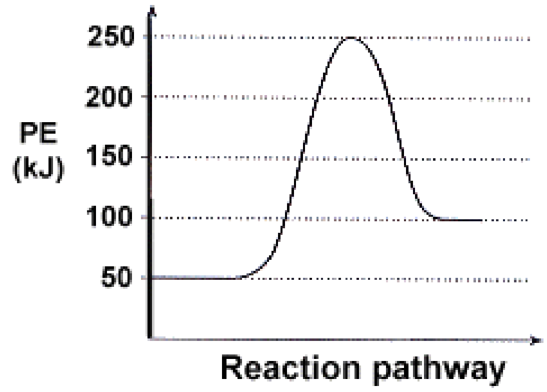
Name: ____ Period: ______________

Unit 13: Rates and Equilibrium- Funsheets

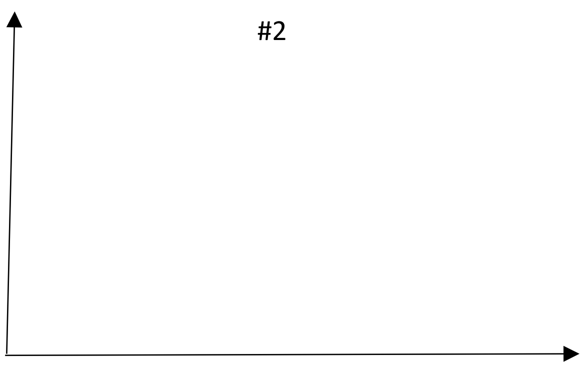
Part A: Reaction Diagrams

1) Answer the following questions based on the potential energy diagram shown here:
   a. Does the graph represent an endothermic or exothermic reaction? ______________________________
   b. Label the position of the reactants, products, and activated complex.
   c. Determine the heat of reaction, ΔH, (enthalpy change) for this reaction. ______________________
   d. Determine the activation energy, E_a for this reaction. ____
   e. How much energy is released or absorbed during the reaction? __________________________________
   f. How much energy is required for this reaction to occur? _____________________________________
   g. Draw a dashed line on the diagram to indicate a potential energy curve for the reaction if a catalyst is added.

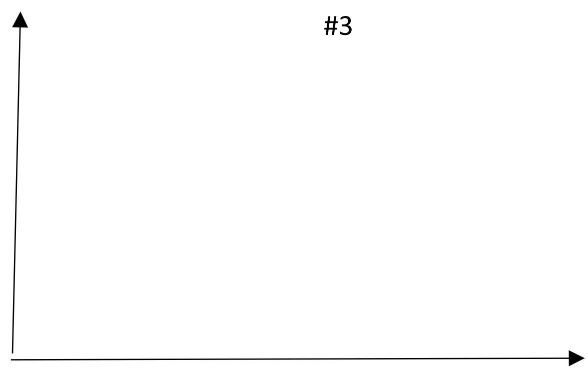


2) Sketch a potential energy curve below that is represented by the following values of ΔH and Ea (activation energy). You may make up appropriate values for the y-axis (potential energy). ΔH = -100 kJ and Ea = 20 kJ
3) Sketch a potential energy curve below that is represented by the following values of ΔH and Ea (activation energy). You may make up appropriate values for the y-axis (potential energy). ΔH = +45 kJ and Ea = 100 kJ

#2



#3

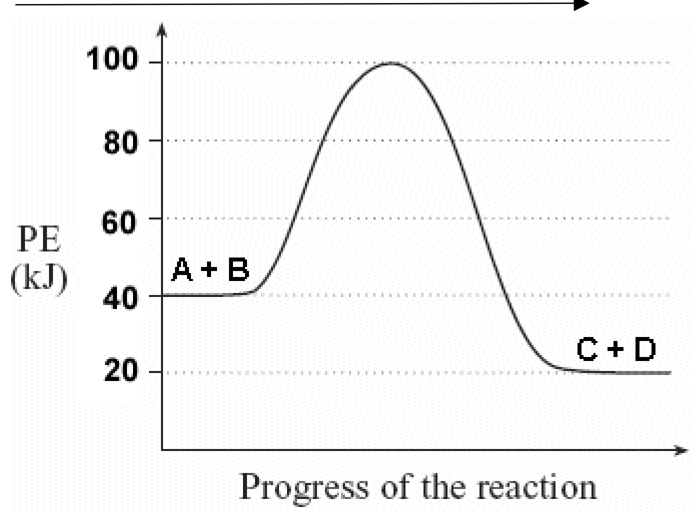


4) Answer the following questions based on the potential energy diagram shown here:
   a. Does the graph represent an endothermic or exothermic reaction?

      ____
   b. Determine the heat of reaction, ΔH, (enthalpy change) for this reaction.

      ____
   c. How much energy is released or absorbed during the reaction?

      ____
   d. How much energy is required for this reaction to occur? _______________________



Part B: Hess's Law- *Include units and show ALL WORK!*

1) Calculate the heat of reaction for: $PbCl_{2\,(s)} + Cl_{2\,(g)} \rightarrow PbCl_{4\,(l)}$ $\Delta H = ?$

   Given the following: $Pb_{(s)} + Cl_{2\,(g)} \rightarrow PbCl_{2\,(s)}$ $\Delta H = -359.40$ kJ

   $Pb_{(s)} + 2\,Cl_{2\,(g)} \rightarrow PbCl_{4\,(l)}$ $\Delta H = -329.30$ kJ

2) From the following heats of reaction: $2\,SO_{2(g)} + O_{2(g)} \rightarrow 2\,SO_{3(g)}$ $\Delta H = -196.00$ kJ

   $2\,S_{(s)} + 3\,O_{2(g)} \rightarrow 2\,SO_{3(g)}$ $\Delta H = -790.00$ kJ

   Calculate the heat of reaction for: $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\Delta H = ?$ kJ

3) Given the following equations: $4\,NH_{3(g)} + 5\,O_{2(g)} \rightarrow 4\,NO_{(g)} + 6\,H_2O_{(l)}$ $\Delta H° = -1170$ kJ

   $4\,NH_{3(g)} + 3\,O_{2(g)} \rightarrow 2\,N_{2(g)} + 6\,H_2O_{(l)}$ $\Delta H° = -1530$ kJ

   Using these two equations, determine the heat of formation, ΔH_f, for nitrogen monoxide. $N_2\,(g) + O_2\,(g) \rightarrow 2NO\,(g)$

4) From the following heats of reaction: $2\,H_2\,(g) + O_2\,(g) \rightarrow 2\,H_2O\,(g)$ $\Delta H = -483.6$ kJ

   $3\,O_2\,(g) \rightarrow 2\,O_3\,(g)$ $\Delta H = +284.6$ kJ

   Calculate the heat of the reaction for: $3\,H_2\,(g) + O_3\,(g) \rightarrow 3\,H_2O\,(g)$

5) Given the following data: $N_2\,(g) + O_2\,(g) \rightarrow 2\,NO\,(g)$ $\Delta H = +180.7$ kJ

   $2\,NO\,(g) + O_2\,(g) \rightarrow 2\,NO_2\,(g)$ $\Delta H = -113.1$ kJ

   $2\,N_2O\,(g) \rightarrow 2\,N_2\,(g) + O_2\,(g)$ $\Delta H = -162.3$ kJ

   Use Hess's law to calculate ΔH for the following reaction: $N_2O\,(g) + NO_2\,(g) \rightarrow 3\,NO\,(g)$

Keep going Part B continues
on the next page!

6) The standard heats of formation of HCl (g) and HBr (g) are -92.0 kJ/mol and -36.4 kJ/mol respectively. Diatomic gases have a heat of formation of 0 kJ Using this information, calculate ΔH for the following reaction:

$Cl_{2\,(g)} + 2\ HBr_{(g)} \rightarrow 2\ HCl_{(g)} + Br_{2\,(g)}$

7) Use the given standard enthalpies of formation to determine the heat of reaction of the following reaction:

$2\ LiOH(s) + CO_2(g) \longrightarrow Li_2CO_3(s) + H_2O(l)$

ΔH^o_f LiOH(s) = -487.23 kJ/mole
ΔH^o_f $Li_2CO_3(s)$ = -1215.6 kJ/mole
ΔH^o_f $H_2O(l)$ = -285.85 kJ/mole
ΔH^o_f $CO_2(g)$ = -393.5 kJ/mole

8) Use the given standard enthalpies of formation to determine the heat of reaction of the following reaction:

$2\ Cl_2(g) + 2\ H_2O(l) \longrightarrow 4\ HCl(g) + O_2(g)$

ΔH^o_f $H_2O(l)$ = -285.8 kJ/mole
ΔH^o_f HCl(g) = -92.3 kJ/mole

9) Calculate ΔH^o_f (kJ) for the following reaction from the listed standard enthalpies of formation:

$4\ NH_3(g) + 5\ O_2(g) \longrightarrow 4\ NO(g) + 6\ H_2O(g)$

ΔH^o_f $NH_3(g)$ = -46.1 kJ
ΔH^o_f NO(g) = +90.2 kJ
ΔH^o_f $H_2O(g)$ = -241.8 kJ

10) The standard enthalpy of formation of propane, C_3H_8, is -103.6 kJ/mole. Calculate the heat of combustion of C_3H_8. The heats of formation of $CO_2(g)$ and $H_2O(l)$ are -394 kJ/mole and -285.8 kJ/mole respectively. Diatomic molecules have a heat of formation of 0 kJ/mole. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

11) The standard enthalpy of formation of propyne, C_3H_4, is +185.4 kJ/mole. Calculate the heat of combustion of C_3H_4. The heats of formation of $CO_2(g)$ and $H_2O(l)$ are -394 kJ/mole and -285.8 kJ/mole respectively.

$C_3H_4 + 4O_2 \rightarrow 3CO_2 + 2H_2O$

12) The standard enthalpy of formation of ethanol, C_2H_5OH, is -277.7 kJ/mole. Calculate the heat of combustion of C_2H_5OH. The heats of formation of $CO_2(g)$ and $H_2O(l)$ are -394 kJ/mole and -285.8 kJ/mole respectively.

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Part C: Vocabulary and Concepts

1) Fill in the blanks: When the products have ___________________________ potential energy than the reactants, the ΔH values is positive. When the products have ___________________________ potential energy than the reactants, the ΔH values is negative.
2) Indicate whether the following are endothermic (ENDO) or exothermic (EXO):
   a. ________ The burning of wood to produce a hot flame.
   b. ________ 4Fe(s) + 3O2(g) → 2Fe2O3(s) + energy
   c. ________ A test tube that feels cold to the touch after two substances have been mixed.
   d. ________ $C(s) + 2\ F_2(g) \longrightarrow CF_4(g)$ $\Delta H^o = -680$ kJ
3) According to the Collision Theory, in order for a reaction to occur molecules must ___________________________ with enough ____________________ and in the proper _________________________________.
4) Explain why all reactions have an activation energy, using your knowledge of collision theory.

____

____

____

5) Describe how the activation energy of a reaction affects the overall rate of the chemical reaction.

____

____

____

6) Model the following reaction and use your model to explain how the atoms are rearranged. Be sure to balance and include a key. ___N_2 (g) + ___H_2 (g) ←→ ___NH_3 (g)

____

____

____

7) What is a reversible reaction?

____

____

8) What is an activated complex? ____

____

9) A ___________________________ speeds up a chemical reaction by lowing the ______________________ energy.
10) What is enthalpy? ____

____

11) What is Hess's Law? ____

____

12) *Circle the correct answer:* If something is (endothermic/exothermic) more heat goes from surroundings into the system. The ΔH value is (positive/negative).
13) *Circle the correct answer*: If something is (endothermic/exothermic) more heat goes from the system into the surroundings. The ΔH value is (positive/negative).
14) What law explains that during a chemical reaction mass is not created or destroyed just rearranged to create new products? ____
15) What law explains that energy is not created or destroyed just transferred between system and surroundings?

____

Part D: Equilibrium Expressions and Constants- *Answer the following and show all work.*

1) Write the following equilibrium expression in each box:
   a. O_3 (g) + NO (g) $\leftarrow\rightarrow$ O_2 (g) + NO_2 (g)
   b. 2CO (g) + O_2 (g) $\leftarrow\rightarrow$ $2CO_2$(g)
   c. NH_4NO_3 (s) $\leftarrow\rightarrow$ N_2O (g) + $2H_2O$ (l)
   d. $2H_2O$ (g) + $\leftarrow\rightarrow$ $2H_2$ (g) + O_2 (g)
   e. 2NO(g) + O_2(g) $\leftarrow\rightarrow$ $2NO_2$(g)
   f. 2Li(s) + 2HCl (aq) $\leftarrow\rightarrow$ H_2 (g) + 2LiCl(aq)

a.	b.

c.	d.	e.	f.

2) Equilibrium is established in the reversible reaction: 2 A (aq) + B (aq) $\leftarrow\rightarrow$ A_2B (aq).
   The equilibrium concentrations are [A]= 0.55M, [B]= 0.33M, and [A_2B]= 0.43 M. What is the equilibrium expression and value of the equilibrium constant, K_c for this reaction?

3) What is the equilibrium expression and equilibrium constant if the equilibrium concentrations are as follows: PCl_5 is 0.0096 M, PCl_3 is 0.0247 M, and Cl_2 is 0.0247M? PCl_5 (g) $\leftarrow\rightarrow$ PCl_3 (g) + Cl_2 (g)

4) At a certain temperature, a container has an equilibrium mixture consisting of 0.102 M of NH_3, 1.03 M N_2, and 1.62 M of H_2. Calculate the K_c for the equilibrium system. N_2 (g) + $3H_2$ (g) $\leftarrow\rightarrow$ $2NH_3$ (g)

5) What is the equilibrium expression and equilibrium constant if the equilibrium consists of 10.0g of NaOH, 0.50M HCl, 1.0L H_2O, and 0.88M NaCl. NaOH (s) + HCl (aq) $\leftarrow\rightarrow$ H_2O (l) + NaCl (aq)

6) At a given temperature, the K_c for the reaction below is 1.40×10^{-2}. If the concentrations of H_2 and I_2 at equilibrium are 2.00×10^{-4} M, find the concentration of HI. 2HI (g) $\leftarrow\rightarrow$ H_2 (g) + I_2 (g)

Part E: Le Chatelier's Principle

1) State Le Chatelier's Principle: ____
____
____

2) Predict which way the following equilibrium systems will shift when the total pressure is increased. (Note: some may have no shift)
   a. N_2 (g) + O_2 (g) ←→ 2NO (g) ________________________________
   b. $2SO_2$ (g) + O_2 (g) ←→ $2SO_3$ (g) ________________________________
   c. $4NH_3$ (g) + $5O_2$ (g) ←→ 4NO (g) + $6H_2O$ (g) ________________________________

3) N_2O_4 (g) is a colorless gas and NO_2 (g) is a dark brown gas. Use Le Chatelier's principle to explain why a flask filled with NO_2 (g) and N_2O_4 (g) will get darker when heated. Use the equation: N_2O_4 (g) + heat ←→ $2NO_2$ (g)
____
____
____

4) List at least 3 ways to increase amount of oxygen gas in the following reaction.
   H_2O_2 (aq) ←→ H_2 (g) + O_2 (g) ΔH= +187.00 kJ
   a. ____
   b. ____
   c. ____

5) Complete the following chart by writing left, right, or none for the equilibrium shift. Write decrease, increases, or remains the same for the concentrations of reactants and products.

12.6 kcal + 2HCl (aq) ←→ H_2(g) + Cl_2(g)

Stress	**Equilibrium Shift**	**[H_2]**	**[Cl_2]**	**[HCl]**
1.Add H_2	Left	_____	decreases	increases
2.Add Cl_2			_____	
3.Add HCl				_____
4.Remove H_2		_____		
5.Remove Cl_2			_____	
6.Remove HCl				_____
7.Increase Temperature				
8.Decrease Temperature				
9.Increase Pressure				
10.Decrease Pressure				

Keep going Part E continues
on the next page!

$$Ca^{+2}(aq) + SO_4^{-2}(aq) + 10.6\ kcal \leftrightarrow CaSO_4(s)$$

(Remember that pure solids and liquids do not affect equilibrium values.)

Stress	Equilibrium Shift	Amount of $CaSO_4(s)$	$[Ca^{+2}]$	$[SO_4^{-2}]$
1.Add $CaSO_4(s)$		_____		
2.Add $CaCl_2$ (adds Ca^{+2})			_____	
3.Add $MgSO_4$ (adds SO_4^{-2})				_____
4.Remove SO_4^{-2}				_____
5.Increase temperature				
6. Decrease temperature				
7. Increase Pressure				
8. Decrease Pressure				

Part F: Vocabulary and Concepts

1) Provide an example of a heterogeneous reaction and an example of a homogeneous reaction. Support your answer.

2) List 5 factors the affect the rate of a reaction:
   a. ____
   b. ____
   c. ____
   d. ____
   e. ____

3) Using the collision theory explain why the rate of a reaction increases when pressure is increased.

4) The process of milk spoiling is a chemical reaction. Using your knowledge of rates of chemical reactions and collision theory, explain why we keep milk in the refrigerator.

5) It has been observed that more gas station fires occur on hot days than on cold days. Explain this phenomenon using your knowledge of collision theory.

Keep going Part F continues
on the next page!

6) What is chemical equilibrium?

7) What is equal at chemical equilibrium?

8) What is constant at chemical equilibrium?

9) At the macroscopic level a system at equilibrium appears to be unchanging. Is it also unchanging at the molecular level? Explain.

10) True or False: At equilibrium the amount of reactants is equal to the amount of products. ___________________

11) What is the formula for writing an equilibrium expression?

12) What do brackets [ ] indicate? ______________________________________

13) List 2 examples of enzymes and explain their function.

14) Model a reaction at equilibrium. Be sure to consider concentration, the fact the equilibrium is dynamic, and rates of forward and reverse reactions. Be sure to include a key. $A + 3B \leftrightarrow A_3B$