**Unit 4: AP Free Response Practice #1** [2018 #1, shortened, 7-ish points]

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

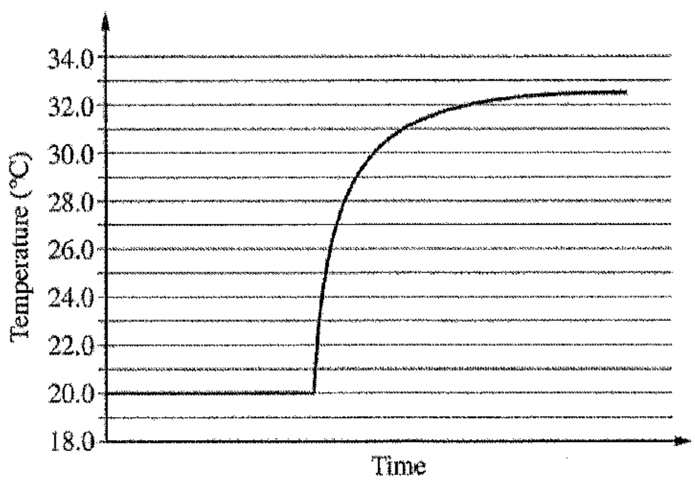
1. A student performs an experiment to determine the value of the ethalpy change, $\Delta H°_{rxn}$, for the oxidation-reduction reaction represented by the balanced equation above.

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 |

a. 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. [*1 point*]

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




b. According to the graph, what is the temperature change of the reaction mixture? [*1 point*]

c. 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 mixure is 3.94 J/(g °C) and that the heat absorbed by the calorimeter is negligible. [*1 point*]

ii. Using the balanced equation for the oxidation-reduction reaction and your answer to part (a), calculate the value of the enthalpy change of the reaction, $\Delta H°_{rxn}$, in $kJ/mol_{rxn}$. Include the appropriate algebraic sign with your answer. [*2 points*]

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 |

d. The magnitude of the enthalpy change of the reaction, $\Delta H^\circ_{rxn}$, in kJ/mol$_{rxn}$, calculated from the results of the second experiment is the same as the result calculated in part (c)(ii). Explain this result. [*1 point*]

e. Write the balanced net ionic equation for the given reaction. [*1 point*]

#1) (a) All sol'ns are equimolar (same # of moles), b/c each has the same volume + molarity. Since 4 mol of NaOCl are required for every 1 mol of $Na_2S_2O_3$ and every 2 mol of NaOH, NaOCl will be used up first, so it is limiting.

b.) 32.5°C − 20.0°C = 12.5°C

c.)(i) $q = mC\Delta T = (15.21\ g)(3.94\ J/g°C)(12.5°C) = 749\ J$

(ii) $0.500\ M \times 0.00500\ L = 0.00250\ mol\ NaOCl \times \frac{1\ mol_{rxn}}{4\ mol\ NaOCl} = 6.25 \times 10^{-4}\ mol_{rxn}$

b/c energy was released!

$\Delta H^\circ_{rxn} = \frac{-0.749\ kJ}{6.25E{-4}\ mol_{rxn}} = -1198.4 = -1.20 \times 10^3\ kJ/mol_{rxn}$

w/ 3 s.f. ☺

d.) Although twice the number of moles of limiting reactant reacted, twice as much heat would be released, so $\frac{2 \times kJ}{2 \times mol_{rxn}}$ = same $\frac{kJ}{mol_{rxn}}$

e.) $Na_2S_2O_{3(aq)} + 4NaOCl_{(aq)} + 2NaOH_{(aq)} \rightarrow 2Na_2SO_{4(aq)} + 4NaCl_{(aq)} + H_2O_{(l)}$

$Na^+$ is a spectator ion! ⇒ not part of net ionic

$$S_2O_3^{2-}{}_{(aq)} + 4OCl^-{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow 2SO_4^{2-}{}_{(aq)} + 4Cl^-{}_{(aq)} + H_2O_{(l)}$$