Past-paper walk-through

Heat Transfer and Thermal Equilibrium ▪ 6.3

eXercise

Questions in this set

- 2018 Q1

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 1

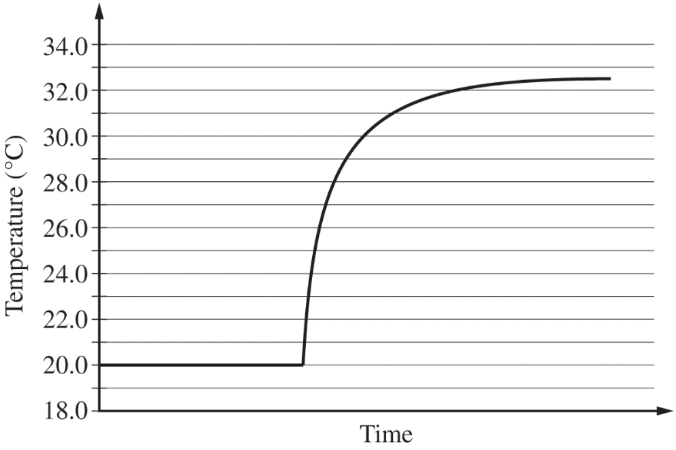
2018 ▪ Q1

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

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.

Question 1



Question 1

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

Question 1

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

Question 1

2018 ▪ Q1

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

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.

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

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

Question 1

2018 ▪ Q1

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

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.

(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.

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.

[Graph of Temperature (°C) vs. Time. Y-axis: Temperature (°C) from 18.0 to 34.0 in increments of 2.0. X-axis: Time (unlabeled scale). The curve starts flat at about 20.0°C, then rises steeply in an S-shaped curve, leveling off at approximately 32.5°C.]

Question 1

2018 ▪ Q1

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

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.

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

Question 1

2018 ▪ Q1

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

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.

(e)(i) The mass of the reaction mixture inside the calorimeter is 15.21 g. 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 $J/(g \cdot {}^\circ C)$ and that the heat absorbed by the calorimeter is negligible.

(e)(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

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

Question 1

2018 ▪ Q1

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

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.

(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.

Question 1

2018 ▪ Q1

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

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.

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

Solution 1

(a)

Mark scheme

- Oxidation number of Cl in NaOCl is $+1$. (Na is $+1$, O is -2, so Cl must be $+1$ for the compound to be neutral.) 1 point is earned for the correct answer of $+1$.

Solution 1

(b)

Mark scheme

- 100.00 mL x (0.500 mol Na2S2O3/1000 mL) x (158.10 g Na2S2O3/1 mol Na2S2O3) = 7.90 g Na2S2O3. 1 point for the correct number of moles of Na2S2O3 (0.0500 mol, may be implicit); 1 point for the correct mass consistent with that number of moles.

Solution 1

(c)

Mark scheme

- NaOCl is the limiting reactant. Given that equal numbers of moles of each reactant ($Na_2S_2O_3$, NaOCl, NaOH) were present initially (same concentration and volume), it follows from the coefficients of the balanced equation $Na_2S_2O_3 + 4\ NaOCl + 2\ NaOH \rightarrow 2\ Na_2SO_4 + 4\ NaCl + H_2O$ (which requires NaOCl in the largest relative amount) that NaOCl will be depleted first. 1 point is earned for identifying the limiting reactant AND providing a valid justification.

Solution 1

(d)

Mark scheme

- From the graph, the final temperature is 32.5 degrees C and the initial temperature is 20.0 degrees C. Delta T = Tf - Ti = 32.5 - 20.0 = 12.5 degrees C. 1 point is earned for the correct value of Delta T.

Solution 1

(e)(i)

Mark scheme

- q = mcDeltaT = (15.21 g)(3.94 J/(g times degree C))(12.5 degrees C) = 749 J. 1 point is earned for the correct calculation of q, consistent with the Delta T value from part (d).

Solution 1

(e)(ii)

Mark scheme

- n(NaOCl) = 5.00 mL x 0.500 mol NaOCl/1000 mL = 0.00250 mol NaOCl. n_rxn = 0.00250 mol NaOCl x (1 mol_rxn/4 mol NaOCl) = 0.000625 mol_rxn (using the limiting reactant from part c). DeltaH_rxn = -0.749 kJ / 0.000625 mol_rxn = -1.20x10^3 kJ/mol_rxn. 1 point is earned for correctly calculating mol_rxn consistent with the limiting reactant in part (c); 1 point is earned for a negative DeltaH_rxn obtained by dividing the calculated q by the calculated mol_rxn.

Solution 1

(f)

Mark scheme

- 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 (DeltaH_rxn) remains the same. Equivalently, DeltaH_rxn = (2mcDeltaT)/(2n) = mcDeltaT/n, so the magnitude is unchanged. 1 point is earned for a valid explanation.

Solution 1

(g)

Mark scheme

- Net ionic equation: S2O3^2-(aq) + 4 OCl^-(aq) + 2 OH^-(aq) -> 2 SO4^2-(aq) + 4 Cl^-(aq) + H2O(l). 1 point is earned for the correct net ionic equation (Na+ spectator ions removed, charge and atoms balanced).