Chemistry 12

Reaction Mechanisms Worksheet

Name: Key
Date:
Block:

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. $CFCl_3$ produces a Cl atom which can be regenerated as a catalyst

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

Ultraviolet 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)

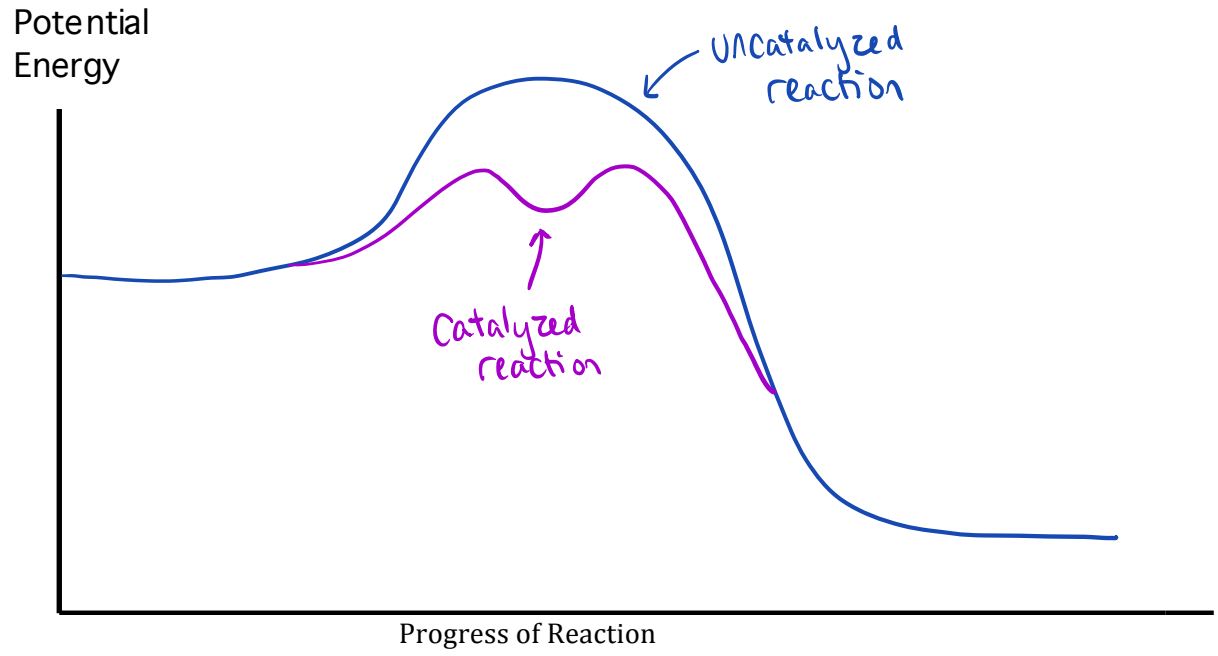
a) Give the equation for the ***overall reaction***.

$O_3 + O \rightarrow 2O_2$

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.

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

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?

The slowest step in the mechanism

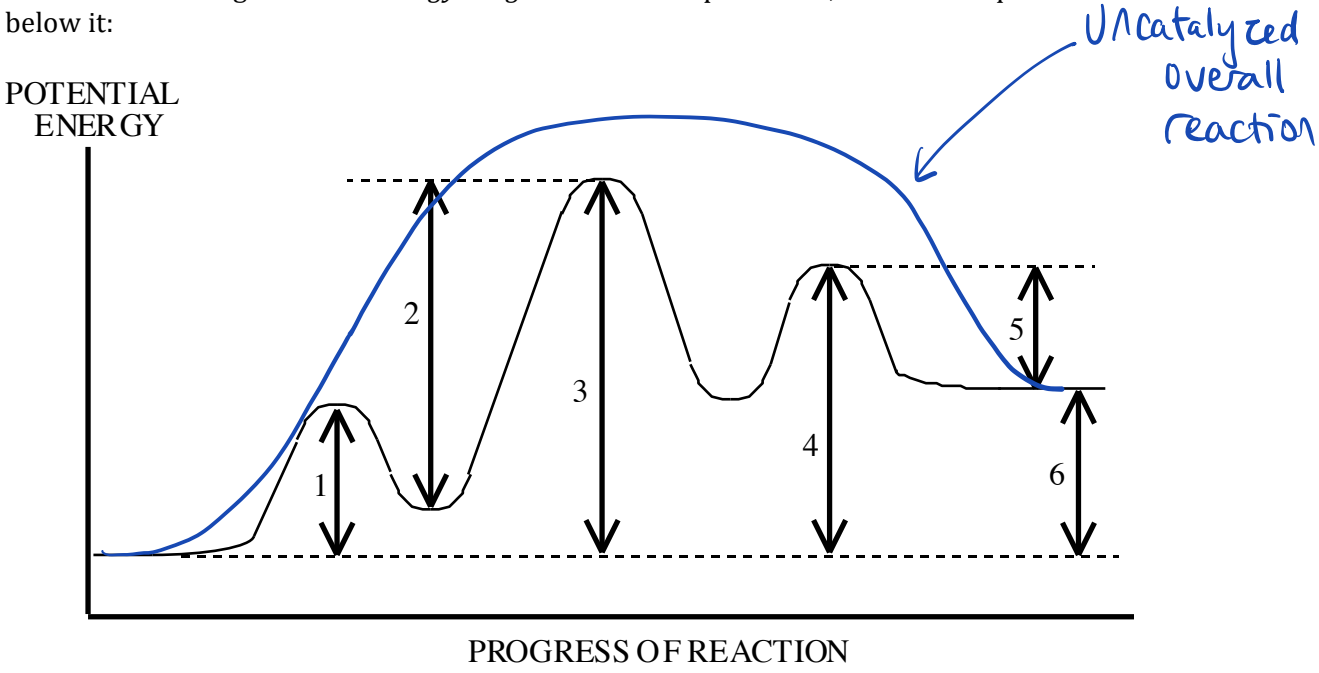
5. What is meant by a ***reaction mechanism***?

A series of elementary steps/reactions that may be added together to give an overall chemical reaction.

6. How are reaction mechanisms determined?

Through a lot of research

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

3

g) Which step would be the ***rate determining step*** in the *forward* reaction?

3

h) In a dashed line or another colour sketch a possible curve that would represent the route for the ***uncatalyzed*** *overall reaction.* Label this 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? Why or why not?

No - there's a small probability of a simultaneous collision of 4 HBr and 1 O_2 particles.

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*** HOOBr , HOBr

d) A catalyst is discovered which increases the rate of *Step 3*. How will this affect the rate of the *overall reaction*? Explain your answer.

It has no impact b/c step 3 is not the rate determining step

e) A catalyst is discovered which increases the rate of *Step 1*. How will this affect the rate of the *overall reaction*? Explain your answer.

It will ↑ the overall reaction rate because step 1 is the RDS

f) Which step has the greatest ***activation energy***?

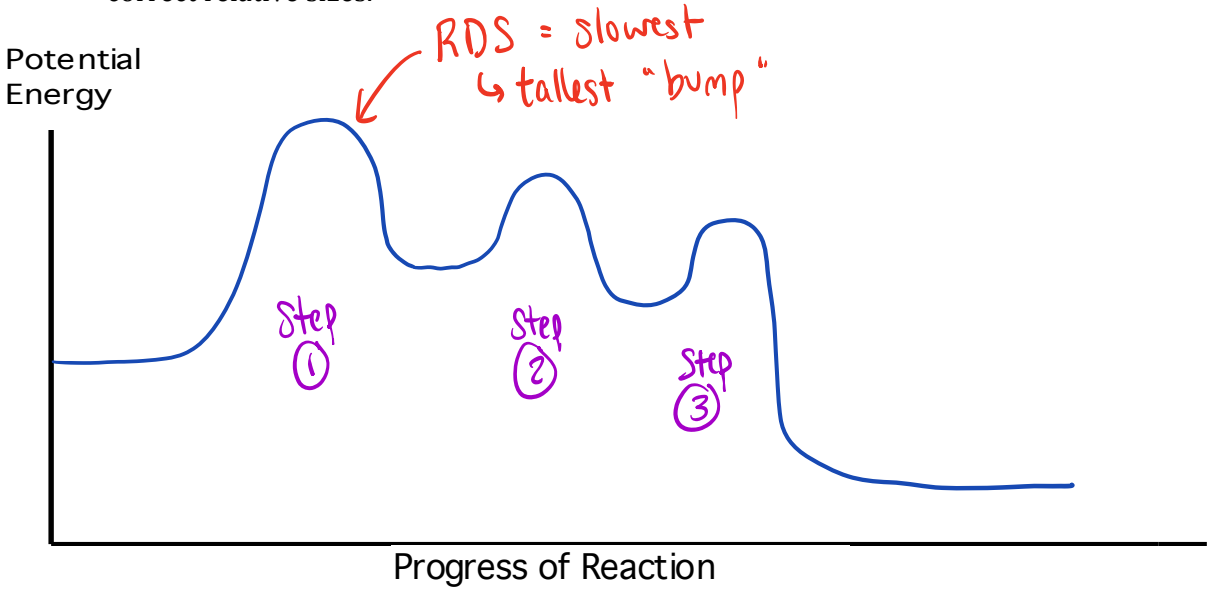
1 (the slowest)

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 ___geometry___.

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 <u>*exothermic*</u>! Make sure you get the "bumps" the correct relative sizes.



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)

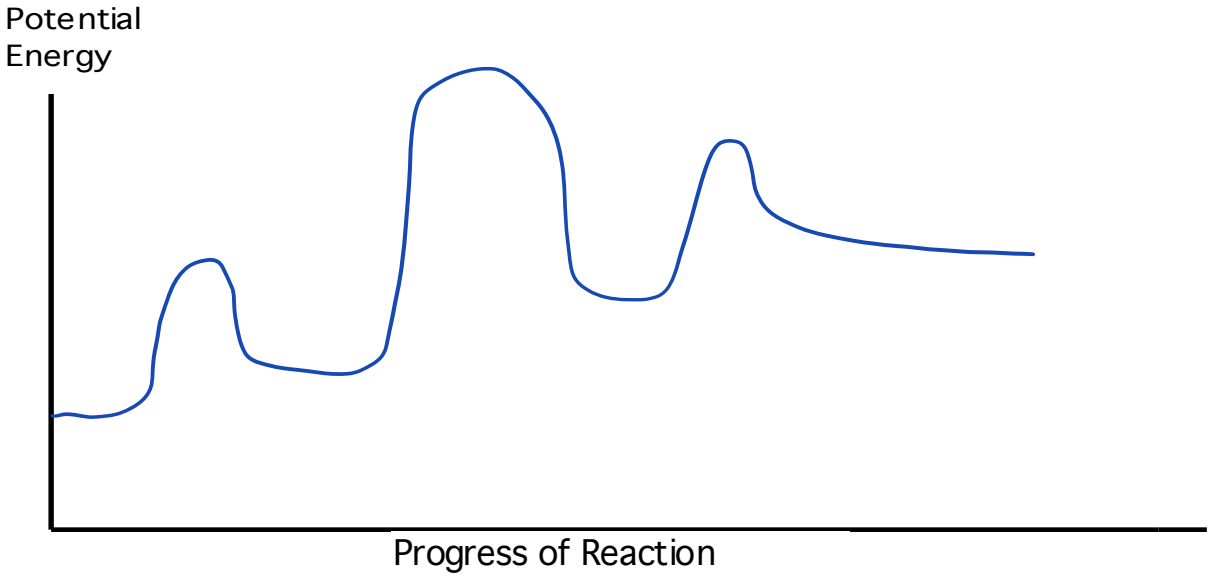
Step 3: $IOH + OH^- \rightarrow \boxed{IO^-} + H_2O$ (fast)

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.



10. Given the following steps for a mechanism:

Step 1: $Br_2 \rightarrow 2Br$ *(fast)*

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

Step 3: $Br + Cl \rightarrow BrCl$ *(fast)*

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

$Br_2 + OCl_2 \rightarrow BrOCl + BrCl$

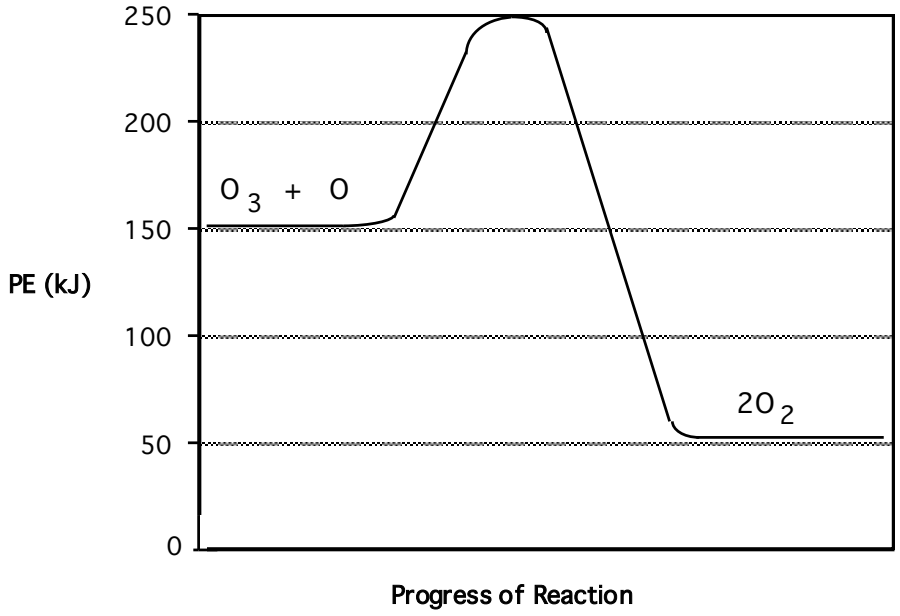
b) A substance is added that *decreases* the *activation energy* for step ***1***. Will this speed speed up, slow down, or have no effect on the rate of the overall reaction? Give a reason for your answer. It's not the RDS

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

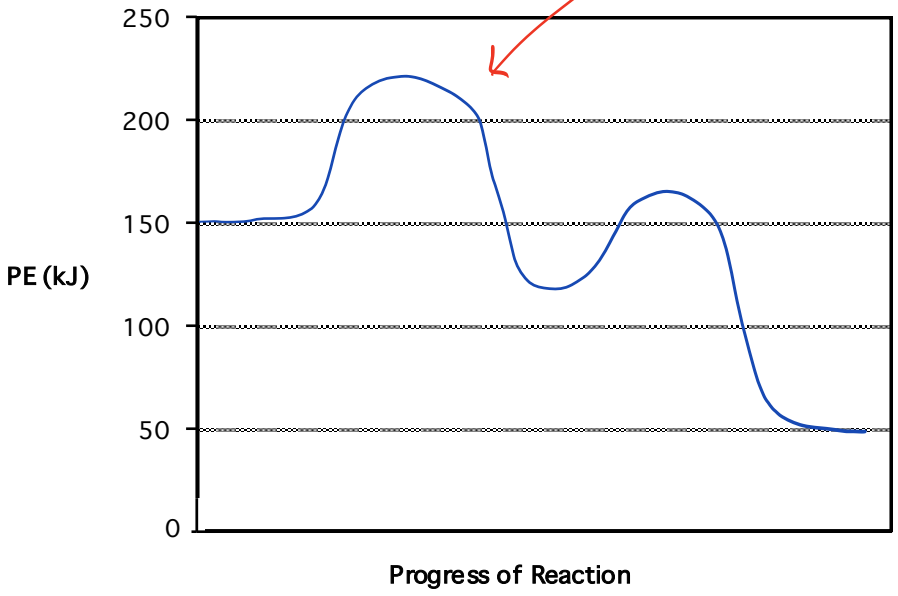
11. The following ***potential energy diagram*** refers to a very slow one-step reaction of ozone (O_3) and oxygen atoms in the upper atmosphere.



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? Explain your answer.

No change - the rxn will continue to take place w/ the lower original E_a

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

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

Would you *agree* or *disagree* with this proposed mechanism? Explain your answer

Step 1 involves the collision of 3 particles, which would be slow

14. Consider the following overall 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***.

<u>Proposed Mechanism One</u>:

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

<u>Proposed Mechanism Two</u>:

Step 1: $2NO_2 \rightarrow N_2O_4$ (fast)
Step 2: $CO + N_2O_4 \rightarrow NO_2 + NO + CO_2$ (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? Explain your answer.

If the rxn rate is not affected by [CO], that would indicate that CO must not be in the RDS. In proposed mechanism #1, CO is not in the RDS, which supports this data