

# UNITS 1 & 2 FREE RESPONSE REVIEW

## General Chemistry

### 1. [5 POINTS]

A sample of an unknown hydrocarbon was burned in air.

- (a) When the hydrocarbon sample was burned in a reaction that went to completion, 2.2 grams of water and 3.6 liters of carbon dioxide were produced under standard conditions. What is the empirical formula of the hydrocarbon? [2 POINTS]

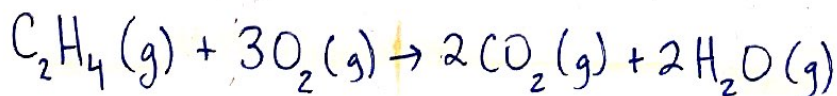
$$\begin{aligned} 3.6 \text{ L CO}_2 &\times \frac{1 \text{ mol CO}_2}{22.4 \text{ L CO}_2} \times \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} = 0.12 \text{ mol C} \\ 2.2 \text{ g H}_2\text{O} &\times \frac{1 \text{ mol H}_2\text{O}}{18.016 \text{ g H}_2\text{O}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = 0.24 \text{ mol H} \end{aligned}$$

}  $\div 0.12$  }  $\begin{matrix} = 1 \\ = 2 \end{matrix}$  }  $\boxed{\text{CH}_2}$

- (b) If the molar mass of the compound was determined to be ~~54.0~~<sup>28.1</sup> g/mol, what is the molecular formula of the hydrocarbon? [2 POINTS]

$$\frac{28.1 \text{ g/mol}}{14.026 \text{ g/mol}} \approx 2 \quad \left( \begin{array}{l} \text{molecular mass is} \\ \text{twice as big} \\ \text{as empirical} \end{array} \right) \Rightarrow 2 \times \text{CH}_2 = \boxed{\text{C}_2\text{H}_4}$$

- (c) Write the balanced equation for the combustion reaction that took place in (a). [1 POINT]





### UNIT 3 FREE RESPONSE REVIEW

#### Electrochemistry

- (d) Predict: will the cell potential,  $E_{\text{cell}}$ , at  $25^{\circ}\text{C}$  for the cell shown above be higher, lower, or equal to the standard cell potential  $E^{\circ}_{\text{cell}}$ , if the initial concentration of  $\text{Ni}(\text{NO}_3)_2$  is  $0.100\text{ M}$  and the initial concentration of  $\text{AgNO}_3$  is  $1.20\text{ M}$ . [2 POINTS]

Decreasing  $[\text{Ni}^{2+}]$ , a product, and increasing  $[\text{Ag}^+]$ , a reactant, will both cause  $Q$  to be lower than under std. conditions. Since the rxn is further from equilibrium,  $E_{\text{cell}}$  will be higher than  $E^{\circ}_{\text{cell}}$ .

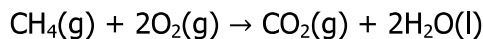
- (e) Is the reaction in the cell thermodynamically favorable under conditions described in part (d)? Justify your answer. [1 POINT]

Yes, b/c the  $E^{\circ}_{\text{cell}}$  is positive, so  $E_{\text{cell}}$  will have an even higher (more positive) voltage, which indicates a thermodynamically favorable rxn.

# UNIT 4 FREE RESPONSE REVIEW

## Thermochemistry and Thermodynamics

### 3. [8 POINTS]



The above reaction for the combustion of methane gas has a standard entropy change,  $\Delta S^\circ$ , with a value of  $-242.7\text{J/mol}\cdot\text{K}$ . The following data are also available.

Compound	$\Delta H_f^\circ$ (kJ/mol)
$\text{CH}_4(\text{g})$	-74.8
$\text{H}_2\text{O}(\text{l})$	-285.9
$\text{CO}_2(\text{g})$	-393.5

- (a) What are the values of  $\Delta H_f^\circ$  and  $\Delta G_f^\circ$  for  $\text{O}_2(\text{g})$ ? [1 POINT]

$\Delta H_f^\circ$  and  $\Delta G_f^\circ$  for  $\text{O}_2(\text{g})$  are both equal to zero. The enthalpy and free energy change of formation of any element in its standard state is zero.

- (b) Calculate the standard change in enthalpy,  $\Delta H^\circ$ , for the combustion of methane. [2 POINTS]

$$\begin{aligned} \Delta H^\circ &= \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants} \\ &= [(-393.5) + (2(-285.9))] - [(-74.8) + (2(0))] \\ &= [-965.3\text{kJ}] - [-74.8\text{kJ}] \end{aligned}$$

$$\Delta H^\circ = -890.5\text{kJ}$$

- (c) Calculate the standard free energy change,  $\Delta G^\circ$ , for the combustion of methane. [2 POINTS]

$$\begin{aligned} \Delta G^\circ &= \Delta H^\circ - T\Delta S^\circ \\ &= (-890,500\text{J}) - (298\text{K})(-242.7\text{J/K}) \end{aligned}$$

\* When NO temperature is given ASSUME 298K (25°C).

$$\Delta G^\circ = -818,200\text{J} = -818.2\text{kJ}$$

- (d) How would the value of  $\Delta S^\circ$  for the reaction be affected if the water produced in the combustion remained in the gas phase? [1 POINT]

$\Delta S^\circ$  would become less negative/more positive.  $\text{H}_2\text{O}(\text{g})$  has more entropy than  $\text{H}_2\text{O}(\text{l})$ . Gas phase is more disordered than liquid phase.

- (e) A 20.0g sample of  $\text{CH}_4(\text{g})$  underwent combustion in a bomb calorimeter with excess oxygen gas.

- (i) Calculate the mass of carbon dioxide produced. [1 POINT]

$$20.0\text{g CH}_4 \times \frac{1\text{ mol CH}_4}{16\text{g CH}_4} \times \frac{1\text{ mol CO}_2}{1\text{ mol CH}_4} \times \frac{44.0\text{g CO}_2}{1\text{ mol CO}_2} = 55.0\text{g CO}_2$$

- (ii) Calculate the heat released by the reaction. [1 POINT]

$$20.0\text{g CH}_4 \times \frac{1\text{ mol CH}_4}{16\text{g CH}_4} \times \frac{890.5\text{kJ}}{1\text{ mol CH}_4} = 1,110\text{kJ of heat released}$$

# UNIT 5 FREE RESPONSE REVIEW

## Kinetics

### 4. [8 POINTS]



The following results were obtained in experiments designed to study the rate of the reaction above:

Experiment	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial rate of disappearance of A (M/sec)
1	0.05	0.05	$3.0 \times 10^{-3}$
2	0.05	0.10	$6.0 \times 10^{-3}$
3	0.10	0.10	$1.2 \times 10^{-2}$
4	0.20	0.10	$2.4 \times 10^{-2}$

(a) Determine the order of the reaction with respect to A. Justify your response. [1 POINT]

Exp 3+4, when [A] is doubled and [B] is held constant the rate also doubles. Therefore, this reaction is first-order with respect to A.

(b) Determine the order of the reaction with respect to B. Justify your response. [1 POINT]

Exp 1+2, when [B] is doubled and [A] is held constant the rate also doubles. Therefore, this reaction is first-order with respect to B.

(c) Write the rate law for the reaction. [1 POINT]

$$\text{Rate} = k[A][B]$$

(d) Calculate the value of the rate constant, k, for the reaction. Include the units. [2 POINTS]

$$\text{Rate} = k[A][B]$$

$$k = \frac{\text{Rate}}{[A][B]}$$

$$= \frac{(1.20 \times 10^{-2} \text{ M/sec})}{(0.10 \text{ M})(0.10 \text{ M})} = \boxed{1.2 \text{ M}^{-1} \text{ sec}^{-1}}$$

\* You could use ANY experiment.

(e) If another experiment is attempted with [A] and [B], both 0.02-molar, what would be the initial rate of disappearance of A? [1 POINT]

$$\text{Rate} = k[A][B]$$

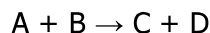
$$= (1.2 \text{ M}^{-1} \text{ sec}^{-1})(0.02 \text{ M})(0.02 \text{ M})$$

$$= \boxed{4.8 \times 10^{-4} \text{ M/sec}}$$

# UNIT 5 FREE RESPONSE REVIEW

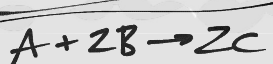
## Kinetics

- (f) The following reaction mechanism was proposed for the reaction above:



- (i) Show the mechanism is consistent with the balanced reaction. [1 POINT]

Add the reactions together



original reaction

- (ii) Show which step is the rate-determining step, and explain your choice. [1 POINT]

The first step of the mechanism is the slow, rate-determining step b/c its rate law is the same as the experimentally determined rate law.  
 $\text{Rate} = k[A][B]$

- (iii) In the mechanism, would D be classified as a catalyst or an intermediate? Justify your response. [1 POINT]

D is an intermediate b/c it is produced in an early step and consumed in a later step.

# UNIT 6 FREE RESPONSE REVIEW

## Equilibrium

### 5. [7 POINTS]

At 25°C, the solubility product constant,  $K_{sp}$ , for nickel hydroxide,  $\text{Ni}(\text{OH})_2$ , is  $1.6 \times 10^{-14}$ .

- (a) Write a balanced equation for the solubility equilibrium for  $\text{Ni}(\text{OH})_2$ . [1 POINT]



- (b) What is the molar solubility of  $\text{Ni}(\text{OH})_2$  in pure water at 25°C? [2 POINTS]

$$K_{sp} = [\text{Ni}^{2+}][\text{OH}^-]^2$$

$$1.6 \times 10^{-14} = (x)(2x)^2$$

$$1.6 \times 10^{-14} = 4x^3$$

\* One  $\text{Ni}^{2+}$  is produced for every  $\text{Ni}(\text{OH})_2$  so the molar solubility of  $\text{Ni}(\text{OH})_2$  will be the same as the concentration of  $\text{Ni}^{2+}$ .

$$x = 1.6 \times 10^{-5} \text{ M} \rightarrow \text{Molar solubility of } \text{Ni}(\text{OH})_2. \text{ Same as } [\text{Ni}^{2+}] \text{ b/c ratio is 1:1.}$$

- (c) Predict whether a precipitate will form when 200.0 milliliters of a  $5.0 \times 10^{-5} \text{ M}$  KOH solution is mixed with 300.0 milliliters of a  $2.0 \times 10^{-4} \text{ M}$   $\text{Ni}(\text{NO}_3)_2$  solution at 25°C. Show calculations to support your prediction. [2 POINTS]

STEP #1

$$\text{Moles of OH}^- \Rightarrow M = \frac{\text{mol}}{L} \Rightarrow 5.0 \times 10^{-5} \text{ M} = \frac{x}{0.200 \text{ L}} \Rightarrow 1.0 \times 10^{-5} \text{ mol OH}^-$$

$$\text{Moles of Ni}^{2+} \Rightarrow M = \frac{\text{mol}}{L} \Rightarrow 2.0 \times 10^{-4} \text{ M} = \frac{x}{(0.300 \text{ L})} \Rightarrow 6.0 \times 10^{-5} \text{ mol (Ni}^{2+})$$

STEP #2

\*Add the volumes\*

$$(0.200 \text{ L} + 0.300 \text{ L}) = 0.500 \text{ L}$$

$$[\text{Ni}^{2+}] = \frac{6.0 \times 10^{-5} \text{ mol}}{(0.500 \text{ L})} = 1.2 \times 10^{-4} \text{ M}$$

STEP #3

$$[\text{OH}^-] = \frac{1.0 \times 10^{-5} \text{ mol}}{(0.500 \text{ L})} = 2.0 \times 10^{-5} \text{ M}$$

STEP #4

$$Q = [\text{Ni}^{2+}][\text{OH}^-]^2$$

$$Q = (1.2 \times 10^{-4} \text{ M})(2.0 \times 10^{-5})^2 = 4.8 \times 10^{-14}$$

$$K < Q, \text{ so precipitate will form.}$$

- (d) At 25°C, 100mL of a saturated  $\text{Ni}(\text{OH})_2$  solution was prepared.

- (i) Calculate the mass of  $\text{Ni}(\text{OH})_2$  present in the solution. [1 POINT]

$$\frac{1.6 \times 10^{-5} \text{ mol}}{L} \times \frac{92.69 \text{ g}}{1 \text{ mol}} = \frac{0.0015 \text{ g}}{L} \Rightarrow (0.0015 \text{ g/L})(0.100 \text{ L}) = 0.00015 \text{ g}$$

- (ii) If the solution is allowed to evaporate to a final volume of 50mL, what will the  $[\text{OH}^-]$  be at this volume? [1 POINT]

B/c the solution is saturated, evaporation will NOT change the concentrations.