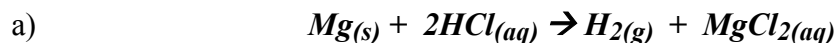


Chemistry 12  
**REVIEW – REACTION KINETICS**

1. Write expressions with which you could express **rates** for the following reactions. (Hint: look at what happens to reactants and products.) Recall that *solid or liquids* can lose or gain mass, *gases* can lose or gain volume and *aqueous solutions* can increase or decrease in concentration. ("a" is done as an example.)

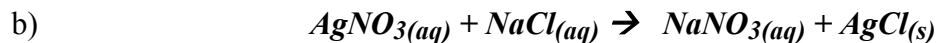


reaction rate =  $\frac{\text{mass of Mg consumed}}{\text{unit time}}$

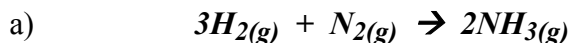
or reaction rate =  $\frac{\text{volume of H}_2 \text{ produced}}{\text{unit time}}$

or reaction rate =  $\frac{\text{decrease in } [\text{HCl}]}{\text{unit time}}$

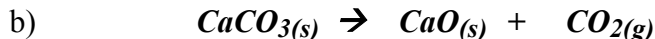
or reaction rate =  $\frac{\text{increase in } [\text{MgCl}_2]}{\text{unit time}}$



2. For each of the following reactions find a **quantity** or **property** which could be monitored in order to measure the rate of reaction. ("a" is done as an example.)



- pressure will decrease as reaction proceeds because you are going from **4 moles** of reactants to **2 moles** of products. Assuming you have a constant volume, less moles exert less pressure.



- Two things could be monitored here. Look at the **states** of everything carefully.

1 – open system:

2 – closed system:

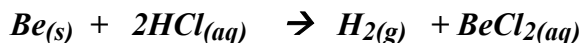


brown                      colourless

Two things could be monitored here.

One is obvious. Look at the **states** of everything carefully for the other one.

3. A chemist wishes to determine the rate of reaction of beryllium with hydrochloric acid. The equation for the reaction is:



A piece of beryllium is dropped into 1.00 L of  $\text{HCl}(\text{aq})$  and the following data were obtained:

Time	Mass of Beryllium
0 s	0.020 g
4 s	0.018 g
8 s	0.016 g
12 s	0.014 g
16 s	0.012 g
20 s	0.010 g

- a) Calculate the **Rate of Reaction** in grams of Be consumed per second.

- b) Calculate the **Rate of Reaction** in moles of Be consumed per second.

- c) What will happen to the  $[\text{HCl}]$  as the reaction proceeds? \_\_\_\_\_

4. When *pentane* ( $C_5H_{12}$ ) is burned in air (*oxygen*), the products *carbon dioxide* and *water* are formed.

a) Write a ***balanced formula equation*** for this reaction.

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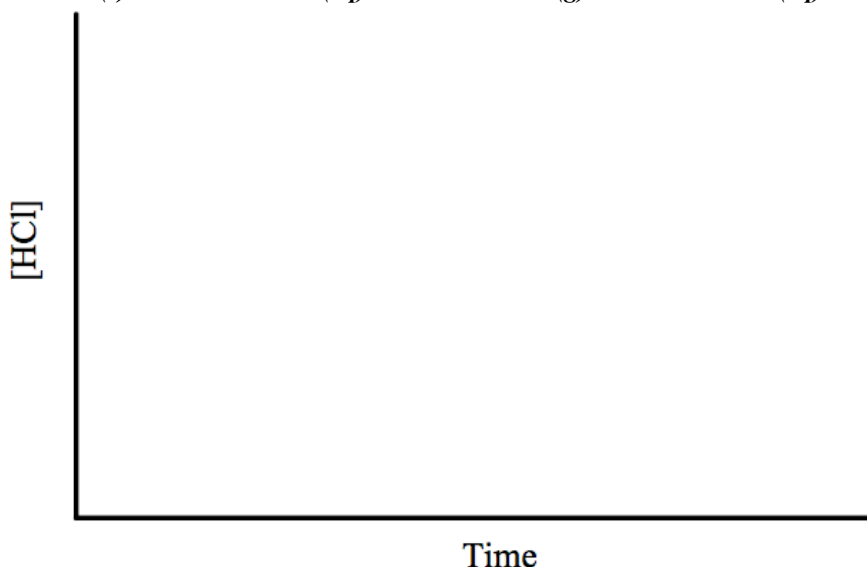
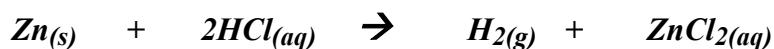
b) If pentane is consumed at an average rate of 2.16 grams/s, determine the rate of consumption of pentane in *moles/s*.

c) If pentane is consumed at an average rate of 0.030 moles/s, determine the rate of consumption of *oxygen* in moles/s.

d) If pentane is consumed at an average rate of 0.030 moles/s, determine the rate of production of  $CO_2$  in moles/s.

e) If pentane is consumed at an average rate of 0.030 moles/s, determine the rate of production of  $CO_2$  in ***grams/s***.

5. On the following set of axes, draw the shape of the curve you would expect if you plotted the ***[HCl]*** vs. ***Time***, starting immediately after the two reactants are mixed. The equation for the reaction is:



Explain how you got that particular shape. Be detailed.

6. How many possible collisions are there between 3  $\text{H}_2$  molecules and 3  $\text{I}_2$  molecules?  
(a diagram may help)

7. a) In a room filled with  $\text{H}_2$  and  $\text{O}_2$  there are about  $10^{32}$  collisions per second. Explain why the reaction between  $\text{H}_2$  and  $\text{O}_2$  at room temperature is so *slow* as to be unnoticeable!

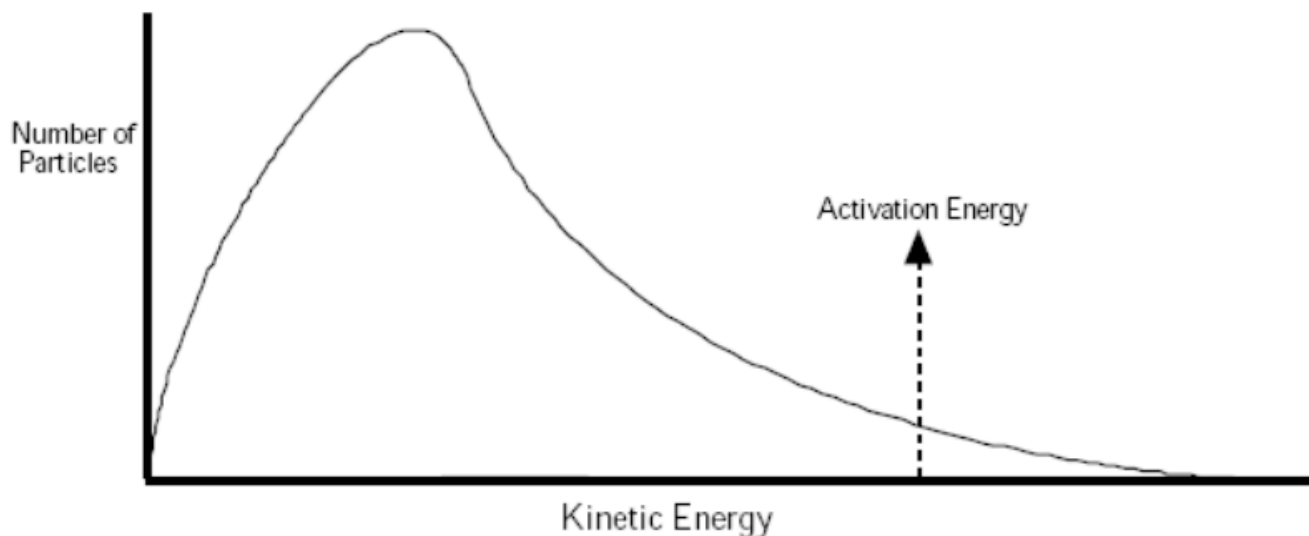
b) Suggest **two** ways in which the reaction in question "7a" could be *speeded up*.

1. \_\_\_\_\_

2. \_\_\_\_\_

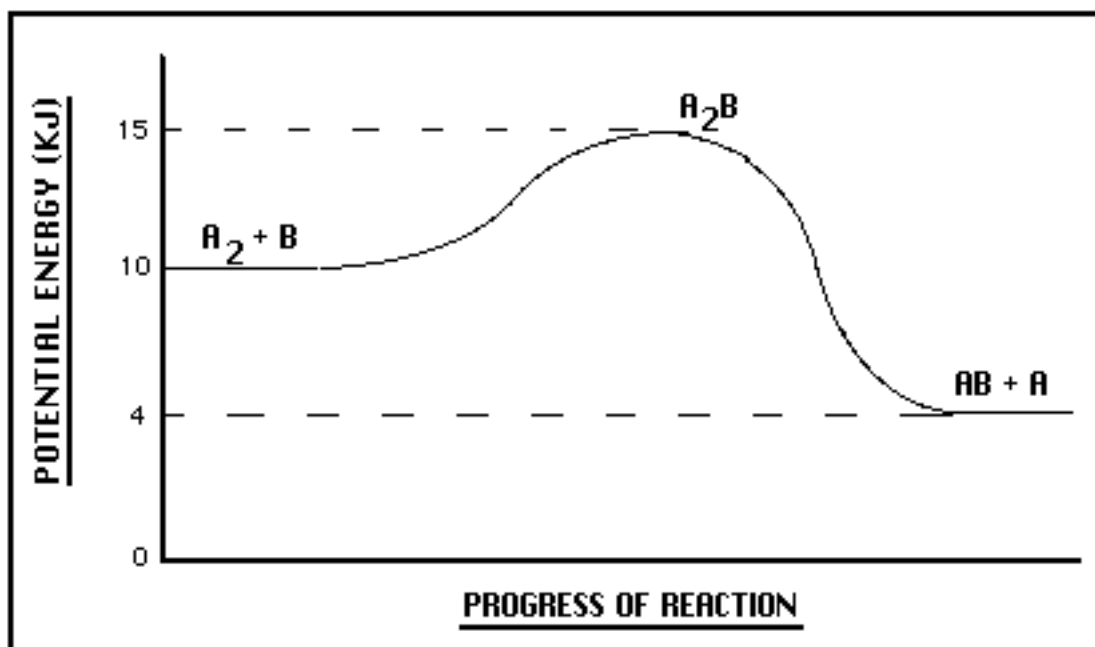
8. What might be done to a *solid catalyst* in order to make it more efficient?

9. a) The following diagram shows a graph of *Number of Particles* vs. the *Kinetic Energy* for a sample of molecules colliding:



Approximately what fraction of the molecules in the sample have enough energy for an effective collision?

- b) On the diagram in question "a", draw the curve you would expect at a higher temperature in which the rate of the reaction is **doubled**. *Be careful to be accurate! Label it.*
10. a) When *two moles of A* react with *one mole of B*, a reaction occurs in which *three moles of C* are formed and *34.5 kJ of heat are given off*. Write an equation for this reaction showing the heat of reaction ( $\Delta H$ ) at the right of the equation.
- \_\_\_\_\_
- b) Write a **thermochemical equation** for the reaction in (a) (ie. the Heat Term is right in the equation.)
- \_\_\_\_\_
- c) Write a thermochemical equation which shows what happens when *3 moles of C decompose* to form *two moles of A* and *1 mole of B*. (See the reaction in "b")
- \_\_\_\_\_
- d) What would happen to the **temperature** of the surroundings if the reaction mentioned in "a" was carried out? \_\_\_\_\_ This type of reaction which **releases heat** is called \_\_\_\_\_.
- e) In the reaction mentioned in question "a" which has **more enthalpy**, the reactants or the products? \_\_\_\_\_
- f) What is meant by **enthalpy**? \_\_\_\_\_
11. Use the following **Potential Energy Diagram** to answer all the questions below:



- a) What is the value of  $\Delta H$  for the *forward* reaction ? \_\_\_\_\_
- b) What is the value of the **activation energy** for the *forward* reaction? \_\_\_\_\_
- c) What is the value of the **activation energy** for the *reverse* reaction? \_\_\_\_\_
- d) Which is a *stronger* bond, A--A or A--B ? \_\_\_\_\_
- e) Explain your answer to (d)

\_\_\_\_\_

\_\_\_\_\_

- f) Which species is the **activated complex**? \_\_\_\_\_
- g) Which set of species has the **lowest potential energy**? \_\_\_\_\_
- h) Is the reaction as written *endothermic* or *exothermic*? \_\_\_\_\_
- i) What is the *minimum energy needed to start* the reaction  $AB + A \rightarrow A_2 + B$  ? \_\_\_\_\_
- j) What happens to the **kinetic energy** (speed) of AB and A as the reaction on as shown on the graph proceeds past the activated complex and toward the products?
- \_\_\_\_\_
- k) For  $A_2$  and B to form the *activated complex* they must have the proper *energy* and the proper \_\_\_\_\_
- l) If a catalyst C is used in this reaction, it takes place by means of a different mechanism. This one involves two steps.



*Draw another curve on the graph with another colour showing the **catalyzed** reaction. (Remember it has two steps so it should have two bumps! Also be aware that one of the bumps is higher than the other!)*

- m) Which step in question (l) is the rate determining step? \_\_\_\_\_
- n) Looking at only the equations for the steps in question "l", how could one tell that "C" is a catalyst?
- \_\_\_\_\_
- \_\_\_\_\_
- o) What is  $\Delta H$  for the reverse reaction to what is shown on the graph? \_\_\_\_\_

- p) What effect did the *catalyst* have on the *activation energy* for the *forward* reaction?

\_\_\_\_\_

For the reverse reaction? \_\_\_\_\_

- q) What effect did the catalyst have on the  $\Delta H$  of the forward reaction? \_\_\_\_\_

The reverse reaction? \_\_\_\_\_

12. Name four instances in which *catalysts* are used in industry or everyday life and tell *which catalysts* are used.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

13. Describe what happens to the *kinetic energy*, *potential energy* and the *total energy* of reactant molecules as they approach each other.
14. Explain *why* a lower *activation energy* for a reaction leads to a greater reaction rate at a given temperature.
15. A small piece of zinc reacts with 2.0 M HCl to produce 12.0 mL of H<sub>2</sub> gas in 30.0 seconds at STP. Calculate the *rate of reaction* @ STP.
- a) In mL of H<sub>2</sub>/second
- b) In *moles of H<sub>2</sub>/second*
16. Which of the following reactions is *most likely* to have the *greatest rate* at room temperature?
- a)  $\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$
- b)  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g})$
- c)  $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
- d)  $\text{Fe}(\text{s}) + \text{S}(\text{s}) \rightarrow \text{FeS}(\text{s})$

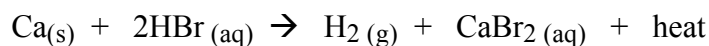
Explain how you arrived at your answer. \_\_\_\_\_

\_\_\_\_\_

17. State whether the following are *endothermic* or *exothermic*.

- a)  $\text{S} + \text{O}_2 \rightarrow \text{SO}_2 \quad \Delta H = -297 \text{ kJ}$  \_\_\_\_\_
- b)  $\text{NO}_2 + 33.8 \text{ kJ} \rightarrow \frac{1}{2} \text{N}_2 + \text{O}_2$  \_\_\_\_\_
- c)  $\text{N}_2 + \text{O}_2 + 90.4 \text{ kJ} \rightarrow 2\text{NO}$  \_\_\_\_\_
- d)  $\text{N}_2\text{H}_4 + \text{O}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O} + 627.6 \text{ kJ}$  \_\_\_\_\_

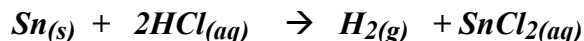
18. Consider the reaction:



State whether the following changes would *increase the rate* or not?:

- a) Let the  $\text{CaBr}_2$  solution evaporate without changing the temperature. \_\_\_\_\_
- b) Allow the  $\text{H}_2(g)$  to escape ..... \_\_\_\_\_
- c) Decrease the temperature. .... \_\_\_\_\_
- d) Increase the temperature. .... \_\_\_\_\_
- e) Increase the  $[\text{HBr}]$  . .... \_\_\_\_\_

19. Consider the *rate* of the following reaction:



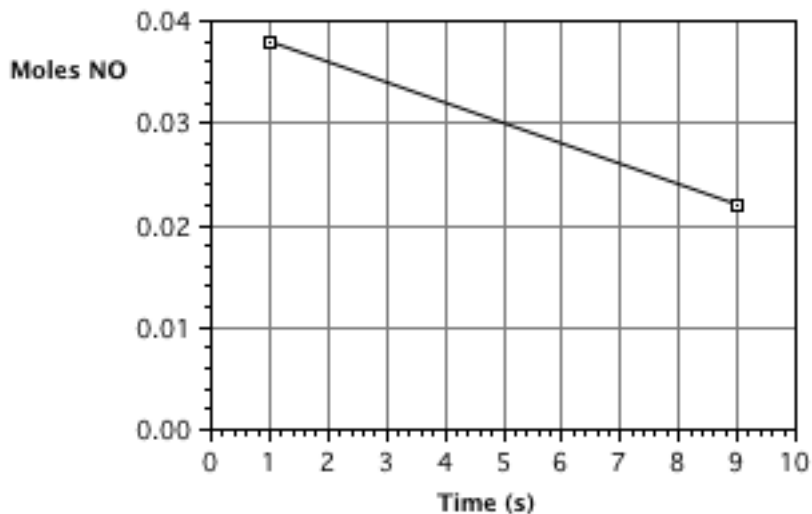
- a) Is it dependent on *temperature*? \_\_\_\_\_. Explain your answer.
- b) Is it dependent on *pressure*? \_\_\_\_\_. Explain your answer.
- c) Is it dependent on *surface area*? \_\_\_\_\_. Explain your answer.



20. Consider the following reaction:

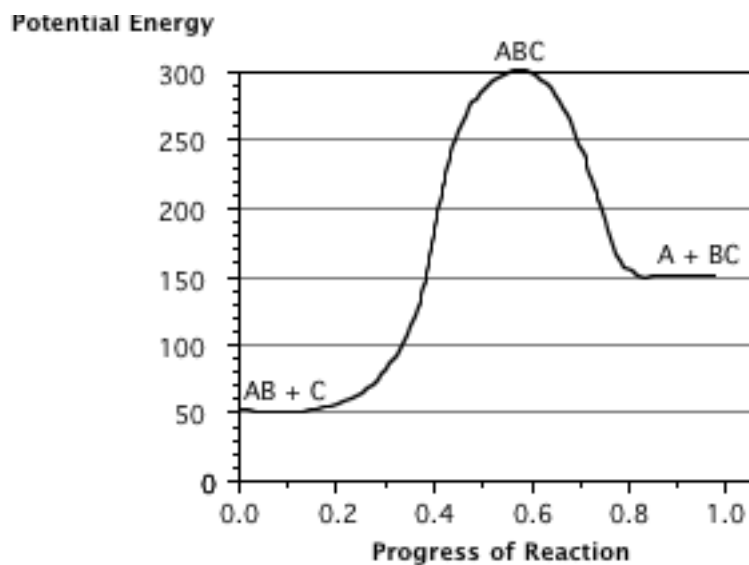


Data collected for the above reaction was used to construct the following graph:



From this graph, determine the **rate of reaction** in moles of NO consumed per second.

21. Use the following **Potential Energy Diagram** to answer the questions below:



- Determine the **Activation Energy** for the *forward* reaction... \_\_\_\_\_ kJ
- Determine the **Activation Energy** for the *reverse* reaction.... \_\_\_\_\_ kJ
- What is the **Enthalpy Change** ( $\Delta H$ ) for the *forward* reaction?.. \_\_\_\_\_ kJ
- What is the **Enthalpy Change** ( $\Delta H$ ) for the *reverse* reaction?.. \_\_\_\_\_ kJ

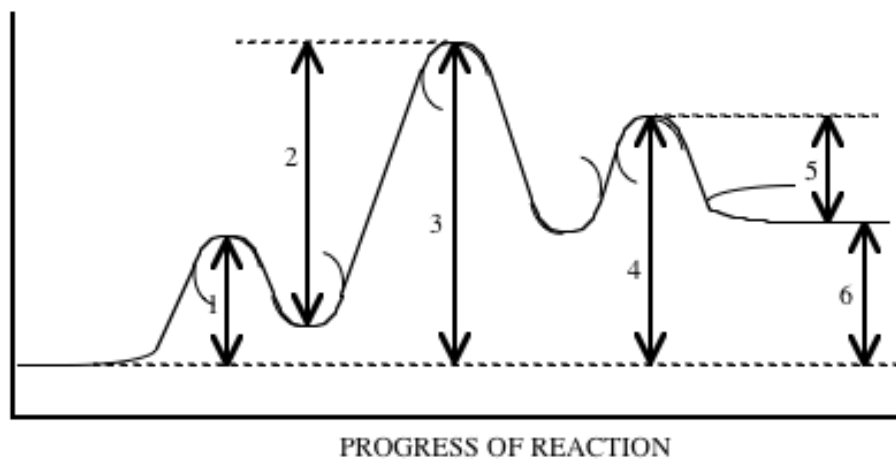
- e) The *forward* reaction is \_\_\_\_\_ thermic.
- f) The *reverse* reaction is \_\_\_\_\_ thermic.
- g) Which species or set of species forms the **Activated Complex**? \_\_\_\_\_
- h) Which bond is *stronger*, A--B or B--C? \_\_\_\_\_. Give a reason for your answer. \_\_\_\_\_
- i) Particles from which species or set of species is moving the *fastest*? \_\_\_\_\_  
State how you arrived at your answer. \_\_\_\_\_
- j) Particles from which species or set of species is moving *most slowly*? \_\_\_\_\_  
State how you arrived at your answer. \_\_\_\_\_
- k) The compound "AB" is a gas and the element "C" is a solid. What effect would grinding "C" into a fine powder have on the graph shown here?

22. What two requirements must be met before a collision between two reactant particles is **effective**?

1. \_\_\_\_\_
2. \_\_\_\_\_

23. Describe what happens to two reactant particles which collide with *less* energy than the **Activation Energy**.

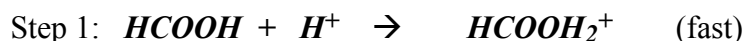
24. Given the following *Potential Energy Diagram* for a 3 step reaction, answer the questions below



- a) Which arrow indicates the *activation energy* for the *first* step of the reverse reaction? \_\_\_\_\_
- b) Which arrow indicates the *activation energy* for the *first* step of the forward reaction? \_\_\_\_\_
- c) Which arrow indicates the *activation energy* for the *second* step of the forward reaction? \_\_\_\_\_
- d) Which arrow indicates the *enthalpy change* ( $\Delta H$ ) or "*heat of reaction*" for the *overall forward* reaction? \_\_\_\_\_
- e) Which arrow indicates the *enthalpy change* ( $\Delta H$ ) or "*heat of reaction*" for the *overall reverse* reaction? \_\_\_\_\_
- f) Which arrow indicates the *activation energy* for the **overall** forward reaction? \_\_\_\_\_
- g) Which step would be the **rate determining step** in the *forward* reaction? \_\_\_\_\_

25. Given the reaction:  $\text{HCOOH} \rightarrow \text{CO} + \text{H}_2\text{O}$

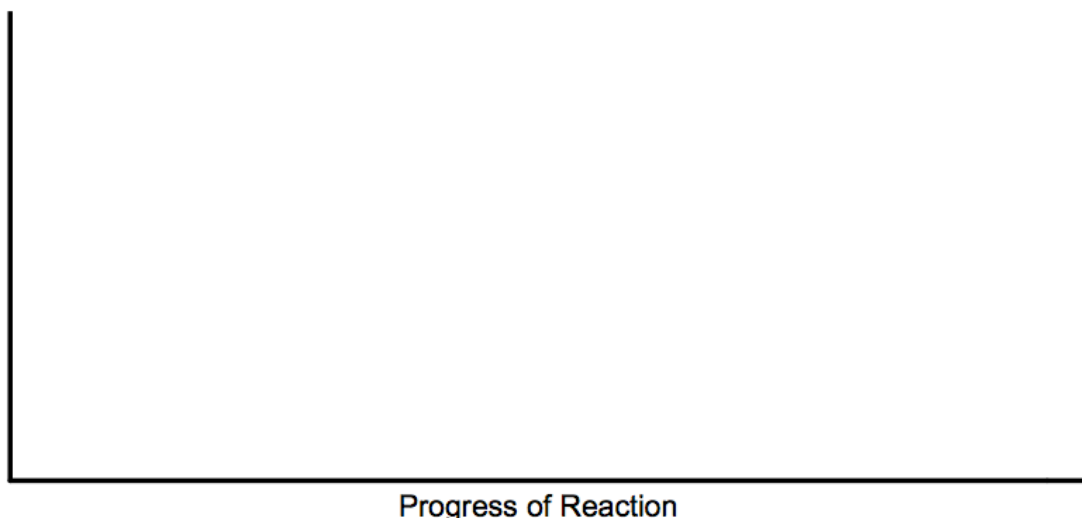
- a) This reaction, without a catalyst, is *very slow* at room temperature. Suggest why.  
\_\_\_\_\_
- b) This reaction is thought to take place by means of the following mechanism when the catalyst  $\text{H}^+$  is added:



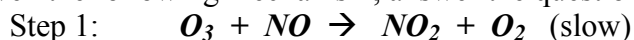
- c) Identify the two **intermediates** \_\_\_\_\_
- d) Identify the **catalyst** in this mechanism \_\_\_\_\_
- e) Another catalyst is discovered which increases the rate of only Step 1. How will this affect the rate of the *overall reaction*? \_\_\_\_\_  
Explain your answer. \_\_\_\_\_
- f) Which step has the greatest **activation energy**? \_\_\_\_\_
- g) How many "bumps" will the potential energy diagram for the catalyzed reaction have?  
\_\_\_\_\_
- h) Which step is called the **rate determining step** in this mechanism? \_\_\_\_\_
- i) In order to have successful collisions, the colliding particles must have **both** the proper amount of *energy* and the proper \_\_\_\_\_

- f) 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.

Potential  
Energy



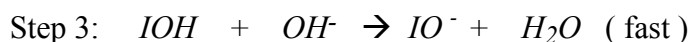
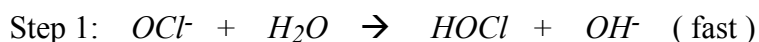
26. Given the following mechanism, answer the questions below:



- a) Give the equation for the **overall reaction**. \_\_\_\_\_
- b) What could the **catalyst** be in this mechanism? \_\_\_\_\_
- c) What is an **intermediate** in this mechanism? \_\_\_\_\_

28. 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!



- b) Which species in the mechanism above acts as a **catalyst**? \_\_\_\_\_
- c) Which three species in the mechanism above are **intermediates**? \_\_\_\_\_
- d) Step \_\_\_\_\_ 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

