WKS
Equilibrium Constants

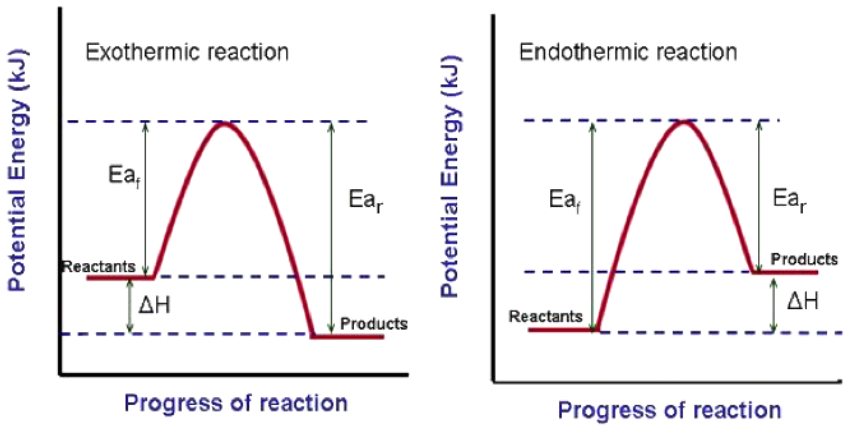
Name Answer Key
Period _____ Date_____

1) Explain what is incorrect about the following statements:
   a) At equilibrium no more reactants are transformed into products.
   In dynamic equilibrium, reactants and products are continually reacting to form the other.

   b) At equilibrium there are equal amounts of reactants and products.
   While the forward and reverse rates are equal, the concentrations of reactants and products are ***constant***. While they may be equal, this is not required.

2) A flask contains a saturated aqueous NaCl solution that is in contact with 10.0 g of undissolved **NaCl powder**. The flask is stoppered and left undisturbed. A year later it is observed that the system contains a **single, large 10.0 g crystal of NaCl** in contact with the solution.
   *Explain how this observation can be used to support the notion that equilibrium is a **dynamic** process.*
   In a saturated solution, dissolving and crystallizing are continually occurring: NaCl (s) $\rightleftharpoons$ NaCl (aq). The powder dissolves more quickly than larger crystals (surface area!), so during equilibrium the larger crystals will tend to grow until only a single large crystal remains.

3) Look at the two energy diagrams at the right (one is exothermic and the other is endothermic). Which reaction would favor reactants at equilibrium? Why?
   Endothermic. The $E_{a,f}$ is larger than $E_{a,r}$ so $k_r > k_f$, so reactants are formed faster than products.



4) Write the K_{eq} expressions for the following reactions. *Remember:* $K_{eq} = \frac{[\text{products}]}{[\text{reactants}]}$ *No numbers!!!*

   a) $N_2\,(g) + O_2\,(g) \rightleftharpoons 2\,NO\,(g)$

   $K_{eq} = \frac{[NO]^2}{[N_2][O_2]}$

   b) $2\,N_2O_5\,(g) \rightleftharpoons 4\,NO_2\,(g) + O_2\,(g)$

   $K_{eq} = \frac{[NO_2]^4[O_2]}{[N_2O_5]^2}$

   c) $4\,H_3O^+\,(aq) + 2\,Cl^-\,(aq) + MnO_2\,(s) \rightleftharpoons Mn^{2+}\,(aq) + 6\,H_2O\,(l) + Cl_2\,(g)$

   $K_{eq} = \frac{[Mn^{2+}][Cl_2]}{[H_3O^+]^4[Cl^-]^2}$

   d) $2\,PbO\,(s) + 3\,O_2\,(g) + C\,(s) \rightleftharpoons 2\,Pb\,(l) + CO_2\,(g) + 2\,SO_2\,(g)$

   $K_{eq} = \frac{[CO_2][SO_2]^2}{[O_2]^3}$

5) A system is described by the equation: $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$
At equilibrium, the concentrations of reactants and products are as follows:
$[SO_2] = 0.75\ M \qquad [O_2] = 0.30\ M \qquad [SO_3] = 0.15\ M$
Write the K_{eq} expression and then solve for the value of K_{eq} for this reaction.

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(0.15)^2}{(0.75)^2(0.30)} = \boxed{0.13}$$

6) A system is described by this equation: $PCl_5(g) \rightleftarrows PCl_3(g) + Cl_2(g)$
The equilibrium constant (K_{eq}) for this reaction is 0.0896
If at one equilibrium position, $[PCl_5] = 0.015\ M$ and $[PCl_3] = 0.78$, what must be the concentration of Cl_2?

$$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]} \Rightarrow [Cl_2] = \frac{K_{eq}[PCl_5]}{[PCl_3]} = \frac{(0.0896)(0.015)}{(0.78)} = \boxed{0.0017\ M}$$

"Q" Questions:

7) A vial contains 0.150 M NO_2 ad 0.300 M N_2O_4. Calculate Q for the reaction, $2\ NO_2(g) \rightleftharpoons N_2O_4(g)$.
HINT: Write the K_{eq} expression, but substitute "Q" for "K_{eq}". Then, put in numbers and solve for "Q".

$$Q = \frac{[N_2O_4]_i}{[NO_2]_i^2} = \frac{(0.300)}{(0.150)^2} = \boxed{13.3}$$

8) A system is described by this equation: $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$, where $K_{eq} = 2.19 \times 10^{-10}$
If the following concentrations are present, the system is not at equilibrium. Which direction must the reaction proceed to achieve equilibrium?
$[COCl_2] = 3.50 \times 10^{-3}\ M$, $[CO] = 1.11 \times 10^{-5}\ M$, AND $[Cl_2] = 1.56 \times 10^{-6}\ M$
HINT: Write the K_{eq} expression, but substitute "Q" for "K_{eq}". Then, put in numbers and solve for "Q". Finally, compare your "Q" value with the given "K_{eq}" value.

$$Q = \frac{[CO]_i[Cl_2]_i}{[COCl_2]_i} = \frac{(1.11\times10^{-5})(1.56\times10^{-6})}{3.50\times10^{-3}} = \boxed{4.95\times10^{-9}}$$

Since $Q > K_{eq}$, [P]/[R] is too large, so the reaction will shift left to consume products and make reactants. (Reverse reaction is faster than forward.)

9) At 448°C, $K_{eq} = 50.5$ for the reaction $H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$
Solve for Q and predict how the reaction proceeds if $[H_2] = 0.150$ M, $[I_2] = 0.175$ M and $[HI] = 0.950$ M

$$Q = \frac{[HI]_i^2}{[H_2]_i[I_2]_i} = \frac{(0.950)^2}{(0.150)(0.175)} = \boxed{34.4}$$

Since $Q < K_{eq}$, [P]/[R] is too small, so the reaction will shift right to consume reactants and make products. (Forward reaction is faster than reverse.)