WS 19.1
Ea = Activation Energy
Assume that 1 square = 10 kJ/mole

1. $H_{2(g)} + I_{2(g)} \text{ -----> } 2\,HI_{(g)}$

a. Draw Lewis dot structures for each substance, above.
b. Discuss why this reaction requires activation energy; refer to specific molecules, above.
c. Based on the graph to the right, what is the ΔH_{rxn}?_____
d. Is this reaction exo- or endo-thermic?_____
e. What is the activation energy?_____
f. This reaction can be catalyzed by either platinum or gold.
If catalyzed by platinum, the Ea is 109 kJ, and with gold, it is 155 kJ.
g. On the graph to the right, sketch the energy diagram if the rxn is catalyzed by Pt.
h. Which is a better catalyst: Pt or Au?_____ (assume cost is not a factor)

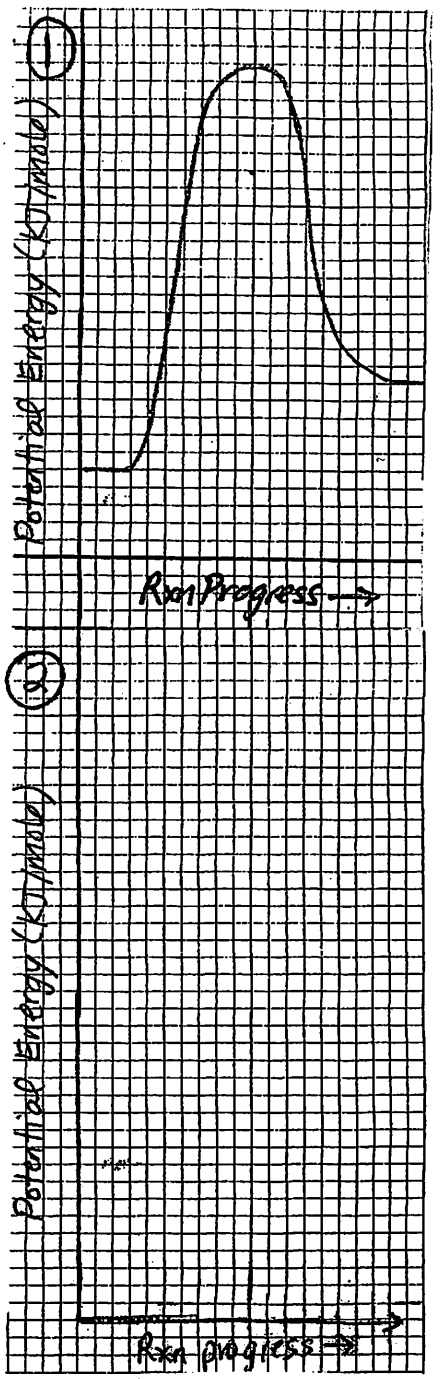
2. $N_{2(g)} + 3\,H_{2(g)} \text{ --------> } 2\,NH_{3(g)}$

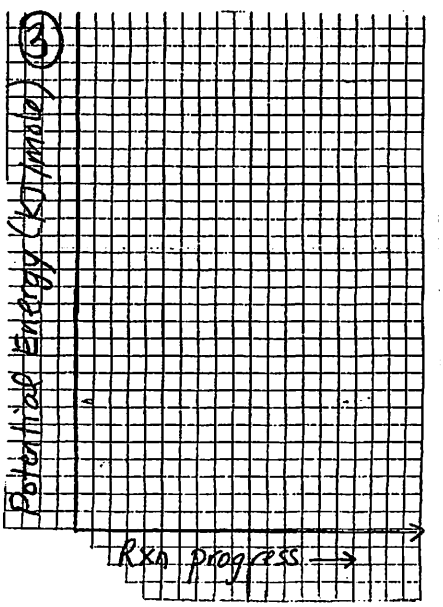
a. Draw Lewis dot structures for each substance, above.
b. This reaction has a ΔH_{rxn} of - 92 kJ and an Ea of 260 kJ/mole.
Is this reaction exo- or endo-thermic?_____
c. Draw the energy diagram for this reaction on the graph to the right.
d. When catalyzed by solid tungsten, the activation energy is 70 kJ/mole.
Sketch the energy diagram, when catalyzed by W, on the same graph.
e. 260 kJ is a fairly large activation energy. Why does this make sense, based on the structures you drew in (a)? Explain.

f. This reaction is called the "Haber Process". Why is this reaction so important?

3. $H_{2(g)} + C_2H_{4(g)} \text{ --------> } C_2H_{6(g)}$

a. Draw Lewis dot structures for each substance, above.
b. This reaction has a ΔH_{rxn} of - 32 kJ and an Ea of 180 kJ/mole.
Is this reaction exo- or endo-thermic?_____
c. Draw the energy diagram for this reaction on the graph.
d. This reaction is often catalyzed by platinum. Sketch the diagram for the catalyzed reaction, on the same graph as the uncatalyzed reaction.
e. Explain how the Pt catalyst works.





6a. Hydrogen peroxide can decompose according to this rxn:

$2\ H_2O_{2\,(aq)} \text{ -------> } 2\ H_2O_{(l)} + O_{2\,(g)}$ Ea = 75 kJ, ΔHrxn = -190. kJ

Without a catalyst, this reaction has an extremely slow rate at room temperature. Catalysts for this reaction include Pt, MnO_2, iodide ion, and the enzyme "catalase." When iodide is the catalyst, the following reaction sequence occurs:

Step 1 $I^{-1} + H_2O_2 \text{ -------> } IO^{-1} + H_2O$ (slow)

Step 2 $IO^{-1} + H_2O_2 \text{ -------> } I^{-1} + H_2O + O_2$ (fast)

a. Add up the above two reactions to obtain the net balanced reaction.

b. Which substance is the "intermediate" in this sequence?_____

c. Explain why I^{-1} fits the definition of a catalyst and explain how it functions as a catalyst. Include energy diagrams as part of your explanation.

7. Formic acid is the active ingredient in the venom of bees and ants. Its name is derived from the Latin term for ant, *formica*; it was first discovered by distilling dead ants. The proper name for this compound is methanoic acid.

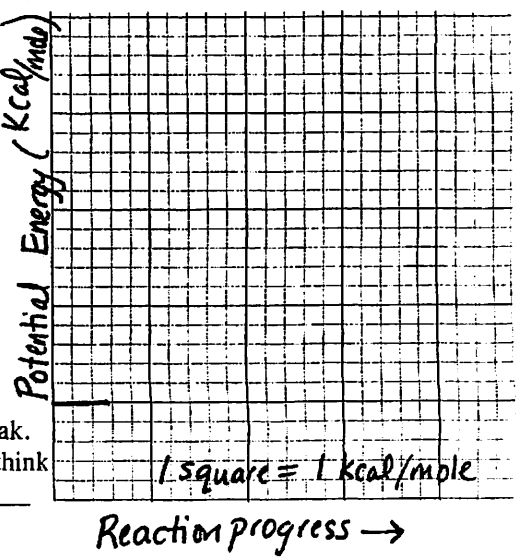
a. Draw the structure of this acid, including all hydrogens and lone pairs.

Methanoic (formic) acid can break down in to carbon monoxide and water. The catalyzed reaction sequence is shown below:

Step 1 $HCO_2H + H_2SO_4 \text{ --------> } HCO_2H_2^{+1} + HSO_4^{-1}$ Ea = 13 kcal, ΔHrxn = 12 kcal.

Step 2 $HCO_2H_2^{+1} \text{ --------> } HCO^{+1} + H_2O$ Ea = 6 kcal, ΔHrxn = 2 kcal.

Step 3 $HCO^{+1} + HSO_4^{-1} \text{ ---------> } H_2SO_4 + CO$ Ea = 1 kcal, ΔHrxn = -1.1 kcal.



b. Add up the above 3 steps to obtain the net (overall) reaction.

c. Which compound or ion is the catalyst in the above sequence?

d. Which compounds or ions are intermediates in the above sequence?

e. Sketch the energy diagram for the reaction sequence on this graph: Assume that 1 square = 1 kcal. Hint: your graph should have 3 peaks.

f. What is the ΔHrxn for the overall reaction?_____

g. Of the three steps, which step would you expect to have the fastest rate of reaction?_____

h. In order for CO to form, one of the carbon-oxygen bonds in formic acid must break. This reaction has a relatively low activation energy. Therefore, which bond do you think breaks in the reaction: The C-O single bond, or the C=O double bond? _____

i. Explain your answer to h: