Energy Changes 2

Name: _____

Class: _____

Date: _____

Time: **71 minutes**

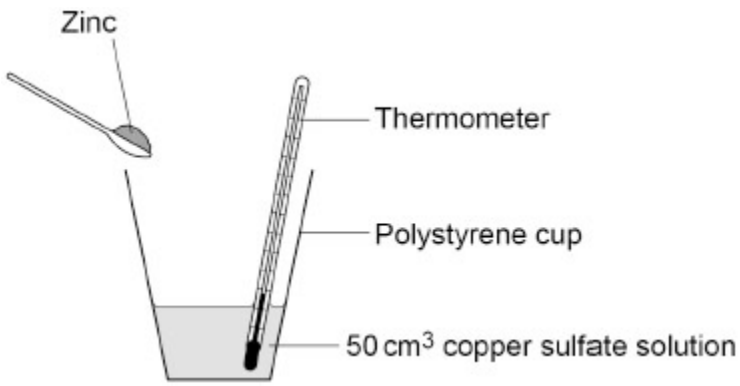
Marks: **65 marks**

Comments:

1. A student investigated the temperature change when different masses of zinc were added to copper sulfate solution.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Pour 50 cm^3 of copper sulfate solution into a polystyrene cup.

2. Measure the starting temperature of the copper sulfate solution.

3. Add 1.0 g of zinc.

4. Stir the mixture.

5. Measure the highest temperature reached.

6. Repeat steps 1 to 5 two more times.

7. Repeat steps 1 to 6 with different masses of zinc.

(a) The student varied the mass of zinc.

What type of variable is the mass of zinc?

Tick (✓) **one** box.

Control ☐

Dependent ☐

Independent ☐

(1)

Zinc reacts with copper sulfate solution to produce salt **A** and copper.

The word equation for the reaction is:

zinc + copper sulfate → salt **A** + copper

(b) What is the name of salt **A**?

_____

(1)

(c) The temperature of the solution increases when zinc reacts with copper sulfate solution.

Give **two** other observations that can be made when zinc reacts with copper sulfate solution.

1 _____

_____

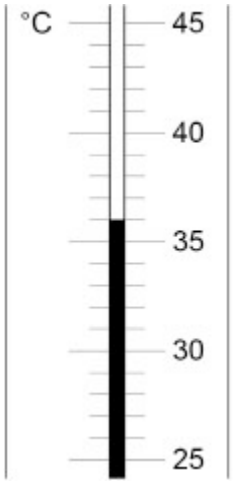
2 _____

_____

(2)

(d) **Figure 2** shows the highest temperature reached in one experiment.

Figure 2



Complete **Table 1**.

Use **Figure 2**.

Table 1

Starting temperature in °C	21
Highest temperature reached in °C	
Temperature increase in °C	

(2)

A teacher repeated the investigation using a digital thermometer.

Table 2 shows the results.

Table 2

Mass of zinc in grams	**Temperature increase in °C**			
	Experiment 1	Experiment 2	Experiment 3	**Mean**
1.0	7.8	7.3	7.7	**B**
2.0	13.1	13.8	13.3	13.4
3.0	20.4	12.9	20.2	20.3

(e) Calculate value **B** in **Table 2**.

_____

_____

_____

B = _____ °C

(2)

(f) The range of the results is the minimum value of temperature increase to the maximum value of temperature increase.

What is the range of temperature increase for the experiment with **2.0 g** of zinc?

Range = _____ °C to _____ °C

(1)

(g) One of the results for **3.0 g** of zinc is anomalous.

Which result is anomalous?

Suggest **one** reason why this result is anomalous.

Anomalous result _____

Reason _____

_____

_____

_____

(2)

(Total 11 marks)

2. This question is about hydrogen chloride (HCl) and hydrogen chlorate (HOCl).

Hydrogen chloride and hydrogen chlorate both form acids when dissolved in water.

(a) Hydrogen chloride gas dissolves in water to form hydrochloric acid.

Give the state symbols for:

- hydrogen chloride
- water
- hydrochloric acid.

Hydrogen chloride _____

Water _____

Hydrochloric acid _____

(1)

(b) A solution of hydrochloric acid has:

- a pH of 2.5
- a concentration of H^+ ions of 3.16×10^{-3} mol/dm^3.

What is the concentration of H^+ ions in a solution of hydrochloric acid that has a pH of 3.5?

_____

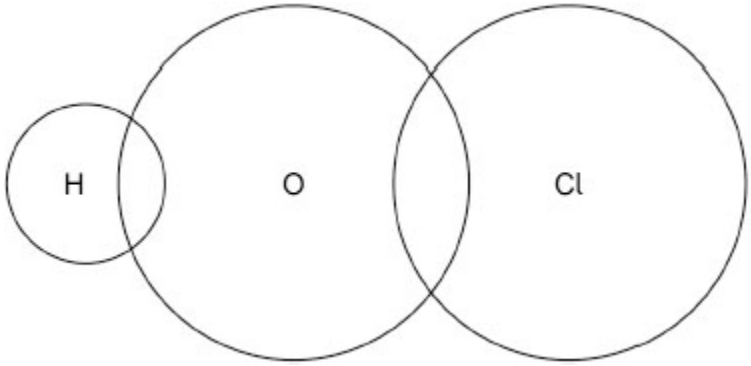
Concentration = _____ mol/dm^3

(1)

(c) **Figure 1** shows the outer shells in one molecule of hydrogen chlorate (HOCl).

Complete the dot and cross diagram to show the electrons in the outer shells.

Figure 1



(2)

(d) Hydrogen chlorate dissolves in water to form a weak acid.

Explain why a weak acid has a higher pH than a strong acid of the same concentration.

_____

_____

_____

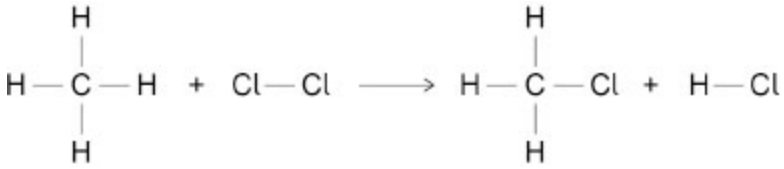
_____

(2)

(e) Hydrogen chloride is produced in the reaction between methane and chlorine.

Figure 2 represents the equation for the reaction.

Figure 2



The table below shows the bond energies.

Bond	C — H	Cl — Cl	C — Cl	H — Cl
Bond energy in kJ/mol	413	243	346	432

Calculate the overall energy change for the reaction.

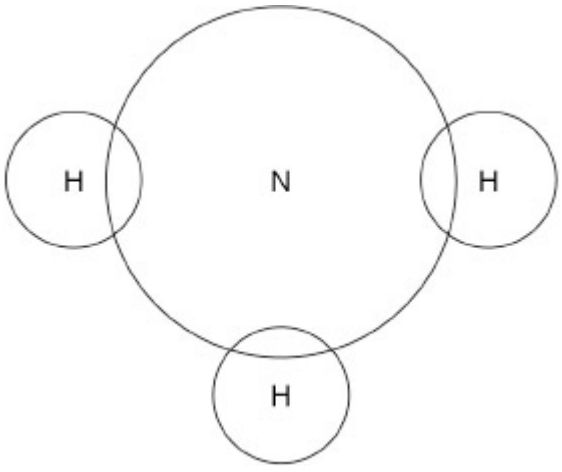
Overall energy change = _____ kJ/mol

(3)

(Total 9 marks)

3. Nitrogen reacts with hydrogen to produce ammonia (NH_3).

(a) Complete the dot and cross diagram for an ammonia molecule.



(2)

(b) The equation for the reaction between nitrogen and hydrogen to produce ammonia is:

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

Calculate the mass of hydrogen that is needed to produce 25 g of ammonia.

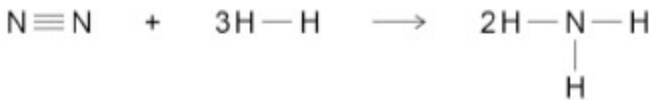
Relative atomic masses (A_r): H = 1 N = 14

Mass of hydrogen = _____ g

(4)

Figure 1 shows the displayed formulae equation for the reaction of nitrogen with hydrogen.

Figure 1



In the reaction the energy released forming new bonds is 93 kJ/mol greater than the energy needed to break existing bonds.

The table below shows bond energies.

Bond	N≡N	H — H	N — H
Bond energy in kJ/mol	945	**X**	391

(c) Calculate the bond energy **X** for the H — H bond.

Use **Figure 1** and the table above.

X = _____ kJ/mol

(5)

(d) Energy is released from the reaction to produce ammonia.

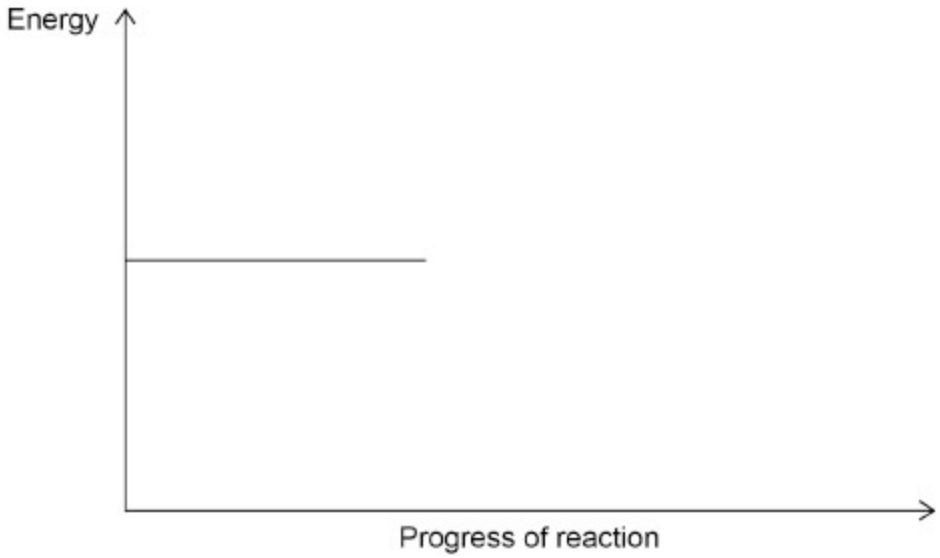
Figure 2 shows part of the reaction profile for the reaction between nitrogen and hydrogen to produce ammonia.

Complete **Figure 2**.

You should:

- complete the profile line
- label the energy level of the reactants and the product
- label the **overall** energy change.

Figure 2



(3)

(Total 14 marks)

4. A student investigated the temperature change when metal **X** was added to copper sulfate solution.

This is the method used.

1. Add 25 cm^3 of copper sulfate solution to a beaker.
2. Measure the temperature of the copper sulfate solution.
3. Add 1.0 g of metal **X** and stir.
4. Measure the highest temperature reached when metal **X** is added to copper sulfate solution.
5. Repeat steps 1 to 4 with different metals.

Figure 1 shows the apparatus used.

Figure 1

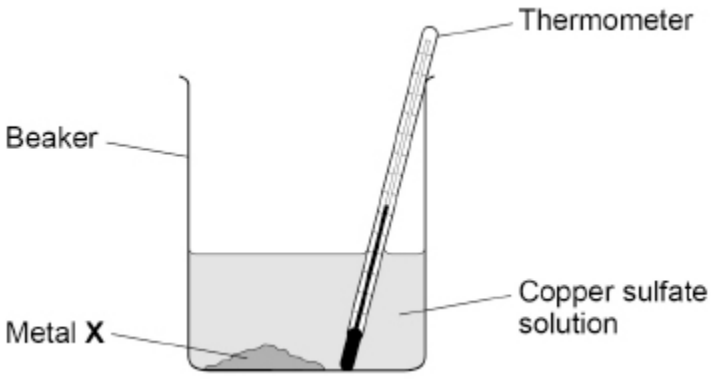
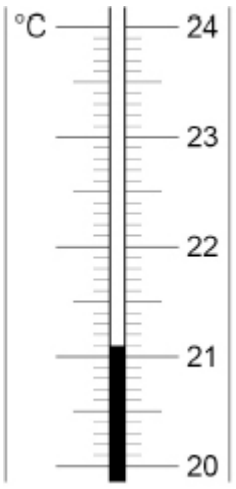


Figure 2 shows the thermometer reading of the copper sulfate solution at the start of the investigation.

Figure 2



(a) The highest temperature reached when metal **X** was added to copper sulfate solution was 35.5 °C

Determine the temperature change when metal **X** is added to copper sulfate solution.

Use **Figure 2**.

Highest temperature = 35.5 °C

Temperature at start = _____ °C

Temperature change = _____ °C

(2)

(b) Give **two** variables the student should keep the same in this investigation.

1. _____

_____

2. _____

_____

(2)

(c) The student repeated the experiment with metal **Y**.

Table 1 shows four results for metal **Y**.

Table 1

	Test 1	**Test 2**	**Test 3**	**Test 4**
Temperature change in °C	9.2	7.3	9.5	9.2

Calculate the mean temperature change for metal **Y**.

Do **not** include the anomalous result in your calculation.

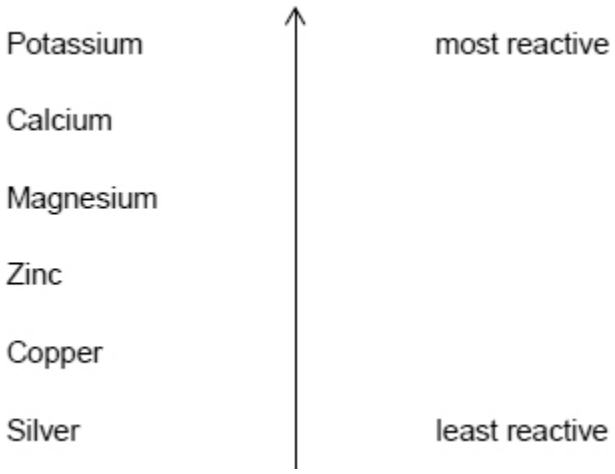
Mean temperature change = _____ °C

(2)

The more reactive the metal added to copper sulfate solution, the greater the temperature change.

Figure 3 shows a reactivity series.

Figure 3



(d) The student repeated the experiment.

The student added:

- magnesium to copper sulfate solution
- an unknown metal **A** to copper sulfate solution.

Table 2 shows the results.

Table 2

Metal	**Temperature change in °C**
Magnesium	12
Metal **A**	8

The student concludes metal **A** is zinc.

Give **one** reason why the student is correct.

Use **Figure 3** and **Table 2**.

_____

_____

(1)

(e) The student did the experiment with silver and copper sulfate solution.

What happens to the temperature of the mixture?

Use **Figure 3**.

Tick (✓) **one** box.

Decreases ☐

Increases ☐

Stays the same ☐

(1)

(f) Suggest **one** reason why the student should **not** add potassium metal to copper sulfate solution.

_____

_____

(1)

(g) 100 cm^3 of the copper sulfate solution contains 1.8 g of copper sulfate.

Calculate the mass of copper sulfate in 25 cm^3 of this copper sulfate solution.

_____

_____

_____

_____

Mass = _____ g

(2)

(Total 11 marks)

5. Methane, ethane, propane and butane all react with oxygen to produce carbon dioxide and water.

(a) Suggest why a mixture of methane and oxygen does **not** react at room temperature.

Answer in terms of particles.

_____

_____

_____

_____

(2)

(b) **Table 1** shows the energy released when methane, ethane and propane react with oxygen to produce carbon dioxide and water.

Table 1

	Compound reacted with oxygen		
	Methane	Ethane	Propane
Formula of compound	CH_4	C_2H_6	C_3H_8
Energy released in kJ/mol	680	1160	1640

Predict the energy released when butane (C_4H_{10}) reacts with oxygen to produce carbon dioxide and water.

_____

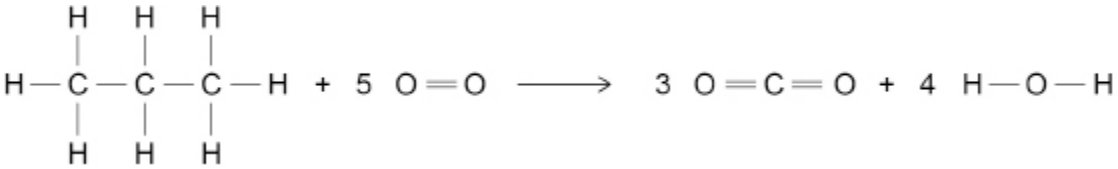
_____

Energy released = _____ kJ/mol

(1)

(c) Propane reacts with oxygen to produce carbon dioxide and water.

The displayed formula equation for the reaction is:



The reaction is exothermic.

In the reaction, the energy released when forming new bonds is 1640 kJ/mol greater than the energy needed when breaking bonds.

Table 2 shows bond energies.

Table 2

Bond	**H–C**	**C–C**	**O=O**	**C=O**	**O–H**
Bond energy in kJ/mol	410	**X**	500	740	460

Calculate the C—C bond energy (**X**).

X = _____ kJ/mol

(5)

(Total 8 marks)

6. This question is about energy change.

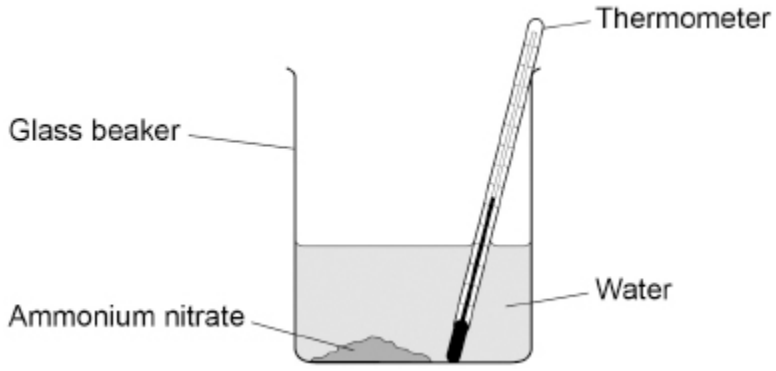
A student investigated the temperature change when 10 g of ammonium nitrate was added to 100 cm^3 of water.

This is the method used.

1. Measure the temperature of 100 cm^3 of water.
2. Add 10 g of ammonium nitrate.
3. Stir once.
4. Measure the temperature of the solution every minute for 7 minutes.

Figure 1 shows the apparatus.

Figure 1



(a) What is the dependent variable in this investigation?

_____

(1)

(b) Give **three** improvements to the investigation to make the results more accurate.

1 _____

_____

2 _____

_____

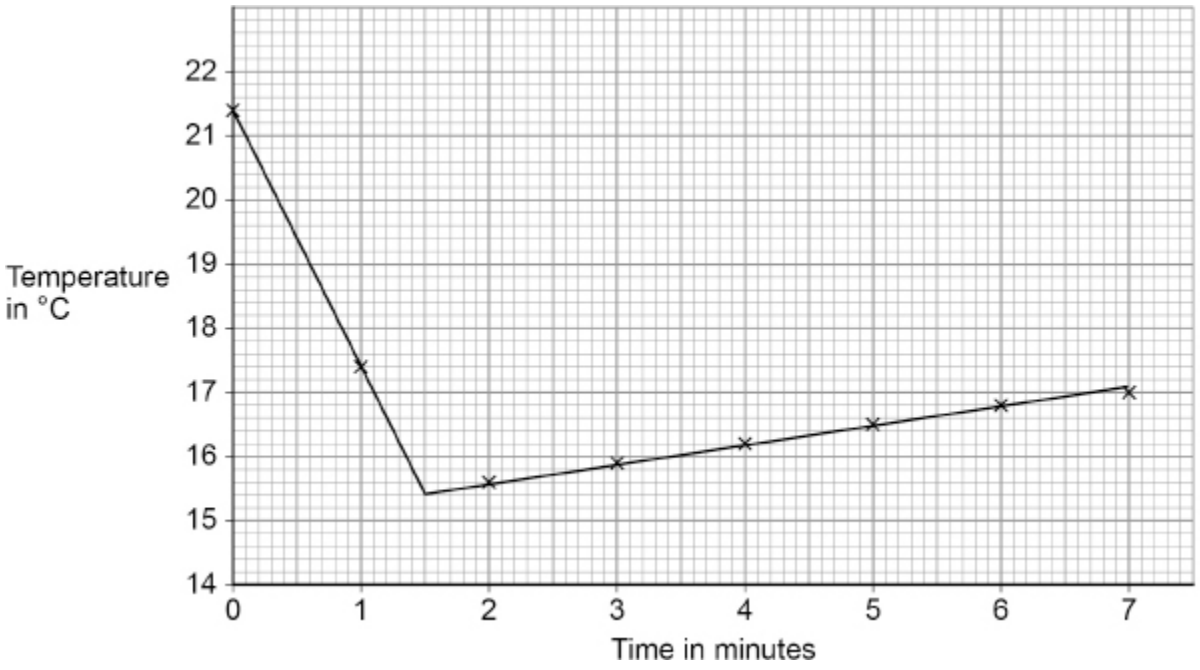
3 _____

_____

(3)

(c) **Figure 2** shows the results.

Figure 2



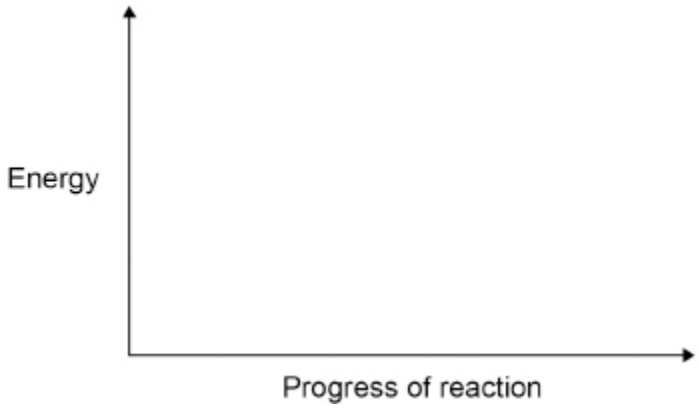
Explain the results.

(4)

(d) Draw a reaction profile for an exothermic reaction.

You should label:

- the energy level of the reactants and of the products
- the activation energy
- the overall energy change.



(4)

(Total 12 marks)

Mark schemes

1.

(a) independent

1

(b) zinc sulfate

allow $ZnSO_4$

1

(c) solution becomes colourless

ignore references to temperature / fizzing

allow solution changes colour

1

(brown / orange) solid produced

allow zinc changes colour

1

(d) (highest temperature =) 36 (°C)

1

(temperature increase = 36 - 21 =) 15 (°C)

allow correct use of an incorrectly determined value for highest temperature

ignore minus sign

1

(e) $(\mathbf{B} =) \frac{7.8 + 7.3 + 7.7}{3}$ **or** $\frac{22.8}{3}$

1

= 7.6 (°C)

OR

$(\mathbf{B} =) \frac{7.8 + 7.7}{2}$ **or** $\frac{15.5}{2}$ (1)

allow 7.8 (°C) if working shown for calculation of the mean using 7.8 and 7.7 (°C)

= 7.75 (°C) (1)

1

(f) (range =) 13.1 (°C to) 13.8 (°C)

allow (range =) 13.8 (°C to) 13.1 (°C)

1

(g) (result) 12.9 (°C)

MP2 is dependent on MP1 being awarded

allow (result / experiment) 2

1

any **one** from:

- (the result is) much lower than the other two results
- (used) less than 3 g zinc

  allow (used) incorrect mass of zinc
- (used) more than 50 cm^3 of copper sulfate (solution)

  allow (used) incorrect volume of copper sulfate (solution)
- the mixture was not stirred

1

[11]

2. (a) (hydrogen chloride) g / (g)
and
(water) l / (l)
and
(hydrochloric acid) aq / (aq)

1

(b) 3.16×10^{-4} (mol/dm^3)

1

(c) 1 pair of electrons in both overlaps

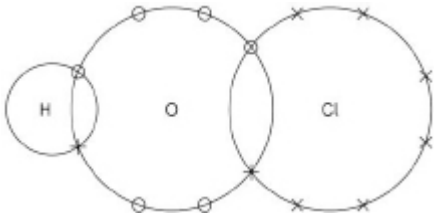
allow any combination of x, o, $e^{(-)}$, • for electrons

1

4 non-bonding electrons on oxygen atom **and** 6 non-bonding electrons on chlorine atom

*do **not** accept non-bonding electrons on hydrogen*

an answer of



*scores **2** marks*

1

(d) a weak acid partially ionises in an aqueous solution

1

(so) produces a lower concentration of hydrogen ions

1

(e) (bonds broken = (4 × 413) + 243 =) 1895

1

(bonds made =(3 × 413) + 346 + 432 =) 2017

1

(energy change = 1895 − 2017 =) (−) 122 (kJ/mol)

allow correct use of an incorrectly determined value for bonds broken and / or bonds made

alternative approach

(bonds broken = 413 + 243 =) 656 (1)

(bonds made = 346 + 432 =) 778 (1)

(energy change = 656 − 778 =) (−) 122 (kJ/mol) (1)

allow correct use of an incorrectly determined value for bonds broken and / or bonds made

1

[9]

3. (a) one shared pair of electrons in each overlap

allow any combination of circles, dots, crosses or $e^{(-)}$

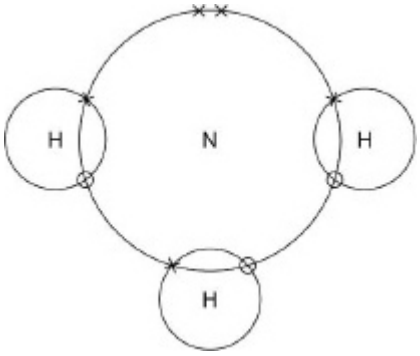
ignore any inner shell electrons on nitrogen

1

2 non-bonding electrons on the outer shell of nitrogen

*do **not** accept non-bonding electrons on hydrogen*

an answer of



*scores **2** marks*

1

(b) (M_r NH_3 = 14 + (3 × 1) =) 17

1

$$\left(\text{moles } NH_3 = \frac{25}{17}\right) = 1.47 \text{ (mols)}$$

allow correct use of incorrectly determined M_r of NH_3

1

(moles $H_2 = 1.47 \times \frac{3}{2}$) = 2.205 (mols)

allow correct use of an incorrectly calculated value of moles of NH_3

1

(mass H_2 = 2.205 × 2)
= 4.41 (g)

allow 4.4117647 (g) correctly rounded to at least 2 significant figures

allow correct use of an incorrectly calculated value of moles of H_2

alternative approach

(2 × M_r NH_3 = 17 × 2 =) 34 (1)

6 g H_2 → 34 g NH_3 (1)

allow correct use of an incorrectly calculated value of 2 × M_r NH_3

$\frac{6}{34}$ × 25 (g) H_2 → 25 g NH_3 (1)

4.41 (g H_2 → 25 g NH_3) (1)

1

(c) (bonds broken =)
945 + 3**X**

1

(bonds made = 6 × 391 =)
2346

1

(energy released = bonds made - bonds broken =)
93 = 2346 - [945 + 3**X**]

allow correct use of incorrectly determined value(s) of bonds broken and/or bonds formed

1

(3**X** =) 1308 (kJ/mol)

1

(**X** =) 436 (kJ/mol)

*allow correct use of an incorrectly determined value for 3**X***

1

(d) correct shape for exothermic reaction with the product line below the level of the reactants line

1

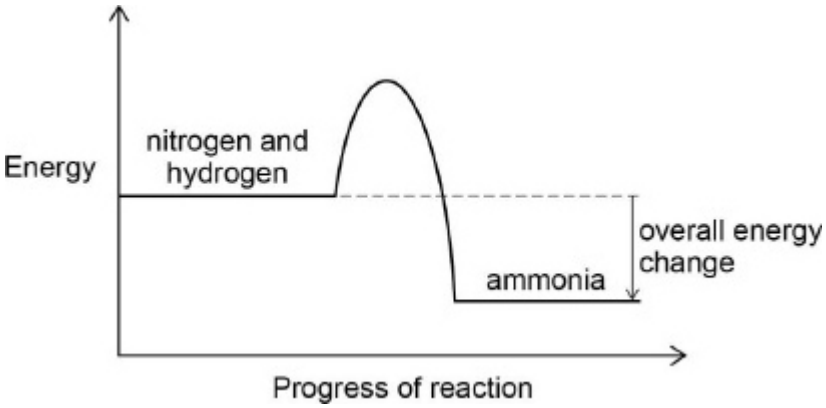
labelled horizontal lines for reactants and product

labelled horizontal lines for nitrogen and hydrogen and ammonia

1

labelled overall energy change

an answer of



scores **3** marks

1

[14]

4. (a) 21.1 (°C)

1

14.4 (°C)

allow correct use of an incorrect start temperature

1

(b) any **two** from:

- surface area of metal
- 25 cm^3 / volume of copper sulfate solution
- concentration of copper sulfate solution
- mass / 1 g of metal

ignore amount
ignore temperature
ignore stirring

2

(c)

$\frac{9.2 + 9.5 + 9.2}{3}$ or $\frac{27.9}{3}$

1

= 9.3 (°C)

*if no other mark awarded allow **1** mark for 8.8 (°C)*

1

(d) (metal **A** / zinc) is less reactive (than magnesium)
or
(metal **A** / zinc) is lower in reactivity series
or
change in temperature is lower (with metal **A** / zinc)

allow converse

1

(e) stays the same

1

(f) too dangerous
or
too reactive

allow potassium would react with water

1

(g)

$\frac{25}{100} \times 1.8$ **or** $\frac{1}{4} \times 1.8$

1

= 0.45 (g)

1

[11]

5. (a) particles collide

1

(but at room temperature) particles have insufficient energy
or
(but) have energy less than the activation energy (so collisions are not successful)

1

(b) 2120 (kJ/mol)

1

(c) (bonds broken =

(8 × 410) + 2 **X** + (5 × 500) = 5780 + 2 **X**

*allow C–C for **X***

allow (bonds broken = (8 × 410) + (5 × 500) = 5780

1

(bonds formed =
(6 × 740) + (8 × 460) = 8120

1

(bonds broken – bonds formed = energy released)
(5780 + 2 **X**) – 8120 = – 1640

allow correct use of incorrect values from step 1 and/or step 2

1

(2 **X** =) 700

allow correct use of incorrect value from step 3

1

(**X** =) 350 (kJ/mol)

1

[8]

6.

(a) temperature (of solution)

allow temperature change

1

(b) any **three** from:

- insulate the beaker
  or
  use polystyrene cup
- add a lid
- stir more (times)
- repeat the experiment **and** calculate the mean (ignoring anomalous results)
- use smaller volume (of water)
- use larger mass of ammonium nitrate
- more accurate balance
- use digital thermometer
  or
  use a more accurate thermometer

3

(c) (from 0 to 1.5 minutes the) temperature decreases

allow the temperature decreases (from 21.4 ºC to 15.4 ºC)

1

(because) ammonium nitrate dissolving is endothermic

1

(then) after 1.5 minutes the temperature increases

(then) after 15.4 ºC the temperature increases

1

(because) energy transfers to the solution from the surroundings

1

(d) labelled horizontal lines for reactants and products, with the product line below the level of the reactant line

1

reaction pathway

allow curve to start / finish anywhere along reactant / product lines

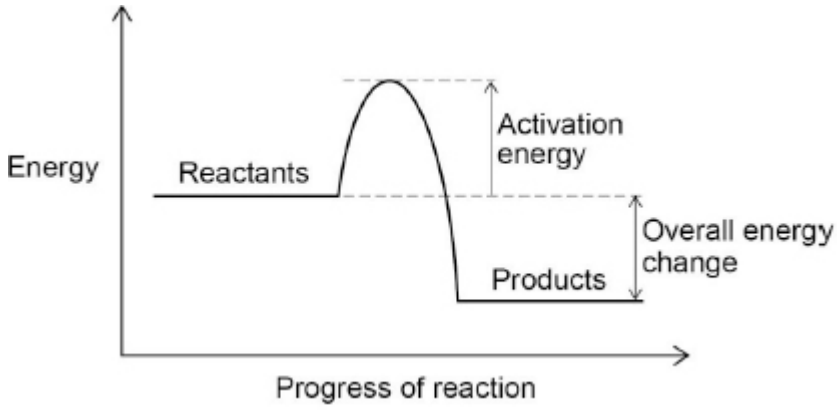
1

line from reactants to maximum labelled activation energy

1

line from reactants to products labelled overall energy change

the diagram below scores 4 marks



1

[12]