

1 DCP/CE

Determining ΔH of a Redox Reaction:

Data Collection:

Quantitative Observations:

Mass of zinc powder: 4.31 ± 0.01 g

Volume of CuSO_4 (aq): 20.00 ± 0.3 ml

Time of
mixing

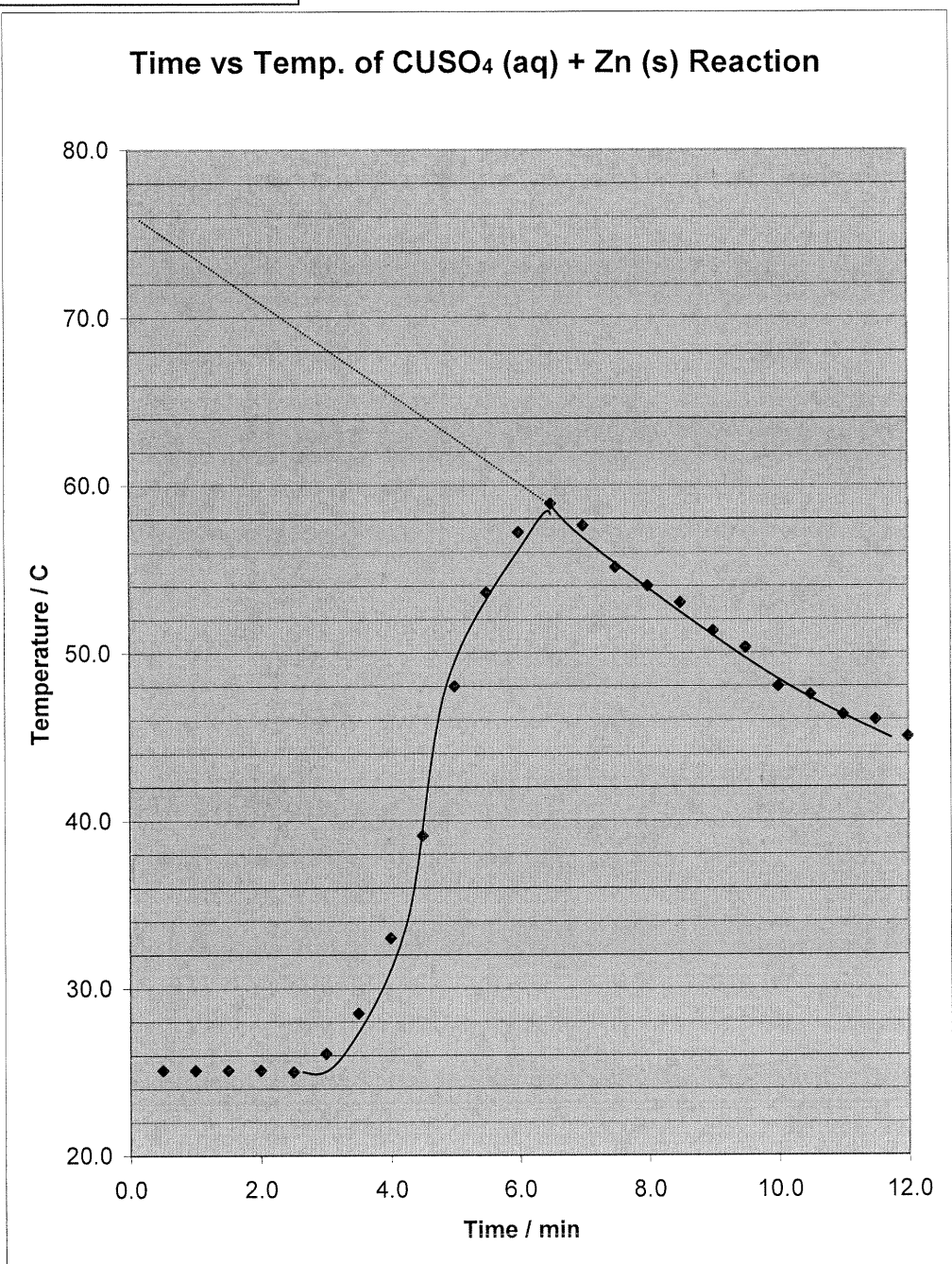
Time / m:s	Temperature / $\pm 0.2^\circ\text{C}$
0	25.1
:30	25.1
1:00	25.1
1:30	25.1
2:00	25.1
2:30	25.0
3:00	28.1
3:30	28.5
4:00	33.0
4:30	39.1
5:00	48.0
5:30	53.6
6:00	57.2
6:30	58.9
7:00	57.6
7:30	55.1
8:00	54.0
8:30	53.0
9:00	51.3
9:30	50.3
10:00	48.0
10:30	47.5
11:00	46.3
11:30	46.0
12:00	45.0

Qualitative Observations:

<u>Before:</u> CuSO_4 (aq): Blue clear solution Same consistency as water Zinc: Greyish, dull metal powder; not fine	<u>During:</u> Gradually solution became more clear. Dark flakes started to form on bottom of cup.	<u>After:</u> Dark, greyish black precipitate Large flakes, dull matter colour Suspended in a clear colourless solution
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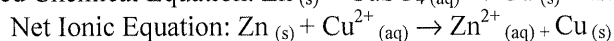
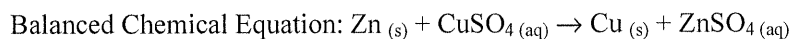
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DATA PRESENTATION:



Data Processing:

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i) Calculate ΔT :

From graph: Final T extrapolated to be $76.0 \pm 0.2^\circ\text{C}$

Initial T extrapolated to be $25.1 \pm 0.2^\circ\text{C}$

$$\Delta T = T_{\text{final}} - T_{\text{initial}}$$

$$= (76.0 \pm 0.2^\circ\text{C}) - (25.1 \pm 0.2^\circ\text{C})$$

$$= 50.9 \pm 0.4^\circ\text{C}; \% \text{ uncertainty} = \frac{0.4}{50.9} \times 100 = 0.79\%$$

$$= 50.9 \pm 0.79\%^\circ\text{C}$$

ii) Calculate Q:

Assuming: Density of solution = 1.00 g/ml; thus 20.0 ml solution will have a mass = 20.0g

Specific heat of solution = 4.184 J/g $^\circ\text{C}$

$$Q = mc\Delta T$$

$$= (20.0\text{g})(4.184\text{ J/g}^\circ\text{C})(50.9 \pm 0.79\%^\circ\text{C})$$

$$= 425(9) \pm 0.79\% \text{ J}$$

iii) Calculate $n_{\text{Cu}^{2+}}$:

$$n_{\text{Cu}^{2+}} = n_{\text{CuSO}_4} = cV$$

$$= (1.00\text{ mol/dm}^3)(0.0200\text{ dm}^3)$$

$$= 0.0200\text{ mol}$$

iv) Calculate ΔH per mole of Cu^{2+} (since CuSO_4 is limiting):

$$\Delta H = -\frac{Q}{n_{\text{Cu}^{2+}}(\text{aq})}$$

$$= -\frac{425(9) \pm 0.79\% \text{ J}}{0.0200\text{ mol}}$$

$$= -213000 \pm 0.79\%$$

$$= -213000 \pm 2000 \text{ J}$$

$$= -213 \pm 2 \text{ kJ}$$

DCP 3

Calculate %difference:

$$\begin{aligned}\% \text{ difference} &= \left| \frac{\text{accepted} - \text{experimental}}{\text{accepted}} \right| * 100\% \\ &= \left| \frac{-213 - (-217)}{-217} \right| * 100\% \\ &= 1.84\%\end{aligned}$$

Conclusion and Evaluation:

CE 1

The purpose of this investigation was achieved in that the value of ΔH for the reaction between $\text{CuSO}_{4(\text{aq})}$ and $\text{Zn}_{(\text{s})}$ was found to be -213 kJ/mol . To account for the error due to heat loss, the graph of temperature vs. time was drawn. The rate of cooling was extrapolated using a line of best fit, which was then extended back to the time of mixing to determine the true rise in temperature. The graph also included values for temperature of the solution for three minutes before the time of mixing to ensure that the CuSO_4 was at a constant temperature.

However, even though the percent uncertainty in the value obtained was only 0.79%, the percent difference when compared with the accepted value (-217 kJ/mol) was 1.84%.

Clearly, since percent difference is greater than percent uncertainty, random error alone cannot account for the discrepancy between the two values.

CE 2

There was a systematic error in assuming the density of the solution to be equal to 1.00 g/ml , such that 20.0 ml of solution had a mass of 20.0 g . Also, there was systematic error in assuming that the specific heat of the solution was $4.184 \text{ J/g}^\circ\text{C}$. Since both assumptions are rough approximations at best, these assumptions skewed the experimental value. In the future, the mass and the specific heat of $\text{CuSO}_{4(\text{aq})}$ should be measured directly to account for these two errors.

Also, despite extrapolating with the graph, there were heat losses that were not accounted for in the procedure. The heat produced by the reaction was absorbed not only by the 20.0 g of solution, but also by the solid metals on the bottom of the calorimeter (the excess zinc and the precipitated copper), and by the calorimeter (the paper cup). However, the latter two heat losses were not accounted for in calculating Q . Thus, Q was calculated to be lower than the true value because these two absorptions of heat were ignored. The error in Q was propagated when calculating ΔH , and caused it to become smaller than the accepted value.

CE 3

In the future, to account for this error, the mass and specific heats of the solid metals should be included, or calculated and accounted for. Less excess zinc could be added to minimize the amount of metals on the bottom of the cup absorbing heat. Also, a styrofoam cup would serve as a better calorimeter because its excellent insulating properties would ensure that very little heat would be absorbed by it. Also, the results should be duplicated in order to improve the quality of measurement to obtain more precise value.

Investigation 3: Student redox enthalpy

Criterion	D	DCP	CE
Achievement level awarded	5		6
Achievement of aspects		c, p, c	c, c, c

Assessment

Data collection and processing

Recording raw data

Complete

The student has recorded all raw data including qualitative observations and uncertainties of the key measured variables. Ideally, the student should have also cited the uncertainty of time measurements. However, this would only have a very small effect on the range of suitable best-fit lines on the graph. Also, since the uncertainties associated with the time measurements would not be subsequently propagated through calculations, this is a case where the principle of “complete not implying perfect” can be applied.

Processing raw data

Partial

The student has made a major error in processing. He extrapolated the temperature back (although the trend line does not appear to be completely appropriate which in itself could reduce the award to partial) but then based ΔT on the temperature at $t=0$ mins, whereas it should have been based on the temperature at $t=3$ mins, that is, when mixing occurred. Although this is a “major” error (as stated in the aspect descriptor) the subsequent calculations to calculate ΔH should be rewarded.

Presenting processed data

Complete

The student has clearly presented calculations and has propagated uncertainties. The final numerical answer is easily identified as such and given to an appropriate number of significant figures in relation to the precision of the input data. It could be argued that the extrapolated line was not best-fit but there is sufficient evidence throughout to make complete the most appropriate aspect award.

Conclusion and evaluation

Concluding

Complete

The conclusion is the final experimental value for ΔH and the justification for its veracity is the quantitative comparison with the literature value, that is, the percentage experimental error (it is important that the teacher’s instructions did not direct the student to do this), and the conclusion as to whether the

percentage error is explained by solely random error or whether systematic error is implied. For this type of investigation where a quantitative property is being experimentally determined this discussion of random and systematic error is required for complete to be awarded. The only concerns are that the student incorrectly switched the accepted and experimental values when calculating the percentage error and also did not cite the source of the literature value, which would have been the proper academic practice. However, there is more than sufficient evidence to award complete.

Evaluating procedure

Complete

The student has not simply listed the weaknesses but shows an appreciation of their importance. Challenging the initial assumptions regarding density and specific heat capacity is a good example of critical thinking and compensates for missing the more obvious heat losses to the external environment.

Improving the investigation

Complete

The improvements relate to the evaluation of the procedure and are realistic. A more precise suggestion as to how to calculate specific heat capacity of the copper sulfate solution would have been appropriate but overall there is sufficient evidence to say that the aspect has been fulfilled.