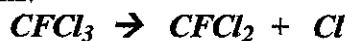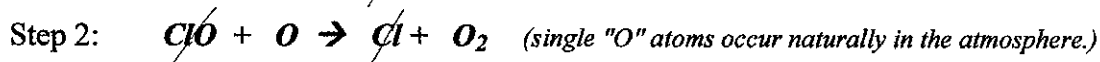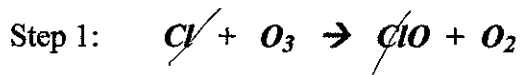# Chemistry 12
Worksheet 1-3 - Reaction Mechanisms

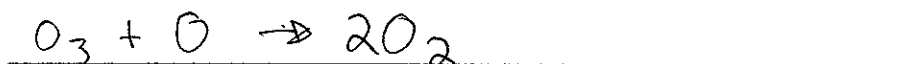1. It is known that compounds called *chlorofluorocarbons* (C.F.C.s) (eg. $CFCl_3$) will break up in the presence of ultraviolet radiation, such as found in the upper atmosphere, forming single chlorine atoms:

    $$CFCl_3 \rightarrow CFCl_2 + Cl$$

    The Cl atoms then react with Ozone (O_3) as outlined in the following mechanism.

    Step 1: $Cl + O_3 \rightarrow ClO + O_2$

    Step 2: $ClO + O \rightarrow Cl + O_2$ *(single "O" atoms occur naturally in the atmosphere.)*

    a) Write the equation for the *overall reaction*. (Using steps 1 and 2)

    $$O_3 + O \rightarrow 2O_2$$

    b) What is the *catalyst* in this reaction? Cl

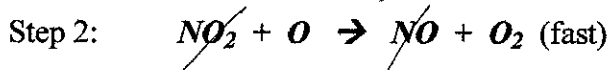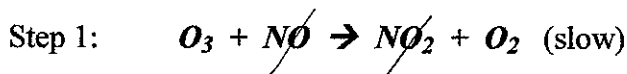   c) Identify an *intermediate* in this reaction ClO

    d) Explain how a *small* amount of chlorofluorocarbons can destroy a *large* amount of ozone.

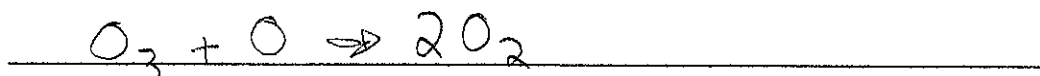   CFCs provide Cl as a catalyst. Since it is regenerated, it keeps on reacting with more O_3

    e) What breaks the bond in the $CFCl_3$ and releases the free Cl atom?

    UV radiation

2. Given the following mechanism, answer the questions below:

    Step 1: $O_3 + NO \rightarrow NO_2 + O_2$ (slow)

    Step 2: $NO_2 + O \rightarrow NO + O_2$ (fast)

    a) Give the equation for the *overall reaction*.

    $$O_3 + O \rightarrow 2O_2$$
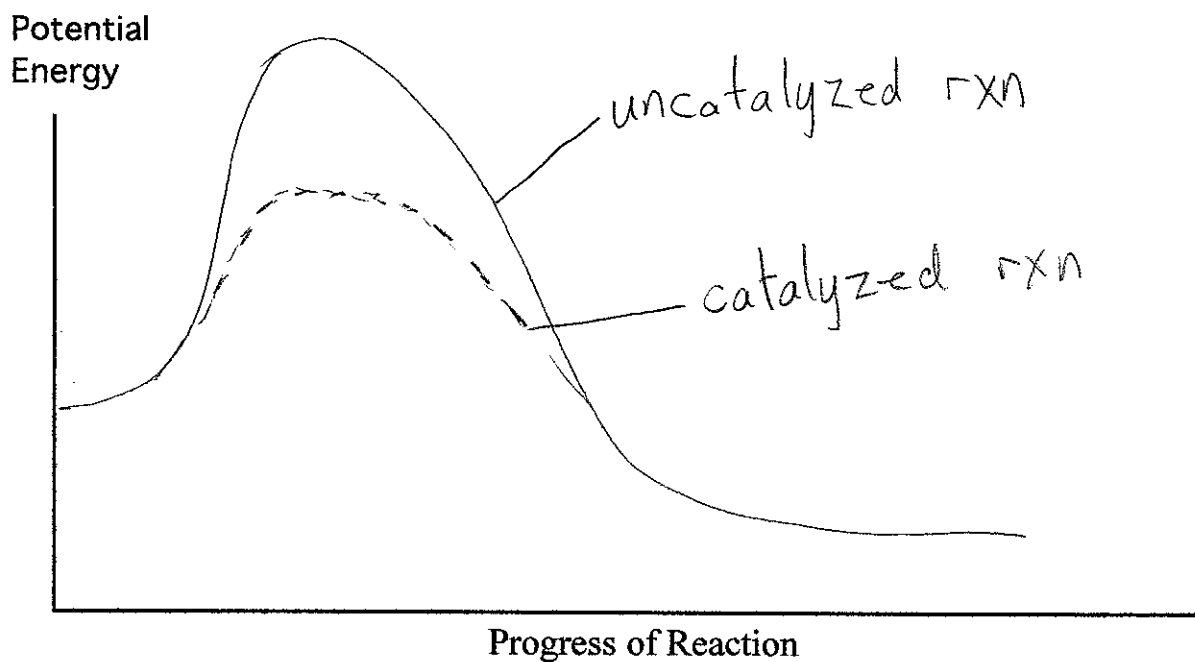
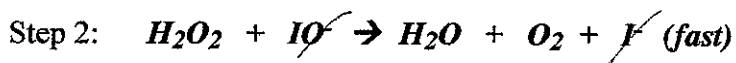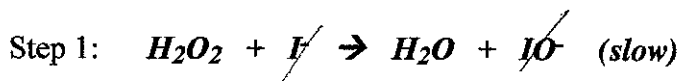   b) What could the *catalyst* be in this mechanism? NO

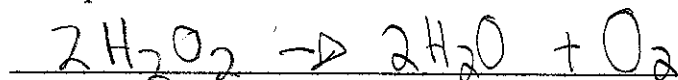   c) What is an *intermediate* in this mechanism? NO_2

d) Given that the **uncatalyzed** overall reaction is a *slow exothermic* reaction, draw a *potential energy graph* which shows the possible shape of the curve for the **uncatalyzed** reaction. On the same graph, show a possible curve for the *catalyzed* reaction.

3. Consider the following mechanism:

Step 1: $H_2O_2 + I^- \rightarrow H_2O + IO^-$ (slow)

Step 2: $H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$ (fast)

a) Give the equation for the overall reaction.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

b) What acts as a *catalyst* in this mechanism? I^-

c) What acts as an *intermediate* in this mechanism? IO^-

4. What is meant by the *rate determining step* in a reaction mechanism?

        slowest step in the mechanism

5. What is meant by a *reaction mechanism*?

        Series (sequence) of steps by which a rxn takes place

6. How are reaction mechanisms determined? Through much study and years of research; it is not determined by just looking at the overall rxn.

7. Given the following *Potential Energy Diagram* for a 3 step reaction, answer the questions

POTENTIAL
ENERGY

PROGRESS OF REACTION
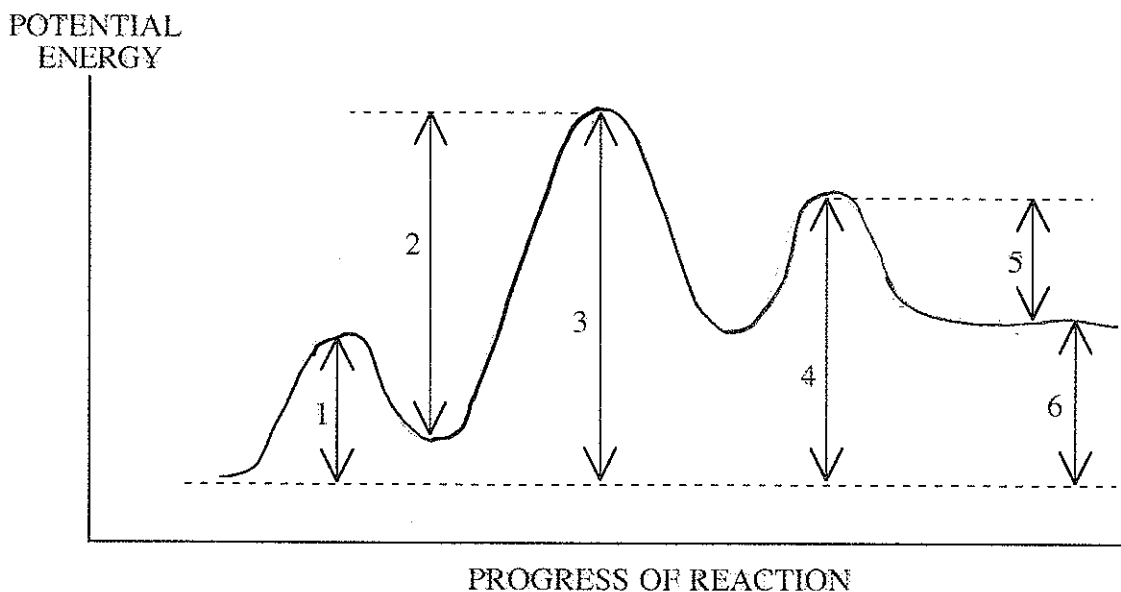
below it:

a) Which arrow indicates the *activation energy* for the *first* step of the reverse reaction?

5

b) Which arrow indicates the *activation energy* for the *first* step of the forward reaction?

1

c) Which arrow indicates the *activation energy* for the *second* step of the forward reaction?

2

d) Which arrow indicates the *enthalpy change* (ΔH) or *"enthalpy change"* for the *overall*

   forward reaction?

6

e) Which arrow indicates the *enthalpy change* (ΔH) or *"enthalpy change"* for the *overall*

   reverse reaction?

6

f) Which arrow indicates the *activation energy* for the **overall** forward reaction?
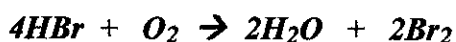
<u>2</u>

g) Which step would be the *rate determining step* in the *forward* reaction?   <u>3</u>

h) In a dashed line or another colour sketch a possible curve that would represent the route for the **uncatalyzed** *overall reaction*. <u>Label this</u> on the graph.
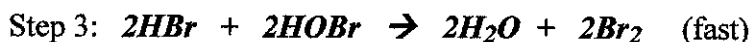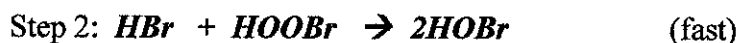
8.   Given the reaction:

$$4HBr + O_2 \rightarrow 2H_2O + 2Br_2$$

a) Would you expect this reaction to take place in a single step?   <u>No</u>

   Why or why not?   <u>5 reactant particles cannot react together at the same time with the correct alignment and KE.</u>

b) This reaction is thought to take place by means of the following mechanism:

   Step 1: $HBr + O_2 \rightarrow HOOBr$ (slow)

   Step 2: $HBr + HOOBr \rightarrow 2HOBr$ (fast)

   Step 3: $2HBr + 2HOBr \rightarrow 2H_2O + 2Br_2$ (fast)

c) Identify the two *intermediates*   <u>HOOBr, HOBr</u>

d) A catalyst is discovered which increases the rate of *Step 3*. How will this affect the rate of the *overall reaction*?   <u>No effect</u>

   Explain your answer.   <u>Only the RDS affects the rate of the overall rxn</u>

e) A catalyst is discovered which increases the rate of *Step 1*. How will this affect the rate of the *overall reaction*?   <u>Rate will be faster</u>

   Explain your answer.   <u>The only way to speed up an overall reaction</u>

f) Which step has the greatest *activation energy*?   <u>Step 1</u>

g) How many "bumps" will the potential energy diagram for the reaction mechanism have?

_____3_____

h) Which step is called the ***rate determining step*** in this mechanism? ____1____

i) In order to have successful collisions, the colliding particles must have **both** the proper

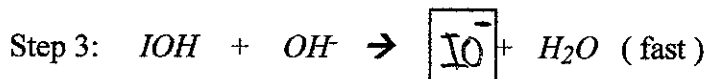amount of *energy* and the proper   ___alignment_____

j) On the set of axes below, draw the shape of the curve you might expect for the reaction in this question. The overall reaction is *exothermic*! Make sure you get the "bumps" the correct relative sizes.

Progress of Reaction
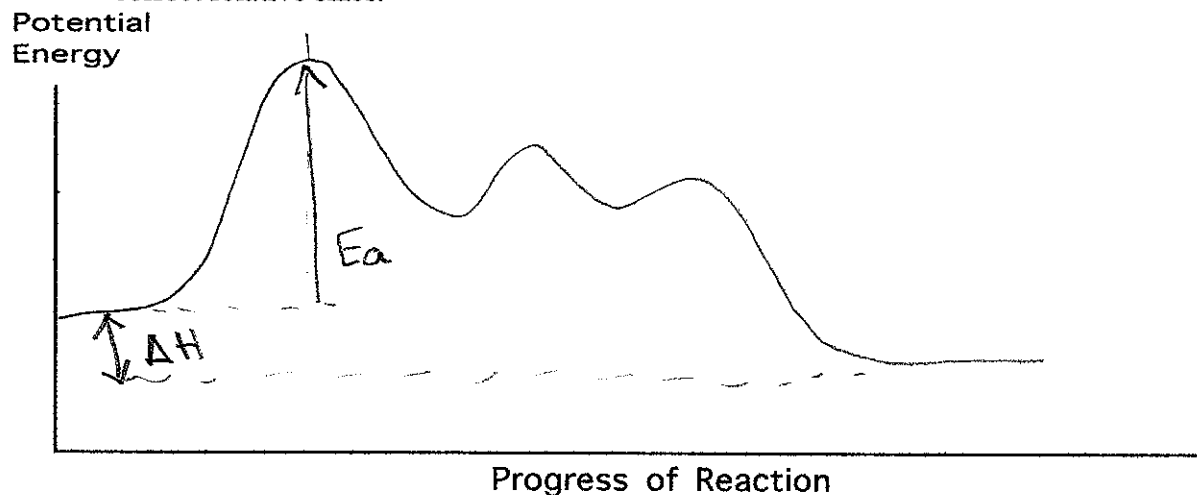
9.   The equation for an ***overall*** reaction is:

$$I^- + OCl^- \rightarrow IO^- + Cl^-$$

a) The following is a proposed *mechanism* for this reaction. One of the species has been left out. ***Determine what that species is and write it in the box.*** Make sure the *charge* is correct if it has one!

Step 1: $OCl^- + H_2O \rightarrow HOCl + OH^-$ (fast)

Step 2: $I^- + HOCl \rightarrow IOH + Cl^-$ (slow)

Step 3: $IOH + OH^- \rightarrow \boxed{IO^-} + H_2O$ (fast)

b) Which species in the mechanism above acts as a ***catalyst?***   ___H_2O___
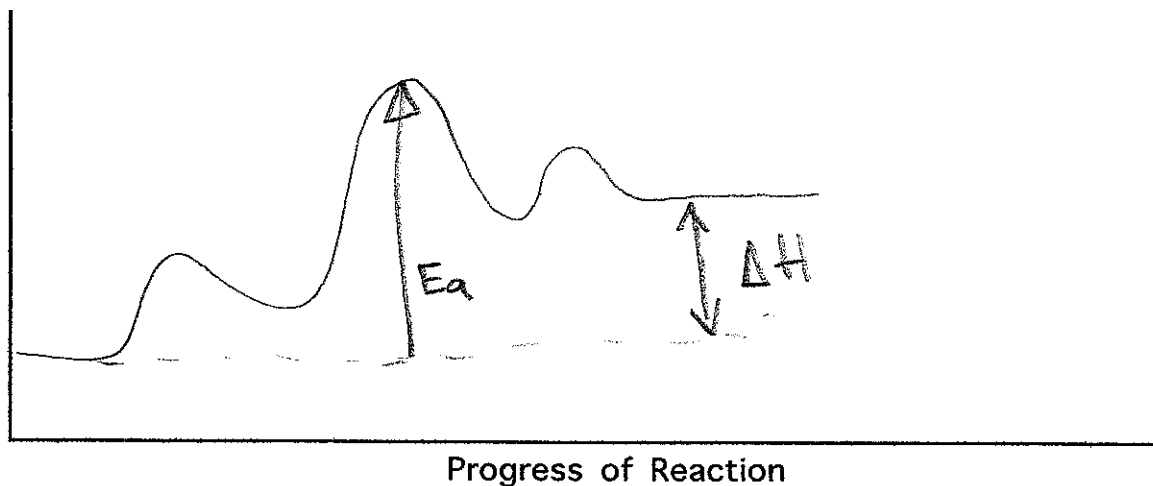
c) Which three species in the mechanism above are ***intermediates?*** $HOCl, OH^-, IOH$

d) Step ___2___ is the ***rate determining step.***

e) On the set of axes below, draw the shape of the curve you might expect for the reaction in this question. The overall reaction is _endothermic_! Make sure you get the "bumps" the correct relative sizes.

**Potential
Energy**

Progress of Reaction

10. Given the following steps for a mechanism:

    Step 1: Br_2 → $2Br$ (*fast*)

    Step 2: Br + OCl_2 → $BrOCl$ + Cl (*slow*)

    Step 3: Br + Cl → $BrCl$ (*fast*)

a) Write the equation for the **overall reaction**.

   $$Br_2 + OCl_2 \rightarrow BrOCl + BrCl$$

b) A substance is added that *decreases* the *activation energy* for step *1*. Will this speed up, slow down, or have no effect on the rate of the overall reaction? __No effect__

   Give a reason for your answer. __Only the slowest step affects the rate__

c) Is there a *catalyst* in this mechanism? __No__. If so, what is it? _____

d) Is there an *intermediate* in this mechanism? __Yes__. If so, what is it? __Br, Cl__

e) Which step is the *rate determining step*? _____2_____

11. The following **potential energy diagram** refers to a very slow one-step reaction of ozone (O_3) and oxygen atoms in the upper atmosphere.
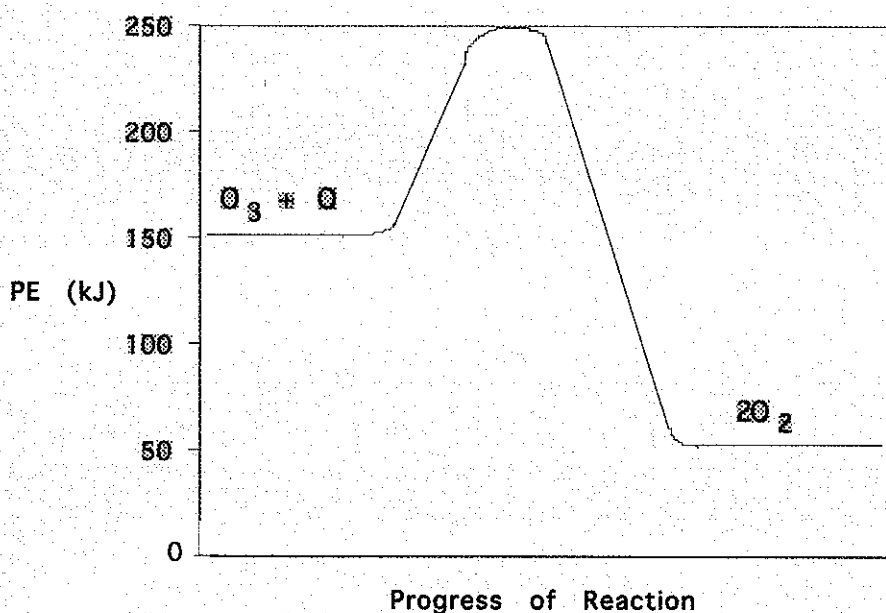
On the axis below, draw a potential energy diagram which could represent the *catalyzed mechanism* for the reaction:

Step 1: $O_3 + NO \rightarrow NO_2 + O_2$ (slow)

Step 2: $NO_2 + O \rightarrow NO + O_2$ (fast)
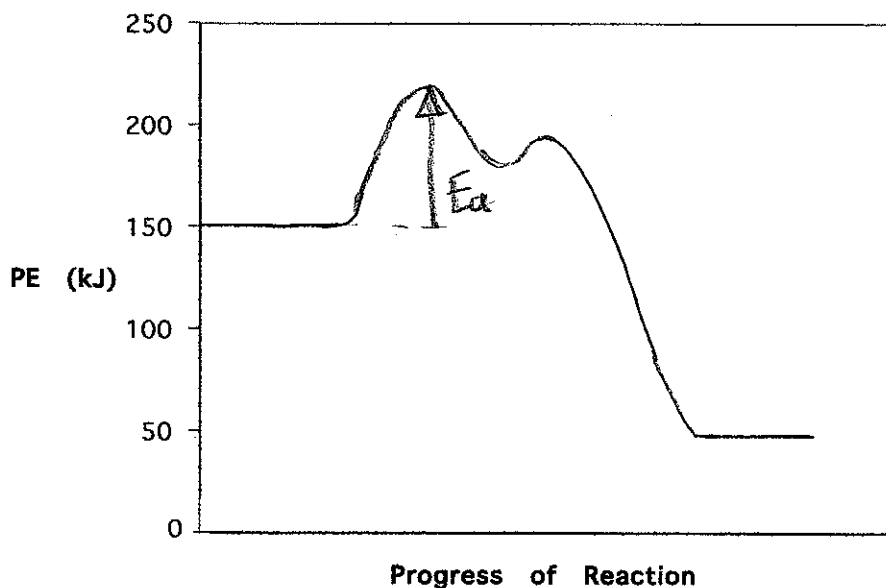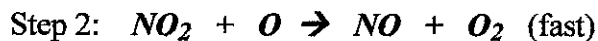
12. A certain chemical can provide a reaction with an alternate mechanism having a *greater* activation energy. What will happen to the *rate of the reaction* when this chemical is added?
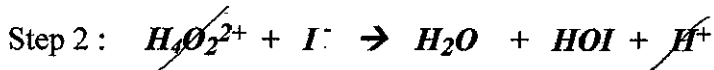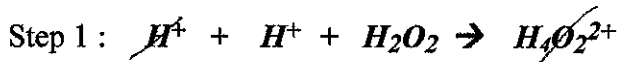   _The rate will slow down_

    Explain your answer. _The activation energy would increase, it would take longer for effective collisions to take place_

13. The following overall reaction is *fast* at room temperature:

    $$H^+ + I^- + H_2O_2 \rightarrow H_2O + HOI$$
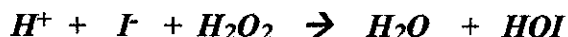
    A student proposes the following two-step mechanism for the above reaction:

    Step 1 : $\cancel{H^+} + H^+ + H_2O_2 \rightarrow H_4O_2^{2+}$

    Step 2 : $H_4O_2^{2+} + I^- \rightarrow H_2O + HOI + \cancel{H^+}$

    Would you *agree* or *disagree* with this proposed mechanism? _Agree_

    Explain your answer _When Step 1 is added to Step 2, we obtain the overall rxn._

14. Consider the following reaction:
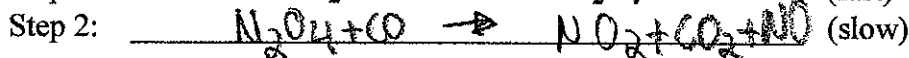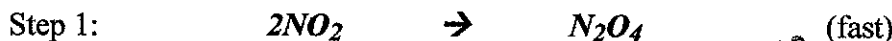 $$CO + NO_2 \rightarrow CO_2 + NO$$
    a) The *first step* in each of two proposed reaction mechanisms for the above reaction is listed below. If each proposed reaction mechanism consists of only *two* steps, **determine the second step for each mechanism.**
    Proposed Mechanism One:

    Step 1: $2NO_2 \rightarrow NO_3 + NO$ (slow)
    Step 2: $NO_3 + CO \rightarrow CO_2 + NO_2$ (fast)

    Proposed Mechanism Two:

    Step 1: $2NO_2 \rightarrow N_2O_4$ (fast)
    Step 2: $N_2O_4 + CO \rightarrow NO_2 + CO_2 + NO$ (slow)
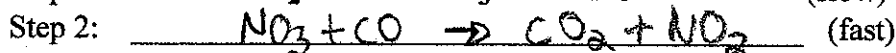
    b) Experimental data show that the rate of the reaction is *not* affected by a change in the

    [CO]. Which of these two mechanisms would be consistent with these data? _Mech. One_

    Explain your answer. _CO is used up during a fast step which does not affect the rxn rate_