**Q1.**(a)     **Figure 1** shows the volume of hydrogen gas collected when a sample of magnesium reacted with an excess of dilute hydrochloric acid.

The rate of this reaction can be studied by measuring the time it takes for a given volume of hydrogen to be collected.

**Figure 1**

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Time / s

(i)      State the meaning of the term *rate of reaction*.

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**(1)**

(ii)     State and explain what has happened to the rate of this reaction at point **W** in **Figure 1**.

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**(2)**

(iii)     In terms of collision theory explain why, at a fixed temperature, the rate of this reaction doubles when the concentration of the hydrochloric acid doubles.

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**(2)**

(b)     In a study of the reaction in part (a), a student referred to activation energy.

(i)      State the meaning of the term *activation energy*.

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**(1)**

(ii)     Complete **Figure 2** by drawing the shape of the reaction profile from reactants to products for an exothermic reaction.
Show the position of the products. Show and label the activation energy.

**Figure 2**

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**(2)**

(c)     Barium metal reacts very quickly with dilute hydrochloric acid, but it reacts more slowly with water.

(i)      Write an equation for the reaction of barium with water.

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**(1)**

(ii)     A solution containing barium ions can be used to show the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction that occurs and state what is observed.

Simplest ionic equation

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Observation

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**(2)**

(iii)     State **one** use of barium sulfate in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .......................................................................................................

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Explanation ............................................................................................

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**(2)**

**(Total 13 marks)**

**Q2.**Group 2 metals and their compounds are used commercially in a variety of processes.

(a)     Strontium is extracted from strontium oxide (SrO) by heating a mixture of powdered strontium oxide and powdered aluminium.

Consider these standard enthalpies of formation.

|  |  |  |  |
| --- | --- | --- | --- |
|   |  | SrO(s) | Al2O3(s) |
|   | ***ΔH*fϴ / kJ mol−1** | – 590 | – 1669 |

3SrO(s) + 2Al(s)       3Sr(s)   +   Al2O3(s)

Use these data and the equation to calculate the standard enthalpy change for this extraction of strontium.

The use of powdered strontium oxide and powdered aluminium increases the surface area of the reactants.
Suggest **one** reason why this increases the reaction rate.

Suggest **one** major reason why this method of extracting strontium is expensive.

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**(5)**

(b)     Explain why calcium has a higher melting point than strontium.

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**(2)**

(c)     Magnesium is used in fireworks. It reacts rapidly with oxygen, burning with a bright white light. Magnesium reacts slowly with cold water.

Write an equation for the reaction of magnesium with oxygen.

Write an equation for the reaction of magnesium with cold water.

Give a medical use for the magnesium compound formed in the reaction of magnesium with cold water.

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**(3)**

**(Total 10 marks)**

**Q3.**Group 2 elements and their compounds have a wide range of uses.

(a)     For parts (a)(i) to (a)(iii), draw a ring around the correct answer to complete each sentence.

|  |  |  |
| --- | --- | --- |
|   |   | decreases. |
| (i) | From Mg(OH)2 to Ba(OH)2, the solubility in water | increases. |
|   |   | stays the same. |

**(1)**

|  |  |  |
| --- | --- | --- |
|   |   | decreases. |
| (ii) | From Mg to Ba, the first ionisation energy | increases. |
|   |   | stays the same. |

**(1)**

|  |  |  |
| --- | --- | --- |
|   |   | decreases. |
| (iii) | From Mg to Ba, the atomic radius | increases. |
|   |   | stays the same. |

**(1)**

(b)     Explain why calcium has a higher melting point than strontium.

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*(Extra space)* .................................................................................................

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**(2)**

(c)     Acidified barium chloride solution is used as a reagent to test for sulfate ions.

(i)      State why sulfuric acid should **not** be used to acidify the barium chloride.

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**(1)**

(ii)     Write the **simplest ionic** equation for the reaction that occurs when acidified barium chloride solution is added to a solution containing sulfate ions.

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**(1)**

**(Total 7 marks)**

**M1.**(a)     (i)      Change in concentration (of a substance / reactant / product) in unit time / given time / per (specified) unit of time

*This may be written mathematically* ***OR*** *may refer to the gradient of a graph of concentration / volume against time*

***OR***

Amount of substance formed / used up in unit time / given time / per (specified) unit of time

*Ignore additional information including reference to collisions*

**1**

(ii)     At **W**

**M1 (QoL)**

The rate / it is zero

M2

The magnesium has all reacted / has been used up

*Ignore reference to the acid being used up*

***OR***

No more collisions possible between acid and Mg

***OR***

Reaction is complete / it has stopped

***OR***

No more hydrogen / product is produced

**2**

(iii)    M1

Twice / double as many particles / hydrogen ions (in a given volume)

*Penalise reference to (hydrochloric acid) molecules in* ***M1***

*Penalise reference to “HCl particles” in* ***M1***

***OR***

Twice / double as much hydrochloric acid

M2

Twice / double as many effective / successful collisions (in a given time)

***OR***

Twice / double as many collisions with either sufficient energy to react ***OR*** with E ≥ Ea

***OR***

double the successful / effective collision frequency

**2**

(b)    (i)      The activation energy is the minimum energy for a reaction to go / start

***OR***

Minimum energy for a successful/ effective collision

**1**

(ii)     M1   Products lower than reactants on the profile

*Mark independently*

M2     Activation energy (*E*a) shown and labelled correctly from reactants to peak of curve

*Mark independently*

**2**

(c)    (i)      Ba + **2**H2O   Ba(OH)2 + H2

*Ba + 2H2O Ba2+ + 2OH− + H2*

*Allow multiples*

*Ignore state symbols*

**1**

(ii)     M1    Ba2+ + SO42−  BaSO4

*Ignore state symbols in* ***M1***

*Not multiples in* ***M1***

M2      White precipitate / solid

*Extra ions must be cancelled*

*Penalise contradictory observations in* ***M2***

**2**

(iii)    M1     Barium meal / barium swallow / barium enema

*Accept a correct reference to* ***M1*** *written in the explanation in* ***M2****, unless contradictory*

***OR***    used in X-rays ***OR*** to block X-rays ***OR*** X-ray contrast medium ***OR*** CT scans

M2      BaSO4 / barium sulfate is insoluble (and therefore not toxic)

*For* ***M2*** *NOT barium ions*

*NOT barium*

*NOT barium meal and NOT “It”*

*Ignore radio-tracing*

**2**

**[13]**

**M2.**(a)    **M1 (could be scored by a correct mathematical expression**

*Correct answer to the calculation gains all of* ***M1****,* ***M2*** *and* ***M3***

M1 *ΔH* = Σ*ΔHf* (**products**) − Σ*ΔH f* (**reactants**)

*Credit 1 mark for − 101 (kJ mol−1)*

***OR*** a correct cycle of balanced equations

M2 = − 1669 − 3(− 590)
= − 1669 + 1770
(This also scores M1)

M3 = **+ 101** (kJ mol−1)

**Award 1 mark ONLY for − 101**

*For other incorrect or incomplete answers, proceed as follows*

*•        check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (****M1*** *and* ***M2****)*

*•        If no AE, check for a correct method; this requires either a correct cycle with 3Sr and 2Al OR a clear statement of* ***M1*** *which could be in words and scores* ***only M1***

**M4 - Using powders**Any **one** from

•        To increase collision frequency / collisions in a given time / rate of collisions

•        To increase the surface contact / contact between the solids / contact between (exposed) particles

*Ignore dividing final answer by 3*

*Penalise* ***M4*** *for reference to molecules.*

**5**

**M5 Major reason for expense of extraction**Any **one** from

•        Aluminium is extracted by electrolysis ***OR*** aluminium extraction uses
         (large amounts of) electricity

•        Reaction / process / It / the mixture requires heat

•        It is endothermic

(b)     Calcium has a higher melting point than strontium, because

*Ignore general Group 2 statements.*

**Correct reference to size of cations / proximity of electrons**M1 (For Ca) delocalised electrons closer to cations / positive ions / atoms / nucleus
***OR*** cations / positive ions / atoms are smaller
***OR*** cation / positive ion / atom or it has fewer (electron) shells / levels

*Penalise* ***M1*** *if either of Ca or Sr is said to have more or less delocalised electrons OR the same nuclear charge.*

*Ignore reference to shielding.*

**Relative strength of metallic bonding**M2 (Ca) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons
***OR***stronger metallic bonding

(assume argument refers to Ca but credit converse argument for Sr)

***CE= 0*** *for reference to molecules or Van der Waals forces or intermolecular forces or covalent bonds.*

**2**

(c)     **M1** **2**Mg + O2   **2**MgO

**M2** Mg + **2**H2O   Mg(OH)2 + H2

*Credit multiples of the equations.*

**M3** Magnesium hydroxide is used as an antacid / relieve indigestion (heartburn) / neutralise (stomach) acidity / laxative

*Not simply “milk of magnesia” in* ***M3***

**3**

**[10]**

**M3.**(a)     (i)      Increases

**1**

(ii)     Decreases

**1**

(iii)    Increases

**1**

(b)     Calcium has a higher melting point than strontium, because

*CE = 0 for reference to molecules or intermolecular forces or covalent bonds*

**Correct reference to size of cations/proximity of electrons**

**M1**   (For Ca) delocalised electron(s) closer to cations / positive ions / nucleus

*Ignore “Van der Waals forces (between atoms)” but penalise if between “molecules”*

       ***OR***  cations / positive ions / atoms are smaller

       ***OR***  cation / positive ion / atom or it has fewer (electron) shells / levels

*Ignore general Group 2 statements*

*Answers must be specific*

**Relative strength of metallic bonding**

**M2**   (For Ca) has stronger attraction between the cations / positive ions / nucleus
and the delocalised electron(s)

*Penalise M1 if Ca or Sr is said to have more or less delocalised electrons*

     ***OR***

     stronger metallic bonding

     (assume argument refers to Ca but accept converse argument for Sr)

*Ignore reference to shielding*

**2**

(c)     (i)     Sulfuric acid / it contains sulfate ions / SO42–

***OR***

*Do not penalise an additional but incorrect formula for sulfate ion.*

Sulfuric acid would form a (white) precipitate

*If only the formula of the sulfate ion is given, it must be correct*

**1**

(ii)     Ba2+ + SO42–  BaSO4 ONLY

*Ignore state symbols*

*No multiples*

**1**

**[7]**