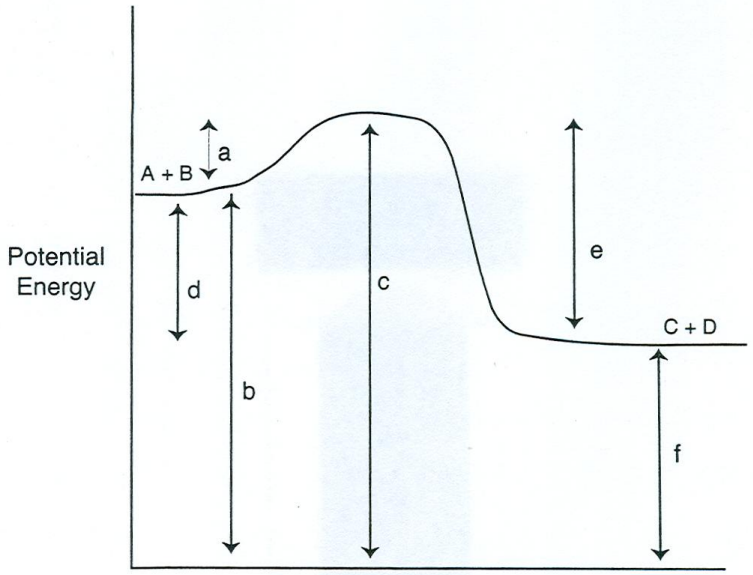
POTENTIAL ENERGY DIAGRAM

Name _____



A + B ↔ C + D + energy

Answer the questions using the graph above.

1. Is the above reaction endothermic or exothermic? _____
2. What letter represents the potential energy of the reactants? _____
3. What letter represents the potential energy of the products? _____
4. What letter represents the heat of reaction (ΔH)? _____
5. What letter represents the activation energy of the forward reaction? _____
6. What letter represents the activation energy of the reverse reaction? _____
7. What letter represents the potential energy of the activated complex? _____
8. Is the reverse reaction endothermic or exothermic? _____
9. If a catalyst were added, what letter(s) would change? _____

ENTROPY

Name _____

Entropy is the degree of randomness in a substance. The symbol for change in entropy is ΔS.

Solids are very ordered and have low entropy. Liquids and aqueous ions have more entropy because they move about more freely, and gases have an even larger amount of entropy. According to the Second Law of Thermodynamics, nature is always proceeding to a state of higher entropy.

Determine whether the following reactions show an increase or decrease in entropy.

1. $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$ _____
2. $H_2O(l) \rightarrow H_2O(s)$ _____
3. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ _____
4. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ _____
5. $KCl(s) \rightarrow KCl(l)$ _____
6. $CO_2(s) \rightarrow CO_2(g)$ _____
7. $H^+(aq) + C_2H_3O_2^-(aq) \rightarrow HC_2H_3O_3(l)$ _____
8. $C(s) + O_2(g) \rightarrow CO_2(g)$ _____
9. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ _____
10. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ _____
11. $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$ _____
12. $2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$ _____
13. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ _____
14. $2NO(g) \rightarrow N_2(g) + O_2(g)$ _____
15. $H_2O(g) \rightarrow H_2O(l)$ _____

GIBBS FREE ENERGY

Name _____

For a reaction to be spontaneous, the sign of ΔG (Gibbs Free Energy) must be negative. The mathematical formula for this value is:

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

where ΔH = change in enthalpy or heat of reaction
T = temperature in Kelvin
ΔS = change in entropy or randomness

Complete the table for the sign of ΔG; +, – or undetermined. When conditions allow for an undetermined sign of ΔG, temperature will decide spontaneity.

ΔH	ΔS	ΔG
–	+	
+	–	
–	–	
+	+	

Answer the questions below.

1. The conditions in which ΔG is always negative is when ΔH is _____ and ΔS is _____ .
2. The conditions in which ΔG is always positive is when ΔH is _____ and ΔS is _____ .
3. When the situation is indeterminate, a low temperature favors the (entropy / enthalpy) factor, and a high temperature favors the (entropy / enthalpy) factor.

Answer Problems 4-6 with always, sometimes or never.

4. The reaction: $Na(OH)_s \rightarrow Na^+(aq) + OH^-(aq)$ + energy will _____ be spontaneous.
5. The reaction: energy + $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ will _____ be spontaneous.
6. The reaction: energy + $H_2O(s) \rightarrow H_2O(l)$ will _____ be spontaneous.
7. What is the value of ΔG if ΔH = -32.0 kJ, ΔS = +25.0 kJ/K and T = 293 K? _____
8. Is the reaction in Problem 7 spontaneous? _____
9. What is the value of ΔG if ΔH = +12.0 kJ, ΔS = -5.00 kJ/K and T = 290. K? _____
10. Is the reaction in Problem 9 spontaneous? _____

EQUILIBRIUM CONSTANT (K)

Name _____

Write the expression for the equilibrium constant K for the reactions below.

1. $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$

2. $2KClO_3(s) \leftrightarrow 2KCl(s) + 3O_2(g)$

3. $H_2O(l) \leftrightarrow H^+(aq) + OH^-(aq)$

4. $2CO(g) + O_2(g) \leftrightarrow 2CO_2(g)$

5. $Li_2CO_3(s) \rightarrow 2Li^+(aq) + CO_3^{-2}(aq)$

CALCULATIONS USING THE EQUILIBRIUM CONSTANT

Name _____

Using the equilibrium constant expressions you determined on page 79, calculate the value of K when:

1. $[NH_3] = 0.0100\ M, [N_2] = 0.0200\ M, [H_2] = 0.0200\ M$

2. $[O_2] = 0.0500\ M$

3. $[H^+] = 1 \times 10^{-8}\ M, [OH^-] = 1 \times 10^{-6}\ M$

4. $[CO] = 2.0\ M, [O_2] = 1.5\ M, [CO_2] = 3.0\ M$

5. $[Li^+] = 0.2\ M, [CO_3^{-2}] = 0.1\ M$

E CHATELIER'S PRINCIPLE

Name _____

e Chatelier's Principle states that when a system at equilibrium is subjected to a stress, the ystem will shift its equilibrium point in order to relieve the stress.

Complete the following chart by writing left, right or none for equilibrium shift, and decreases, increases or remains the same for the concentrations of reactants and products, and for the value of K.

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 22.0 \text{ kcal}$$

Stress	Equilibrium Shift	$[N_2]$	$[H_2]$	$[NH_3]$	K
1. Add N_2	right	———	decreases	increases	remains the same
2. Add H_2			———		
3. Add NH_3				———	
4. Remove N_2		———			
5. Remove H_2			———		
6. Remove NH_3				———	
7. Increase Temperature					
8. Decrease Temperature					
9. Increase Pressure					
10. Decrease Pressure					

LE CHATELIER'S PRINCIPLE CONTINUED

Name _____

$12.6\ kcal + H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

Stress	Equilibrium Shift	$[H_2]$	$[I_2]$	[HI]	K
1. Add H_2	right	———	decreases	increases	remains the same
2. Add I_2			———		
3. Add HI				———	
4. Remove H_2		———			
5. Remove I_2			———		
6. Remove HI				———	
7. Increase Temperature					
8. Decrease Temperature					
9. Increase Pressure					
10. Decrease Pressure					

$NaOH(s) \leftrightarrow Na^+(aq) + OH^-(aq) + 10.6\ kcal$ (Remember that pure solids and liquids do not affect equilibrium values.)

Stress	Equilibrium Shift	Amount NaOH(s)	$[Na^+]$	$[OH^-]$	K
1. Add NaOH(s)		———			
2. Add NaCl (Adds Na^+)			———		
3. Add KOH (Adds OH^-)				———	
4. Add H^+ (Removes OH^-)				———	
5. Increase Temperature					
6. Decrease Temperature					
7. Increase Pressure					
8. Decrease Pressure					

SOLUBILITY PRODUCT CONSTANT (K_{SP})

Name _____

1. What is the solubility, in moles/liter, of AgBr if the $K_{SP} = 5.0 \times 10^{-13}$?

2. If the solubility of $Li_2CO_3 = 0.15$ moles/liter, what is its K_{SP} at this temperature?

3. What is the solubility, in moles/liter, of PbI_2 if the $K_{SP} = 8.5 \times 10^{-9}$?

4. If the solubility of $Ag_2CrO_4 = 7.2 \times 10^{-5}$ moles/liter, what is its K_{SP}?

5. How many moles of AgCl will dissolve in 500. mL of water if the $K_{SP} = 1.7 \times 10^{-10}$?