Question 1

$$Na_2S_2O_3(aq) + 4\ NaOCl(aq) + 2\ NaOH(aq) \rightarrow 2\ Na_2SO_4(aq) + 4\ NaCl(aq) + H_2O(l)$$

A student performs an experiment to determine the value of the enthalpy change, ΔH°_{rxn}, for the oxidation-reduction reaction represented by the balanced equation above.

(a) Determine the oxidation number of Cl in NaOCl.

+1	1 point is earned for the correct answer.

(b) Calculate the number of grams of $Na_2S_2O_3$ needed to prepare 100.00 mL of 0.500 *M* $Na_2S_2O_3(aq)$.

$100.00\text{ mL} \times \frac{0.500\text{ mol } Na_2S_2O_3}{1000\text{ mL}} \times \frac{158.10\text{ g } Na_2S_2O_3}{1\text{ mol } Na_2S_2O_3}$ $= 7.90\text{ g } Na_2S_2O_3$	1 point is earned for the correct number of moles of $Na_2S_2O_3$ (may be implicit). 1 point is earned for the correct calculation of mass of $Na_2S_2O_3$ consistent with the number of moles.

In the experiment, the student uses the solutions shown in the table below.

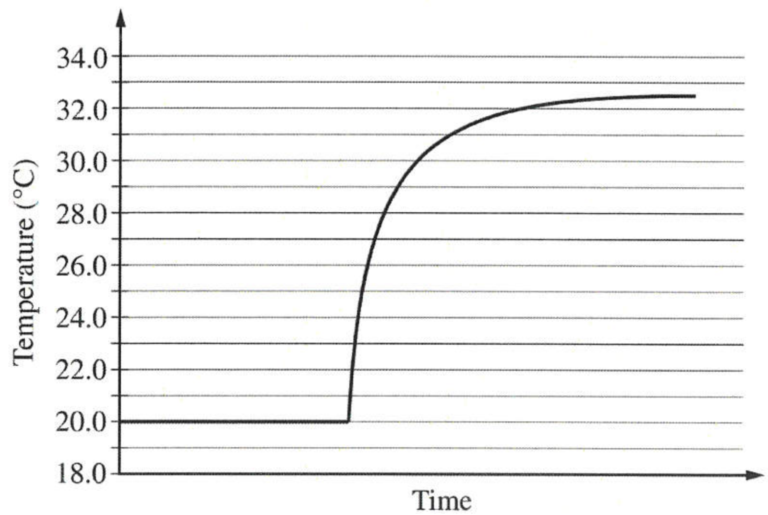
Solution	Concentration (*M*)	Volume (mL)
$Na_2S_2O_3(aq)$	0.500	5.00
NaOCl(*aq*)	0.500	5.00
NaOH(*aq*)	0.500	5.00

(c) Using the balanced equation for the oxidation-reduction reaction and the information in the table above, determine which reactant is the limiting reactant. Justify your answer.

NaOCl is the limiting reactant. Given that equal numbers of moles of each reactant were present initially, it follows from the coefficients of the reactants in the balanced equation that NaOCl will be depleted first.	1 point is earned for identifying the limiting reactant <u>and</u> providing a valid justification.

Question 1 (continued)

The solutions, all originally at 20.0°C, are combined in an insulated calorimeter. The temperature of the reaction mixture is monitored, as shown in the graph below.



(d) According to the graph, what is the temperature change of the reaction mixture?

From the graph the final temperature is 32.5°C. $\Delta T = T_f - T_i = 32.5°C - 20.0°C = 12.5°C$	1 point is earned for the correct value of ΔT.

(e) The mass of the reaction mixture inside the calorimeter is 15.21 g.

(i) Calculate the magnitude of the heat energy, in joules, that is released during the reaction. Assume that the specific heat of the reaction mixture is 3.94 J/(g·°C) and that the heat absorbed by the calorimeter is negligible.

$q = mc\Delta T$ $= (15.21\text{ g})(3.94\text{ J/(g·°C)})(12.5°C) = 749\text{ J}$	1 point is earned for the correct calculation of q consistent with the ΔT value from part (d).

(ii) Using the balanced equation for the oxidation-reduction reaction and your answer to part (c), calculate the value of the enthalpy change of the reaction, ΔH°_{rxn}, in kJ/mol$_{rxn}$. Include the appropriate algebraic sign with your answer.

Question 1 (continued)

$n_{NaOCl} = 5.00 \text{ mL} \times \frac{0.500 \text{ mol NaOCl}}{1000 \text{ mL NaOCl}} = 0.00250 \text{ mol NaOCl}$ $n_{rxn} = 0.00250 \text{ mol NaOCl} \times \frac{1 \text{ mol}_{rxn}}{4 \text{ mol NaOCl}} = 0.000625 \text{ mol}_{rxn}$ $\Delta H^\circ_{rxn} = \frac{-0.749 \text{ kJ}}{0.000625 \text{ mol}_{rxn}} = -1.20 \times 10^3 \text{ kJ/mol}_{rxn}$	1 point is earned for correctly calculating the value of mol_{rxn} consistent with the limiting reactant in part (c). 1 point is earned for a negative ΔH°_{rxn} obtained by dividing the calculated value of q by the calculated value of mol_{rxn}.

The student repeats the experiment, but this time doubling the volume of each of the reactants, as shown in the table below.

Solution	Concentration (M)	Volume (mL)
$Na_2S_2O_3(aq)$	0.500	10.0
$NaOCl(aq)$	0.500	10.0
$NaOH(aq)$	0.500	10.0

(f) The magnitude of the enthalpy change, ΔH°_{rxn}, in kJ/mol_{rxn}, calculated from the results of the second experiment is the same as the result calculated in part (e)(ii). Explain this result.

By doubling the volumes, the number of moles of the reactants are doubled, which doubles the amount of energy produced. Therefore the amount of heat per mole will remain the same. OR In the second experiment, $\Delta H^\circ_{rxn} = \frac{2mc\Delta T}{2n} = \frac{mc\Delta T}{n} = \Delta H^\circ_{rxn}$. Thus the magnitude is the same as calculated in the first experiment.	1 point is earned for a valid explanation.

(g) Write the balanced net ionic equation for the given reaction.

$S_2O_3^{2-}(aq) + 4\,OCl^-(aq) + 2\,OH^-(aq) \rightarrow 2\,SO_4^{2-}(aq) + 4\,Cl^-(aq) + H_2O(l)$	1 point is earned for the correct net ionic equation.