The problems in this review are designed to help prepare you for your upcoming exam. Questions pertain to material covered in the course and are intended to reflect the topics likely to appear in the exam. Keep in mind that this worksheet was created by CARE tutors, and while it is thorough, it is not comprehensive. In addition to exam review sessions, CARE also hosts regularly scheduled tutoring hours.

**Equilibrium Reactions**

1. For reversible reactions, equilibrium is where the net flow is 0 – products are formed at the same rate as reactants

2. Remember Le Chatelier’s Principle: a reaction will try to restore equilibrium. If you add products to a reaction at equilibrium, it will shift towards the reactants

Consider the following exothermic reaction in a closed container

$$\text{PCl}_3 (g) + \text{Cl}_2 (g) \leftrightarrow \text{PCl}_5 (g)$$

Which of the following statements is false?

a) Addition of PCl$_3$ to the container will shift the equilibrium toward formation of more PCl$_5$

b) An increase in temperature will shift the equilibrium toward formation of more PCl$_3$

c) Addition of a catalyst will have no effect on the equilibrium position

d) Removal of Cl$_2$ from the container will shift the equilibrium towards the formation of more PCl$_3$

e) An increase in the volume of the container will shift the equilibrium toward formation of more PCl$_5$
Consider the following exothermic reaction:

\[
\text{CH}_4 \text{(g)} + 2 \text{O}_2 \text{(g)} \leftrightarrow \text{CO}_2 \text{(g)} + 2 \text{H}_2\text{O} \quad \Delta H = -891 \text{ kJ}
\]

How many of the following five statements are true?

(I) If CH\(_4\) is added at some constant temperature, the reaction shifts right and K decreases

(II) If CO\(_2\) is added at some constant temperature, the reactions shift left and K decreases

(III) If the temperature is increased, the reaction shifts left and K decreases

(IV) If the pressure is decreased by increasing the volume at some constant temperature the reaction shifts left

(V) If, in a rigid container at constant temperature, the pressure is increased by adding Argon gas, the reaction shifts right

a) 1 b) 2 c) 3 d) 4 e) 5

Solubility Constant

1. The equilibrium constant K is based on the concentrations at equilibrium
2. The reaction quotient Q is based on the concentrations at any given point
3. If Q<K, the reaction is forming more products. If Q>K, it is forming more reactant
4. Pay attention to coefficients when writing ICE tables and K calculation
5. K\(_p\) is used for partial pressures, just make sure to convert if you need K\(_c\)

Note: You can determine which way the reaction is shifting, but as long as some reactants are present, some products form and visa versa

Self-contained breathing apparatuses sometimes use the following reaction to produce oxygen gas:

\[
4\text{KO}_2 \text{(s)} + 2\text{CO}_2 \text{(g)} \leftrightarrow 2\text{K}_2\text{CO}_3 \text{(s)} + 3\text{O}_2 \text{(g)} \quad K = ?
\]

At a particular temperature, an equilibrium mixture of this reaction contains 2 mol of KO\(_2\) (s), \(4 \times 10^{-10}\) mol CO\(_2\) (g), 1 mol K\(_2\)CO\(_3\) (s) and 0.4 mol of O\(_2\) (g) all in a 4.0 L container. Calculate the value for the equilibrium constant, K, for this reaction

a) \(4 \times 10^{17}\) b) \(1 \times 10^9\) c) \(1 \times 10^{17}\) d) \(4 \times 10^9\) e) \(6.4 \times 10^{18}\)
Consider when 1.0 mole of A(g) and 1.0 mole of B(g) are added to a 2.0 L container and the following balanced reaction occurs:

\[ A \text{(g)} + 2 \text{B(g)} \leftrightarrow 2 \text{C(g)} + 3 \text{D(g)} \]

Which of the following statements must be true regarding this reaction once equilibrium has been reached?

a) The value of the equilibrium constant for this reaction must be greater than 1 (\( K > 1 \))

b) The value of the equilibrium constant for this reaction must be less than 1 (\( K < 1 \))

c) The value of the equilibrium constant for this reaction must be equal to 1 (\( K = 1 \))

d) At equilibrium, the concentration of B (g) must be equal to the concentration of C (g) (\([B]_e = [C]_e\))

e) At equilibrium, the concentration of B (g) must be smaller than the concentration of A (g) (\([B]_e < [A]_e\))

Molar Solubility

1. Molar solubility tells us the number of moles dissolved into liter solvent before mixture becomes saturated

2. Higher \( K_{sp} \) indicates a more soluble compound

Calculate the molar solubility of \( \text{Ca}_3(\text{PO}_4)_2 \) (s) in a 1.0 \( \times \) 10\(^{-2}\)M \( \text{Ca(NO}_3)_2 \) solution. \( K_{sp} \) for \( \text{Ca}_3(\text{PO}_4)_2 = 1.3 \times 10^{-32} \)

a) \( 5.7 \times 10^{-14} \) mol/L  

b) \( 1.6 \times 10^{-14} \) mol/L  

c) \( 1.6 \times 10^{-7} \) mol/L  

d) \( 3.2 \times 10^{-13} \) mol/L  

e) \( 1.1 \times 10^{-10} \) mol/L

Consider a theoretical iconic compound formed from \( M^{4+} \) and \( Y^{3-} \) ions. Which of the following mathematical statements correctly relates \( K_{sp} \) to the molar solubility for the ionic compound formed from \( M^{4+} \) and \( Y^{3-} \)? Note: \( s = \text{molar solubility} \)

a) \( K_{sp} = 7s^{12} \)  

b) \( K_{sp} = 9775s^{12} \)  

c) \( K_{sp} = 256s^{5} \)  

d) \( K_{sp} = 12s^{7} \)  

e) \( K_{sp} = 6912s^{7} \)
Energy Change during Reactions

1. \( H = q + w = q + \Delta(PV) \)

2. \( Q \) is positive if energy is added to the system, negative if into environment

3. \( W_{by} \) is negative if work is done on the system, positive if by the system

Suppose you add 45 J of heat to a system and let it do 10 J of expansion work, then return the system to its initial state by cooling and compression. Which of the following statements must be true for the overall process

a) \( \Delta H < \Delta E \)

b) The quantity of work done in the compression step must be exactly equal to the quantity if work done by the system in the expansion step

c) \( \Delta H = 70 \text{ J} \)

d) In the compression step, \( q = -45 \text{ J} \)

e) The change in the internal energy for this overall process is zero

Which of the following statements correctly describes the signs of \( q \) and \( w \) for the following process at \( P = 1 \text{ atm} \) and \( T = 298 \text{ K} \)

\[ H_2O \ (g) \rightarrow H_2O \ (l) \]

a) \( q \) and \( w_{on} \) are negative

b) \( q \) is positive, \( w_{on} \) is negative

c) \( q \) is negative, \( w_{on} \) is positive

d) \( q \) and \( w_{on} \) are both positive

e) \( q \) and \( w_{on} \) are both zero
Calorimetry/Enthalpy

1. Heat Capacity \( (C) \) has units J/°C and is individually measured for a given volume of a substance

2. Specific Heat \( (C_v) \) can have different units (ex. J/mole°C or J/kg°C) but is universal for an element or compound

3. For specific heat make sure to cancel out the units by multiplying by mass or moles

4. Calorimeters measure the heat exchange between the system and the surroundings

5. Calorimetry can determine if a reaction is exothermic or endothermic

6. For ideal calorimeters, heat lost by the system = -heat gained by the surroundings

A coffee-cup calorimeter contains 100.0g of water at 24.3°C. A 10.0g sample of NaCl is added to the water in the calorimeter. After the solid is dissolved, the temperature of the solution is 23.1°C. Calculate the enthalpy change for the dissolution of sodium chloride in kJ per mole NaCl. Assume the heat capacity of the solution is 4.16 J/g°C

a) 550 J/mol b) -3.2 kJ/mol c) 3.2 kJ/mol d) -550 kJ/mol

Given the following two reactions at 298K and 1 atm, which of the statements is true?

A. \( \text{N}_2 \ (g) + \text{O}_2 \ (g) \rightarrow 2 \text{NO} \ (g) \quad \Delta H_A \)

B. \( \text{NO} \ (g) + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2 \ (g) \quad \Delta H_B \)

a) \( \Delta H_B^o \) for \( \text{NO}_2 \ (g) \) = \( \Delta H_B \)

b) \( \Delta H_f^o \) for \( \text{NO} \ (g) \) = -\( \Delta H_A \)

c) \( \Delta H_A = \Delta H_B \)

d) \( \Delta H_f^o \) for \( \text{NO}_2 \ (g) \) = \( \Delta H_B + \frac{1}{2} \Delta H_A \)

e) None of the above statements are true
Given the following data:

\[
\begin{align*}
I_2 (s) + Cl_2 (g) & \rightarrow 2 ICl (g) \quad \Delta H = 34 \text{ kJ} \\
Cl_2 (g) & \rightarrow 2 Cl (g) \quad \Delta H = 242 \text{ kJ} \\
I_2 (g) & \rightarrow 2 I(g) \quad \Delta H = 151 \text{ kJ} \\
I_2 (g) & \rightarrow I_2 (s) \quad \Delta H = -63 \text{ kJ}
\end{align*}
\]

Calculate the I-Cl bond energy in ICl

a) 211 kJ/mol  
   b) 490 kJ/mol  
   c) 439 kJ/mol  
   d) 262 kJ/mol  
   e) 243 kJ/mol