Q13.

A student carried out an experiment to find the temperature rise for a reaction between hydrochloric acid and sodium hydroxide solution.

- The student used a measuring cylinder to place 50 cm^3 of 0.400 mol dm^{-3} hydrochloric acid into a glass beaker.
- The student recorded the temperature at one-minute intervals for three minutes.
- At the fourth minute the student added 50 cm^3 of 0.400 mol dm^{-3} sodium hydroxide solution and stirred to mix the solutions, but did not record the temperature.
- The student recorded the temperature at one-minute intervals for a further eight minutes.

The results are shown in the table.

Time / min	0	1	2	3	4	5	6	7	8	9	10	11	12
Temperature / °C	19.8	19.8	19.8	19.8		21.4	21.7	21.6	21.5	21.4	21.3	21.2	21.1

(a) Plot a graph of temperature against time on the grid below.

Use your graph to find the temperature rise, ΔT, at the fourth minute.
Show your working on the graph by drawing suitable lines of best fit.

ΔT ____________________ °C

(5)

(b) The uncertainty in each of the temperature readings from the thermometer used in this experiment was ±0.1° C

Calculate the percentage uncertainty in the value for the temperature rise.

Percentage uncertainty ____________________

(1)

(c) Suggest a change to the experiment that would minimise heat loss.

____

____

(1)

(d) Suggest and explain another change to the experiment that would decrease the percentage uncertainty in the use of the same thermometer.

____

____

____

____

(2)

(e) A second student completed an experiment to determine the enthalpy of neutralisation for the reaction between ethanedioic acid solution (HOOCCOOH) and potassium hydroxide solution.

The student added 25 cm^3 of 0.80 mol dm^{-3} ethanedioic acid solution to 75 cm^3 of 0.60 mol dm^{-3} potassium hydroxide solution.
The temperature increased by 3.2 °C

Give an equation for the reaction between ethanedioic acid solution and potassium hydroxide solution.
Calculate the enthalpy change (ΔH) per mole of water formed in this reaction.
Assume that the specific heat capacity of the reaction mixture is 4.2 J K^{-1} g^{-1}
Assume that the density of the reaction mixture is 1.00 g cm^{-3}

Equation ____

ΔH ____________________ kJ mol^{-1}

(5)

(f) In a similar experiment to that in **part (e)**, the enthalpy of neutralisation for the reaction between sulfuric acid and potassium hydroxide solution was found to be –57.0 kJ mol^{-1} per mole of water formed.

Suggest an explanation for the difference between this value and your answer to **part (e)**.

(If you were unable to obtain an answer to **part (e)** you should assume a value of –28.5 kJ mol^{-1}. This is **not** the correct answer.)

____

____

____

____

____

____

(2)
(Total 16 marks)

Q14.

A student planned and carried out an experiment to determine the enthalpy of reaction when magnesium metal displaces zinc from aqueous zinc sulfate.

$$Mg(s) + Zn^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Zn(s)$$

The student used this method:

- A measuring cylinder was used to transfer 50 cm^3 of a 1.00 mol dm^{-3} aqueous solution of zinc sulfate into a glass beaker.
- A thermometer was placed in the beaker.
- 2.08 g of magnesium metal powder were added to the beaker.
- The mixture was stirred and the maximum temperature recorded.

The student recorded a starting temperature of 23.9 °C and a maximum temperature of 61.2 °C.

(a) Show by calculation which reactant was in excess.

Use the data to calculate the experimental value for enthalpy of reaction in kJ mol^{-1}(Assume that the specific heat capacity of the solution is 4.18 J $K^{-1}g^{-1}$and the density of the solution is 1.00 g cm^{-3}).

Reactant in excess ____________________

Enthalpy of reaction ____________________ kJ mol^{-1}

(6)

(b) Another student used the same method and obtained a value for the enthalpy of reaction of −142 kJ mol^{-1}

A data book value for the enthalpy of reaction is −310 kJ mol^{-1}

Suggest the most likely reason for the large difference between the student's experimental value and the data book value.

____

____

____

(1)

(c) Suggest how the students' method, and the analysis of the results, could be improved in order to determine a more accurate value for the enthalpy of reaction.

Justify your suggestions.

Do not refer to the precision of the measuring equipment. Do not change the amounts or the concentration of the chemicals.

(6)

(Total 13 marks)

Q15.

Anhydrous magnesium chloride, $MgCl_2$, can absorb water to form the hydrated salt $MgCl_2.4H_2O$

$$MgCl_2(s) + 4H_2O(l) \longrightarrow MgCl_2.4H_2O(s)$$

(a) Suggest **one** reason why the enthalpy change for this reaction cannot be determined directly by calorimetry.

(1)

(b) Some enthalpies of solution are shown in Table 1.

Table 1

Salt	**Enthalpy of solution / kJ mol^{-1}**
$MgCl_2(s)$	−155
$MgCl_2.4H_2O(s)$	−39

Calculate the enthalpy change for the absorption of water by $MgCl_2(s)$ to form $MgCl_2.4H_2O(s)$.

Enthalpy change ____________________ kJ mol^{-1}

(2)

(c) Describe how you would carry out an experiment to determine the enthalpy of solution of anhydrous magnesium chloride.

You should use about 0.8 g of anhydrous magnesium chloride.

Explain how your results could be used to calculate the enthalpy of solution.

(6)

(d) Anhydrous magnesium chloride can be formed by direct reaction between its elements.

$$Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)$$

The free-energy change, ΔG, for this reaction varies with temperature as shown in **Table 2**.

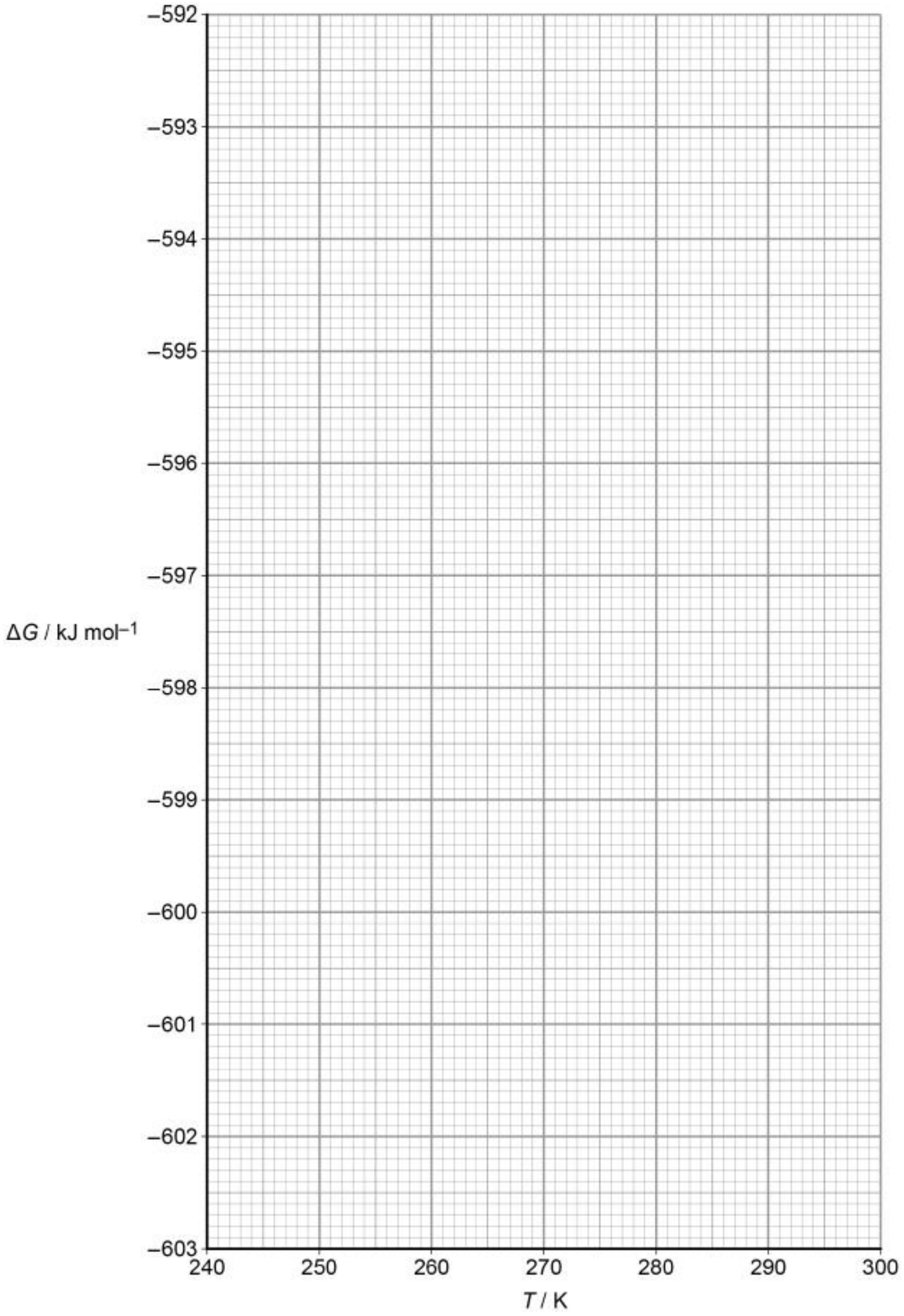
Table 2

T / K	ΔG / kJ mol^{-1}
298	−592.5
288	−594.2
273	−596.7
260	−598.8
240	−602.2

Use these data to plot a graph of free-energy change against temperature on the grid below.

Calculate the gradient of the line on your graph and hence calculate the entropy change, ΔS, in J K^{-1} mol^{-1}, for the formation of anhydrous magnesium chloride from its elements.

Show your working.



ΔS ____ J K^{-1} mol^{-1}

(5)

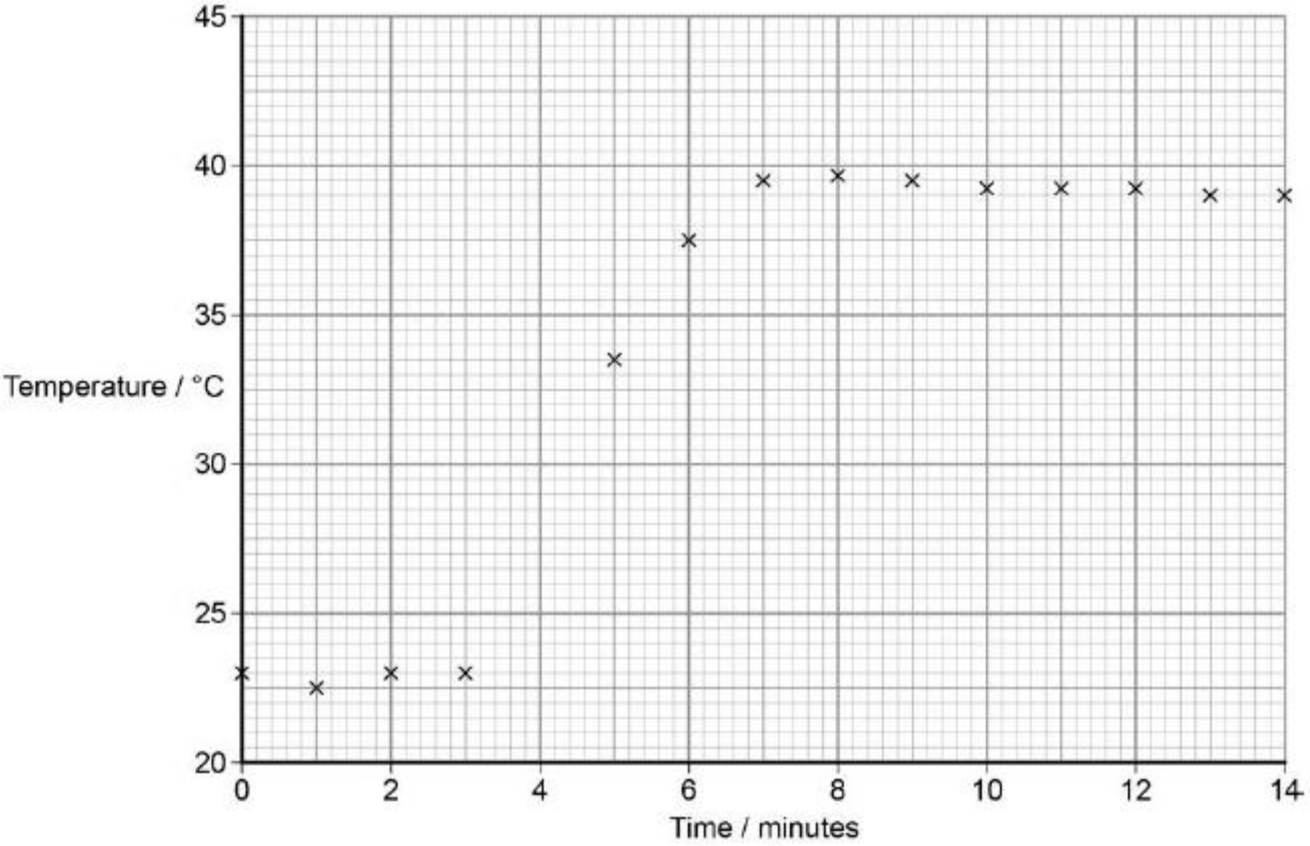
(Total 14 marks)

Q16.

A student carried out a reaction between magnesium ribbon and aqueous trichloroethanoic acid in order to determine the enthalpy change. The equation for the reaction is shown:

$$Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$$

The student measured the initial temperature of the trichloroethanoic acid and again every minute for 3 minutes before adding the magnesium ribbon at the fourth minute.
The student continued to measure the temperature every minute for a further 10 minutes.
The graph for these measurements is shown below.



The student used 240 mg of magnesium and 10.0 cm^3 of aqueous trichloroethanoic acid (an excess).

Use these data and information determined from the graph above to calculate the enthalpy change, in kJ mol^{-1}, for this reaction.
Show your working.
Give your answer to an appropriate precision.
(The specific heat capacity of water = 4.18 J K^{-1} g^{-1})

Enthalpy change = ___________ kJ mol^{-1}

(Total 7 marks)

Q17.

What is the temperature rise, in K, when 504 J of heat energy are absorbed by 0.110 kg of solid iron?
Specific heat capacity of iron = 0.448 J K^{-1} g^{-1}

A 9.78×10^{-2} ○

B 1.02×10^{1} ○

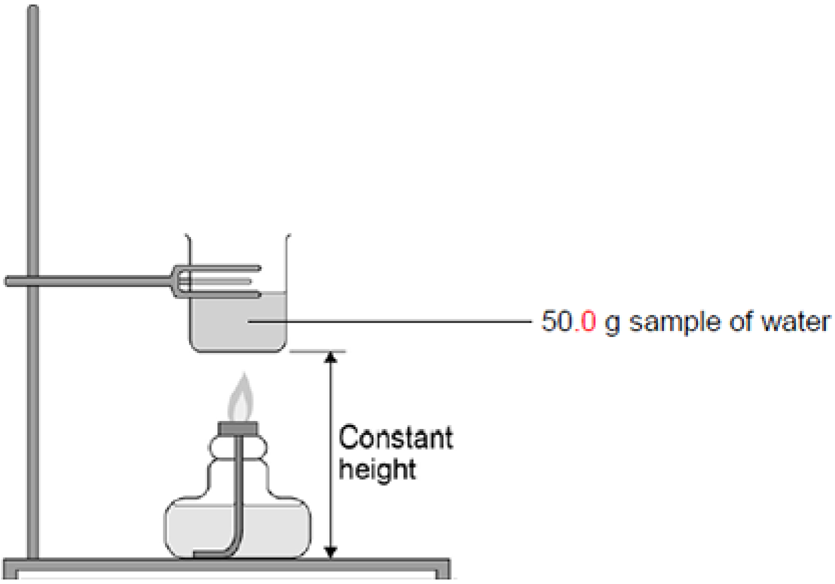
C 2.83×10^{2} ○

D 1.02×10^{4} ○

(Total 1 mark)

Q18.

The figure below shows apparatus used in an experiment to determine the enthalpy of combustion of leaf alcohol.



The alcohol is placed in a spirit burner and weighed. The burner is lit and the alcohol allowed to burn for a few minutes. The flame is extinguished and the burner is re-weighed. The temperature of the water is recorded before and after heating.

The following table shows the results obtained.

Initial mass of spirit burner and alcohol / g	56.38
Final mass of spirit burner and alcohol / g	55.84
Initial temperature of water / °C	20.7
Final temperature of water / °C	40.8

(a) Write an equation for the complete combustion of leaf alcohol ($CH_3CH_2CH{=}CHCH_2CH_2OH$).

____

(1)

(b) Use the results from the table above to calculate a value for the enthalpy of combustion of leaf alcohol. Give units in your answer.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Enthalpy of combustion = ____________ Units = ____________

(4)

(c) State how your answer to part (b) is likely to differ from the value quoted in reference sources.
Give **one** reason for your answer.

____

____

____

____

____

(2)

(d) A 50.0 g sample of water was used in this experiment.

Explain how you could measure out this mass of water without using a balance.

____

____

____

____

____

(2)

Mark Scheme

Q13.

(a) **M1** Temperature on the y-axis and uses sensible scales (i.e. minimum 20 little squares for each °C on y-axis)

Lose mark if temperature scale starts at 0°C

*This mark scores if all points fit on the grid. Do not penalise M1 if extrapolation to 4 mins goes off the grid – this is penalised in **M3**.*

1

M2 Plots all the points correctly (± half a small square)

Lose mark if the points go off the grid Ignore a plotted point at 4 mins used to work out ΔT

1

M3 Draws two best fit lines (0-3 mins) and (6-12 mins)

Both lines must be straight and through all points except 5th minute; lose mark if the lines are kinked/doubled. Any line through 5th minute loses mark

*"S-shaped curve" through points loses **M3** and **M4***

1

M4 Extrapolates both lines to at least the 4th minute

Lose mark if the extrapolation goes off the grid.

1

M5 21.9 – 19.8 = 2.1 (°C)

Allow calculation of ΔT from S-shaped curve as: Value at 4th minute – 19.8 but not if 0 (°C)

ΔT value ecf from incorrect lines/extrapolation

ΔT must be to at least 1dp

If value of ΔT = 2.1, then award M5

1

(b) 0.2 / 2.1 × 100 = 9.5 %

Conseq on (a)

Ignore no of sfs.

1

(c) Replace the glass beaker with a polystyrene cup / insulate the glass beaker / use a lid

Ignore use more dilute solutions

Ignore suggested materials for insulation

Do not allow copper calorimeter / bomb calorimeter

1

(d) Increase magnitude of temperature change

Ignore references to volume changes

1

by increasing the concentration of the acid/alkali

Mark independently

1

(e) **M1** HOOCCOOH + 2KOH → K_2(OOCCOO) + $2H_2O$

__M1__ – equation (allow ionic KOH / $_2C_2O_4$)

$H_2C_2O_4 + 2KOH \rightarrow K_2C_2O_4 + 2H_2O$

ignore state symbols

allow multiples

Mark independently

M2 q (= mc∆T) = 100 × 4.2 × 3.2 = 1344 J

__M2__ – process

(ignore sign here)

(allow calculations involving 4.18 which leads to 1338 J)

1

M3 n HOOCCOOH = 25 × 0.800 / 1000 = <u>0.020</u>
n KOH = 75 × 0.6 / 1000 = <u>0.045</u>

M3 – calculations of amounts, in moles, of both the ethanedioic acid and potassium hydroxide (both calculations needed)

1

M4 Moles of water = <u>0.040</u> moles

__M4__ – answer (stated or used in calculation of ∆H)

1

M5 ∆H = –1.344/0.04

= – 33.6 (kJ mol^{-1})

__M5__ – ecf on __M2__ and __M4__

Answer must be negative and to at least 2sf

∆H = – __M2__ (in kJ) / M4

–32.5 - –34 scores 4/4 (__M2-M5__ + equation)

+32.5 - +34 scores 3/4 (__M2__, __M3__, __M4__ + equation)

–65 - –68 scores 3/4 (+ equation)

+65 - +68 scores 2/4 (+ equation)

–52 - –54 scores 3/4 (+ equation)

+52 - +54 scores 2/4 (+ equation)

2

(f) HOOCCOOH is a weak acid / not fully dissociated

H_2SO_4 is a strong(er)acid / fully dissociated / dissociates more

1

(more) <u>energy</u> needed to break bonds/complete dissociation / dissociation is endothermic

So less energy is needed for dissociation of sulfuric acid

Ignore references to heat loss

1

[16]

Q14.

(a) M1 Amount $ZnSO_4 = 1.0 \times \frac{50}{1000}$ mol or Amount $ZnSO_4$ = 0.050 mol

Mark M1 and M2 independently

1

M2 Amount Mg = $\frac{2.08}{24.3}$ mol or Amount Mg = 0.0856 mol
(Hence Mg in excess)

1

M3 $Q = mc\Delta T$

M3 could be scored in M4

1

M4 $Q = 50.0 \times 4.18 \times 37.3$
or Q = 7795.7 J

If an error in M4, lose M4 and M5 and only award M6 for correct use of their incorrect M4 and division by their correct limiting reagent

1

M5 (Energy released per mole) $\frac{7.796}{0.05}$ kJ mol^{-1} or $\frac{7.796}{0.05}$ J mol^{-1}

M5 division by their limiting reagent

1

M6 $\Delta H = -156$ kJ mol^{-1}

1

(b) Heat loss (from the apparatus would mean the experimental value is smaller / lower / less exothermic than the data source)

1

(c) Marks awarded for this answer will be determined by the quality of the communication as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking.

Level 3 (5 – 6 marks)
Covers 3 Stages with matching justifications
Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:

- argument is well structured with minimum repetition or irrelevant points
- accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar

Level 2 (3 – 4 marks)
Covers 2 Stages with matching justification. OR covers 3 Stages with incomplete justification
Answer has some omissions but is generally supported by some of the relevant points below:

- the argument shows some attempt at structure
- the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar

Level 1 (1 – 2 marks)
Covers 1 Stage with matching justification. OR covers 2 Stages with incomplete justification
Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure. Unstructured answer. Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency

Level 0 (0 marks)

Insufficient correct chemistry

Indicative Chemistry Content

Stage 1 Improved insulation
1a Insulate the beaker or use a polystyrene cup or a lid
1b To reduce heat loss

Stage 2 Improved temperature recording
2a Record the temperature for a suitable time before adding the metal
2b To establish an accurate initial temperature
OR
2c Record temperature values at regular time intervals
2d To plot the temperature results against time on a graph

Stage 3 Improved analysis of results
3a Extrapolate the cooling back to the point of addition
3b To establish a (theoretical) maximum temperature OR temperature change (e.g. at the 4th minute) OR adjust for the cooling /apply a cooling correction
3a and 3b could be seen on an extrapolated sketch graph

(Note– IGNORE use of measuring equipment with greater precision)

6

[13]

Q15.

(a) Not possible to prevent some dissolving

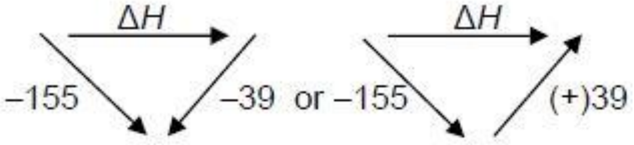
ALLOW It is soluble / dissolves / other hydrates may form / suggestions related to difficulty of measuring T (change) of a solid

1

(b) ($\Delta_{\text{hyd}}H$ =) –155 – (–39)

OR labelled cycle

Minimum needed for 'labelled cycle'



1

–116 (kJ mol^{-1})

1/2 for (+)116 or for –29 or for seeing –116 that has then be processed further

1

(c) This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question

Level 3 (5 – 6 marks)

All stages are covered and the explanation of each stage is correct and virtually complete. Stage 2 must include use of a graphical method for Level 3 (i.e. 'highest T reached' method is max Level 2)

Answer communicates the whole explanation, including reference to enthalpy, coherently and shows a logical progression through all three stages.Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:
For the answer to be coherent there must be some indication of **how** the graph is used to find ΔT

Level 2 (3 – 4 marks)

All stages are covered (NB 'covered' means min 2 from each of stage 1 and 3) but the explanation of each stage may be incomplete or may contain inaccuracies
OR two stages covered and the explanations are generally correct and virtually complete

Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete

Level 1 (1 – 2 marks)

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies
OR only one stage is covered but the explanation is generally correct and virtually complete

Answer shows some progression between two stages

Level 0 (0 marks)

Insufficient correct Chemistry to warrant a mark

Indicative Chemistry Content

Stage 1 Method

(1a) Measures water with named appropriate apparatus
(1b) Suitable volume/mass / volume/mass in range 10 – 200 cm^3/g
(1c) Into insulated container / polystyrene cup (NOT just 'lid')
(1d) Add known mass of $MgCl_2(s)$
(1e) Use of 'before and after' weighing method. NOT 'added with washings'

Stage 2 Measurements (could mark from diagram)

(2a) Record initial temperature (min 2 measurements)
(2b) Record T at regular timed intervals for 5+ mins / until trend seen
(2c) Plot T vs time

Stage 3 Use of Results (3a and 3b could come from diagram)

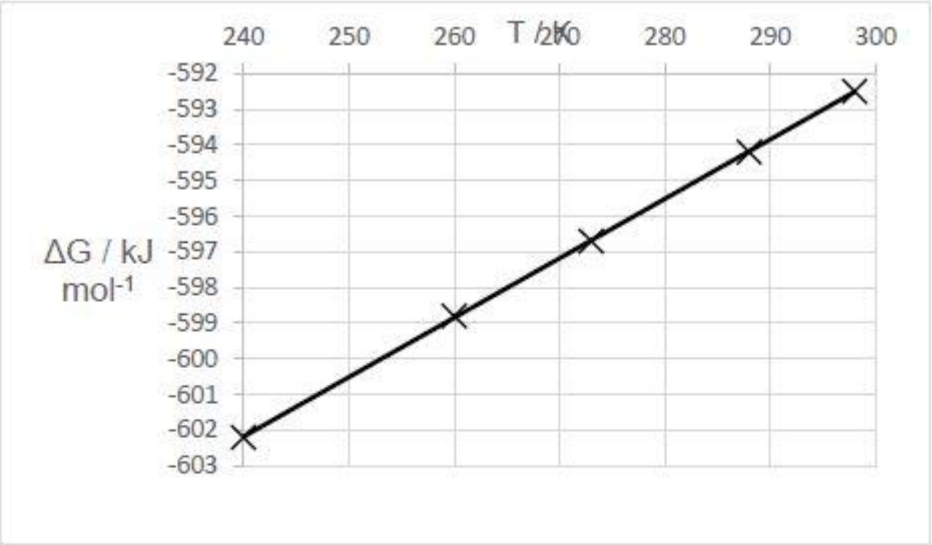
(3a) Extrapolate lines to when solid added (to find initial and final T)
(3b) $T_{\text{final}} - T_{\text{initial}} = \Delta T$ / idea of finding ΔT from graph at point of addition
(3c) q = mcΔT
(3d) amount = mass/Mr (0.80/95.3 = 8.39×10^{-3} mol)
(3e) $\Delta H_{\text{soln}} = -q/8.39 \times 10^{-3}$ or in words

This could all be described in words without showing actual calculations but describing stages

If method based on 'combustion' Max Level 1

6

(d)



M1 *= 5 points correctly plotted*

M2 *= line drawn correctly (NOT if curved, doubled or kinked)*

(Check line of best fit –

if through 250, -600.5 and 280, -595.5 +/- one small square then award ***M2****, if all crosses on line award* ***M1*** *as well)*

2

Gradient = $\Delta(\Delta G)/\Delta T$ = 0.167 (kJ K^{-1} mol^{-1})

1

($\Delta G = \Delta H - T\Delta S$ so gradient = $-\Delta S$)

ΔS = –167 (J K^{-1} mol^{-1})

M4 *= unit conversion i.e.* ***M3*** *× 1000; M5 = –sign (process marks)*

Correct answer with sign gets ***M3****,* ***M4*** *and M5*

ALLOW –163 to –171

1+1

[14]

Q16.

TWO correct extrapolations of best fit straight lines

__Max 5/7__ if no extrapolations or best fit straight lines drawn

1

Use of their lines to calculate the temperature change at the 4th minute

1

(17 °C)

Q = mcΔT

Q = 10 × 4.18 × [student's temperature change]

Q = [710.6 J]

Correct numbers inserted into expression.

1

Moles of Mg = 0.24 / 24.3 = 0.00988 mol

1

ΔH = 710.6 / 0.00988 = 71923.07 J mol^{-1}

1

ΔH = –72 (kJ mol^{-1})

Must be negative to score M6

1

Answer to 2 significant figures

1

[7]

Q17.

B

[1]

Q18.

(a) $C_6H_{11}OH + 8\frac{1}{2}O_2 \longrightarrow 6CO_2 + 6H_2O$

1

(b) Temperature rise = 20.1

$q = 50.0 \times 4.18 \times 20.1 = 4201$ (J)

1

Mass of alcohol burned = 0.54 g and M_r alcohol = 100.0

∴ mol of alcohol = $n = 0.54 / 100 = 0.0054$

1

Heat change per mole = $q / 1000n$ **OR** q / n

= 778 kJ mol^{-1} **OR** 778 000 J mol^{-1}

1

ΔH = –778 kJ mol^{-1} **OR** –778 000 J mol^{-1}

M4 is for answer with negative sign for exothermic reaction

Units are tied to the final answer and must match

1

(c) Less negative than the reference

1

Heat loss **OR** incomplete combustion **OR** evaporation of alcohol **OR** heat transferred to beaker not taken into account

1

(d) Water has a known density (of 1.0 g cm^{-3})

1

Therefore, a volume of 50.0 cm^3 could be measured out

1

[9]