Mole of Reaction

Massachusetts Insight
Workshop
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AP Chemistry Exam Equations for Thermochemistry

THERMODYNAMICS / ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\begin{aligned} \Delta G^\circ &= \Delta H^\circ - T\Delta S^\circ \\ &= -RT \ln K \\ &= -nFE^\circ \end{aligned}$$

$$I = \frac{q}{t}$$

$$E_{cell} = E_{cell}^\circ - \frac{RT}{nF} \ln Q$$

2018 AP Chemistry Exam Question 1 Slide 1

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

1. A student performs an experiment to determine the value of the enthalpy change, ΔH°_{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
$NaOCl(aq)$	0.500	5
$NaOH(aq)$	0.500	5

(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.

2018 AP Chemistry Exam Question 1 Slide 2

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

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$n_{Na_2S_2O_3} = n_{NaOCl} = n_{NaOH} = 0.0050\ L \cdot 0.500\ mol/Liter = 0.0025\ mol$

	$Na_2S_2O_3(aq)$ +	$4\ NaOCl(aq)$ +	$2\ NaOH(aq)$ →	$2\ Na_2SO_4(aq)$ +	$4\ NaCl(aq)$ +	$H_2O(l)$
Initial	0.0025 mol	0.0025 mol	0.0025 mol	0	0	0
Change						
Final						

2018 AP Chemistry Exam Question 1 Slide 3

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Initial	0.0025 mol	0.0025 mol	0.0025 mol	0	0	0
Change	-0.000625 mol	-0.0025 mol	-0.00125 mol	+0.00125	+0.0025 mol	+0.000625 mol
Final						

2018 AP Chemistry Exam Question 1 Slide 4

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

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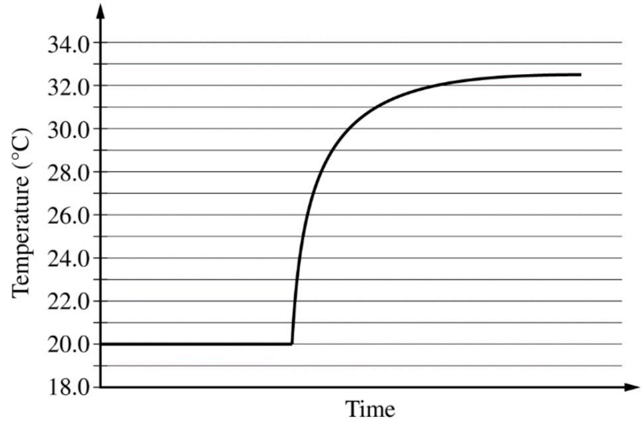
Initial	0.0025 mol	0.0025 mol	0.0025 mol	0	0	0
Change	-0.000625 mol	-0.0025 mol	-0.00125 mol	+0.00125	+0.0025 mol	+0.000625 mol
Final	0.00187 mol	0 mol	0.00125 mol	+0.00125	+0.0025 mol	+0.000625 mol

NaOCl is the limiting reagent

2018 AP Chemistry Exam Question 1 Slide 5

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

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?

2018 AP Chemistry Exam Question 1 Slide 6

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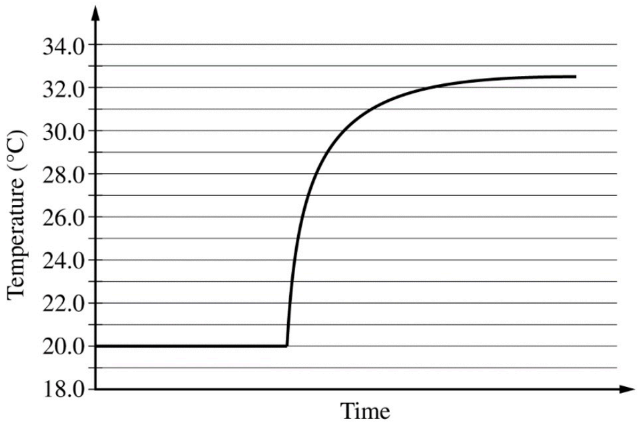

(d) According to the graph, what is the temperature change of the reaction mixture?

ΔT = 32.5 ˚C – 20.0 ˚C = 12.5 ˚C

2018 AP Chemistry Exam Question 1 Slide 7

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

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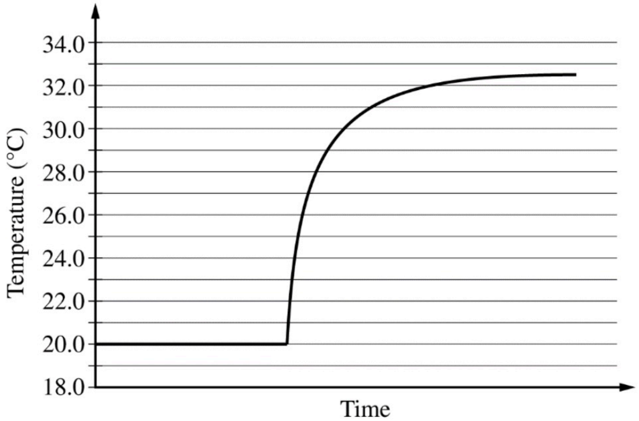


(d) According to the graph, what is the temperature change of the reaction mixture?

$\Delta T = 32.5\ ˚C - 20.0\ ˚C = 12.5\ ˚C$

(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.

$$q_{rxn} = -q_{solution} = -(mass \cdot c \cdot \Delta T)_{solution}$$
$$q_{rxn} = -(15.21\ g \cdot 3.94\ J/(g \cdot {}^\circ C) \cdot 12.5\ ˚C)_{solution}$$
$$q_{rxn} = -749\ J$$

2018 AP Chemistry Exam Question 1 Slide 8

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

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?

$$\Delta T = 32.5\ ^\circ C - 20.0\ ^\circ C = 12.5\ ^\circ C$$

(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.

$$q_{rxn} = -q_{solution} = -(mass \cdot c \cdot \Delta T)_{solution}$$

$$q_{rxn} = -(15.21\ g \cdot 3.94\ J/(g\cdot ^\circ C) \cdot 12.5\ ^\circ C)_{solution}$$

$$q_{rxn} = -749\ J$$

(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.

$$\Delta H_{rxn} = q_{rxn}/mol_{rxn} = -\ 749\ J/0.0025\ mol_{NaOCl}\ (4\ mol_{NaOCl}/1\ mol_{rxn})$$

$$\Delta H_{rxn} = -1.20 \times 10^6\ J/mol_{rxn} = -1.20 \times 10^3\ kJ/mol_{rxn}$$

2018 AP Chemistry Exam Question 1 Slide 9

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

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.

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

2018 AP Chemistry Exam Question 1 Slide 10

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

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.

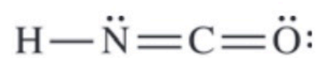
(g) Write the balanced net ionic equation for the given reaction.

$$S_2O_3^{2-}(aq) + 4\ OCl^-(aq) + 2\ OH^-(aq) \rightarrow 2\ SO_4^{2-}(aq) + 4\ Cl^-(aq) + H_2O(l)$$

2017 AP Chemistry Exam Question 2 Slide 1

$$HCNO(g) \rightleftarrows HNCO(g)$$

fulminic acid *isocyanic acid*

Fulminic Acid	Isocyanic Acid
	

(b) Using the Lewis electron-dot diagrams of fulminic acid and isocyanic acid shown in the boxes above and the table of average bond enthalpies below, determine the value of' ΔH° for the reaction of HCNO(g) to form HNCO(g).

Bond	Enthalpy (kJ/mol)	Bond	Enthalpy (kJ/mol)	Bond	Enthalpy (kJ/mol)
N–O	201	C=N	615	H–C	413
C=O	745	C≡N	891	H–N	391

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THERMODYNAMICS / ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -RT \ln K$$

$$= -nF E^\circ$$

$$I = \frac{q}{t}$$

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln Q$$

Mathematical Equations NOT on AP Chemistry Exam Equations Pages

$$\Delta H^{\circ}_{rxn} = \Sigma\,(\text{Bond Energy(reactants)}) - \Sigma\,(\text{Bond Energy(products)})$$

2017 AP Chemistry Exam Question 2 Slide 1

$$HCNO(g) \rightleftarrows HNCO(g)$$

fulminic acid *isocyanic acid*

Fulminic Acid	Isocyanic Acid
H—C≡N—Ö:	H—N̈=C=Ö:

(b) Using the Lewis electron-dot diagrams of fulminic acid and isocyanic acid shown in the boxes above and the table of average bond enthalpies below, determine the value of' ΔH° for the reaction of HCNO(g) to form HNCO(g).

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N–O	201	C=N	615	H–C	413
C=O	745	C≡N	891	H–N	391

ΔH°_{rxn} = Σ (Bond Energy(reactants)) - Σ (Bond Energy(products))

2017 AP Chemistry Exam Question 2 Slide 2

$$HCNO(g) \rightleftarrows HNCO(g)$$

fulminic acid *isocyanic acid*

Fulminic Acid	Isocyanic Acid
H—C≡N—Ö:	H—N̈=C=Ö:

(b) Using the Lewis electron-dot diagrams of fulminic acid and isocyanic acid shown in the boxes above and the table of average bond enthalpies below, determine the value of' ΔH° for the reaction of HCNO(g) to form HNCO(g).

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N–O	201	C=N	615	H–C	413
C=O	745	C≡N	891	H–N	391

$$\Delta H^\circ_{rxn} = \Sigma\text{ (Bond Energy(reactants))} - \Sigma\text{ (Bond Energy(products))}$$

$$\Delta H^\circ_{rxn} = BE(H\text{-}C) + BE(C\equiv N) + BE(N\text{-}O) - (BE(H\text{-}N) + BE(N{=}C) + BE(C{=}O))$$

$$\Delta H^\circ_{rxn} = 413\text{ kJ/mol} + 891\text{ kJ/mol} + 201\text{ kJ/mol} - (391\text{ kJ/mol} + 615\text{ kJ/mol} + 745\text{ kJ/mol})$$

$$\Delta H^\circ_{rxn} = -246\text{ kJ/mol}_{rxn}$$