Centre Number						Candidate Number				
Surname	Model Answers									
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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TOTAL	

AQA

General Certificate of Education
Advanced Subsidiary Examination
June 2015

Chemistry

CHEM2

Unit 2 Chemistry in Action

Tuesday 2 June 2015 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  - use good English
  - organise information clearly
  - use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

Section A

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

1 Chlorine is an important industrial chemical.

1 (a) Chlorine is formed when $KMnO_4$ reacts with hydrochloric acid.
The ionic equation for this redox reaction is

$$16H^+ + 2MnO_4^- + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$$

1 (a) (i) Deduce the half-equation for the oxidation of chloride ions to chlorine.

[1 mark]

$2Cl^- \longrightarrow Cl_2 + 2e^-$

1 (a) (ii) Give the oxidation state of manganese in the MnO_4^- ion.

[1 mark]

+7

1 (a) (iii) Deduce the half-equation for the reduction of the MnO_4^- ions in acidified solution to manganese(II) ions and water.

[1 mark]

(1) basic half equation: $Mn^{+7} + 5e^- \longrightarrow Mn^{+2}$ (2) Put oxygens in $MnO_4^- + 5e^- \rightarrow Mn^{+2}$

(3) Balance with H^+ and H_2O: $MnO_4^- + 5e^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O$

1 (b) Chlorine behaves as an oxidising agent in the extraction of bromine from seawater.
In this process, chlorine gas is bubbled through a solution containing bromide ions.

1 (b) (i) Write the **simplest ionic** equation for the reaction of chlorine with bromide ions.

[1 mark]

$Cl_2 + 2Br^- \longrightarrow 2Cl^- + Br_2$

1 (b) (ii) Give **one** observation that would be made during this reaction.

(Bromine being formed)

[1 mark]

Turns the solution orange

1 (b) (iii) In terms of electrons, state the meaning of the term **oxidising agent**.

[1 mark]

Causes another species to be oxidised (to lose electrons).

1 (c) In sunlight, chlorine can also oxidise water slowly to form oxygen.

Write an equation for this reaction.
Give the oxidation state of chlorine in the chlorine-containing species that is formed.

[2 marks]

Equation

$2Cl_2 + 2H_2O \longrightarrow 4HCl + O_2$

Oxidation state of chlorine in the species formed -1

1 (d) Explain why chlorine has a lower boiling point than bromine.

[2 marks]

Chlorine is smaller than bromine and therefore the intermolecular forces between the molecules are weaker (vdws).

10

2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them. State what is observed in each case.

2 (a) Butan-2-ol and 2-methylpropan-2-ol **[3 marks]**

Reagent Acidified potassium dichromate

Observation with butan-2-ol → 2° alcohol oxidised to ketone.

turns green (from orange)

Observation with 2-methylpropan-2-ol → 3° alcohol - cannot be easily oxidised.

Remains orange.

2 (b) Propane and propene **[3 marks]**

Reagent Bromine

Observation with propane

Remains orange

Observation with propene → adds across double bond.

goes colourless (from orange)

2 (c) Aqueous silver nitrate and aqueous sodium nitrate

[3 marks]

Reagent HCl

Observation with aqueous silver nitrate → forms silver chloride ppt.

forms a white ppt

Observation with aqueous sodium nitrate

Remains Colourless.

2 (d) Aqueous magnesium chloride and aqueous barium chloride

[3 marks]

Reagent H_2SO_4

Observation with aqueous magnesium chloride

forms a white ppt → forms insoluble $MgSO_4$.

Observation with aqueous barium chloride

Remains Colourless

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Turn over for the next question

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

3 The elements in Group 2 from Mg to Ba can be used to show the trends in properties down a group in the Periodic Table.

3 (a) State the trend in atomic radius for atoms of the elements down Group 2 from Mg to Ba Give a reason for this trend.

[2 marks]

Trend Increases

Reason As you go down the group, the number of orbitals increase.

3 (b) The Group 2 elements react with water.

3 (b) (i) State the trend in reactivity with water of the elements down Group 2 from Mg to Ba

[1 mark]

Increases

3 (b) (ii) Write an equation for the reaction of strontium with water.

[1 mark]

$Sr + 2H_2O \longrightarrow Sr(OH)_2 + H_2$

3 (c) Give the **formula** of the hydroxide of the element in Group 2 from Mg to Ba that is most soluble in water.

Remember your trends! $Ba(OH)_2$ most soluble! BaSO4 least soluble!

[1 mark]

$Ba(OH)_2$.

5

4 Hydrogen is produced in industry from methane and steam in a two-stage process.

4 (a) In the first stage, carbon monoxide and hydrogen are formed. The equation for this reaction is

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

forward reaction is endothermic

4 (a) (i) Use Le Chatelier's principle to state whether a high or low temperature should be used to obtain the highest possible equilibrium yield of hydrogen from this first stage. Explain your answer.

[3 marks]

Temperature High temperature

Explanation As ΔH is +ve then forward reaction is endothermic, therefore increasing temperature moves equilibrium position to the right to counteract the increase in temperature.

4 (a) (ii) Le Chatelier's principle suggests that a high pressure will produce a low yield of hydrogen in this first stage.

Explain, in terms of the behaviour of particles, why a high operating pressure is used in industry.

[2 marks]

High pressure used as it will increase the rate of reaction so will reach equilibrium faster. This is because particles are closer together and therefore there are more frequent collisions.

4 (a) (iii) A nickel catalyst is used in the first stage.

Explain why the catalyst is more effective when coated onto an unreactive honeycomb.

[2 marks]

The honeycomb gives it a much larger surface area - this will increase the number of successful collisions on the surface of the catalyst.

4 (b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ mol}^{-1}$$

Use Le Chatelier's principle to state the effect, if any, of a **decrease** in the total pressure on the yield of hydrogen in this second stage. Explain your answer.

[2 marks]

Effect No effect.

Explanation Same number of moles on either side of the equation.

9

Turn over for the next question

5 There are many uses of halogenated organic compounds despite environmental concerns.

5 (a) Bromotrifluoromethane is used in fire extinguishers in aircraft.
Bromotrifluoromethane is formed when trifluoromethane reacts with bromine.

$$CHF_3 + Br_2 \longrightarrow CBrF_3 + HBr$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

5 (a) (i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Br_2 **[4 marks]**

After 'initial step' trick is to use the radical you formed each time!

Initiation step

$Br_2 \longrightarrow 2Br^{\bullet}$

First propagation step

$Br^{\bullet} + CHF_3 \longrightarrow HBr + {}^{\bullet}CF_3$

Second propagation step

${}^{\bullet}CF_3 + Br_2 \longrightarrow CF_3Br + Br^{\bullet}$

A termination step

$^{\bullet}CF_3 + {}^{\bullet}CF_3 \longrightarrow C_2F_6$

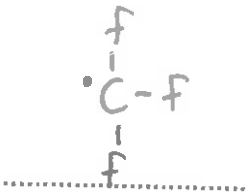
5 (a) (ii) State **one** condition necessary for the initiation of this reaction. **[1 mark]**

UV light → used to break Br–Br bond.

5 (b) Bromine-containing and chlorine-containing organic compounds may have a role in the decomposition of ozone in the upper atmosphere.

5 (b) (i) Draw an appropriate **displayed formula** in the space provided to complete the following equation to show how $CBrF_3$ may produce bromine atoms in the upper atmosphere.

[1 mark]

$CBrF_3 \longrightarrow$  + $Br\bullet$

5 (b) (ii) In the upper atmosphere, it is more likely for $CBrF_3$ to produce bromine atoms than it is for $CClF_3$ to produce chlorine atoms.

Suggest **one** reason for this.

[1 mark]

C – Br bond is weaker and therefore easier to break than C – Cl bond.

Question 5 continues on the next page

5 (b) (iii) Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone. The overall equation for the decomposition of ozone is

$$2O_3 \longrightarrow 3O_2$$

Write **two** equations to show how bromine atoms (Br•) act as a catalyst in the decomposition of ozone.

Explain how these two decomposition equations show that bromine atoms behave as a catalyst. **[3 marks]**

As you can see Br• also formed & end = catalyst!

Equation 1

$Br^{\bullet} + O_3 \longrightarrow BrO^{\bullet} + O_2$

Equation 2

$BrO^{\bullet} + O_3 \longrightarrow Br^{\bullet} + 2O_2$

Explanation Br• regenerated at the end so not used up in the reaction.

10

6 Butane and propanal are compounds with M_r = 58.0, calculated using data from your Periodic Table.

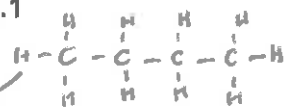
6 (a) A mass spectrometer can be used to distinguish between samples of butane and propanal.

Table 1 shows some precise relative atomic mass values.

Table 1

Atom	Precise relative atomic mass
^{1}H	1.00794
^{12}C	12.00000

6 (a) (i) Use data from **Table 1** to show that, to 3 significant figures, a more accurate value for the M_r of butane is 58.1



[1 mark]

C_4H_{10}

$(4 \times 12.00000) + (10 \times 1.00794)$

$= 58.0794 \therefore 58.1$

6 (a) (ii) State why the precise relative atomic mass quoted in **Table 1** for the ^{12}C isotope is exactly 12.00000

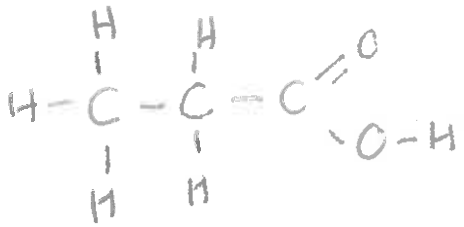
[1 mark]

By definition! All other values are compared to C-12.

Question 6 continues on the next page

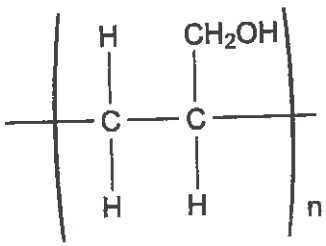
6 (b) Draw a **displayed formula** for the organic product that is formed when propanal is oxidised by warm Tollens' reagent.

[1 mark]



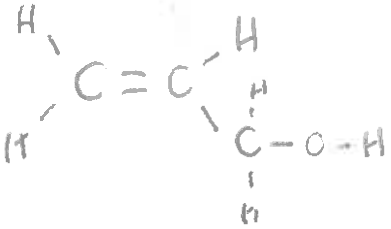
Remember displayed means all bonds, don't forget the O-H bond!

6 (c) Prop-2-en-1-ol is an isomer of propanal and can be polymerised to form a polymer represented by the following structure.



6 (c) (i) Draw the structure of prop-2-en-1-ol.

[1 mark]



Doesn't have to be displayed but helps.

6 (c) (ii) Deduce the type of polymerisation that results in the formation of this polymer from prop-2-en-1-ol.

[1 mark]

Addition polymerisation.

6 (c) (iii) There are two functional groups in prop-2-en-1-ol. Each of these functional groups contains a bond with a characteristic absorption range in the infrared spectrum.

Use **Table A** on the Data Sheet to suggest a bond and its absorption range for each of the two functional groups.

[2 marks]

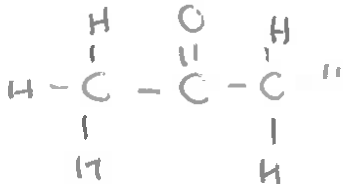
Bond 1 C=C Absorption range 1620-1680

Bond 2 O-H Absorption range 3230 - 3550

6 (d) Compound **X** is another isomer of propanal. The infrared spectrum of **X** shows an absorption in the range 1680–1750 cm^{-1}.

6 (d) (i) Draw the structure of **X**.

[1 mark]



Propanone would also have the C=O group.

6 (d) (ii) Which of the following, **A**, **B**, **C** or **D**, represents the type of isomerism shown by **X** and propanal?

Write the correct letter, **A**, **B**, **C** or **D**, in the box.

[1 mark]

A chain isomerism
B E–Z isomerism
C functional group isomerism
D position isomerism

Ketone + aldehydes are different functional groups.

C

9

7 (a) Propanone can be formed when glucose comes into contact with bacteria in the absence of air.

7 (a) (i) Balance the following equation for this reaction of glucose to form propanone, carbon dioxide and water.

[1 mark]

2 $C_6H_{12}O_6$ ⟶ 3 CH_3COCH_3 + 3 CO_2 + 3 H_2O

7 (a) (ii) Deduce the role of the bacteria in this reaction.

[1 mark]

Catalyses (speeds up) the reaction.

7 (b) Propanone is also formed by the oxidation of propan-2-ol.

7 (b) (i) Write an equation for this reaction using [O] to represent the oxidising agent.

[1 mark]

$CH_3CH(OH)CH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$

7 (b) (ii) State the class of alcohols to which propan-2-ol belongs.

[1 mark]

2° alcohol.

7 (c) A student determined a value for the enthalpy change when a sample of propanone was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 150 g of water increased by 8.0 °C when 4.50×10^{-3} mol of pure propanone was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of propanone is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

[3 marks]

$q = mc\Delta T$ $q = 150 \times 4{\cdot}18 \times 8{\cdot}0$

$q = 5016$ J

$\frac{5016}{4{\cdot}50 \times 10^{-3}} = 1114666{\cdot}667$ J mol^{-1} OR $\div 1000 = -1114{\cdot}6$ kJ mol^{-1}

don't forget negative sign as it is exothermic!

Question 7 continues on the next page

7 (d) Define the term **standard enthalpy of combustion.**

[3 marks]

The enthalpy change when 1mol of a substance reacts completely in oxygen, when all substances are in their standard states under standard conditions.

7 (e) Use the mean bond enthalpy data in **Table 2** and the equation given below **Table 2** to calculate a value for the standard enthalpy change when gaseous propanone is burned.

[3 marks]

Table 2

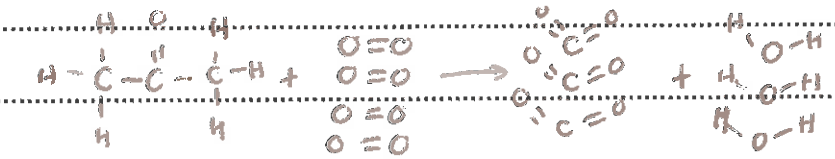
	C–H	C–C	C–O	O–H	C=O	O=O
Mean bond enthalpy / kJ mol^{-1}	412	348	360	463	805	496

Reactants Products

$$CH_3COCH_3(g) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(g)$$

always find it helpful to draw all the bonds!

Reactants − Products = ΔH



2 × 348 } = 3973 : 4 × 496 = 1984 : 6 × 805 = 4830 : 6 × 463 = 2778
6 × 412 }
1 × 805 }

= 5957 : 7608

5957 − 7608 = −1651 kJmol^{-1}

7 (f) Suggest **two** reasons why the value obtained by the student in Question **7 (c)** is different from the value calculated in Question **7 (e)**.

[2 marks]

Reason 1 Heat loss to the surroundings (Not all absorbed by the apparatus).

Reason 2 Incomplete combustion may have occured.

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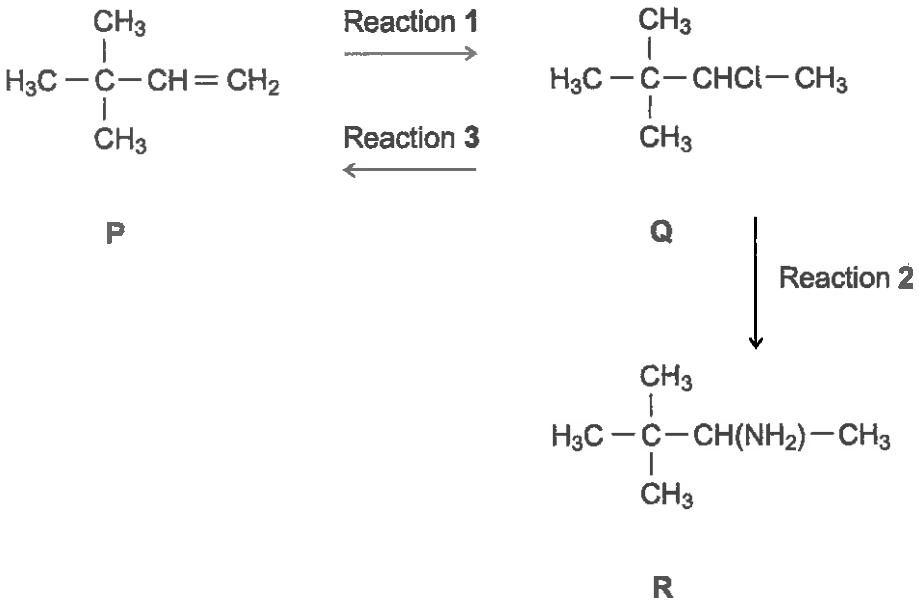
Turn over for the next question

Section B

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

8 Consider the following scheme of reactions.



8 (a) Give the IUPAC name for compound **P** and that for compound **Q**.

[2 marks]

P 3,3-dimethylbut-1-ene

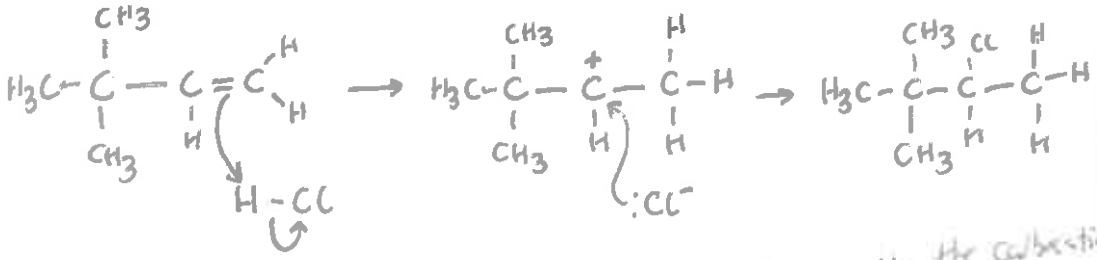
Q 3-chloro-2,2-dimethylbutane

8 (b) The conversion of **P** into **Q** in Reaction **1** uses HCl

Name and outline a mechanism for this reaction.

[5 marks]

Electrophilic Addition



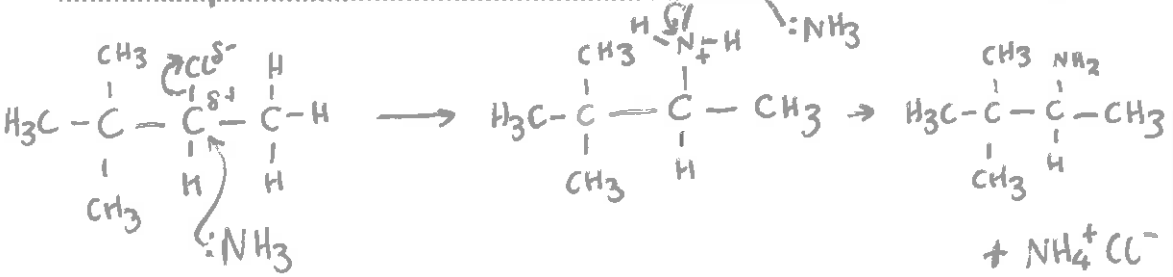
Though technically the carbocation could be on the other carbon (minor product though) - it must be on this one to form Q!

8 (c) The conversion of **Q** into **R** in Reaction **2** uses NH_3

Name and outline a mechanism for this reaction.

[5 marks]

Nucleophilic Substitution



Though the extra mole of NH_3 is necessary here it makes more sense in my own mind.

Question 8 continues on the next page

8 (d) State the type of reaction shown by Reaction **3**.

Identify a reagent for this reaction.

Give **one** condition necessary for a high yield of product when **Q** is converted into **P**.

[3 marks]

Type: Elimination

Reagent: NaOH

Conditions: Reflux under ethanolic conditions

8 (e) Hydrogen bromide (HBr) could be used in the overall conversion of **P** into **R**, instead of using HCl
Hydrogen bromide is made by the reaction of NaBr with concentrated phosphoric acid.
Concentrated sulfuric acid is **not** used to make HBr from NaBr

Write an equation for the reaction of NaBr with H_3PO_4 to produce HBr and Na_3PO_4 only.

Identify **two** toxic gases that are formed, together with HBr, when NaBr reacts with concentrated H_2SO_4

State the role of H_2SO_4 in the formation of these two toxic gases.

[4 marks]

$3NaBr + H_3PO_4 \longrightarrow 3HBr + Na_3PO_4$

$NaBr + H_2SO_4 \longrightarrow NaHSO_4 + HBr$

$2HBr + H_2SO_4 \longrightarrow Br_2 + SO_2 + 2H_2O$

toxic gases!

H_2SO_4 is an oxidising agent as it oxidises the Br^- ion to Br_2 while itself being reduced from $S^{+6} \rightarrow S^{+4}$.

19

9 Vanadium is an important metal. Ferrovanadium, an alloy of iron and vanadium, is used to make a strong type of vanadium-steel. Pure vanadium is used in nuclear reactors.

9 (a) **Table 3** shows some standard enthalpy of formation data.

Table 3

	$V_2O_5(s)$	CaO(s)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–1560	–635

In the oldest method of extraction of vanadium, V_2O_5 is reacted with calcium at a high temperature.

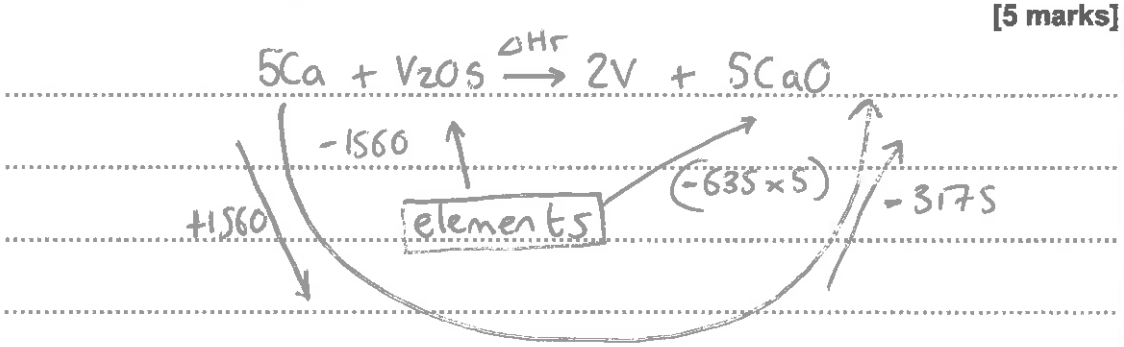
$$5Ca(s) + V_2O_5(s) \longrightarrow 2V(s) + 5CaO(s)$$

Use data from **Table 3** and the equation to calculate the standard enthalpy change for this reaction.

State the type of reaction that V_2O_5 has undergone.

Suggest **one** major reason why this method of extracting vanadium is expensive, other than the cost of heating the reaction mixture.

[5 marks]



1560 + (-3175) = -1615 kJmol^{-1}

Redox Reaction. It is expensive as it is difficult to obtain pure Calcium - usually by electrolysis.

Question 9 continues on the next page

9 (b) Ferrovanadium is produced by the reaction of aluminium with a mixture of V_2O_5 and iron(III) oxide.

Write an equation for the reaction of aluminium with iron(III) oxide.

State the change in oxidation state of aluminium in this reaction.

[2 marks]

$2Al + Fe_2O_3 \longrightarrow 2Fe + Al_2O_3$

Al: zero to +3 Fe: +3 to zero.

9 (c) Pure vanadium, for nuclear reactors, is formed by the reaction of hydrogen with purified VCl_2

Write an equation for this reaction in which the only other product is HCl gas.

Identify **two** hazards in this process, other than the fact that it operates at a high temperature.

Deduce why this process produces **pure** vanadium, other than the fact that purified VCl_2 is used.

[4 marks]

$VCl_2 + H_2 \longrightarrow V + 2HCl$

- HCl is toxic and corrosive.
- Hydrogen is explosive.

- The only other product is HCl and this is very easily removed because it is a gas at the temperatures used.

11

END OF QUESTIONS