine with the oxygen rather than with the nitrogen.

(a) State **one** reason why the molecule of nitrogen, N_2, is so unreactive.

.....[1]

Topic **Chem 3** Q# 29/ ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(c) The molecule dichlorocarbene, CCl_2, can be produced under certain conditions. It is highly unstable, reacting with water to produce carbon monoxide and a strongly acidic solution.

(i) Suggest the electron arrangement in CCl_2 and draw a dot-and-cross diagram showing this. Predict the shape of the molecule.

(ii) Construct an equation for the reaction of CCl_2 with water.

.....

[3]

[Total: 8]

Topic **Chem 3** Q# 30/ ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

Section A

Answer **all** questions in the spaces provided.

1 **(a)** The Group IV oxides CO_2 and SiO_2 differ widely in their physical properties. Describe these differences and explain them in terms of their structure and bonding.

.....

.....

.....

..... [3]

Topic **Chem 5** Q# 31/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 **(a)** Explain what is meant by the term *bond energy*.

.....

.....

[2]

Topic **Chem 5** Q# 32/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

(e) Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

One of the steps during this reaction is the following process.

$$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$$

(iii) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of this step.

ΔH = ... kJ mol^{-1}

(iv) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of the similar reaction:

$$I^{\bullet} + CH_3CH_3 \rightarrow HI + CH_3CH_2^{\bullet}$$

ΔH = ... kJ mol^{-1}

(v) Hence suggest why it is **not** possible to make iodoethane by reacting together iodine and ethane.

..... [3]

Topic **Chem 5** Q# 33/ ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(c) When $SiCl_4$ vapour is passed over Si at red heat, Si_2Cl_6 is formed. Si_2Cl_6 contains a Si-Si bond.
The reaction of Si_2Cl_6 and Cl_2 re-forms $SiCl_4$.

$$Si_2Cl_6(g) + Cl_2(g) \rightarrow 2SiCl_4(g)$$

Use bond energy data from the *Data Booklet* to calculate $\Delta H^\ominus$ for this reaction.

$\Delta H^\ominus$ = ... kJ mol^{-1} [2]

Topic **Chem 5** Q# 34/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Nitrogen monoxide, NO, is formed in a reversible reaction when air is heated to the temperature of a car engine.

(ii) The enthalpy change of formation of nitrogen monoxide is +90 kJ mol^{-1}. What is the enthalpy change for the following reaction?

$$2NO(g) \rightarrow N_2(g) + O_2(g) \qquad \Delta H_r = \text{.....} \text{ kJ mol}^{-1}$$ [1]

(iv) Using bond enthalpy values from the *Data Booklet* and your answer in **(ii)** above, calculate a value for the bond energy of nitrogen monoxide.

bond energy = ... kJ mol^{-1} [2]

Topic **Chem 5** Q# 35/ ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

Section A

Answer **all** questions in the spaces provided.

1 **(a)** The halogens chlorine and bromine react readily with hydrogen.

$$X_2(g) + H_2(g) \longrightarrow 2HX(g) \qquad [X = Cl \text{ or } Br]$$

(iii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ for this reaction when

X = C*l*,

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

X = Br.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iv) What is the major reason for the difference in these two $\Delta H^{\ominus}$ values?

..... [5]

(b) Some halogens also react readily with methane.

$$CH_4(g) + X_2(g) \longrightarrow CH_3X(g) + HX(g)$$

(ii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ of this reaction for the situation where X is iodine, I.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iii) Hence suggest why it is not possible to make iodomethane, CH_3I, by this reaction.

..... [3]15

Topic **Chem 5** Q# 36/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) When sulfur is heated under pressure with chlorine, the major product is SCl_2 (C*l*-S-C*l*).

$$S_8(g) + 8Cl_2(g) \longrightarrow 8SCl_2(g)$$

Use data from the *Data Booklet* to calculate the enthalpy change, ΔH, for this reaction. The eight sulfur atoms in the S_8 molecule are all joined in a single ring by single bonds.

ΔH = ...kJ mol^{-1}
[2]

1 Iodine is found naturally in compounds in many different oxidation states.

(a) Iodide ions, I^-, react with acidified $H_2O_2(aq)$ to form iodine, I_2, and water.
This reaction mixture is shaken with cyclohexane, C_6H_{12}, to extract the I_2.
Cyclohexane is immiscible with water.

(i) Identify the role of $H_2O_2(aq)$ in its reaction with I^- ions in acidic conditions.

Write an ionic equation for the reaction.

role .....

ionic equation .....

.....

[2]

1 Iodine is found naturally in compounds in many different oxidation states.

(a) Iodide ions, I^-, react with acidified $H_2O_2(aq)$ to form iodine, I_2, and water.
This reaction mixture is shaken with cyclohexane, C_6H_{12}, to extract the I_2.
Cyclohexane is immiscible with water.

(b) The Group 1 iodides all form stable ionic lattices and are soluble in water.

(c) The concentration of $Cu^{2+}(aq)$ in a solution can be determined by the reaction of Cu^{2+} ions with I^- ions.

reaction 1 $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

The I_2 produced in reaction 1 is titrated against a solution containing thiosulfate ions, $S_2O_3^{2-}$, using a suitable indicator.

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

(i) A 25.0 cm^3 portion of a $Cu^{2+}(aq)$ solution reacts with an excess of $I^-(aq)$.
The end-point of the titration occurs when 22.30 cm^3 of 0.150 mol dm^{-3} $S_2O_3^{2-}(aq)$ is added.

Calculate the concentration of $Cu^{2+}(aq)$ in the original solution.

concentration of $Cu^{2+}(aq)$ = ... mol dm^{-3} [2]

(ii) Identify a suitable indicator for the titration.

..... [1]

Topic **Chem 6** Q# 39/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 5b/www.SmashingScience.org

A three-step mechanism for this reaction is shown.

step 1 $ClO^- + H_2O \rightarrow HClO + OH^-$

step 2 $I^- + HClO \rightarrow HIO + Cl^-$

step 3 $HIO + OH^- \rightarrow H_2O + IO^-$

(iii) Identify a step that involves a redox reaction. Explain your answer.

.....

..... [1]

Topic **Chem 6** Q# 40/ ALvl Chemistry/2017/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 The compound nitrosyl bromide, NOBr, can be formed by the reaction shown.

$$2NO + Br_2 \rightleftharpoons 2NOBr$$

(a) Using oxidation numbers, explain why this reaction is a redox reaction.

.....

.....

..... [2]

Topic **Chem 7** Q# 41/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

(c) Methylamine, CH_3NH_2, is a monodentate ligand.

(e) Methylamine is a Brønsted-Lowry base.

Write an equation showing how methylamine dissolves in water to give an alkaline solution.

..... [1]

Topic **Chem 7** Q# 42/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6 The names of many drugs used in medicine often include parts of the names of the functional groups their molecules contain.

(b) The drug named ketamine readily reacts with protons as shown.

$$\text{ketamine} + H^+ \rightarrow [\text{ketamine-H}]^+$$

(i) State the role of ketamine in this reaction.

..... [1]

Topic **Chem 7** Q# 43/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) Calcium nitrate, $Ca(NO_3)_2$, is used in fertilisers and can be prepared by an acid-base reaction.

Write an equation for the preparation of calcium nitrate by an acid-base reaction.

..... [1]

(c) Copper(I) oxide and copper(II) oxide can both be used in the ceramic industry to give blue, green or red tints to glasses, glazes and enamels.

The table lists the $\Delta H_f^\ominus$ values for some compounds.

compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$Cu_2O(s)$	–168.6
$CuO(s)$	–157.3
$Cu(NO_3)_2(s)$	–302.9
$NO_2(g)$	+33.2

(i) Copper(II) oxide can be produced in a pure form by heating copper(II) nitrate. Use suitable $\Delta H_f^\ominus$ values from the table to calculate the $\Delta H^\ominus$ for this reaction.

$$Cu(NO_3)_2(s) \rightarrow CuO(s) + 2NO_2(g) + \tfrac{1}{2}O_2(g)$$

$\Delta H^\ominus$ = ... kJ mol^{-1}

(ii) Copper(I) oxide can be produced from copper(II) oxide.

- Use suitable $\Delta H_f^\ominus$ values from the table to calculate $\Delta H^\ominus$ for the reaction.

$$2CuO(s) \rightleftharpoons Cu_2O(s) + \tfrac{1}{2}O_2(g)$$

$\Delta H^\ominus$ = ... kJ mol^{-1}

- Hence suggest whether a low or a high temperature of oxidation would favour the production of copper(I) oxide. Explain your reasoning.

.....

.....

[4]

[Total: 16]

8 In a world with a rapidly increasing population, access to clean drinking water is critical. For many countries, groundwater sources, rather than stored rainwater or river-water, are vital. *Groundwater* is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. The World Health Organisation (WHO) provides maximum recommended concentrations for different ions present in drinking water.

(a) The geological nature of the soil determines the chemical composition of the groundwater. The table shows some ions which may contaminate groundwater.

ion present	WHO maximum permitted concentration / mg dm^{-3}
Ba^{2+}	0.30
Cl^-	250.00
NO_3^-	50.00
Pb^{2+}	0.01
Na^+	20.00
SO_4^{2-}	500.00

(i) Nitrate, NO_3^-, ions are difficult to remove from groundwater. What is the reason for this?

.....

(ii) State which ions in the table above are likely to be removed from the water by treatment with powdered limestone, $CaCO_3$, giving reasons for each of your answers.

.....

.....

.....

[4]

(b) Nitrates and phosphates can enter water courses such as rivers or streams as a result of human activity. Both of these ions are nutrients for algae.

(i) What is the origin of these nitrates?

.....

(ii) Suggest an origin for the phosphates found in water courses.

.....

(iii) What effect do nitrates and phosphates have on water courses?

.....

.....

[3]

Topic **Chem 7** Q# 46/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 **(a)** **(i)** Using the symbol **HZ** to represent a Brønsted-Lowry acid, write equations which show the following substances acting as Brønsted-Lowry bases.

NH_3 + →

CH_3OH + →

(ii) Using the symbol B^- to represent a Brønsted-Lowry base, write equations which show the following substances acting as Brønsted-Lowry acids.

NH_3 + →

CH_3OH + →

[4]

(b) State briefly what is meant by the following terms.

(i) reversible reaction

.....

(ii) dynamic equilibrium

.....

.....

[2]

Topic **Chem 7** Q# 47/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 **(a)** State briefly what is meant by the following terms.

(i) reversible reaction

.....

(ii) dynamic equilibrium

.....

.....

[2]

Topic **Chem 9** Q# 48/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1(a)/www.SmashingScience.org

(ii) Silicon forms a low boiling point chloride which reacts with water.

Write an equation to show the reaction of the chloride with water.

..... [1]

2 **(a)** Complete the table to show the number of **unpaired** electrons in the outer shell of each of the gaseous atoms, Na to Ar.

	Na	Mg	Al	Si	P	S	Cl	Ar
number of unpaired electrons								

[3]

(b) **(i)** Complete the table for the reactions of two Period 3 chlorides with water.

Period 3 chloride	observations	pH of solution formed
$SiCl_4$		
PCl_5		

[3]

(ii) Write an equation for the reaction between $SiCl_4$ and H_2O.

..... [1]

[Total: 7]

Section A

Answer **all** the questions in the spaces provided.

1 **(a)** Write down what you would see, and write equations for the reactions that occur, when silicon(IV) chloride and phosphorus(V) chloride are separately mixed with water.

silicon(IV) chloride

.....

.....

phosphorus(V) chloride

.....

.....

[4]

(d) Write equations, including state symbols, for the reactions, if any, of the following two oxides with water. Suggest values for the pH of the resulting solutions.

oxide	equation	pH of resulting solution
Na_2O		
MgO		

[3]

3 **(a)** State and explain the variation in the oxidation numbers of the chlorides of the elements Na, Mg, Al and Si.

.....

.....

.....

.....[2]

(b) Describe the reaction of phosphorus(V) chloride with water, and write an equation for the reaction.

.....

.....[2]

(c) When microwave radiation is passed through phosphorus(III) chloride, PCl_3, at low pressure, a new chloride of phosphorus, **B**, is formed.
B contains 69.6% by mass of chlorine and 30.4% by mass of phosphorus, and its M_r is approximately 200.

(i) Calculate the empirical and molecular formulae of **B**.

.....

(ii) Assuming phosphorus and chlorine show their typical valencies, draw the displayed formula of **B**, showing all bonds and lone pairs.

.....

(iii) Calculate the oxidation number of phosphorus in **B**.

.....

(iv) One mole of **B** reacts with four moles of water.
Suggest the structure of the phosphorus-containing product of this reaction.

.....

[6]

Topic **Chem 9** Q# 53/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 **(a)** Write a balanced equation for the reaction of each of the following chlorides with water.

phosphorus(V) chloride .....

silicon(IV)chloride.....

[2]

Topic **Chem 9** Q# 54/ ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

Section A

Answer **all** questions in the spaces provided.

1 **(a)** Phosphorus and sulfur are two non-metallic elements on the right hand side of the Periodic Table.
For each of these elements describe the observations you would make when it burns in air, and write a balanced equation for the reaction.

phosphorus

observation .....

equation .....

sulfur

observation .....

equation .....

[4]

Topic **Chem 9** Q# 55/ ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(c) Lead(II) oxide reacts with both acids and bases.

(i) What is the name given to oxides that have this property?

.....

(ii) Write a balanced equation for the reaction between PbO and NaOH.

.....

[2]

Topic **Chem 10** Q# 56/ ALvl Chemistry/2020/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(b) (i) Write an equation for the reaction between BaO and H_2O.
Include state symbols.

..... [1]

Topic **Chem 10** Q# 57/ ALvl Chemistry/2019/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 The elements in Group 2 include magnesium, calcium, strontium and barium.

(a) (i) Write an equation for the change representing the first ionisation energy of magnesium.
Include state symbols.

..... [1]

(ii) Write an equation for the reaction of strontium with cold water. Include state symbols.

..... [1]

(iii) Describe and explain the trend in reactivity observed in the reactions of these Group 2 metals with cold water.

.....

.....

..... [1]

(b) The Group 2 metal nitrates decompose when heated.

(i) Describe fully what is seen when anhydrous calcium nitrate is heated in a test-tube and decomposition occurs.

.....

..... [1]

(ii) Write an equation for the decomposition of calcium nitrate.

..... [1]

Topic **Chem 10** Q# 58/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 (a) Describe what you would see when calcium and barium are heated separately with oxygen.

calcium .....

barium .....
[2]

(c) Magnesium carbonate was heated in an open test-tube. It was difficult to see whether a thermal decomposition reaction took place.

Explain why.

.....

.....

..... [2]

Topic **Chem 10** Q# 59/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1(a)/www.SmashingScience.org

(b) Element **A** is in the same period as silicon. Element **A** reacts with dilute nitric acid to form a nitrate. This nitrate decomposes on heating to form an oxide.

(i) Write an equation for the decomposition of the nitrate.

..... [2]

(ii) The oxide of element **A** has a high melting point.

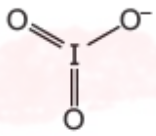
Suggest the structure and bonding present in the oxide of **A**.

..... [1]

Topic **Chem 11** Q# 60/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3 Iodates are compounds that contain the IO_3^- anion.

(a) The IO_3^- anion is shown.



(b) The reaction of iodine and hot aqueous sodium hydroxide is similar to that of chlorine and hot aqueous sodium hydroxide. Sodium iodate, $NaIO_3$, is formed as one of the products.

Suggest an equation for the reaction of iodine and hot aqueous sodium hydroxide.

..... [1]

Topic **Chem 11** Q# 61/ ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(d) Describe how the colours of the silver halides, and their relative solubilities in $NH_3(aq)$, can be used to distinguish between solutions of the halide ions Cl^-, Br^- and I^-.

.....

.....

.....

.....

.....

.....

..... [4]

Topic **Chem 11** Q# 62/ ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 **(a)** The halogens chlorine and bromine react readily with hydrogen.

$$X_2(g) + H_2(g) \rightarrow 2HX(g) \qquad [X = Cl \text{ or } Br]$$

(i) Describe how you could carry out this reaction using chlorine.

.....

(ii) Describe **two** observations you would make if this reaction was carried out with bromine.

.....

..... [3]

Topic **Chem 12** Q# 63/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

(c) Acid rain can have a major impact on natural waters, particularly lakes. In recent years there has been a worldwide effort to reduce the amount of acid rain produced.

(i) Write equations to show the production of acid rain from sulfur dioxide, SO_2.

.....

.....

(ii) The use of fossil fuels is one major source of sulfur dioxide.
Name another major industrial source.

.....

[2]

[Total: 9]

Topic **Chem 12** Q# 64/ ALvl Chemistry/2013/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 Because of the lack of reactivity of the nitrogen molecule, extreme conditions need to be used to synthesise ammonia from nitrogen in the Haber process.

(a) Suggest an explanation for the lack of reactivity of the nitrogen molecule, N_2.

.....

.....

[1]

(b) Under conditions of high temperature, nitrogen and oxygen react together to give oxides of nitrogen.

(i) Write an equation for a possible reaction between nitrogen and oxygen.

.....

(ii) State **two** situations, one natural and one as a result of human activities, in which nitrogen and oxygen react together.

.....

.....

(iii) What is the main environmental effect of the presence of nitrogen oxides in the atmosphere?

.....

[4]

Topic **Chem 12** Q# 65/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Nitrogen monoxide, NO, is formed in a reversible reaction when air is heated to the temperature of a car engine.

(iii) Explain why nitrogen monoxide is formed in the car engine.

.....

.....

[1]

Topic **Chem 12** Q# 66/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 The combustion of fuels in motor vehicles, trains, aeroplanes and power stations produces the pollutant gas NO_2.

(a) Write an equation to show how NO_2 is formed in these situations.

.....

.....[1]

(b) **(i)** How is the NO_2 removed from the exhaust gases of motor vehicles?

.....

.....

(ii) Write an equation for this process.

.....

.....

[2]

Topic **Chem 12** Q# 67/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Taken together, nitrogen and oxygen make up 99% of the air. Oxygen is by far the more reactive of the two gases, and most of the substances that react with air combine with the oxygen rather than with the nitrogen.

(a) State **one** reason why the molecule of nitrogen, N_2, is so unreactive.

.....

.....[1]

Despite the apparent lack of reactivity of N_2, nitrogen atoms have been found to form bonds with almost all of the elements in the Periodic Table. Lithium metal reacts with nitrogen gas at room temperature to give lithium nitride, Li_3N. Magnesium produces magnesium nitride, Mg_3N_2, as well as magnesium oxide, when heated in air.

(c) Lithium reacts readily with nitrogen, and because of this Li_3N has been considered as a possible intermediate in the 'fixing' of nitrogen to make ammonia-based fertilisers.

$$N_2(g) \xrightarrow{+\,Li} Li_3N \xrightarrow{+\,H_2O} NH_3 + \mathbf{A}$$

(i) Construct an equation for the reaction between Li_3N and H_2O, and hence identify compound **A**.

.....

.....

(ii) Using your knowledge of the Haber process, consider **one** advantage and **one** disadvantage of using lithium as a means of fixing nitrogen, rather than the Haber process.

advantage of the lithium method

.....

.....

disadvantage of the lithium method

.....

[3]

(d) Another possible advantage of Li_3N is that it contains a large percentage by mass of nitrogen. Another fertiliser that contains a large percentage by mass of nitrogen is urea, NH_2CONH_2.

(i) Calculate and compare the percentages by mass of nitrogen in Li_3N and NH_2CONH_2.

.....

.....

.....

(ii) What *class* of organic compound is urea?

.....

(iii) Write an equation for the production of ammonia by the reaction between urea and water.

.....

(iv) Urea can be applied directly to the soil either before or during the growing of crops.
What would be a major **disadvantage** of using lithium nitride in this way?

.....

.....

[5]

Topic **Chem 13** Q# 68/ ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

(iii) Alanine exists as a pair of optical isomers. The structure of one optical isomer is shown in Fig. 5.2.

Draw the three-dimensional structure of the other optical isomer of alanine.

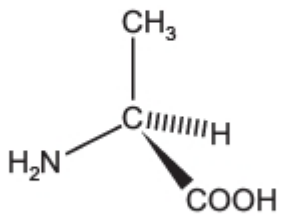
optical isomer 1	optical isomer 2
	

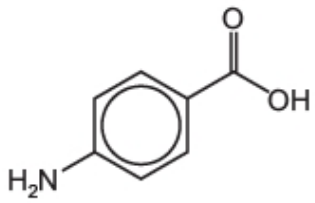
Fig. 5.2

[1]

Topic **Chem 13** Q# 69/ ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 Compounds **F** and **J** are shown in Fig. 4.1.

F



J

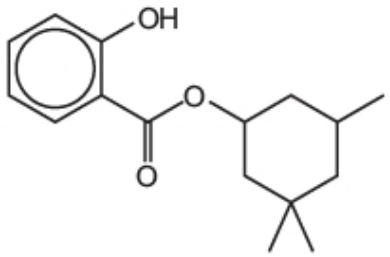


Fig. 4.1

(ii) State the number of chiral centres in a molecule of **F** and in a molecule of **J**.

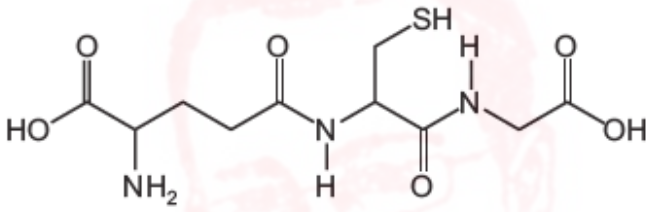
number of chiral centres in: **F** = ... **J** = ...

[1]

Topic **Chem 13** Q# 70/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

(c) Glutathione is a naturally occurring compound found in plants.

glutathione

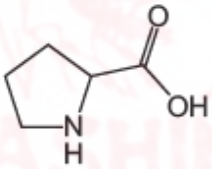


(i) On the diagram of glutathione, label each chiral centre with an asterisk (*). [1]

Topic **Chem 13** Q# 71/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 7/www.SmashingScience.org

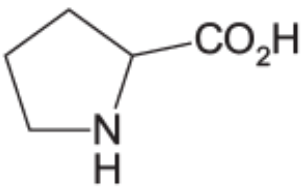
7 Proline (Pro) is a naturally occurring amino acid.

proline



(a) Proline is often found bonded to glycine (Gly) in a protein.

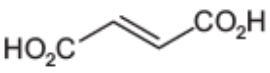
(vii) Identify with an asterisk (*) the chiral centre in proline.



[1]

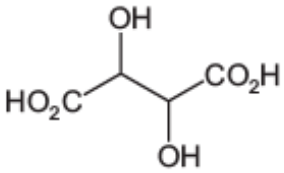
6 Fumaric acid is a naturally occurring dicarboxylic acid.

fumaric acid

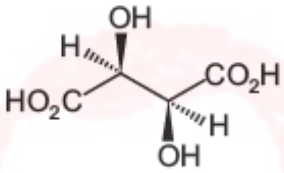


(c) Fumaric acid reacts with cold, dilute, acidified manganate(VII) to form compound **P**.

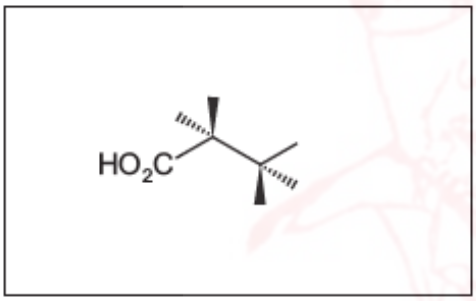
P

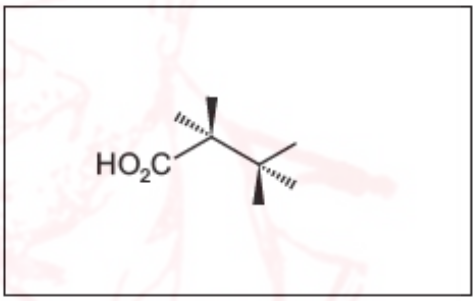


Only three stereoisomers of **P** exist. One of the stereoisomers is shown.



Complete the three-dimensional diagrams in the boxes to show the **other** two stereoisomers of **P**.





[2]

(b) 2-aminopropanoic acid, $CH_3CH(NH_2)CO_2H$, can polymerise under suitable conditions. No other monomer is involved in this reaction.

(ii) 2-aminopropanoic acid, $CH_3CH(NH_2)CO_2H$, exists as two stereoisomers.

Draw three-dimensional diagrams to show the two stereoisomers of 2-aminopropanoic acid. State the type of stereoisomerism shown.

type of stereoisomerism .....

[2]

(e) Compound **V** is a carboxylic acid which contains a chiral centre. It also has the molecular formula $C_5H_{10}O_2$.

(i) Explain what is meant by the term *chiral centre*.

.....

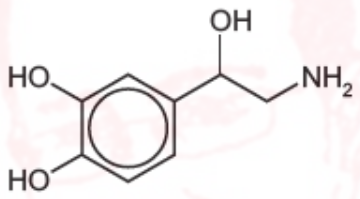
..... [1]

(ii) Suggest a structure for **V**.

[1]

[Total: 11]

9 Noradrenaline is a hormone found in humans.



noradrenaline

(a) Give the molecular formula of noradrenaline.

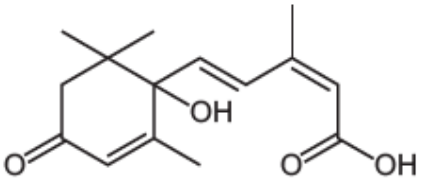
..... [1]

(b) State whether or not noradrenaline shows stereoisomerism. Explain your answer.

.....

..... [1]

8 Abscisic acid, $C_{15}H_{20}O_4$, is a plant hormone.

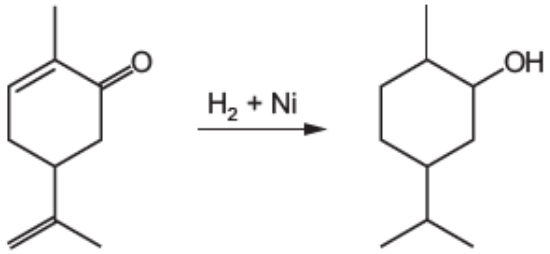


abscisic acid, $C_{15}H_{20}O_4$

(a) On the diagram of abscisic acid, use an asterisk (*) to label each chiral carbon atom. [1]

Topic **Chem 13** Q# 77/ ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 Carvone occurs in spearmint and a stereoisomer of carvone occurs in caraway seeds. Treating either isomer with hydrogen over a nickel catalyst produces a mixture of isomers with the structural formula **X**.



carvone **X**

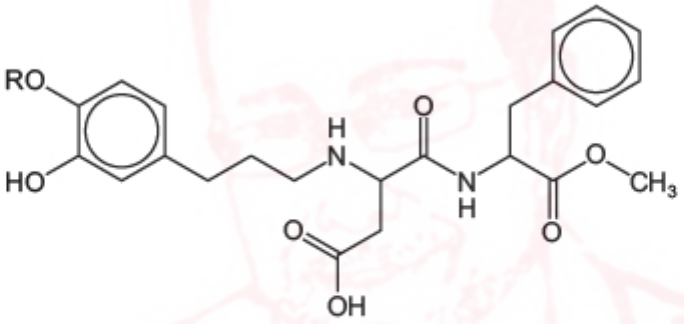
(a) (i) State the type of stereoisomerism carvone can show. Explain your answer.

.....

..... [1]

Topic **Chem 13** Q# 78/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 7/www.SmashingScience.org

7 The compound *Advantame* is a sweetener that tastes approximately 25 000 times sweeter than sucrose.



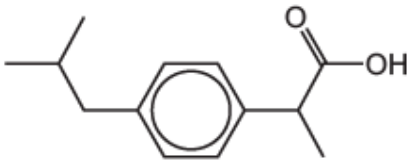
Advantame

(a) *Advantame* is optically active.

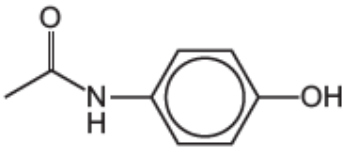
On the diagram of *Advantame*, circle all the chiral carbon atoms. [1]

Topic **Chem 13** Q# 79/ ALvl Chemistry/2016/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 Ibuprofen and paracetamol are pain-relief drugs.



ibuprofen



paracetamol

(b) Ibuprofen contains a chiral centre and shows stereoisomerism.

(i) State what is meant by the term *chiral centre*.

.....

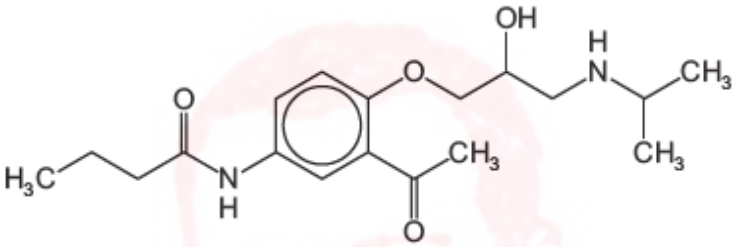
..... [1]

(ii) Draw the two stereoisomers of ibuprofen.

[2]

Topic **Chem 13** Q# 80/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 8/www.SmashingScience.org

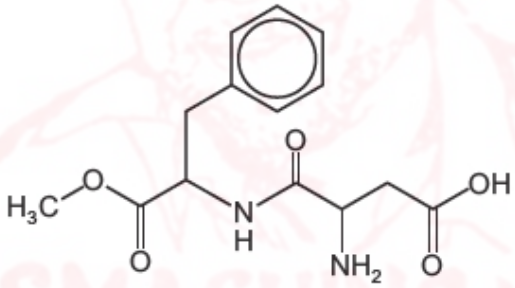
(b) On the diagram of acebutolol below, draw a **circle** around any chiral carbon atoms.



[1]

Topic **Chem 13** Q# 81/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 10/www.SmashingScience.org

10 (a) Aspartame is an artificial sweetener that has the structure shown below.

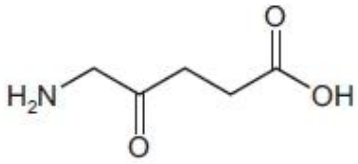


aspartame

(i) Draw a circle around each chiral centre in aspartame. [1]

Topic **Chem 13** Q# 82/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

(b) Aminolaevulinic acid is involved in the synthesis of haemoglobin and chlorophyll.

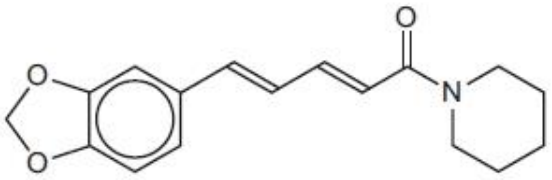


aminolaevulinic acid

Name the **three** functional groups in aminolaevulinic acid.

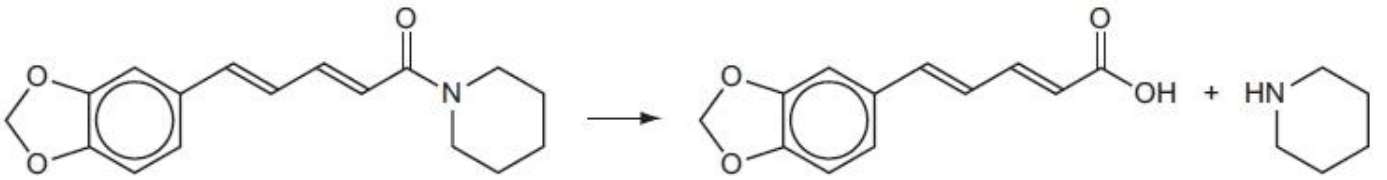
..... [2]

3 Piperine is the compound responsible for the hot taste of black pepper.



piperine

Piperine is an amide and can be broken down as follows:



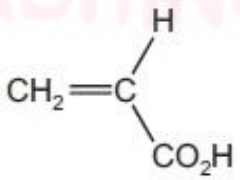
piperine piperic acid piperidine

(b) (i) How many stereoisomers are there with the same structural formula as piperic acid (including piperic acid itself)?

.....

(ii) Draw the skeletal structure of a stereoisomer of piperic acid, different to the one shown above.

[2]



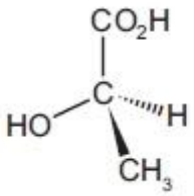
K

(b) *Acrylic acid* is the common name for compound **K**.
Suggest the systematic (chemical) name of **K**.

.....

[1]

(ii) The structure of lactic acid is shown.



(b) Lactic acid exists in two stereoisomeric forms. Draw the other form in the box.

[1]

3 Indigo is the dye used in blue jeans. Although originally extracted from plants of the type *indigofera*, it is now almost entirely made artificially.

Indigo is insoluble in water but this disadvantage can be overcome by converting it into the water-soluble colourless leuco-indigo. If cloth soaked in a solution of leuco-indigo is left to dry in the air, the leuco-indigo is converted into the insoluble blue indigo, which is precipitated out onto the fibres of the cloth.

indigo leuco-indigo

(a) (i) Give the molecular formula of indigo.

..... [1]

Section A

Answer **all** questions in the spaces provided.

1 (a) The halogens chlorine and bromine react readily with hydrogen.

$$X_2(g) + H_2(g) \rightarrow 2HX(g) \qquad [X = Cl \text{ or } Br]$$

(b) Some halogens also react readily with methane.

$$CH_4(g) + X_2(g) \rightarrow CH_3X(g) + HX(g)$$

(i) What conditions are needed to carry out this reaction when X is bromine, Br?

..... [1]

(c) Halogenoalkanes can undergo *homolytic fission* in the upper atmosphere.

(i) Explain the term *homolytic fission*.

.....

.....

(ii) Suggest the most likely organic radical that would be formed by the homolytic fission of bromochloromethane, CH_2BrCl. Explain your answer.

.....

.....

.....

[3]

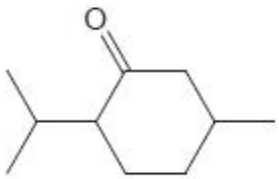
(d) The reaction between propane and chlorine produces a mixture of many compounds, four of which are structural isomers with the molecular formula $C_3H_6Cl_2$.
Draw the structural or skeletal formulae of these isomers, and indicate any chiral atoms with an asterisk (*).

[3]

[Total: 18]

Topic **Chem 13** Q# 88/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 Menthone, $C_{10}H_{18}O$, is a cyclic ketone that occurs in oil of peppermint.

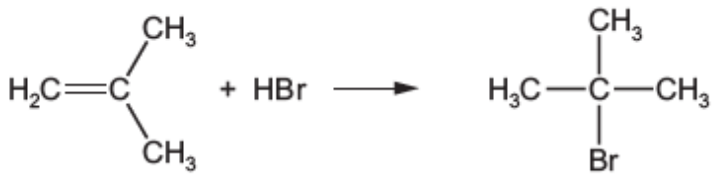


menthone

(a) Use asterisks (*) on the formula above to identify any chiral centres in the molecule of menthone. [2]

(c) Halogenoalkanes can be formed from the reaction of an alkene with a hydrogen halide.

Methylpropene reacts with hydrogen bromide to form 2-bromo-2-methylpropane.



methylpropene 2-bromo-2-methylpropane

(i) Draw the mechanism of this reaction. Include all relevant curly arrows, dipoles and charges.

[3]

(ii) 1-bromo-2-methylpropane is also formed in this reaction.

Explain why 2-bromo-2-methylpropane will be the **major** product in this reaction.

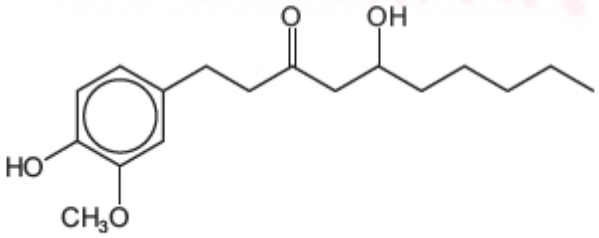
.....

.....

..... [1]

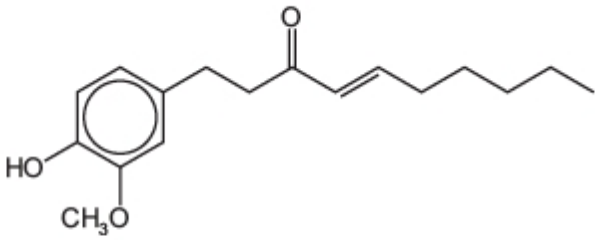
8 The root of the ginger plant contains compounds with medicinal and flavouring properties. Three of the more important compounds are gingerol, shogaol and zingerone.

(a) The structure of gingerol is shown. The CH_3O– group in gingerol is unreactive.



gingerol

(b) The structure of shogaol is shown.



shogaol

(i) State the *type of reaction* needed to convert gingerol into shogaol.

..... [1]

(ii) State the reagents and conditions needed to convert gingerol into shogaol.

reagents .....

conditions .....

[1]

(iii) Shogaol reacts with hot, concentrated acidified manganate(VII) ions to form two organic products, Q and R.

Draw the structures of Q and R.

Q R

[2]

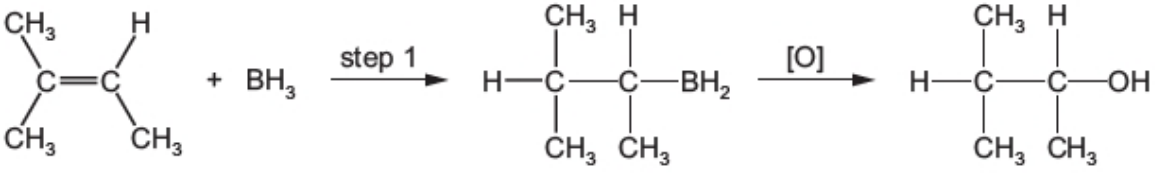
Topic **Chem 14** Q# 91/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 Boron forms many useful compounds.

(a) The compound diborane, B_2H_6, can be used as a rocket fuel.
It can be prepared by the reaction of boron trifluoride, BF_3, with sodium borohydride, $NaBH_4$.

(c) Borane, BH_3, is used to synthesise alcohols from alkenes.
The reaction occurs in two steps.

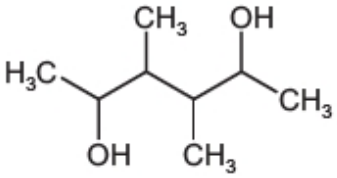
The BH_2 group from BH_3 bonds to the **least** substituted carbon atom of the double bond, and the remaining H from BH_3 bonds to the other carbon.



(i) Suggest the *type of reaction* in step 1.

..... [1]

(ii) The diol **Y** can be prepared by the same method.



Y

Draw the structure of the **diene** which could be used to prepare diol **Y**.

[1]

Topic **Chem 14** Q# 92/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

7 **(a)** Long chain alkanes such as 4-methylheptane can be 'cracked' to produce shorter chain hydrocarbons.

4-methylheptane

→ **B** C_3H_8 + a mixture of **C**, **D** and **E** (isomers of C_5H_{10})

(i) State the conditions necessary for this reaction to take place.

..... [1]

(ii) Suggest the structure of **B**.

B

[1]

Topic **Chem 14** Q# 93/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

(b) Propene, $CH_3CH=CH_2$, reacts with bromine to give 1,2-dibromopropane.

(i) How is this reaction usually carried out?

..... [1]

(ii) State the *type of reaction* that is occurring here.

..... [1]

(iii) Draw the mechanism of this reaction, including the structures of any intermediates, and any dipoles, lone pairs and curly arrows to show the movements of electrons.

[2]

Topic **Chem 14** Q# 94/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 10/www.SmashingScience.org

10 In recent years there has been worldwide interest in the possible extraction of 'shale gas' (a form of natural gas) as an important energy source.

(a) One of the problems associated with using shale gas is its variable composition.
Table 1 shows the percentage composition of shale gas from four different sources **J**, **K**, **L** and **M**.

source	CH_4	C_2H_x	C_3H_y	CO_2	N_2
J	80.3	8.1	2.3	1.4	7.9
K	82.1	14.0	3.5	0.1	0.3
L	88.0	0.8	0.7	10.4	0.1
M	77.5	4.0	0.9	3.3	14.3

In the formulae above, ***x*** and ***y*** are variables.

Table 1

(i) Draw the structures of **three** possible compounds with the formula C_3H_y.

[2]

(ii) Which source of shale gas, **J**, **K**, **L** or **M**, will provide the most energy when burned? Explain your answer.

.....

..... [1]

(iii) Suggest **two** methods by which carbon dioxide can be removed from shale gas.

1 .....

.....

2 .....

..... [2]

(b) **Table 2** shows a comparison of the relative amounts of pollutants produced when shale gas, fuel oil and coal are burned to produce **the same amount of energy**.

air pollutant	shale gas	fuel oil	coal
CO_2	117	164	208
CO	0.040	0.033	0.208
NO_2	0.092	0.548	0.457
SO_2	0.001	1.12	2.59
particulates	0.007	0.84	2.74

Table 2

(i) Suggest why shale gas produces the smallest amount of CO_2.

.....

..... [1]

(ii) Explain which of the three fuels, shale gas, fuel oil or coal, is the **largest** contributor to 'acid rain'.

fuel .....

.....

..... [1]

(iii) Suggest a reason why fuel oil and coal produce more NO_2 than shale gas.

.....

..... [1]

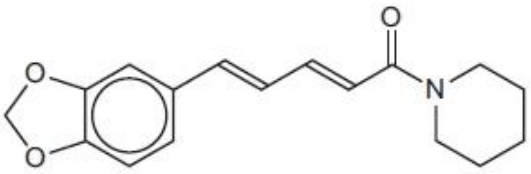
(iv) State **one** environmental consequence of raised levels of

- CO, ...
- CO_2. .....

[2]

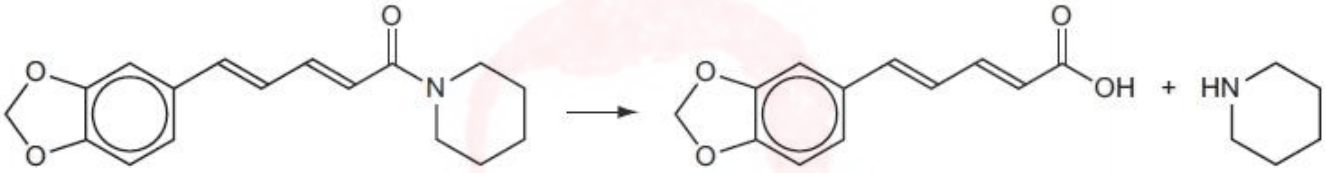
Topic **Chem 14** Q# 95/ ALvl Chemistry/2014/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 Piperine is the compound responsible for the hot taste of black pepper.



piperine

Piperine is an amide and can be broken down as follows:



piperine piperic acid piperidine

(iii) Suggest structures for the compounds that would be formed when piperic acid is treated with an **excess** of hot concentrated acidified $KMnO_4$.

[2]

Topic **Chem 14** Q# 96/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 The combustion of fuels in motor vehicles, trains, aeroplanes and power stations produces the pollutant gas NO_2.

(c) Suggest whether the production of the pollutant NO_2 would be reduced if fossil fuels were replaced by hydrogen as a fuel for combustion. Explain your answer.

.....

.....[1]

Topic **Chem 15** Q# 97/ ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 6/www.SmashingScience.org
NOT WITH Q# 6 part b

6 The reaction between 1-chloro-1-phenylethane and hydroxide ions to produce 1-phenylethanol is:

$$\underset{\text{1-chloro-1-phenylethane}}{C_6H_5CHClCH_3} + OH^- \rightarrow \underset{\text{1-phenylethanol}}{C_6H_5CH(OH)CH_3} + Cl^-$$

The rate of this reaction can be studied by measuring the amount of hydroxide ions that remain in solution at a given time. The reaction can effectively be stopped if the solution is diluted with an ice-cold solvent.

The answer mentioned below from (b)(i) "The reaction mechanism is an Sn1"

(c) (i) Use your answers in **(b)(i)** to help you to draw the mechanism for the reaction of 1-chloro-1-phenylethane with hydroxide ions, including the following.

- all relevant lone pairs and dipoles
- curly arrows to show the movement of electron pairs
- the structures of any transition state or intermediate

[3]

(ii) This reaction was carried out using a single optical isomer of 1-chloro-1-phenylethane.

Use your mechanism in **(i)** to predict whether the product will be a single optical isomer or a mixture of two optical isomers. Explain your answer.

.....

..... [1]

Topic **Chem 15** Q# 98/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 In aqueous solution, 2-chloro-2-methylpropane, $(CH_3)_3CCl$, reacts with sodium hydroxide, NaOH. This is a nucleophilic substitution reaction.

$$(CH_3)_3CCl(aq) + NaOH(aq) \rightarrow (CH_3)_3COH(aq) + NaCl(aq)$$

(a) Show the mechanism for this reaction. Include all necessary curly arrows, lone pairs and relevant dipoles.

[3]

Topic **Chem 15** Q# 99/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

(b) (i) Describe and explain the trend in bond energies of the C–X bond in halogenoalkanes, where X = F, Cl, Br or I.

.....

.....

(ii) Describe the relationship between the reactivity of halogenoalkanes, RX, and the bond energies of the C–X bond.

.....

.....

[3]

(e) Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

(i) State the conditions needed for this reaction.

.....

(ii) State the *type of reaction* occurring here.

.....

One of the steps during this reaction is the following process.

$$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$$

(vi) Complete the following equations of some possible steps in the formation of chloroethane.

$Cl_2 \rightarrow$ .....

$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$

$CH_3CH_2^{\bullet}$ + ... → ..... + ...

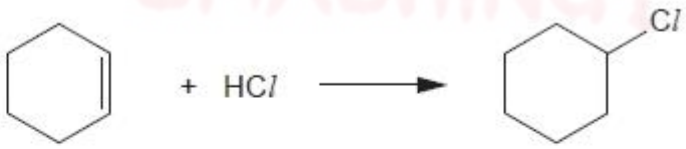
..... + ... → CH_3CH_2Cl

[5]

[Total: 19]

Topic **Chem 15** Q# 100/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

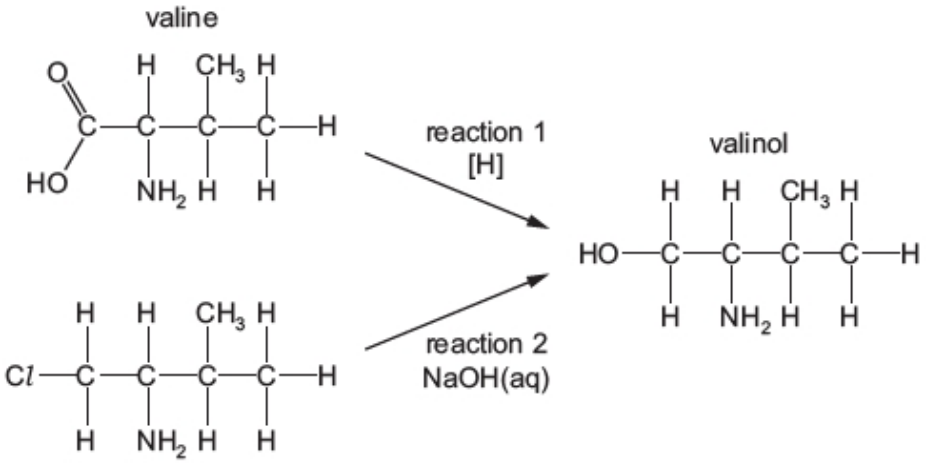
(d) Chlorocyclohexane can be prepared by bubbling $HCl(g)$ through a solution of cyclohexene.



Suggest the mechanism of this 2-stage reaction by means of a diagram. Include all whole or partial charges, and represent the movements of electron pairs by curly arrows.

[3]

6 Valinol can be synthesised by the following reactions. Reaction 1 uses valine as the starting material.



(a) (i) Write an equation for reaction 1, using [H] to represent the reducing agent.

..... [1]

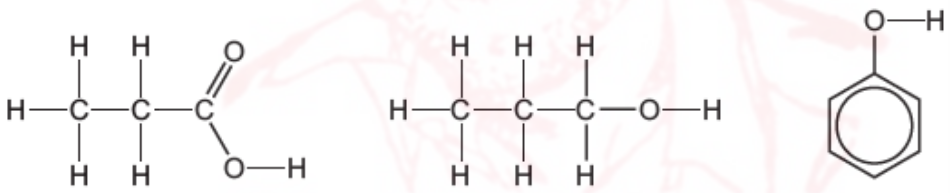
(ii) Suggest a suitable reagent for reaction 1.

..... [1]

(iii) Name the mechanism for reaction 2.

..... [1]

7 The three substances shown all have some acidic properties.



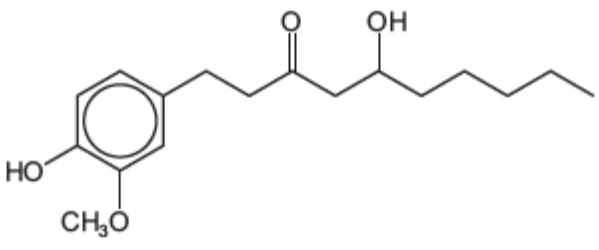
propanoic acid propan-1-ol phenol

(a) Write an equation for the reaction between propan-1-ol and sodium metal.

..... [1]

8 The root of the ginger plant contains compounds with medicinal and flavouring properties. Three of the more important compounds are gingerol, shogaol and zingerone.

(a) The structure of gingerol is shown. The CH_3O– group in gingerol is unreactive.



gingerol

Gingerol reacts with acidified potassium dichromate(VI).

State the *type of reaction* and the functional group change which occurs during this reaction.

type of reaction .....

functional group change

from ..... to .....

[1]

Topic **Chem 17** Q# 104/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6 The names of many drugs used in medicine often include parts of the names of the functional groups their molecules contain.

(b) The drug named ketamine readily reacts with protons as shown.

$$\text{ketamine} + H^+ \rightarrow [\text{ketamine-H}]^+$$

Ketamine gives an orange precipitate with 2,4-dinitrophenylhydrazine (2,4-DNPH).

(ii) Suggest the functional group in the ketamine molecule responsible for this observation.

..... [1]

Topic **Chem 17** Q# 105/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 4/www.SmashingScience.org

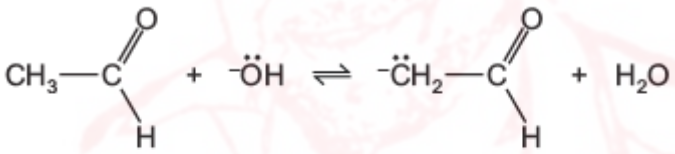
4 **(a)** Ethanal, CH_3CHO, dimerises in alkaline solution according to the following equation.

$$2CH_3CHO \rightarrow CH_3CH(OH)CH_2CHO$$

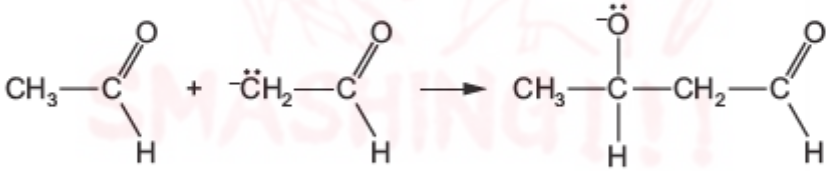
The initial rate of this reaction was measured, starting with different concentrations of CH_3CHO and OH^-. The following results were obtained.

(b) **(i)** A three-step mechanism has been proposed for the reaction in **(a)**.

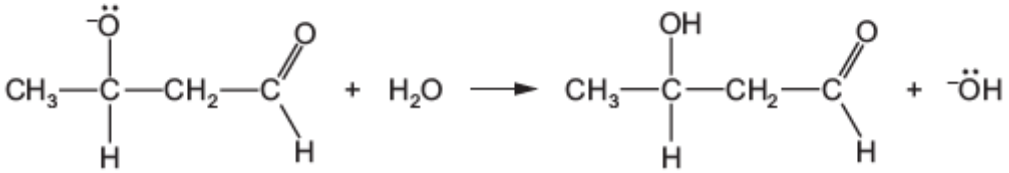
step 1



step 2



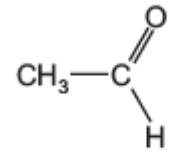
step 3

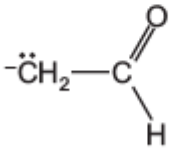


(c) Name the mechanism occurring in steps 2 and 3.

..... [1]

(d) Using the diagram below, show the mechanism for step 2 showing the relevant curly arrows and dipoles.



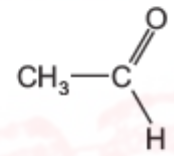


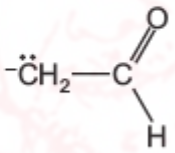
[2]

(c) Name the mechanism occurring in steps 2 and 3.

..... [1]

(d) Using the diagram below, show the mechanism for step 2 showing the relevant curly arrows and dipoles.





[2]

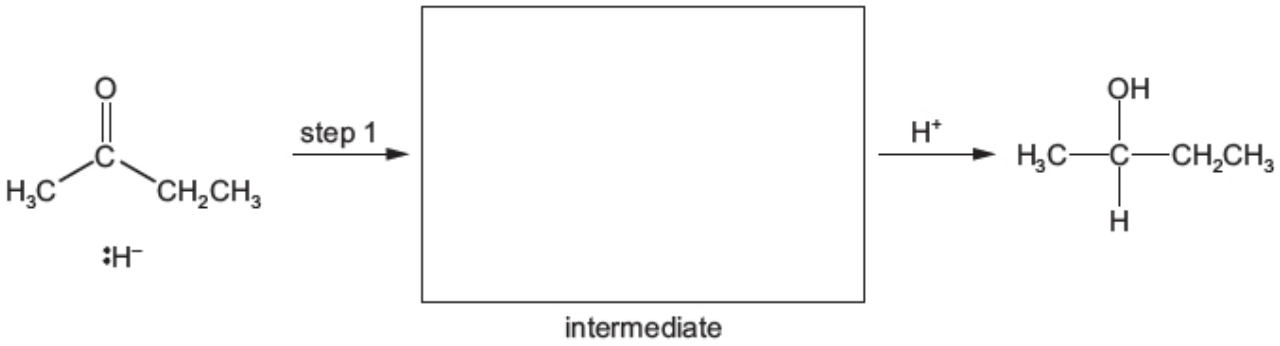
Topic **Chem 17** Q# 106/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 Boron forms many useful compounds.

(a) The compound diborane, B_2H_6, can be used as a rocket fuel.
It can be prepared by the reaction of boron trifluoride, BF_3, with sodium borohydride, $NaBH_4$.

(b) Primary and secondary alcohols can be formed by the reaction of carbonyl compounds with $NaBH_4$, which is a source of hydride ions, H^-.

Complete the mechanism for the reaction of butanone with hydride ions, H^-, and draw the intermediate in the box. Include all necessary curly arrows and relevant dipoles.



[3]

3 Indigo is the dye used in blue jeans. Although originally extracted from plants of the type *indigofera*, it is now almost entirely made artificially.

Indigo is insoluble in water but this disadvantage can be overcome by converting it into the water-soluble colourless leuco-indigo. If cloth soaked in a solution of leuco-indigo is left to dry in the air, the leuco-indigo is converted into the insoluble blue indigo, which is precipitated out onto the fibres of the cloth.

indigo leuco-indigo

[1]

(b) (i) What *type of reaction* is the conversion of indigo into leuco-indigo?

.....

(ii) Suggest a laboratory reagent for this reaction.

.....

[2]

6 **(a)** The reaction producing tri-iodomethane (iodoform) can be used as a test for the presence of certain groups within a molecule.

(i) State the reagents and conditions used for this reaction.

.....

(ii) Write the structural formula of **one** functional group that would give a positive result with this iodoform reaction.

.....

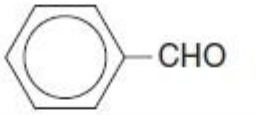
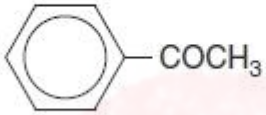
(iii) What do you observe in a positive test?

.....

.....

6 **(a)** The reaction producing tri-iodomethane (iodoform) can be used as a test for the presence of certain groups within a molecule.

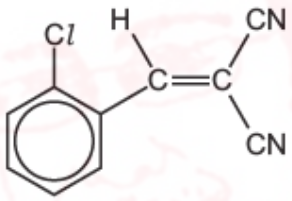
(iv) In the following table place a tick (✓) in the column against each compound that would give a positive result with this test, and a cross (✗) against each compound that would give a negative result.

compound	result
CH_3OH	
CH_3CH_2OH	
CH_3CHO	
CH_3CO_2H	
	
	

[6]

Topic **Chem 20** Q# 110/ ALvl Chemistry/2017/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 Compound **P** contains several functional groups.



P

(b) Compound **P** can be polymerised.

Draw a section of the polymer of **P** showing **two** repeat units.
Name the type of polymerisation.

type of polymerisation .....

[2]

Topic **Chem 20** Q# 111/ ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

8 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.

(c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.

polymer .....

reason .....

.....

.....

[2]

Topic **Chem 20** Q# 112/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9 In today's world, many traditional materials have been replaced by different sorts of polymers. This includes rigid polymers such as those used in car bodies to replace steel and flexible polymers like those used in textiles to replace cotton or wool.

(a) (i) To form a polymer, what is the **minimum** number of functional groups that the monomer must possess?

.....

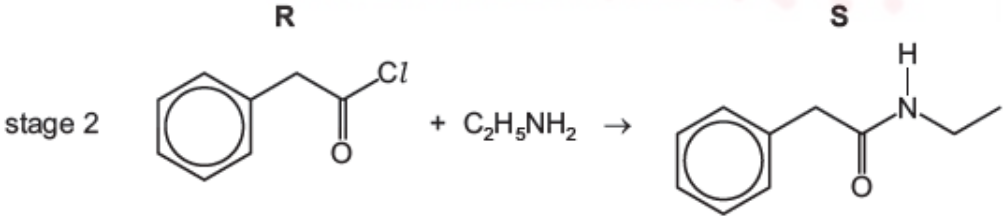
(ii) Illustrate your answer to (i) with the structure of a possible monomer.

[2]

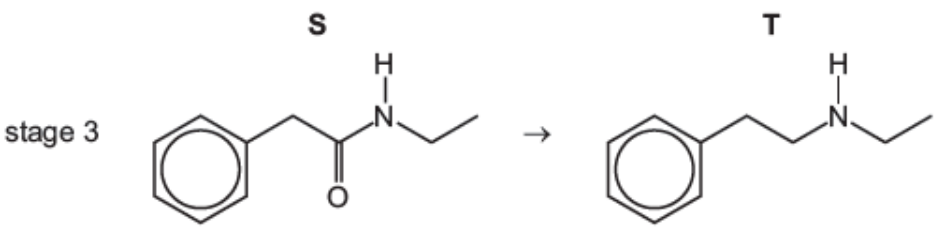
Topic **Chem 22** Q# 113/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9 Compound **T** is made by a three-stage synthesis.

(b) In stage 2, compound **R** reacts with ethylamine to form compound **S**.



(c) In stage 3, compound **S** reacts with a suitable reagent to form compound **T**.



(d) The relative abundance of the molecular ion peak in the mass spectrum of ethylamine is 62.

(i) Calculate the relative abundance of the M+1 peak in the mass spectrum of ethylamine.

relative abundance = ... [1]

(ii) The mass spectrum of compound **T** contains several fragments. The *m/e* values of two of these fragments are 29 and 91.

Draw the structures of the ions responsible for these peaks.

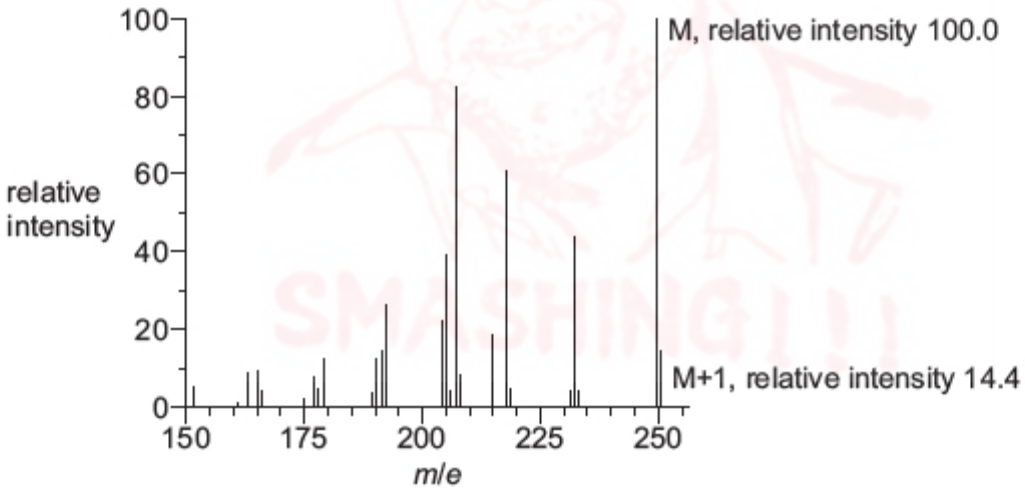
m/e	structure of ion
29	
91	

[2]

Topic **Chem 22** Q# 114/ ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 4/www.SmashingScience.org

(d) Compound **J**, $C_xH_yO_z$, is also found in some cereals.

Part of the mass spectrum of **J** is shown. The M and M+1 peaks are labelled, along with their relative intensities.



(i) Calculate the number of carbon atoms, *x*, present in **J**.

x = ... [2]

(ii) The mass spectrum has a peak at *m/e* = 205.

Suggest the identity of the fragment lost from **J** to form this peak.

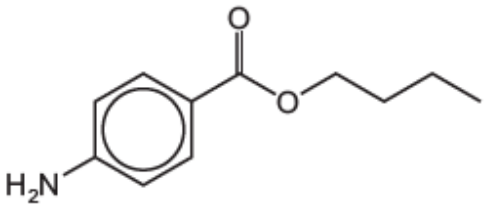
..... [1]

[Total: 12]

Topic **Chem 22** Q# 115/ ALvl Chemistry/2019/w/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9 The structure of butamben is shown.

butamben



(a) Butamben can act as a base.

(d) The mass spectrum of butamben includes peaks at *m/e* 92 and 57.

Identify the fragments responsible for these peaks.

m/e 92 = ...

m/e 57 = ...

[1]

[Total: 10]

Topic **Chem 22** Q# 116/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

8 **(a)** The mass spectrum of compound **X**, $C_5H_{10}O_2$, is recorded.

The peak heights of the M and M+1 peaks are 22.65 and 1.25 respectively.

(i) Use these data to show that there are five carbon atoms present in one molecule of **X**.

Show your working.

[1]

(ii) The mass spectrum has a peak at *m/e* = 57.

Complete the equation to show the fragmentation of **X** to produce this peak.

$[C_5H_{10}O_2]^+ \rightarrow$ ..... + ...

[2]

Topic **Chem 22** Q# 117/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6 The names of many drugs used in medicine often include parts of the names of the functional groups their molecules contain.

(b) The drug named ketamine readily reacts with protons as shown.

$$\text{ketamine} + H^+ \rightarrow [\text{ketamine-H}]^+$$

Ketamine gives an orange precipitate with 2,4-dinitrophenylhydrazine (2,4-DNPH).

The mass spectrum of ketamine is determined. Two peaks close to the molecular ion peak, M, are observed with the relative abundances shown in the table.

peak	m/e	relative abundance
M	237	100.0
M+1	238	14.3
M+2	239	33.3

(iii) Use the numbers in the table to show that there are 13 carbon atoms in a ketamine molecule.

[1]

In addition to carbon and hydrogen atoms, each molecule of ketamine contains **one** atom of each of **three** different elements. These are called heteroatoms. One of these heteroatoms is a halogen.

(iv) Use the figures in the table to suggest the identity of this halogen. Explain your answer.

.....

..... [1]

(v) Another peak in the mass spectrum of ketamine has an m/e value of 240.

Predict the relative abundance of this peak.

relative abundance = ... [1]

(vi) Use the information in **(b)** to complete the molecular formula of ketamine by working out the identities of the **three** different heteroatoms and the number of hydrogen atoms present.

$C_{13}H$

[1]

Topic **Chem 22** Q# 118/ ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) (i) The mass spectrum of a halogenoalkane containing one chlorine atom **or** bromine atom will show an additional peak at M+2.

State the isotopes of chlorine and bromine responsible for M+2 peaks.

chlorine ..... bromine .....

[1]

(ii) The mass spectrum of bromochloromethane, CH_2BrCl, has a molecular ion peak, M, at an *m/e* value of 128. It also has M+2 and M+4 peaks.

Suggest the identity of the molecular ions that give rise to these peaks.

M peak .....

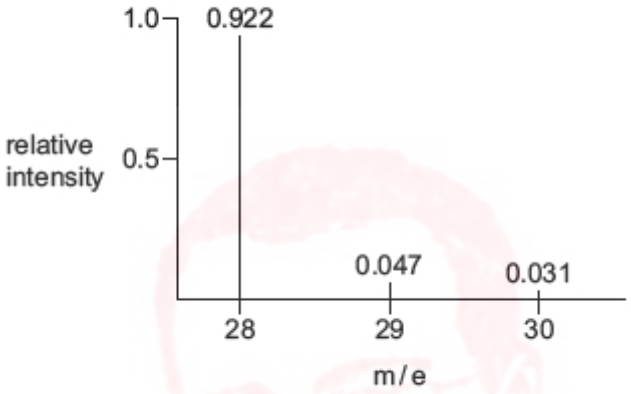
M+2 peak .....

M+4 peak .....

[2]

Topic **Chem 22** Q# 119/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 (a) (i) The mass spectrum of silicon is shown.

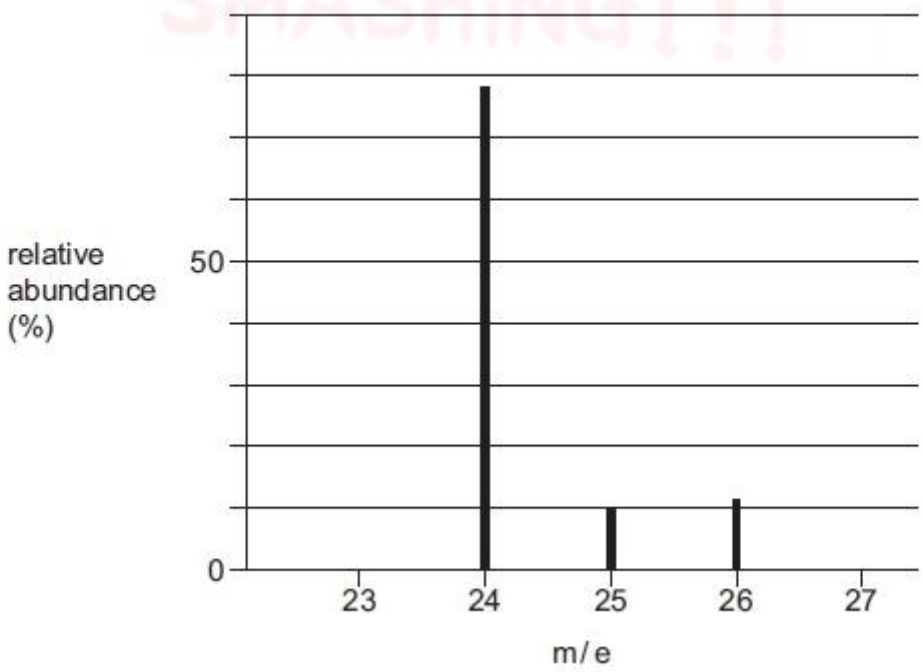


Calculate the A_r of silicon. Give your answer to **two** decimal places.

A_r = ... [1]

Topic **Chem 22** Q# 120/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 (a) The mass spectrum of the element magnesium is shown below.



(i) From the mass spectrum, complete the table with the relative abundances of the three isotopes.

isotope	relative abundance
^{24}Mg	
^{25}Mg	
^{26}Mg	

[1]

(ii) Use your values in **(i)** to calculate the relative atomic mass, A_r, of magnesium to **two** decimal places.

A_r (Mg) = ... [1]

Topic **Chem 22** Q# 121/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 **(a)** Natural phosphorus consists of one isotope, ^{31}P. Chlorine exists naturally as two isotopes, ^{35}Cl and ^{37}Cl, in the relative abundance ratio of 3 : 1.

(i) The mass spectrum of PCl_3 contains several peaks corresponding to a number of molecular fragments.

Suggest the isotopic composition of the fragments with the following mass numbers.

mass number	isotopic composition
101	
103	
105	

(ii) Predict the relative ratios of the peak heights of the three peaks corresponding to these fragments.

.....

[4]

Topic **Chem 22** Q# 122/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

(c) Propene was treated with bromine in the presence of chloride ions and the product analysed using mass spectrometry.

A group of peaks was found in the range *m/e* 156–160 with the following relative heights.

m/e	relative height
156	3
158	4
160	1

(i) Identify the species responsible for each of these peaks.

156 .....

158 .....

160 .....

A large peak was present in the spectrum with a *m/e* value of less than 20.

(ii) Suggest the *m/e* value for the peak and the species that produced it.

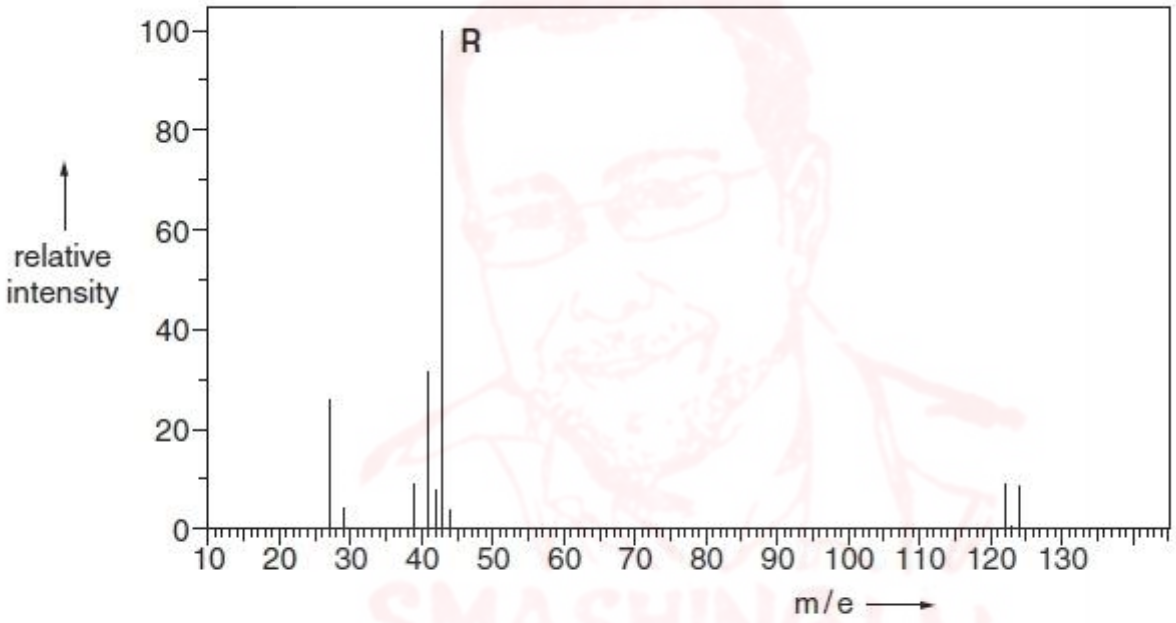
m/e .....

species .....

[4]

Topic **Chem 22** Q# 123/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

(c) The mass spectrum shown was obtained from a compound of formula C_pH_qX, where *X* represents a halogen atom.



(i) Deduce the identity of *X*, giving a reason.

X is .....

.....

(ii) If the relative heights of the M and M+1 peaks are 9 and 0.3 respectively, calculate the value of *p*. Use this value and the m / e value of the molecular ion to calculate the value of *q*, and hence the molecular formula of the compound. Show your working.

(iii) Suggest a formula for the ion responsible for the peak labelled **R**.

.....

[4]

(d) In the fragmentation of alcohols which occurs in a mass spectrometer, small stable, neutral molecules are sometimes produced. Suggest the identity of **two** such molecules, each with an M_r less than 30.

(i) ..... (ii) .....

[2]

Mark Scheme ALvl Chem 1 to 22 P4 22m to 09w **AS Material in Paper 4** 348marks

Topic Chem 1 **Q# 1/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a)	Ca $3s^23p^64s^2$ **and** Ca^{2+} $3s^23p^6$	1

Topic Chem 1 **Q# 2/** ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a)	oxygen: $(1s^2)\ 2s^22p^4$ fluorine: $(1s^2)\ 2s^22p^5$	1

Topic Chem 2 **Q# 3/** ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(a)(ii)	$20 \times [0.9(+2) + 0.1(+3)] - 2x = 0$ $\therefore x = 21$	1

Topic Chem 2 **Q# 4/** ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(b)(iii)	$3SiF_4 + 2H_2O \rightarrow 2H_2SiF_6 + SiO_2$	1

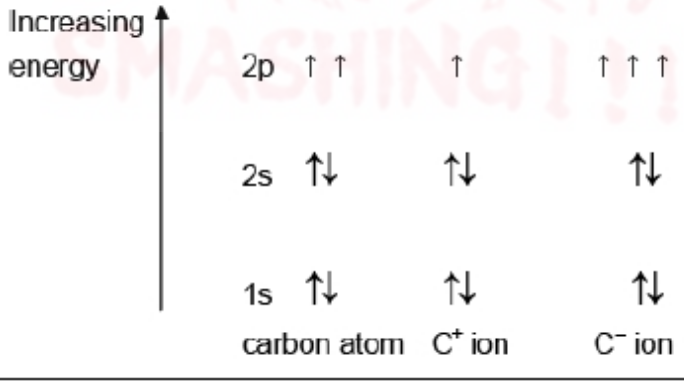
Topic Chem 2 **Q# 5/** ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)	$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$	
	balanced with all formulae correct	1
	state symbols	1

Topic Chem 2 **Q# 6/** ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(b)	giant ionic	1
	strong bond / attraction between **AND** positive and negative ions / anions and cations / Na^+ and O^{2-} / oppositely charged ions	1

Topic Chem 2 **Q# 7/** ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 (a)		2

Topic Chem 2 **Q# 8/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 (a)	$4BF_3 + 3NaBH_4 \rightarrow 2B_2H_6 + 3NaBF_4$	1

Topic Chem 2 **Q# 9/** ALvl Chemistry/2013/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(c) $n(H_2) = 8/24 = 0.33$ mol [1]

from equation, this is produced from 0.22 mol of Al ecf (× 2/3) [1]

A_r(Al) = 27 thus mass of Al = 27 × 0.22 = 5.9 – 6 g hence 5.9–6.0% ecf (× 27) [1]

[3]

Topic Chem 2 **Q# 10/** ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

(b) moles of oxygen = 9.3/16 = 0.581 mol
moles of lead = 90.7/207 = 0.438 mol (both 3 s.f.) (1)

so formula is Pb_3O_4 (1) **[2]**

Topic Chem 2 **Q# 11/** ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(c) (i) any **two** from:
brown fumes or vapour evolved / gas relights glowing splint / black solid formed (2)

(ii) $2Cu(NO_3)_2 \rightarrow 2CuO + 4NO_2 + O_2$ (1) **[3]**

Topic Chem 2 **Q# 12/** ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) (i) **2** $Ca_3(PO_4)_2$ + **6** SiO_2 + **10** C ⟶ **1** P_4 + **6** $CaSiO_3$ + **10** CO (2)

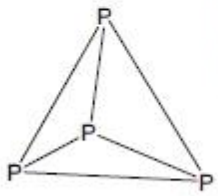
Topic Chem 2 **Q# 13/** ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(ii)

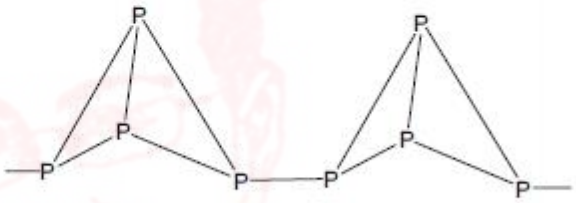
allotrope	type of structure	type of bonding
white	**simple / molecular**	**covalent**
red	**giant / polymeric**	**covalent**

(4)

(iii)



white P_4 (1)



red P_n (1)

(in each case P has to be trivalent. Many alternatives allowable for the polymeric red P) (2)
(8 max 7) **[7]**

Topic Chem 2 **Q# 14/** ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(d) (i) Ca = 28.2/40.1 = 0.703 ⇒ 1
C = 25.2/12 = 2.10 ⇒ 3
H = 1.4/1 = 1.4 ⇒ 2
O = 45.1/16 = 2.82 ⇒ 4 (1 mark for initial step of calc'n)

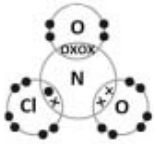
formula is $CaC_3H_2O_4$ (1) [2]

(ii) malonic acid must be $C_2H_4O_4$, i.e. $\mathbf{CH_3(CO_2H)_2}$ (must be structural) [1]
[3]

Topic Chem 3 **Q# 15/** ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(a)	3 bonding-pair centres and one lone pair (on iodine)	1
3(b)	$3I_2 + 6NaOH \rightarrow NaIO_3 + 5NaI + 3H_2O$	1

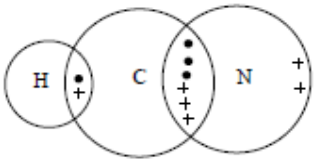
Topic Chem 3 **Q# 16/** ALvl Chemistry/2019/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(a)	 **M1:** eight electrons around N atom [N=O, N-O, N-Cl with N-O as dative] **M2:** all other electrons correct	2

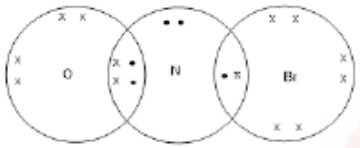
Topic Chem 3 **Q# 17/** ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(d)	**M1** bond angle 104–105° **M2** **explanation** two lone pairs and two bonding pairs **M3** lone pairs repel more	3

Topic Chem 3 **Q# 18/** ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(a)(ii)		1
3(a)(iii)	C: sp **and** N: sp angle 180°	2

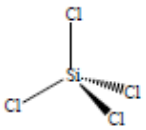
Topic Chem 3 **Q# 19/** ALvl Chemistry/2017/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)	N +2 to +3 (and oxidised)	1
	Br_2/Br 0 to –1 (and reduced)	1
1(b)		
	3 bonding pairs around N (in a structure involving NOBr)	1
	rest of molecule correct	1

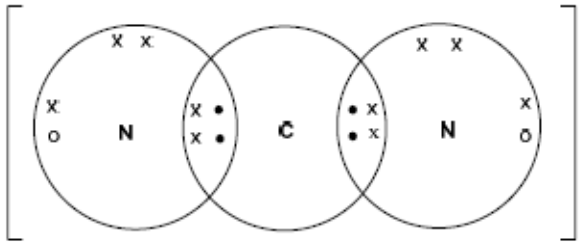
Topic Chem 3 **Q# 20/** ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(a)(i)		1 + 1
	16 electrons on each diagram	1
2(a)(ii)	HNC = 115–125° AND NCO = 180°	1
2(a)(iii)	cyanic acid, because it's a stronger / higher bond enthalpy / triple / C≡N / more electrons involved bond	1

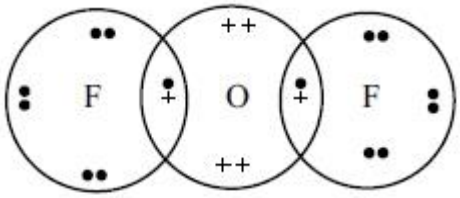
Topic Chem 3 **Q# 21/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(a)(iii)	 diagram	1
	bond angle = 109.5	1
1(a)(iv)	SiO_2	1
	SiO_2 is giant covalent / molecular but $SiCl_4$ is simple molecular / covalent	1

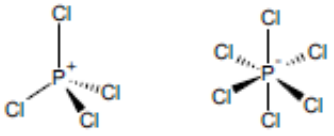
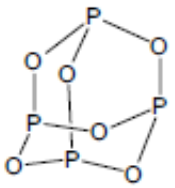
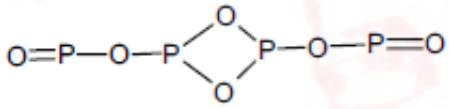
Topic Chem 3 **Q# 22/** ALvl Chemistry/2016/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(c)(i)		2

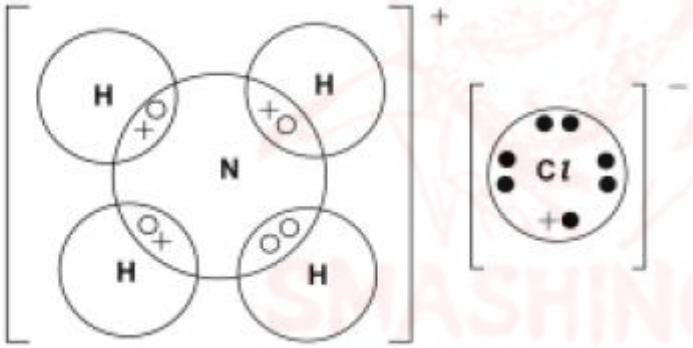
Topic Chem 3 **Q# 23/** ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) (i)	F_2O / OF_2	1
(ii)		1
(iii)	bent ***or*** non-linear	1

Topic Chem 3 **Q# 24/** ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(b) (i)	PCl_5 5 bonding pairs around P	1	
(ii)		1 1	[3]
(c) (i)	 P_4O_6 structure where each P has three P-O bonds and each O has two P-O bonds e.g. 	1	

Topic Chem 3 **Q# 25/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) 

8 e⁻ around chlorine [1]
1 H–electron (+) on the Cl^- ion [1]
3 covalent (ox) and one dative (oo) around N [1]

Topic Chem 3 **Q# 26/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

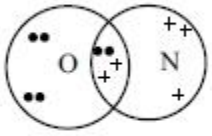
4 (a) (i) volatilities decrease down the group [1]

due to greater van der Waals (VDW) forces (*intermolecular is not sufficient*) [1]

due to larger no of electrons [1]

Topic Chem 3 **Q# 27/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2. (a) (i)



[1]

Topic Chem 3 **Q# 28/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 **(a)** N≡N triple bond is (very) strong
or the N_2 molecule has no polarity [1]

Topic Chem 3 **Q# 29/** ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(c) **(i)** $Cl\overset{+}{:}C\overset{-}{:}Cl$ *or* $Cl{=}C{-}Cl$ (1)

bent *or* non-linear *or* angle = 100–140° (1)

(ii) $CCl_2 + H_2O \longrightarrow CO + 2HCl$ (1) [3]

Topic Chem 3 **Q# 30/** ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 **(a)** CO_2 is a gas (at room temperature); SiO_2 is a high melting solid [1]
CO_2: simple / discrete molecular / covalent [1]
SiO_2: giant covalent *or* macromolecular / giant molecular [1]
[3]

Topic Chem 5 **Q# 31/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 **(a)** (the energy change) when 1 mol of bonds [1]
is broken in the gas phase [1]

Topic Chem 5 **Q# 32/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

(iii) ΔH = E(C-H) – E(H-Cl) = 410 – 431 = **–21** kJ mol^{-1} [1]

(iv) ΔH = E(C-H) – E(H-I) = 410 – 299 = **+111** kJ mol^{-1} ecf [1]

(v) The reaction with iodine is endothermic *or* ΔH is positive *or* requires energy [1]

Topic Chem 5 **Q# 33/** ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(c) bonds broken are Si-Si and Cl-Cl = 222 + 244 = 466 kJ mol^{-1}
bonds formed are 2 × Si-Cl = 2 × 359 = 718 kJ mol^{-1}
ΔH = **–252** kJ mol^{-1} [2]

[2]

Topic Chem 5 **Q# 34/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(ii) –180 kJ mol^{-1} [1]

(iv) –180 = 2 E(NO) – 994 – 496 [1]
E(NO) = **+655 kJ mol^{-1}** [1]

Topic Chem 5 **Q# 35/** ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(iii) H-H = 436 Cl-Cl = 244 H-Cl = 431

ΔH = 436 + 244 – 2(431) = –182 kJ mol^{-1} [2]

H-H = 436 Br-Br = 193 H-Br = 366

ΔH = 436 + 193 – 2(366) = –103 kJ mol^{-1} [2]

(iv) H-Br bond is weaker than the H-Cl bond – allow converse. [1]

(b) **(i)** light [1]

(ii) bonds broken = C-H & I-I = 410 + 151 = 561
bonds made = C-I & H-I = 240 + 299 = 539
ΔH = 551 – 539 = +22 kJ mol^{-1} [2]

(iii) The overall reaction is endothermic *or* no strong bonds/only weak bonds are formed *or* high E_{act} [1]
[4]

Topic Chem 5 **Q# 36/** ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) bond energies: S-S = 264 kJ mol^{-1}
C*l*-C*l* = 244 kJ mol^{-1}
S-C*l* = 250 kJ mol^{-1}

$\Delta H = 8 \times 264 + 8 \times 244 - 16 \times 250 = +64$ kJ mol^{-1} (2) **[2]**

Topic Chem 6 **Q# 37/** ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)(i)	oxidising agent [1] $H_2O_2 + 2H^+ + 2I^- \rightarrow 2H_2O + I_2$ [1]	2

Topic Chem 6 **Q# 38/** ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(c)(i)	M1: moles of thiosulfate = $0.02230 \times 0.150 = 3.345 \times 10^{-3}$ M2: $[Cu^{2+}] = 2 \times ½ \times 3.345 \times 10^{-3} \div 0.0250 =$ **0.134** (mol dm^{-3}) ecf	2
1(c)(ii)	starch	1

Topic Chem 6 **Q# 39/** ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5(b)(iii)	step 2 **and** C*l* is reduced / oxid no. decreases / oxid no. +1 → –1 *or* step 2 **and** I is oxidised / oxid no. increases / oxid no. –1 → +1	1

Topic Chem 6 **Q# 40/** ALvl Chemistry/2017/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(a)	N +2 to +3 (and oxidised)	1
	Br_2/Br 0 to –1 (and reduced)	1

Topic Chem 7 **Q# 41/** ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4(e)	$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$	1

Topic Chem 7 **Q# 42/** ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6(b)(i)	ketamine is acting as a base	1
6(b)(ii)	carbonyl group	1

Topic Chem 7 **Q# 43/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b)	$Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO_3)_2 + 2H_2O$ **or** $CaO + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O$	1

Topic Chem 7 **Q# 44/** ALvl Chemistry/2014/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(c) (i) $\Delta H^\ominus = +2 \times 33.2 - 157.3 + 302.9 = (+)212$ kJ mol^{-1} ecf **[2]**

(ii) $\Delta H^\ominus = -168.6 + 2 \times 157.3 = (+)146$ kJ mol^{-1} **allow** ecf from **(c)(i)** **[1]**
high T/temperature since ΔH is positive/endothermic **[1]**

Topic Chem 7 **Q# 45/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

8 (a) (i) (nitrates are) soluble **[1]**

(ii) $Ba^{(2+)}$ **and** $Pb^{(2+)}$ **[1]**

$SO_4^{(2-)}$ **[1]**

$BaCO_3/PbCO_3/CaSO_4$ are insoluble **[1]**

[4]

(b) (i) fertilisers/animal manure **[1]**

(ii) washing powder/detergents/fertilisers/animal manure **[1]**

(iii) growth/production of algae/weeds/plants
or eutrophication **[1]**

[3]

Topic Chem 7 **Q# 46/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 (a) (i) $NH_3 + HZ \longrightarrow NH_4^+ + Z^-$ [1]
$CH_3OH + HZ \longrightarrow CH_3OH_2^+ + Z^-$ [1]

(ii) $NH_3 + B^- \longrightarrow NH_2^- + BH$ [1]
$CH_3OH + B^- \longrightarrow CH_3O^- + BH$ [1]

[4]

(b) (i) a reaction that can go in either direction [1]

(ii) **rate** of forward = **rate** of backward reaction
or forward/back reactions occurring but concentrations of all species do not change [1]

[2]

Topic Chem 7 **Q# 47/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 (a) (i) One that can go in either direction. [1]

(ii) both forward & reverse reactions are going on at the same time, but the concentrations of all species do not change (owtte)
or rate of forward = rate of backward reaction [1]

Topic Chem 9 **Q# 48/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(a)(ii)	$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$	1

Topic Chem 9 **Q# 49/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 (a)	<table><tr><td>Na</td><td>Mg</td><td>Al</td><td>Si</td><td>P</td><td>S</td><td>Cl</td><td>Ar</td></tr><tr><td>1</td><td>0</td><td>1</td><td>2</td><td>3</td><td>2</td><td>1</td><td>0</td></tr></table>	3
(b) (i)	$SiCl_4$ white solid/ppt **or** misty/white/steamy fumes pH 0–3 PCl_5 misty/white/steamy fumes pH 0–3	3
(ii)	$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$	1
		7

Topic Chem 9 **Q# 50/** ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) $SiCl_4$: **white** solid *or* **white/steamy** fumes [1]

$SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$ [1]

PCl_5: fizzes *or* white/steamy fumes [1]
$PCl_5 + 4H_2O \longrightarrow H_3PO_4 + 5HCl$ [1]
[4]

Topic Chem 9 **Q# 51/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

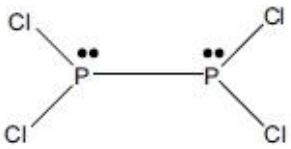
(d) $Na_2O(s) + H_2O(aq/l) \longrightarrow 2NaOH(aq)$ [1]
$MgO(s) + H_2O(aq/l) \longrightarrow Mg(OH)_2(s)$ *or* $Mg(OH)_2(aq)$ [1]
pH 12.5-14 [NaOH] **AND** 8-10.5 [$Mg(OH)_2$] respectively [1]
[3]

Topic Chem 9 **Q# 52/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 (a) (+)1; (+)2; (+)3; (+)4 [1]
O.N. corresponds to the no. of electrons in outer/valence shell/lost [1]

(b) PCl_5 fizzes or white/misty fumes or heat evolved [1]
$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ *or* $PCl_5 + 3H_2O \rightarrow HPO_3 + 5HCl$
(allow partial hydrolysis: $PCl_5 + H_2O \rightarrow POCl_3 + 2HCl$) [1]

(c) (i) P = 30.4/31 = 0.98 Cl = 69.6/35.5 = 1.96 [1]
Thus E.F = PCl_2 [1]
$M_r(PCl_2)$ = 102, so 2 × PCl_2 = 204 ≈ 200, so M.F. = P_2Cl_4 [1]

(ii) 

(ignore lone pairs on Cl) [1]

(iii) O.N. = (+)2 [1]

(iv) $(HO)_2P$-$P(OH)_2$ *or* H(HO)P(=O)-P(=O)(OH)H ecf from structure in (ii) [1]
Allow HO-P-OH or HO-P=O
|
H

Topic Chem 9 **Q# 53/** ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ (1)

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ (or giving H_2SiO_3, $Si(OH)_4$ etc.) (1) **[2]**

Topic Chem 9 **Q# 54/** ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) P: burns with white / yellow flame *or* copious white smoke / fumes produced (1)

$4P$ (or P_4) + $5O_2 \longrightarrow P_4O_{10}$ (1)

S: burns with blue flame / choking / pungent gas produced (1)

$S + O_2 \longrightarrow SO_2$ (1) [4]

Topic Chem 9 **Q# 55/** ALvl Chemistry/2009/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(c) (i) amphoteric [1]

(ii) $2NaOH + PbO \longrightarrow Na_2PbO_2 + H_2O$ [1]
(*or* $NaOH + PbO + H_2O \longrightarrow NaPb(OH)_3$ etc.)

[2]

Topic Chem 10 **Q# 56/** ALvl Chemistry/2020/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(b)(i)	$BaO(s) + H_2O(l) \rightarrow Ba(OH)_2(aq)$ [1]	1

Topic Chem 10 **Q# 57/** ALvl Chemistry/2019/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6(a)(i)	$Mg(g) \rightarrow Mg^+(g) + e^-$	1
6(a)(ii)	$Sr(s) + 2H_2O(l) \rightarrow Sr(OH)_2(aq) + H_2(g)$	1
6(a)(iii)	more reactive **and** easier to ionise down the group OR more reactive **and** ionisation energies decrease down the group	1
6(b)(i)	brown gas **and white** solid	1
6(b)(ii)	$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$	1

Topic Chem 10 **Q# 58/** ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4(a)	calcium – red flame	1
	barium – green flame	1
4(c)	the gas is colourless / looks like air / cannot be seen	1
	appearance of solid doesn't change / white solid becomes white solid	1

Topic Chem 10 **Q# 59/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(b)(i)	$2A(NO_3)_2 \rightarrow 2AO + 4NO_2 + O_2$ correct formula balanced equation	2 1 1
1(b)(ii)	giant ionic	1

Topic Chem 11 **Q# 60/** ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(b)	$3I_2 + 6NaOH \rightarrow NaIO_3 + 5NaI + 3H_2O$	1

Topic Chem 11 **Q# 61/** ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(d) AgC*l* white [1]
AgBr cream [1]
AgI yellow [1]

Solubility decreases down the group [1]

[4]

Topic Chem 11 **Q# 62/** ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) (i) *either* burn *or* shine light/uv on mixture of H_2 + Cl_2 *but* NOT heat [1]

(ii) red/orange/brown colour of bromine decolourises/disappears
steamy/misty/white fumes produced
container gets warm/hot [2]

Topic Chem 12 **Q# 63/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

(c) (i) *any one of:*

$2SO_2 + O_2 \longrightarrow 2SO_3$ **and** $SO_3 + H_2O \longrightarrow H_2SO_4$

or $SO_2 + NO_2 \longrightarrow SO_3 + NO$ **and** $SO_3 + H_2O \longrightarrow H_2SO_4$

or $SO_2 + ½O_2 + H_2O \longrightarrow H_2SO_4$ [1]

(ii) roasting sulfide ores/extraction of metals from sulfide ores [1]

[2]

Topic Chem 12 **Q# 64/** ALvl Chemistry/2013/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 (a) (due to the) strong N≡N bond [1]
[1]

(b) (i) Any balanced equation forming a stable nitrogen oxide
e.g. $N_2 + O_2 \longrightarrow 2NO$
or
$N_2 + 2O_2 \longrightarrow 2NO_2$ [1]

(ii) in lightning [1]

in an engine/combustion of fuels (or a specific example) [1]

(iii) (NO_x produces) acid rain *or* forms (photochemical) smog [1]
[4]

Topic Chem 12 **Q# 65/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(iii) (formation of NO is endothermic) so high T **and** equilibrium pushed over to NO side.
or high T **and** needed to break N-N bond in N_2 [1]

Topic Chem 12 **Q# 66/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 (a) $N_2 + 2O_2 \rightarrow 2NO_2$ (*or* via NO) *or* $2NO + O_2 \rightarrow 2NO_2$ [1]

(b) (i) catalytic converter **and** passing the exhaust gases over a catalyst/Pt/Rh [1]

(ii) $NO_2 + 2CO \rightarrow ½N_2 + 2CO_2$ ***or*** similar [1]
Allow $2NO_2 + CH_4 \rightarrow CO_2 + N_2 + 2H_2O$

Topic Chem 12 **Q# 67/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 (a) N≡N triple bond is (very) strong
or the N_2 molecule has no polarity [1]

(b) $3Mg(s) \rightarrow 3Mg^{2+}(g)$ $\quad \Delta H_1 = 3 \times 148 + 3 \times 2186 = 7002$
$N_2(g) \rightarrow 2N^{3-}(g)$ $\quad \Delta H_2 = 994 + 2 \times 2148 = 5290$

$LE = -\Delta H_1 - \Delta H_2 - 461 = \mathbf{-12{,}753}$ (kJ mol^{-1}) (–[1] for each error) [3]

(c) (i) $Li_3N + 3H_2O \rightarrow NH_3 + 3LiOH$ (balanced equation) [1]

(ii) advantage: no high pressure/temperature/catalyst needed/standard conditions used [1]

disadvantage: Li is expensive
or Li would need to be recycled/removed
or LiOH by-product is corrosive/strongly basic
or this would be a batch, rather than continuous process [1]

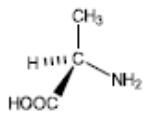
(d) (i) Li_3N: 100 × 14/35 = 40% N [1]
urea: 100 × 28/60 = 47% N [1]

(ii) amide [1]

(iii) $NH_2CONH_2 + H_2O \rightarrow 2NH_3 + CO_2$
or $\rightarrow NH_2CO_2H + NH_3$
or $NH_2CONH_2 + 2H_2O \rightarrow 2NH_3 + H_2CO_3$ [1]

(iv) The LiOH would be strongly alkaline
or would increase the pH of the soil
or would 'burn' the crops/reduce plant growth/stunt plants
or would contaminate the environment [1]

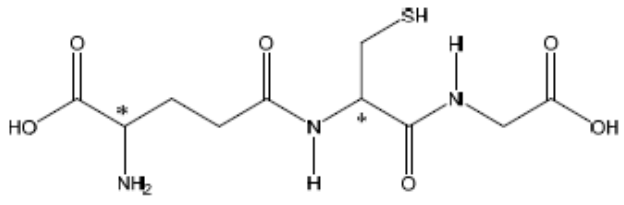
Topic Chem 13 **Q# 68/** ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5(b)(iii)		1

Topic Chem 13 **Q# 69/** ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4(a)(ii)	0 (zero) in F AND 2 (two) in J	1

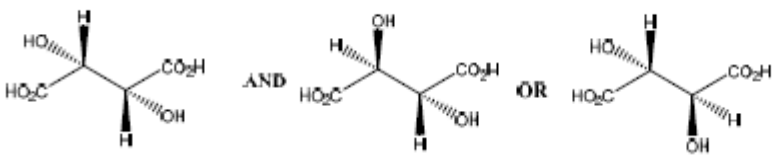
Topic Chem 13 **Q# 70/** ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

7(c)(i)		1

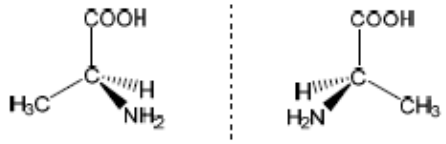
Topic Chem 13 **Q# 71/** ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 7/www.SmashingScience.org

7(c)(vii)	Asterisk on *$CHCO_2H$	1

Topic Chem 13 **Q# 72/** ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6(c)		2

Topic Chem 13 **Q# 73/** ALvl Chemistry/2020/w/TZ 1/Paper 4/Q# 10/www.SmashingScience.org

10(b)(ii)	 3D, tetrahedral, both isomers of 2-aminopropanoic acid [1] optical [1]	2

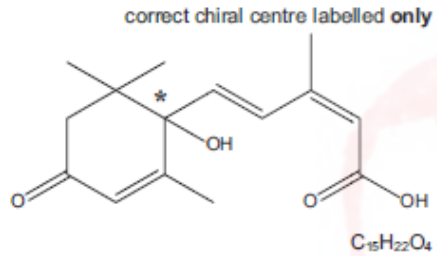
Topic Chem 13 **Q# 74/** ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

8(e)(i)	this is a (carbon) atom which has four different atoms or groups attached to it	1
8(e)(ii)	$CH_3CH_2CH(CH_3)COOH$	1

Topic Chem 13 **Q# 75/** ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9(a)	$C_8H_{11}O_3N$	1
9(b)	yes, as it has a chiral C atom	1

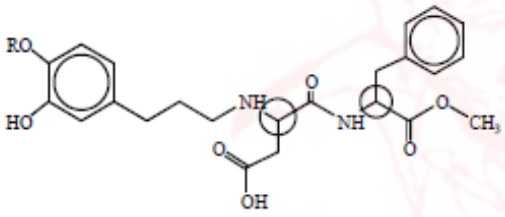
Topic Chem 13 **Q# 76/** ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

8(a)	correct chiral centre labelled **only**  $C_{15}H_{22}O_4$	1

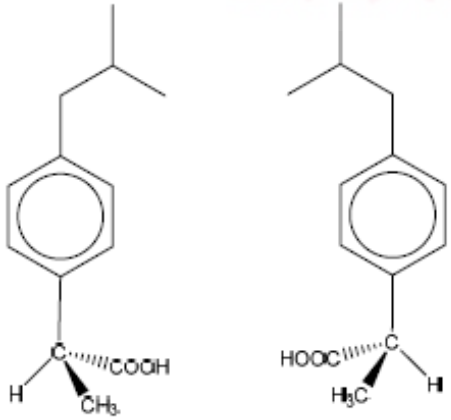
Topic Chem 13 **Q# 77/** ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4(a)(i)	optical, because it contains a / one chiral C-atom or chiral C-atoms or chiral atom / centre or C* indicated or C with 4 **different** groups	1

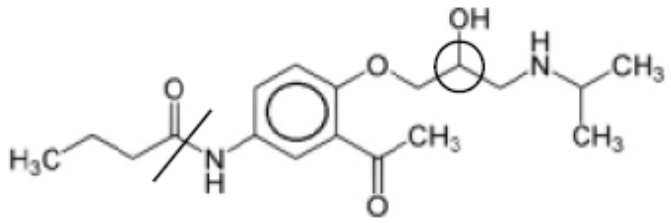
Topic Chem 13 **Q# 78/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 7/www.SmashingScience.org

7(a)		1

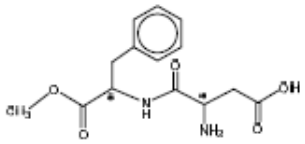
Topic Chem 13 **Q# 79/** ALvl Chemistry/2016/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6(b)(i)	(chiral centre is a) carbon OR atom that has four different groups / atoms / species attached to it	1
6(b)(ii)	 one correct isomer second diagram shows second isomer	1 1 2

Topic Chem 13 **Q# 80/** ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 8/www.SmashingScience.org

(b)		1

Topic Chem 13 **Q# 81/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 10/www.SmashingScience.org

10 (a) (i)		1

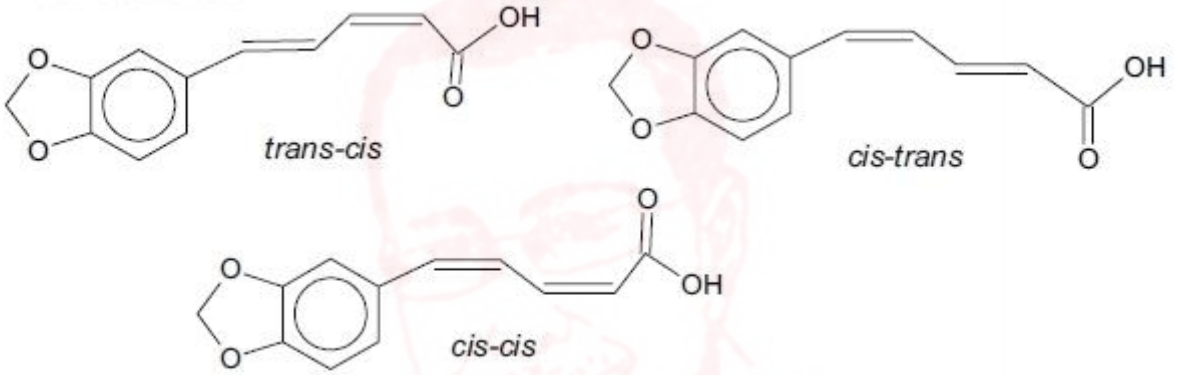
Topic Chem 13 **Q# 82/** ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

(b)	ketone, amine, carboxylic acid two correct 1 mark, all three 2	2	[2]

Topic Chem 13 **Q# 83/** ALvl Chemistry/2014/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(b) (i) four isomers [1]

(ii) must be skeletal



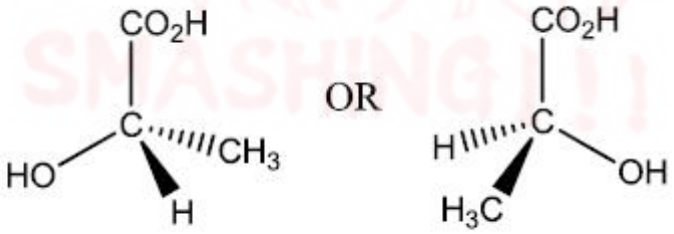
[1]

Topic Chem 13 **Q# 84/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

(b) propenoic acid [1]

Topic Chem 13 **Q# 85/** ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

(b)



or correct diagram of the S isomer

Topic Chem 13 **Q# 86/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3. (a) (i) $C_{16}H_{10}N_2O_2$ [1]

Topic Chem 13 **Q# 87/** ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(b) (i) light [1]

(c) (i) homolytic fission is the breaking of a bond to form (two) radicals/neutral species/ odd-electron species [1]

(ii) $\bullet CH_2Cl$ [1]
the C-Br bond is the weakest or needs least energy to break/breaks most easily [1]
[3]

(d)

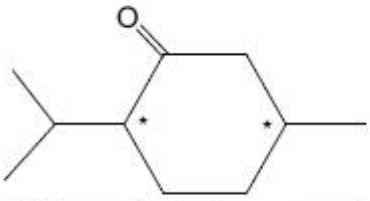
4 structures: [2]
2 or 3 structures: [1]

Correct chiral atom identified [1]

[3]

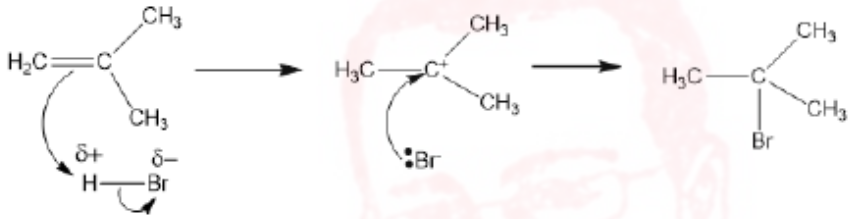
Topic Chem 13 **Q# 88/** ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 (a)

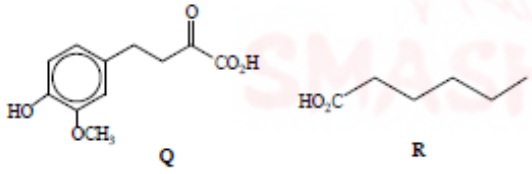


(1) for each centre – more than 2 centres shown deduct 1 mark **[2]**

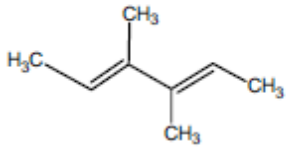
Topic Chem 14 **Q# 89/** ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(c)(i)	 **M1** correct dipole on HBr **AND** any correct curly arrow [1] **M2** two other correct curly arrows **AND** lone pair required on Br^- [1] **M3** intermediate [1]	3
1(c)(ii)	(major product is) formed via the most stable tertiary carbocation / intermediate **OR** tertiary halogenoalkane formed via more stable carbocation / intermediate	1

Topic Chem 14 **Q# 90/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 8/www.SmashingScience.org

8(b)(i)	dehydration / elimination	1
8(b)(ii)	heat with Al_2O_3 **OR** heat with H_3PO_4/H_2SO_4	1
8(b)(iii)	 Q R	2

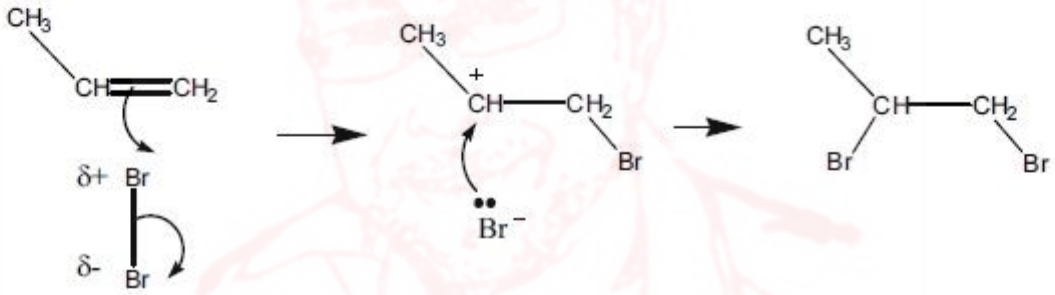
Topic Chem 14 **Q# 91/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

(c) (i)	(electrophilic) addition	1
(ii)		1
(d) (i)	*any four of* M1: σ-bonds between C–C **or** C–H M2: π-bonds formed from overlap of p-orbitals M3: (π-bonds/electrons) above and below the ring M4:bonds/electrons are delocalised M5: bond angle 120° M6: intermediate C–C bond length / all C–C same length / strength M7: carbons are sp^2 hybridised	3

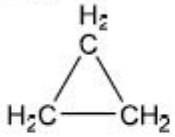
Topic Chem 14 **Q# 92/** ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

7	(a) (i)	heat with catalyst ***or*** heat with Al_2O_3/SiO_2	1
	(ii)	**B** is $CH_3CH_2CH_3$	1

Topic Chem 14 **Q# 93/** ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

7	(a) (i)	heat with catalyst ***or*** heat with Al_2O_3/SiO_2	1
	(ii)	**B** is $CH_3CH_2CH_3$	1
	(iii)	**C** is $CH_2=CHCH_2CH_2CH_3$ **D** and **E** are $CH_3CH=CHCH_2CH_3$ (one shown as cis, the other as trans) **F** is $CH_3CH_2CH_2CO_2H$ **G** is CH_3CO_2H **H** is $CH_3CH_2CO_2H$	1 1 1
	(iv)	geometrical *or* cis-trans *or* *E*–*Z*	1
	(b) (i)	No particular conditions ***or*** in the dark	1
	(ii)	electrophilic addition	1
	(iii)	 	1 1

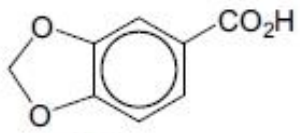
Topic Chem 14 **Q# 94/** ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 10/www.SmashingScience.org

10	(a) (i)	any **three** of the following structures $CH_3CH_2CH_3$ $CH_3CH=CH_2$ $CH_3C\equiv CH$ $CH_2=C=CH_2$  	2
	(ii)	**K** since it has the greatest % of hydrocarbons/carbon-containing compounds ***or*** 99.6 % of it is burnt for energy	1
	(iii)	any **two** from • reacted with lime/CaO/soda lime/$Ca(OH)_2$/KOH/NaOH/ • liquefied under pressure/≥5 atm • dissolved in water under pressure/≥5 atm	2

(b) (i)	have a shorter carbon / hydrocarbon chain ***or*** shorter hydrocarbon ***or*** fewer carbon atoms in its chain ***or*** have high H / C ratio	1
(ii)	Coal produces the largest amount of SO_2 ***or*** largest combined amount of SO_2 and NO_2	1
(iii)	they burn at higher temperatures ***or*** release more heat on burning	1
(iv)	CO – the gas is toxic/poisonous ***or*** references to Hb **and** ability to carry oxygen	1
	CO_2 – the gas contributes to global warming	1

Topic Chem 14 **Q# 95/** ALvl Chemistry/2014/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(iii)



+ CO_2 *or* $HO_2C\text{-}CO_2H$

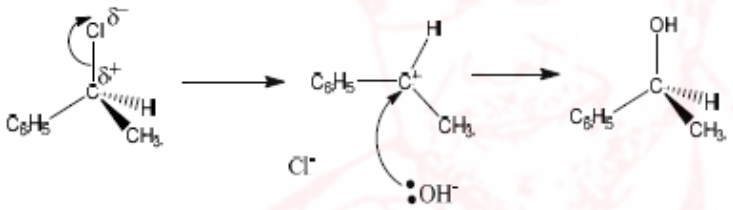
[1] [1]

Topic Chem 14 **Q# 96/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

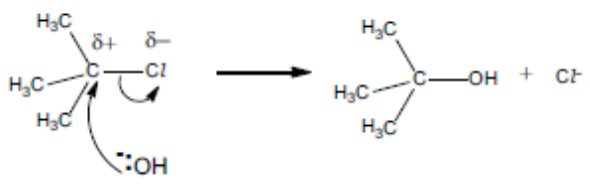
(c) No, it wouldn't be reduced. Because the reaction in **(a)** does not presuppose a particular fuel (owtte) [1]

Allow formed from N_2 and O_2 in air during combustion

Topic Chem 15 **Q# 97/** ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6(c)(i)	 C-C*l* dipole and first curly arrow	1
	intermediate cation	1
	OH^- with lone pair and curly arrow	1
6(c)(ii)	Beginning with candidate's mechanism in (c)(i): **If S_N1:** racemate / mixture of / two optical isomers will be formed, because: the intermediate is planar / has a plane of symmetry / OH^- can approach from top or bottom or from any direction **If S_N2:** one optical isomer because attack always from fixed direction / from same side / the "configuration" always inverts / there is an asymmetric transition state	1

Topic Chem 15 **Q# 98/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 (a)	M1: dipole on C–C*l* bond M2: curly arrow breaking C–C*l* bond M3: curly arrow from the oxygen on ⁻OH (lone pair needs to be shown) to carbon in C–C*l* bond **and** Cl^- (ion) formed in the mechanism 	3

Topic Chem 15 **Q# 99/** ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

(b) (i) (C-X bond energy) decreases/becomes weaker (from F to I) [1]

due to bond becoming longer/not such efficient orbital overlap [1]

(ii) (as the bond energy of C-X decreases) the halogenalkanes become more reactive (answer must imply that it is from F to I) [1]

[3]

(e) (i) light/UV/hν *or* 300°C [1]

(ii) (free) radical substitution [1]

(vi) $Cl_2 \longrightarrow 2Cl^{\bullet}$ [1]

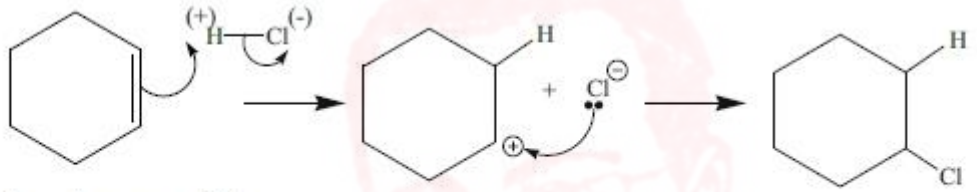
$CH_3CH_2^{\bullet} + Cl_2 \longrightarrow CH_3CH_2Cl + Cl^{\bullet}$ [1]

$CH_3CH_2^{\bullet} + Cl^{\bullet} \longrightarrow CH_3CH_2Cl$ [1]

[8]

Topic Chem 15 **Q# 100/** ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

(d)



2 curly arrows (1)
carbocation intermediate + Cl^- (1)
lone pair on Cl^- and last curly arrow (1) **[3]**

Topic Chem 16 **Q# 101/** ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6(a)(i)	$(CH_3)_2CHCHNH_2COOH + 4[H] \rightarrow (CH_3)_2CHCHNH_2CH_2OH + H_2O$ **OR** $C_5H_{11}NO_2 + 4[H] \rightarrow C_5H_{13}NO + H_2O$	1
6(a)(ii)	lithium aluminium hydride / $LiAlH_4$ (in dry ether)	1
6(a)(iii)	nucleophilic substitution	1

Topic Chem 16 **Q# 102/** ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

7(a)	$2C_3H_7OH + 2Na \rightarrow 2C_3H_7ONa + H_2$	1

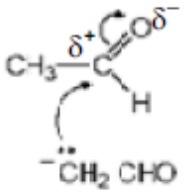
Topic Chem 16 **Q# 103/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 8/www.SmashingScience.org

8(a)	oxidation of –OH / alcohol to C=O / ketone / carbonyl	1

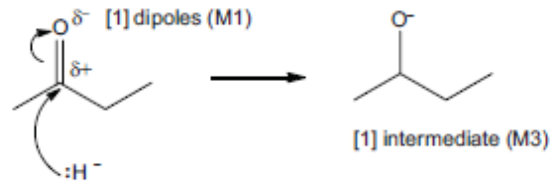
Topic Chem 17 **Q# 104/** ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6(b)(ii)	carbonyl group	1

Topic Chem 17 **Q# 105/** ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 4/www.SmashingScience.org

(c)	nucleophilic addition	1
(d)	**M1**: both curly arrows **M2**: dipole correctly shown 	1 1

Topic Chem 17 **Q# 106/** ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

(b)	 [1] both curly arrows (M2) arrow must come from lone pair	3

Topic Chem 17 **Q# 107/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(b) (i) reduction *or* redox [1]

(ii) $NaBH_4$ or $LiAlH_4$ (**NOT** H_2 + Ni) [1]

[2]

Topic Chem 17 **Q# 108/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 (a) (i) aqueous alkaline iodine ***or*** $I_2 + OH^-(aq)$ allow NaClO + KI [1]

(ii) CH_3CO- ***or*** $CH_3CH(OH)$- [1]

(iii) Pale yellow ppt. ***or*** antiseptic smell [1]

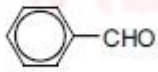
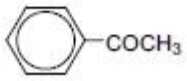
Topic Chem 17 **Q# 109/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 6/www.SmashingScience.org

6 (a) (i) aqueous alkaline iodine ***or*** $I_2 + OH^-(aq)$ allow NaClO + KI [1]

(ii) CH_3CO- ***or*** $CH_3CH(OH)$- [1]

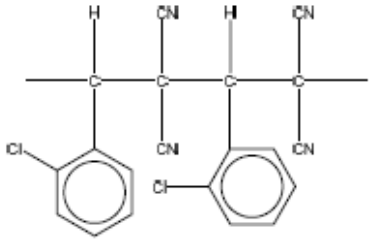
(iii) Pale yellow ppt. ***or*** antiseptic smell [1]

(iv)

compound	result
CH_3OH	×
CH_3CH_2OH	✓
CH_3CHO	✓
CH_3CO_2H	×
	×
	✓

•✓•✓•✓ [3]

Topic Chem 20 **Q# 110/** ALvl Chemistry/2017/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5(b)		1
	addition (polymerisation)	1

Topic Chem 20 **Q# 111/** ALvl Chemistry/2011/w/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

(c) PVC [1]
Combustion would produce HC*l* / dioxins as a pollutant [1]
or
nylon/acrylic [1]
Combustion would produce HCN [1]
[2]

Topic Chem 20 **Q# 112/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9 (a) (i) One [1]

(ii) Any alkene (***or*** allow a cyclic amide, as in caprolactam) [1]

Topic Chem 22 **Q# 113/** ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9(d)(i)	relative abundance = 2 carbons × 1.1 × 0.62 = **1.36 / 1.4** [1] min 2sf	1
9(d)(ii)	$CH_3CH_2^+$ / $C_2H_5^+$ [1]	2

Topic Chem 22 **Q# 114/** ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 4/www.SmashingScience.org
[Cannot see where mark 2 in 4(d)(i) should be given; but it is 2 marks in the question paper]

4(d)(i)	x = 14.4 / 100 × 100 / 1.1 = 13.1 13 carbon atoms (some working required)	1
4(d)(ii)	(250 – 205 = 45, so) CO_2H / C_2H_5O	1

Topic Chem 22 **Q# 115/** ALvl Chemistry/2019/w/TZ 1/Paper 4/Q# 9/www.SmashingScience.org

9(d)	$C_6H_4NH_2^+$ **and** $CH_3CH_2CH_2CH_2^+$ [1]	1

Topic Chem 22 **Q# 116/** ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

8(a)(i)	no. of carbons = 100 × 1.25 / (22.65 × 1.1) (= **5.02**)	1
8(a)(ii)	M1: C_2H_5O M2: $C_3H_5O^+$ (positive sign required for m / e = 57 fragment)	2

Topic Chem 22 **Q# 117/** ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 6/www.SmashingScience.org

6(b)(iii)	n = (100 / 1.1) x (14.3 / 100) = 13.0 OR n = (14.3 / 1.1) = 13.0	1
6(b)(iv)	the ratio of the (M:M+2) peaks is 3:1 **AND** halogen is chlorine / C*l*	1
6(b)(v)	relative abundance = 14.3 / 3 = 4.77 (4.8) OR RA = 14.3 × 33.3 / 100 = 4.76 (4.8)	1
6(b)(vi)	$C_{13}H_{16}NOCl$	1

Topic Chem 22 **Q# 118/** ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(b)(i)	^{37}Cl **and** ^{81}Br	1
1(b)(ii)	M peak $CH_2^{35}Cl^{79}Br$ M+2 peak $CH_2^{37}Cl^{79}Br$ OR $CH_2^{35}Cl^{81}Br$ M+4 peak $CH_2^{37}Cl^{81}Br$ two correct scores 1 mark all 3 correct scores 2 marks	2

Topic Chem 22 **Q# 119/** ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(a)(i)	(28 × 0.922) + (29 × 0.047) + (30 × 0.031) = 28.11	1

Topic Chem 22 **Q# 120/** ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 (a) (i)

isotope	relative abundance
^{24}Mg	78–79
^{25}Mg	10
^{26}Mg	12–11

(total must add up to 100 %) **1**

(ii) e.g. 0.78x24 + 0.10x25 + 0.12x26 = **24.34** **1**

Topic Chem 22 **Q# 121/** ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 (a) (i)	$101 = P^{35}Cl^{35}Cl$ $103 = P^{35}Cl^{37}Cl$ $105 = P^{37}Cl^{37}Cl$	1 1 1	
(ii)	9:6:1	1	**[4]**

Topic Chem 22 **Q# 122/** ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 7/www.SmashingScience.org

(c) (i) $156 = C_3H_6{}^{35}Cl^{79}Br^+$ [1]
$158 = C_3H_6{}^{37}Cl^{79}Br^+$ [1]
$158 = C_3H_6{}^{35}Cl^{81}Br^+$ [1]
$160 = C_3H_6{}^{37}Cl^{81}Br^+$ [1]

(ii) *m/e* = 15 Species = CH_3^+ [1]
[5 max 4]

Topic Chem 22 **Q# 123/** ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 8/www.SmashingScience.org

(c) (i) **X** is bromine – M and (M+2) peaks almost same height [1]

(ii) $\frac{M}{M+1} = \frac{100}{1.1} \times \frac{9}{n} = \frac{100}{0.3}$ 1.1 × n

Hence $n = \frac{100 \times 0.3}{1.1 \times 9} = 3.03$ p = 3

(answer + working) [1]

(If the mass peak is at 122 and the compound contains Br and 3 C atoms then Q = (122 – 79 – 36)) thus **Q = 7** ecf from **(ii)** [1]

(The compound is C_3H_7Br)

(iii) *(R is at m/e 43)*, hence $\mathbf{C_3H_7^+}$ [1]

(d) Any **two** from H_2, H_2O, CO, C_2H_4, C_2H_2, CH_4 2 × [1]