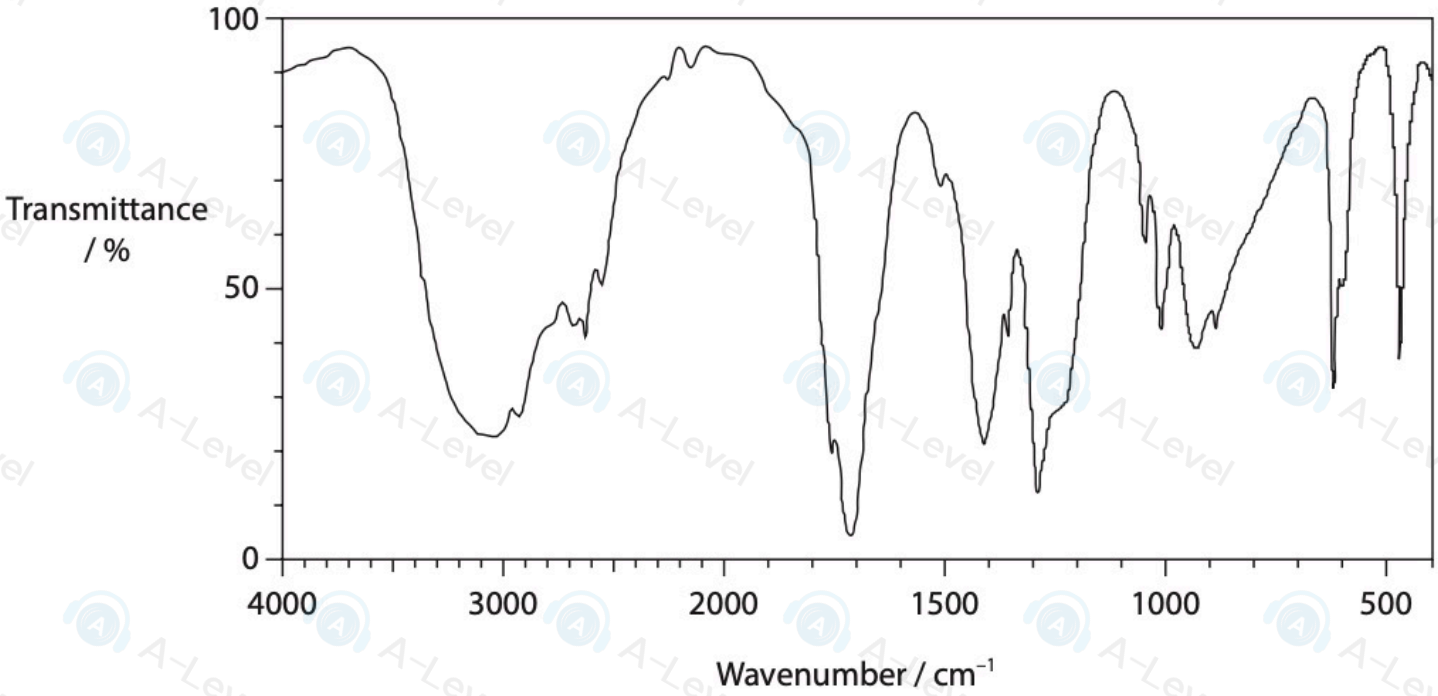
15 An infrared spectrum for a compound containing **one** functional group is shown.



Which functional group is most likely to be present in this compound?

Refer to your Data Booklet.

- ☒ **A** an aldehyde
- ☒ **B** an alcohol
- ☒ **C** a carboxylic acid
- ☒ **D** a ketone

7 Which ion contains vanadium with an oxidation number of **+4**?

- ☒ **A** VO^{2+}
- ☒ **B** VO_2^+
- ☒ **C** VO_3^-
- ☒ **D** VO_4^{3-}

(Total for Question 7 = 1 mark)

6 Which sequence shows the hydrogen halides in order of **decreasing** boiling temperature?

- ☒ **A** HF > HCl > HBr > HI
- ☒ **B** HF > HI > HBr > HCl
- ☒ **C** HI > HF > HCl > HBr
- ☒ **D** HI > HBr > HCl > HF

(Total for Question 6 = 1 mark)

---

10 Bromine, $Br_2(l)$, can be disposed of safely by reaction with aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$.

$$Br_2(l) + 2Na_2S_2O_3(aq) \rightarrow 2NaBr(aq) + Na_2S_4O_6(aq)$$

What is the minimum volume, in cm^3, of 0.5 mol dm^{-3} $Na_2S_2O_3(aq)$ needed to react completely with 0.01 mol of $Br_2(l)$?

- ☒ **A** 0.01
- ☒ **B** 0.04
- ☒ **C** 10
- ☒ **D** 40

(Total for Question 10 = 1 mark)

12 Magnesium nitrate decomposes on heating.

$$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

A sample of magnesium nitrate decomposed completely.

The total volume of gas formed was 1200 cm^3, measured at room temperature and pressure (r.t.p.).

What mass of magnesium nitrate was used?

[M_r $Mg(NO_3)_2$ = 148.3 Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

- ☒ **A** 1.48 g
- ☒ **B** 2.97 g
- ☒ **C** 7.42 g
- ☒ **D** 14.8 g

(Total for Question 12 = 1 mark)

---

5 A compound, which is a white solid, gives a red flame test and produces a colourless, acidic gas when heated.

What is the identity of the compound?

- ☒ **A** calcium carbonate
- ☒ **B** calcium nitrate
- ☒ **C** sodium carbonate
- ☒ **D** strontium nitrate

15 A volume of 10.0 cm^3 of magnesium chloride solution was added to an excess of sodium hydroxide solution, forming a precipitate of magnesium hydroxide. After filtering and drying, 0.398 g of magnesium hydroxide was obtained.

What was the concentration of the magnesium chloride solution?

[M_r $Mg(OH)_2$ = 58.3]

- ☒ **A** 0.00683 mol dm^{-3}
- ☒ **B** 0.0137 mol dm^{-3}
- ☒ **C** 0.683 mol dm^{-3}
- ☒ **D** 1.37 mol dm^{-3}

(Total for Question 15 = 1 mark)

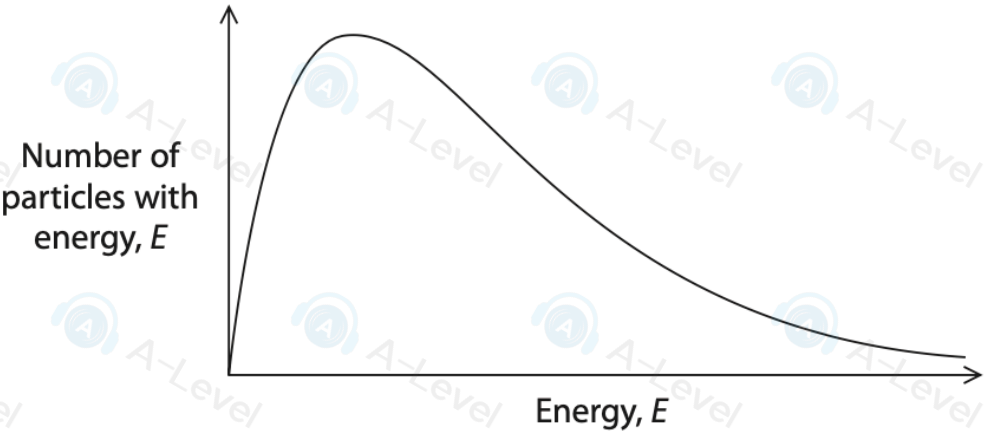
---

7 Which reaction involves the oxidation of a Group 7 element?

- ☒ **A** $Br_2 + F_2 \rightarrow 2BrF$
- ☒ **B** $U + 3ClF_3 \rightarrow UF_6 + 3ClF$
- ☒ **C** $2F_2 + 2H_2O \rightarrow 4HF + O_2$
- ☒ **D** $KCl + H_2SO_4 \rightarrow HCl + KHSO_4$

(Total for Question 7 = 1 mark)

17 The distribution of molecular energies for a sample of gas in a sealed container is shown.



(a) Why does the distribution of energies start at the origin, (0,0)?

(1)

- ☒ **A** some molecules have no energy
- ☒ **B** all molecules possess some energy
- ☒ **C** the temperature is 0 K
- ☒ **D** some molecules do not have enough energy to react

(b) Some of the gas is removed and then the container is resealed and the gas is cooled.

How does the new distribution of molecular energies compare to the original sample?

(1)

	Area under the curve	Position of peak
☒ **A**	does not change	shifts to the left
☒ **B**	decreases	shifts to the left
☒ **C**	does not change	shifts to the right
☒ **D**	decreases	shifts to the right

(Total for Question 17 = 2 marks)

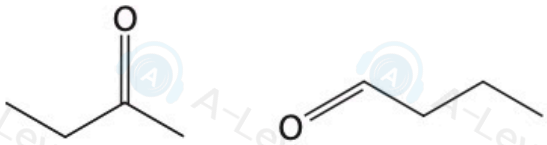
10 When lithium reacts with excess oxygen, only lithium oxide is formed.
When sodium reacts with excess oxygen, sodium oxide and sodium peroxide are both formed.

What is the main reason why sodium peroxide is formed?

- ☒ **A** sodium is more reactive than lithium
- ☒ **B** sodium has a lower first ionisation energy than lithium
- ☒ **C** the sodium ion has a larger ionic radius than the lithium ion
- ☒ **D** the sodium ion has a higher charge density than the lithium ion

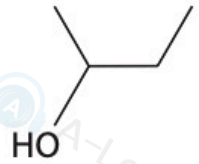
(Total for Question 10 = 1 mark)

12: This question is about organic compounds containing four carbon atoms.

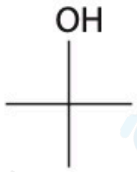


butanone

butanal



butan-2-ol



methylpropan-2-ol

(a) Which compound has peaks in its mass spectrum at *m/z* 74 and 45?

(1)

- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** butan-2-ol
- ☒ **D** methylpropan-2-ol

(b) Which compound can be oxidised to form a ketone?

(1)

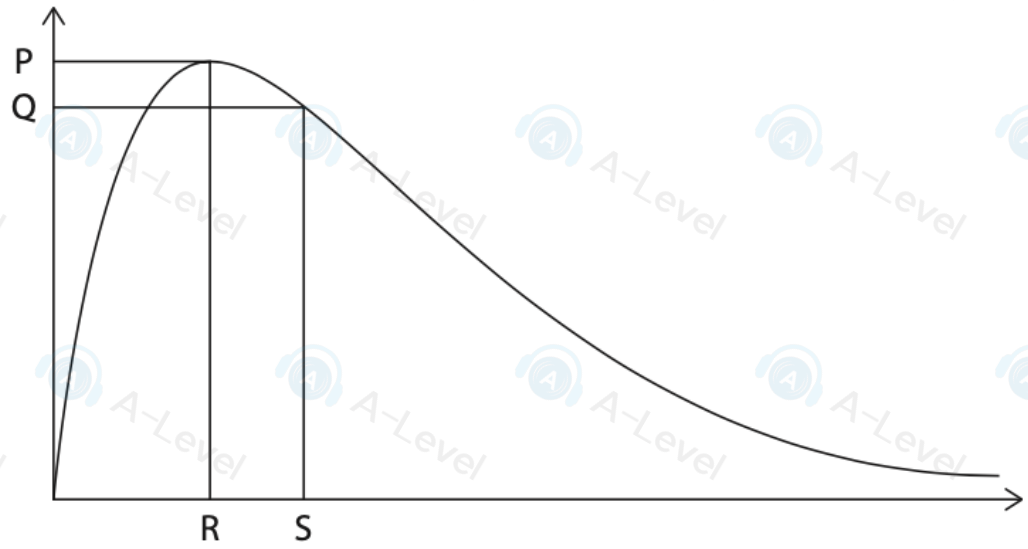
- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** butan-2-ol
- ☒ **D** methylpropan-2-ol

(c) Which compound forms a red precipitate when warmed with Fehling's solution?

(1)

- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** butan-2-ol
- ☒ **D** methylpropan-2-ol

1 A Maxwell-Boltzmann distribution of molecular energies is shown.



(a) Which letter represents the mean energy of the molecules?

(1)

- ☒ **A** letter P
- ☒ **B** letter Q
- ☒ **C** letter R
- ☒ **D** letter S

(b) What happens to the curve when the temperature is **decreased**?

(1)

- ☒ **A** the peak becomes higher and further to the right
- ☒ **B** the peak becomes higher and further to the left
- ☒ **C** the peak becomes lower and further to the right
- ☒ **D** the peak becomes lower and further to the left

9 What are the only products formed when chlorine reacts with **cold** aqueous sodium hydroxide?

- ☒ **A** sodium chloride, sodium chlorate(I) and water
- ☒ **B** sodium chloride, sodium chlorate(V) and water
- ☒ **C** sodium chlorate(I) and water
- ☒ **D** sodium chloride and sodium chlorate(I)

14 Which species contains an element with an oxidation number of +4?

- ☒ **A** CrO_4^{2-}
- ☒ **B** MnO_4^{2-}
- ☒ **C** H_2SO_4
- ☒ **D** Na_2CO_3

8 When sodium bromide reacts with concentrated sulfuric acid, sodium hydrogensulfate is always formed.

What other product(s) are formed in this reaction?

- ☒ **A** hydrogen bromide only
- ☒ **B** bromine and hydrogen bromide only
- ☒ **C** bromine, hydrogen bromide and sulfur dioxide only
- ☒ **D** bromine, hydrogen bromide, sulfur dioxide and sulfur only

(Total for Question 8 = 1 mark)

9 Compound **Q** produces

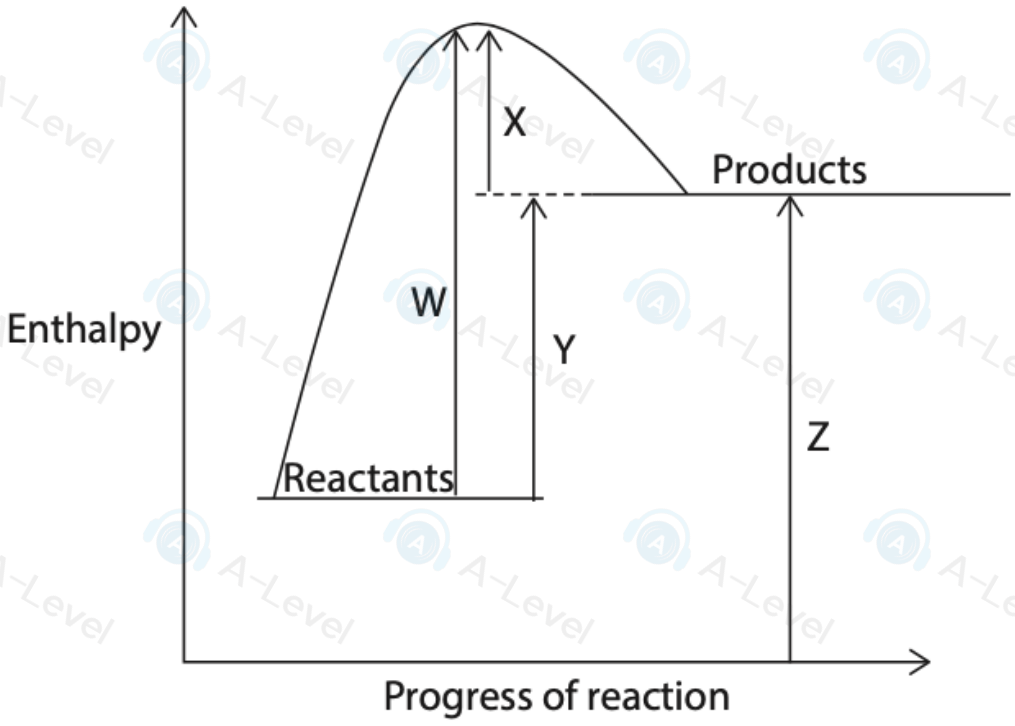
- a red colour in a flame test
- a white precipitate when aqueous potassium sulfate is added to a solution of the compound.

What is compound **Q**?

- ☒ **A** LiCl
- ☒ **B** $NaNO_3$
- ☒ **C** $Sr(NO_3)_2$
- ☒ **D** $BaCl_2$

(Total for Question 9 = 1 mark)

2 The reaction profile for a reaction is shown.



Which arrow represents the activation energy of the forward reaction?

- ☒ **A** letter W
- ☒ **B** letter X
- ☒ **C** letter Y
- ☒ **D** letter Z

2 Which expression gives the standard enthalpy change, in kJ mol^{-1}, for the reaction shown?

$$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$$

$\Delta_f H^{\ominus}$ values: $BaCO_3(s) = -1216\,kJ\,mol^{-1}$

$BaO(s) = -554\,kJ\,mol^{-1}$

$CO_2(g) = -394\,kJ\,mol^{-1}$

☒ **A** −554 − 394 + 1216

☒ **B** −554 − 394 − 1216

☒ **C** 554 + 394 + 1216

☒ **D** 554 + 394 − 1216

(Total for Question 2 = 1 mark)

9: In an experiment to measure the rate of reaction, a sample of magnesium ribbon, of mass 0.24 g, was added to 25 cm^3 sulfuric acid, of concentration 1.00 mol dm^{-3}.

In a second experiment, a sample of magnesium **powder**, of mass 0.24 g, was added to 50 cm^3 sulfuric acid of the same concentration.

What are the expected differences in observations in the second experiment?

	Rate of reaction	Total volume of hydrogen produced
☒ **A**	no change	no change
☒ **B**	no change	increases
☒ **C**	increases	no change
☒ **D**	increases	increases

15 Silver nitrate, in aqueous ethanol, is added separately to four halogenoalkanes.

Which would form a silver halide precipitate in the shortest time?

☒ **A** 1-bromobutane

☒ **B** 1-chlorobutane

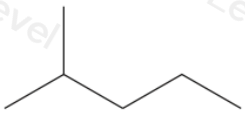
☒ **C** 1-fluorobutane

☒ **D** 1-iodobutane

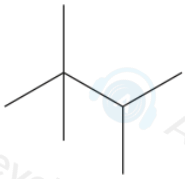
(Total for Question 15 = 1 mark)

4 Which of these alkanes would be expected to have the **highest** boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 4 = 1 mark)

13 Chloroethane reacts with aqueous potassium hydroxide to produce ethanol.

(a) What is the role of the hydroxide ion in this reaction?

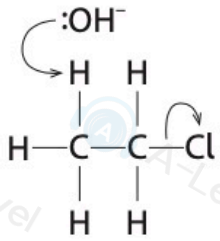
(1)

- ☒ **A** reducing agent
- ☒ **B** nucleophile
- ☒ **C** electrophile
- ☒ **D** base

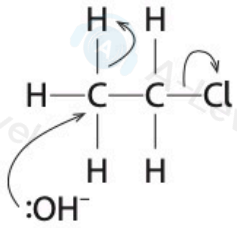
(b) Which mechanism shows the correct movement of electrons in this reaction?

(1)

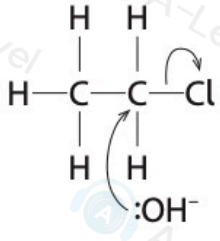
☒ **A**



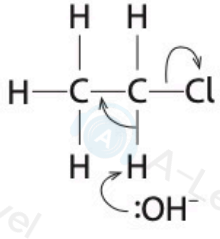
☒ **B**



☒ **C**



☒ **D**



18 Propan-1-ol may be converted into propene.

$$CH_3CH_2CH_2OH \rightarrow CH_3CH{=}CH_2 + H_2O$$

(a) Which reagent is used for this reaction?

(1)

- ☒ **A** 50% sulfuric acid
- ☒ **B** ethanolic potassium hydroxide
- ☒ **C** phosphoric(V) acid
- ☒ **D** red phosphorus

(b) The reaction is best classified as

(1)

- ☒ **A** elimination
- ☒ **B** hydrolysis
- ☒ **C** reduction
- ☒ **D** substitution

(Total for Question 18 = 2 marks)

---

6 Which compound does **not** contain an element with an oxidation number of –1?

- ☒ **A** HF
- ☒ **B** NaH
- ☒ **C** H_2O_2
- ☒ **D** CH_4

(Total for Question 6 = 1 mark)

2 The equilibrium between methane and steam is shown.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ\,mol^{-1}$$

(a) What would be the effect of **lowering** the temperature?

(1)

- ☒ **A** rate increases, yield increases
- ☒ **B** rate increases, yield decreases
- ☒ **C** rate decreases, yield increases
- ☒ **D** rate decreases, yield decreases

(b) What would be the effect of **increasing** the pressure?

(1)

- ☒ **A** rate increases, yield increases
- ☒ **B** rate increases, yield decreases
- ☒ **C** rate decreases, yield increases
- ☒ **D** rate decreases, yield decreases

(c) Some bond enthalpies are shown.

Bond	Bond enthalpy / kJ mol^{-1}
H—H	436
C≡O	1077
O—H	464

What is the bond enthalpy, in kJ mol^{-1}, of the C—H bond?

(1)

- ☒ **A** 198
- ☒ **B** 313
- ☒ **C** 416
- ☒ **D** 532

13 Compound **X** gives a red flame test and a solution of **X** produces a white precipitate when added to nitric acid and silver nitrate solution.

Which could be compound **X**?

- ☒ **A** LiCl
- ☒ **B** NaCl
- ☒ **C** NaBr
- ☒ **D** RbBr

12 A sample of 25.0 cm^3 of 0.205 mol dm^{-3} sulfuric acid was titrated with sodium hydroxide solution. The titre obtained was 14.60 cm^3.

(a) What is the concentration of the sodium hydroxide solution?

(1)

- ☒ **A** 0.176 mol dm^{-3}
- ☒ **B** 0.239 mol dm^{-3}
- ☒ **C** 0.351 mol dm^{-3}
- ☒ **D** 0.702 mol dm^{-3}

(b) What is the percentage error in the titre?

[The burette is accurate to 0.05 cm^3 per reading]

(1)

- ☒ **A** 0.10%
- ☒ **B** 0.34%
- ☒ **C** 0.40%
- ☒ **D** 0.68%

8 A 20 g sample of iron(III) sulfate, $Fe_2(SO_4)_3$, was dissolved in water. How many sulfate ions are in the solution formed?

[Assume M_r $Fe_2(SO_4)_3 = 400$
Avogadro constant, $L = 6.0 \times 10^{23}$ mol^{-1}]

☒ **A** 3×10^{22}

☒ **B** 9×10^{22}

☒ **C** 1.2×10^{23}

☒ **D** 1.5×10^{23}

3 The enthalpy change of reaction, $\Delta_r H$, for the equation shown can be calculated using bond enthalpy data.

$$\tfrac{1}{2}H_2(g) + \tfrac{1}{2}Cl_2(g) \rightarrow HCl(g)$$

Bond	Bond enthalpy / kJ mol^{-1}
H—H	436
Cl—Cl	242
H—Cl	431

The expression that should be used in the calculation is

☒ **A** $(0.5 \times 436 + 0.5 \times 242) - 431$

☒ **B** $(2 \times 431) - (436 + 242)$

☒ **C** $431 - (0.5 \times 436 + 0.5 \times 242)$

☒ **D** $(436 + 242) - (2 \times 431)$

(Total for Question 3 = 1 mark)

10: Which change increases the proportion of particles in a reaction that have sufficient energy to react?

- ☒ **A** an increase in reaction temperature
- ☒ **B** a decrease in reaction temperature
- ☒ **C** an increase in reactant concentration
- ☒ **D** a decrease in reactant concentration

(Total for Question 10 = 1 mark)

(b) An alternative method for producing methanal uses a silver catalyst at a temperature of 650 °C. The reaction is shown.

$$CH_3OH(g) \rightarrow HCHO(g) + H_2(g)$$

Suggest **one** advantage and **one** disadvantage of this method, other than the cost of the silver catalyst.

(2)

Advantage

.....

.....

Disadvantage

.....

.....

(c) Explain how the infrared spectra of methanol and methanal can be used to distinguish between the two compounds, stating the relevant bond stretching vibrations and their wavenumber ranges.

(2)

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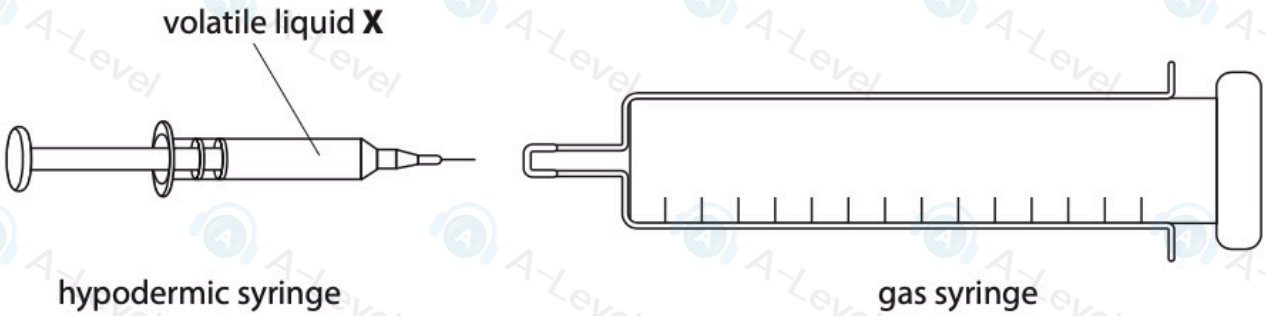
(Total for Question 21 = 7 marks)

TOTAL FOR SECTION B = 39 MARKS

18 A student determined the molecular mass of an unknown volatile organic liquid, **X**, using the apparatus shown.
The student used a hypodermic syringe to inject a sample of liquid **X** into a gas syringe.
The gas syringe was placed in an oven and liquid **X** vaporised.



hypodermic syringe gas syringe

Results

Mass of hypodermic syringe and liquid **X** before injection	5.71 g
Mass of hypodermic syringe and liquid **X** after injection	5.59 g
Mass of **X** added to the gas syringe	0.12 g
Temperature of oven	95 °C
Pressure of gas in the gas syringe	99 kPa
Volume of gas syringe after **X** had been vaporised	81 cm^3

(a) Calculate the relative molecular mass of liquid **X**.

$pV = nRT$ Gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$

(5)

(b) Each molecule of **X** contains carbon atoms, hydrogen atoms, and **one** atom of oxygen.
Identify **X**, by name or formula, using your answer from (a).

(1)

20 An organic compound, acetoin, is one of the compounds that gives butter its characteristic flavour.

(a) Acetoin contains 54.5 % by mass of carbon and 9.1 % by mass of hydrogen. The remainder is oxygen.

(i) Calculate the empirical formula of acetoin.
You must show all your working.

(3)

(ii) The molar mass of acetoin is 88.0 g mol^{-1}.

Use this information to calculate the molecular formula of acetoin.

(1)

(b) Acetoin contains **two** functional groups.

(i) Some chemical tests were carried out on acetoin. These tests identify **one** of the two functional groups.

Acetoin produced steamy fumes when reacted with PCl_5.

Acetoin did **not** react with sodium hydrogencarbonate solution.

Acetoin turned hot acidified potassium dichromate(VI) solution from orange to green.

State what can be deduced from each of these three tests and hence identify this functional group.

(3)

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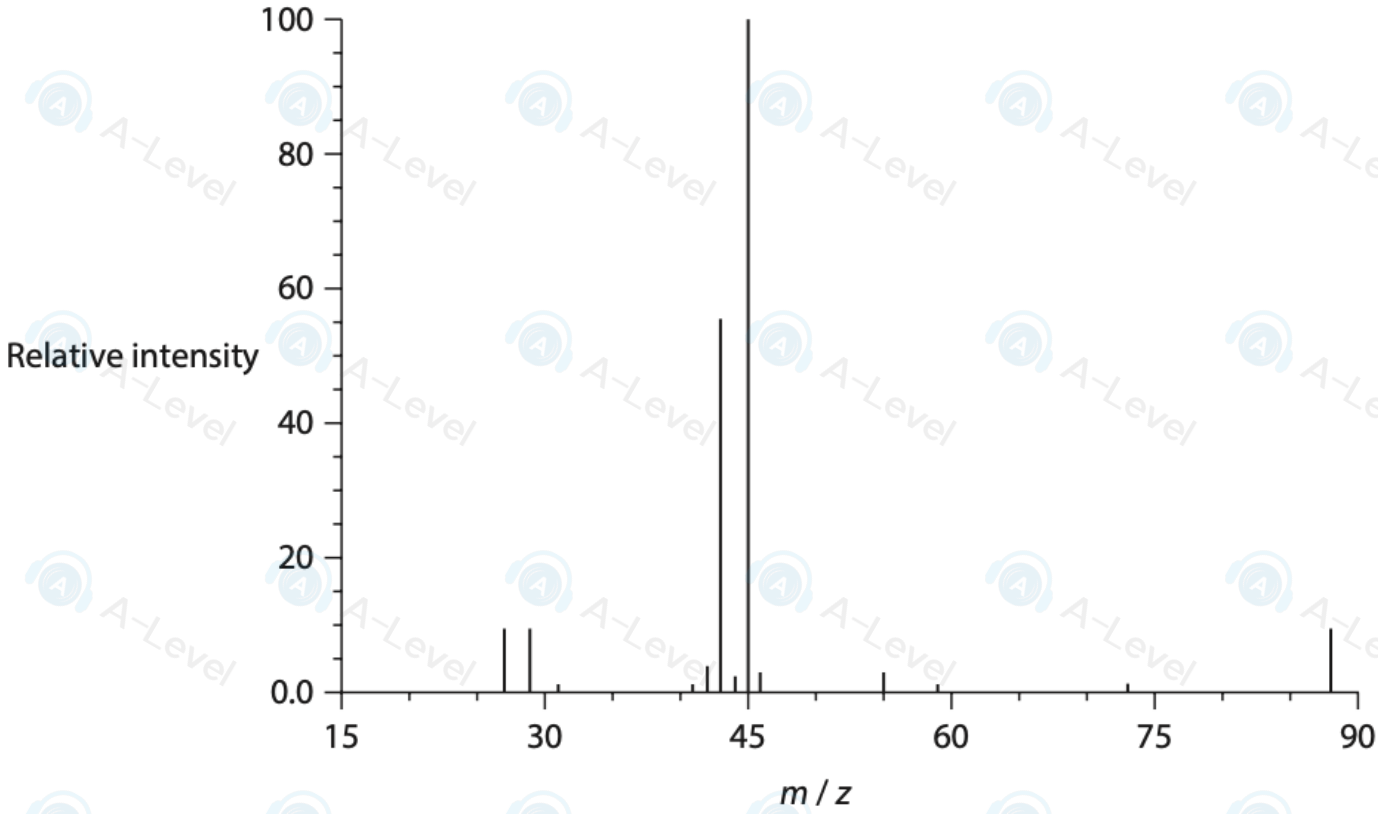
(ii) Acetoin also contains the carbonyl group C═O, in the form of a ketone **not** an aldehyde.

Use page 5 of your Data Booklet to show how infrared spectra data could be used to prove that acetoin contains a ketone not an aldehyde.
Complete the table.

(3)

	Bond	Wavenumber range / cm^{-1}
Absorption present in acetoin but not in an aldehyde		
One absorption present in an aldehyde but not in acetoin		
Another absorption present in an aldehyde but not in acetoin		

(iii) Part of the mass spectrum of acetoin is shown.



Determine a possible structure of acetoin using your answer to part (b)(i), the information given in (b)(ii) and the mass spectrum.

In your answer, identify the two ions responsible for the two peaks of highest intensity.

(3)

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

18 Calcium hypochlorite, $Ca(ClO)_2$, is used for water treatment in swimming pools. It is produced in the reaction between $Ca(OH)_2$ and Cl_2.

$$2Ca(OH)_2(aq) + 2Cl_2(g) \rightarrow Ca(ClO)_2(aq) + CaCl_2(aq) + 2H_2O(l)$$

(a) State the type of reaction occurring in the production of $Ca(ClO)_2$. Justify your answer using oxidation numbers.

(3)

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(b) Calculate the percentage atom economy by mass for the production of $Ca(ClO)_2$ in this reaction.

(2)

(c) A swimming pool has the dimensions 50 m × 25 m × 2.0 m.
The water in this swimming pool has a $Ca(ClO)_2$ concentration of 4.2 mg dm^{-3}.

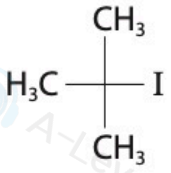
(i) Calculate the mass, **in kg**, of $Ca(ClO)_2$ required to treat the water needed to completely fill this swimming pool.

(3)

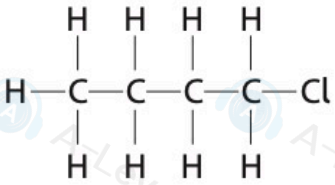
(ii) Calculate the volume of Cl_2, at room temperature and pressure, needed to make the mass of $Ca(ClO)_2$ calculated in (c)(i).

(3)

17 This question is about two halogenoalkanes, **A** and **B**, which have the structures shown.



A



B

(a) (i) Name compound **A**.

(1)

.....

(ii) Draw the **skeletal** formula of **B**.

(1)

(b) (i) Describe what you would observe when separate samples of **A** and **B** are warmed with silver nitrate dissolved in aqueous ethanol.

(2)

Observation with **A**

.....

Observation with **B**

.....

(ii) Give **two** reasons why **A** reacts more quickly than **B** when warmed with silver nitrate dissolved in aqueous ethanol.

(2)

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.....

(c) (i) Write an equation for the reaction of **B** with an alcoholic solution of potassium cyanide and name the organic product.

(2)

Equation:

Name

.....

(ii) Suggest why this type of reaction is important in organic synthesis.

(1)

.....

.....

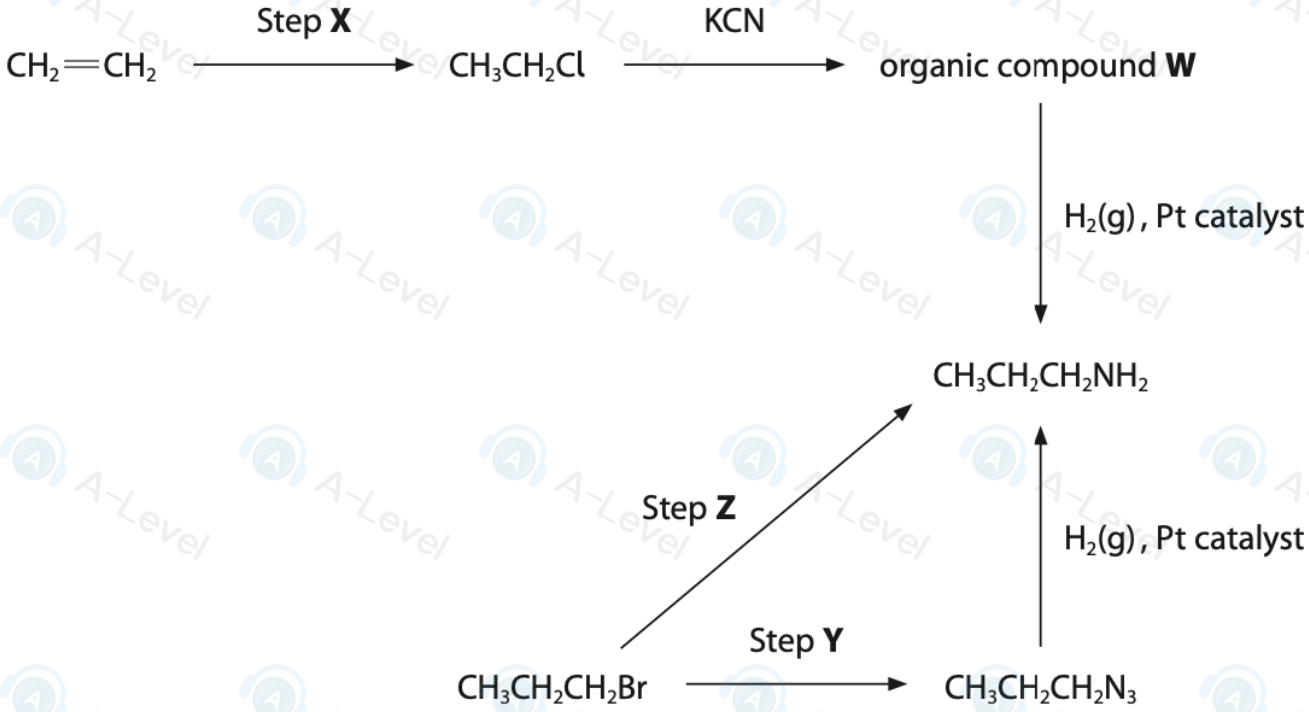
.....

.....

(Total for Question 17 = 9 marks)

20 This question is about the synthesis of propylamine, $CH_3CH_2CH_2NH_2$.

Three routes for the synthesis of $CH_3CH_2CH_2NH_2$ are shown.



(a) Identify, by name or formula, the reagent used in Step **X**.

(1)

.....

(b) Give the structure of organic compound **W**.

(1)

(c) The reagent used in Step **Y** is potassium azide, KN_3.
This is a source of the azide ion, N_3^-, which acts as a nucleophile.

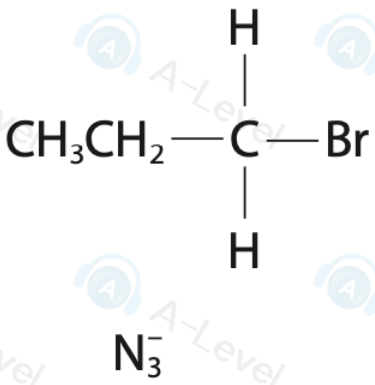
(i) Complete a possible dot-and-cross diagram for N_3^-.
Show outer electrons only.

(2)



(ii) Complete the mechanism for Step **Y**.
Include curly arrows, and any relevant lone pairs and dipoles.

(3)



(d) Step **Z** is carried out by reacting ammonia with 1-bromopropane.

(i) Give the conditions for this reaction.

(2)

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(ii) Suggest why the yield of $CH_3CH_2CH_2NH_2$ obtained using Step **Z** is low.

(1)

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(Total for Question 20 = 10 marks)

18 This question is about Group 2 carbonates.

Group 2 carbonates decompose on heating to form the corresponding metal oxide and carbon dioxide. The general equation is shown.

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

(a) A sample of magnesium carbonate was heated for 4 minutes.
The mass of the sample decreased from 4.17 g to 2.35 g.

Calculate the percentage of magnesium carbonate that has decomposed.

[Molar mass of magnesium carbonate = 84.3 g mol^{-1}]

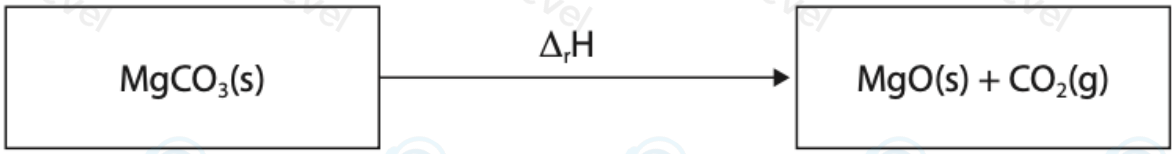
(3)

(b) The enthalpy change, $\Delta_r H$, for the thermal decomposition of magnesium carbonate, $MgCO_3$, can be calculated using the data in the table.

Substance	Enthalpy change of formation / kJ mol^{-1}
$MgCO_3$	−1095.8
MgO	−601.7
CO_2	−393.5

(i) Complete the Hess cycle with two arrows and correct species and state symbols in the box.

(2)



(ii) Calculate the enthalpy change for the thermal decomposition of magnesium carbonate, $\Delta_r H$. Include a sign and units in your answer.

(2)

(c) Explain how the enthalpy change for the thermal decomposition of calcium carbonate, $CaCO_3$, compares to that for magnesium carbonate in (b)(ii).

(3)