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*.)

a) $Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)}$

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

or $$\text{reaction rate} = \frac{\text{volume of } H_2 \text{ produced}}{\text{unit time}}$$

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

or $$\text{reaction rate} = \frac{\text{increase in [}MgCl_2\text{]}}{\text{unit time}}$$

b) $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

c) $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

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*.)

a) $3H_{2(g)} + N_{2(g)} \rightarrow 2NH_{3(g)}$

- *pressure will <u>decrease</u> 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.*

b) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

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

1 – open system:

2 – closed system:

c) $2NO_{2(g)} \rightarrow N_2O_{4(g)}$

brown colourless

<u>Two</u> 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:

$Be_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + BeCl_{2(aq)}$

A piece of beryllium is dropped into 1.00 L of $HCl_{(aq)}$ 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 *<u>grams</u> of Be consumed per second.*

b) Calculate the ***Rate of Reaction*** in *<u>moles</u> of Be consumed per second.*

c) What will happen to the [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.

   _____

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

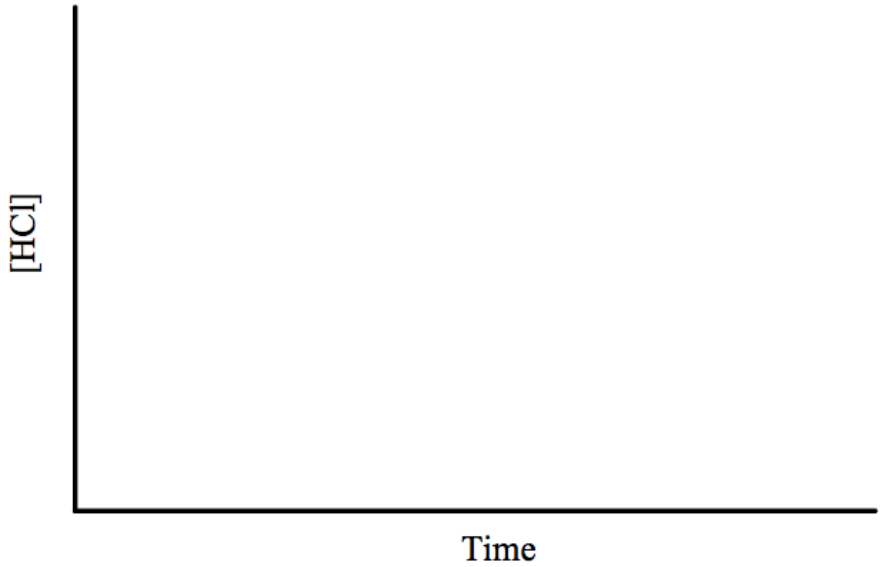
   c) If pentane is consumed at an average rate of 0.030 moles/s, determine the rate of consumption of *oxygen* in moles/s.

   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:

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$$



Explain how you got that particular shape. Be detailed.

6. How many possible collisions are there between 3 H_2 molecules and 3 I_2 molecules? (*a diagram may help*)

7. a) In a room filled with H_2 and O_2 there are about $\boldsymbol{10^{32}}$ collisions per second. Explain why the reaction between H_2 and 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*.

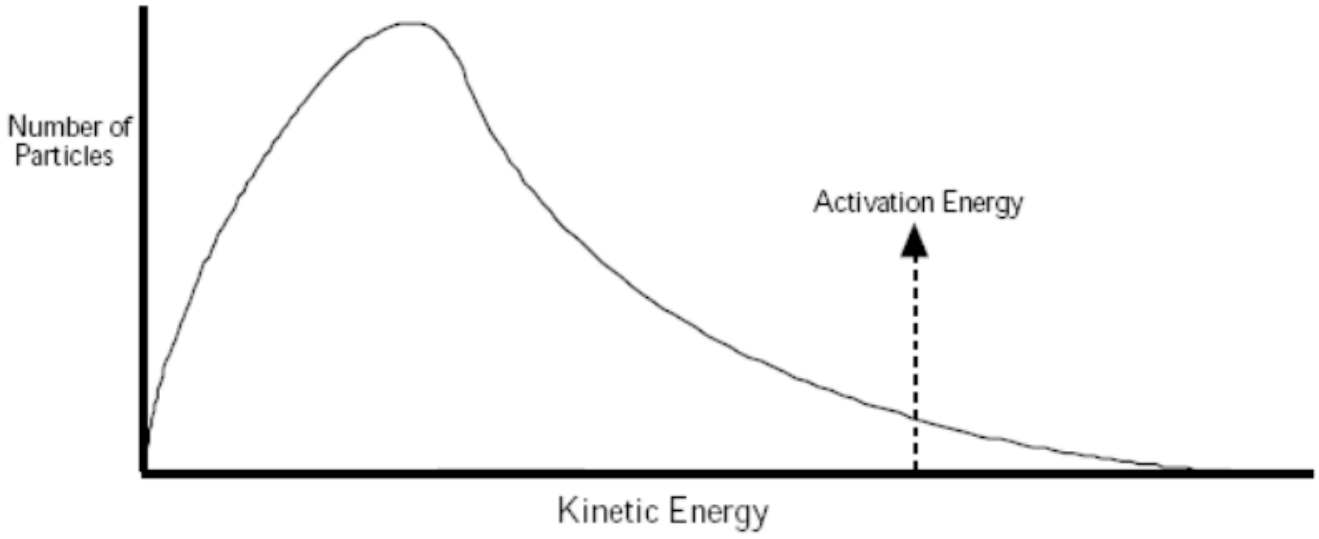
1._____

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 (ΔH) 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")*

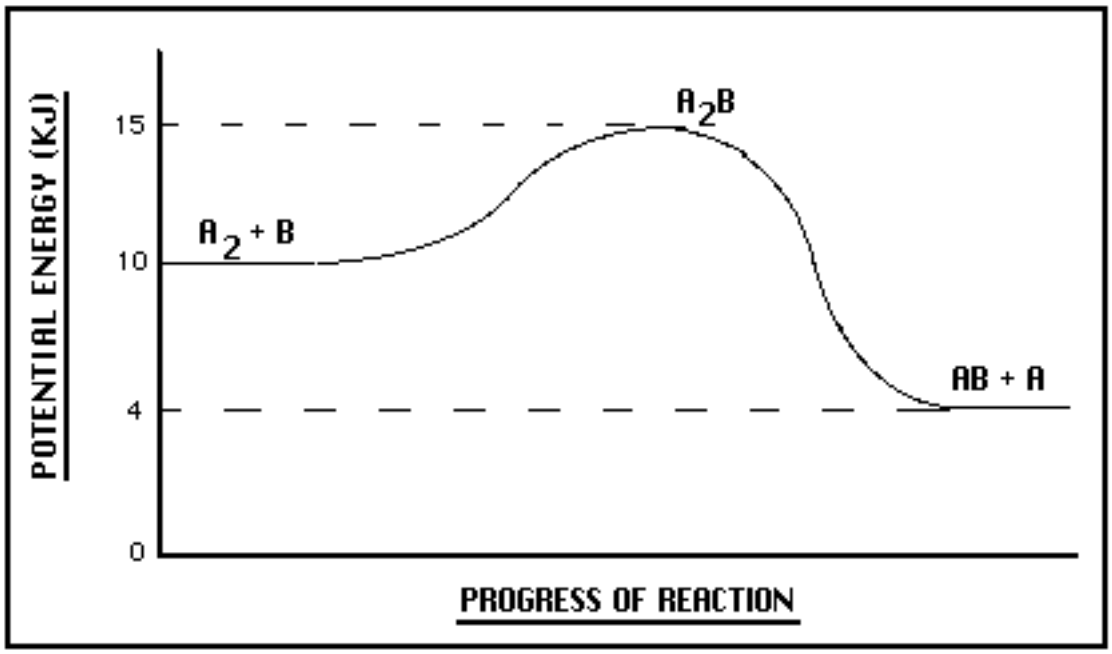
_____

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 ΔH 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.

$A_2 + C \rightarrow AC + A$ (slow)

$AC + B \rightarrow AB + C$ (fast)

Draw another curve on the graph with another colour showing the ***catalyzed*** *reaction. (Remember it has <u>two</u> steps so it should have <u>two bumps</u>! Also be aware that one of the bumps is <u>higher</u> 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 ΔH 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 ΔH 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_2 gas in 30.0 seconds at STP. Calculate the ***rate of reaction*** @ STP.

a) In mL of H_2/second

b) In ***moles of H_2/second***

16. Which of the following reactions is ***most likely*** to have the *greatest rate* at room temperature?

a) $Ag^+_{(aq)} + I^-_{(aq)} \rightarrow AgI_{(s)}$

b) $H_{2\,(g)} + Cl_{2\,(g)} \rightarrow 2HCl_{\,(g)}$

c) $C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4H_2O_{\,(g)}$

d) $Fe_{\,(s)} + S_{(s)} \rightarrow FeS_{\,(s)}$

Explain how you arrived at your answer._____

_____

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

a) $S + O_2 \rightarrow SO_2 \quad \Delta H = -297$ kJ _____

b) $NO_2 + 33.8$ kJ $\rightarrow 1/2\ N_2 + O_2$ _____

c) $N_2 + O_2 + 90.4$ kJ $\rightarrow 2NO$ _____

d) $N_2H_4 + O_2 \rightarrow N_2 + H_2O + 627.6$ kJ _____

18. Consider the reaction:

$Ca_{(s)} + 2HBr_{(aq)} \rightarrow H_{2\,(g)} + CaBr_{2\,(aq)} +$ heat

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

a) Let the $CaBr_2$ solution evaporate without changing the temperature. _____

b) Allow the $H_{2\,(g)}$ to escape …….. _____

c) Decrease the temperature. ..... _____

d) Increase the temperature. ..... _____

e) Increase the [HBr] . ..... _____

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

$$\boldsymbol{Sn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + SnCl_{2(aq)}}$$

a) Is it dependent on *temperature*? _____. Explain your answer.

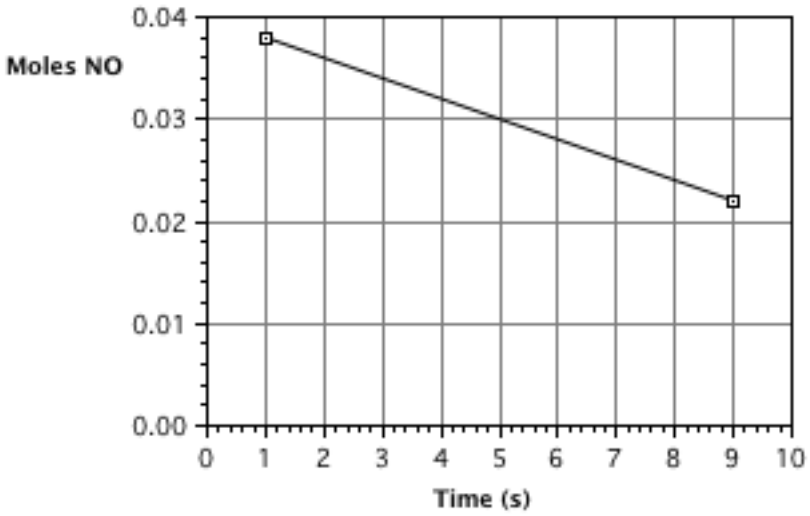
b) Is it dependent on *pressure*? _____. Explain your answer.

c) Is it dependent on *surface area*? _____. Explain your answer.

20. Consider the following reaction:

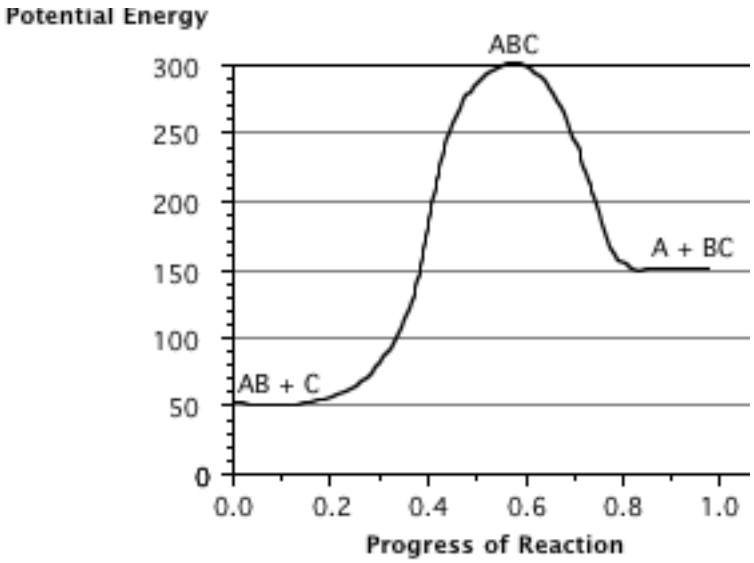
$$2NO_{(g)} + 2H_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$$

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:



a) Determine the ***Activation Energy*** for the *forward* reaction... _____kJ

b) Determine the ***Activation Energy*** for the *reverse* reaction.... _____kJ

c) What is the ***Enthalpy Change*** (ΔH) for the *forward* reaction?.._____kJ

d) What is the ***Enthalpy Change*** (ΔH) 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?

_____

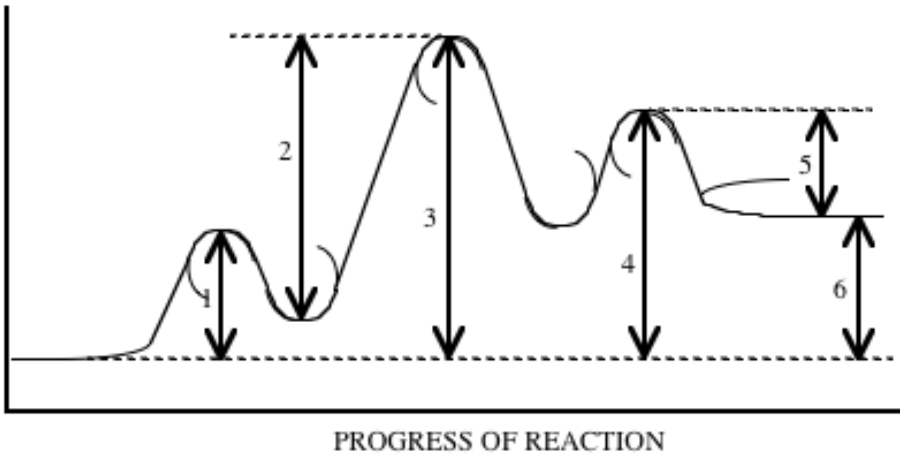
22. What two requirements must be met before a collision between two reactant particles is ***effective***?

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* (ΔH) *or "heat of reaction"* for the *overall* **forward** reaction? _____

e) Which arrow indicates the *enthalpy change* (ΔH) *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: $HCOOH \rightarrow CO + H_2O$

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 H^+ is added:

Step 1: $HCOOH + H^+ \rightarrow HCOOH_2^+$ (fast)

Step 2: $HCOOH_2^+ \rightarrow H_2O + HCO^+$ (slow)

Step 3: $HCO^+ \rightarrow CO + H^+$ (fast)

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***? _____

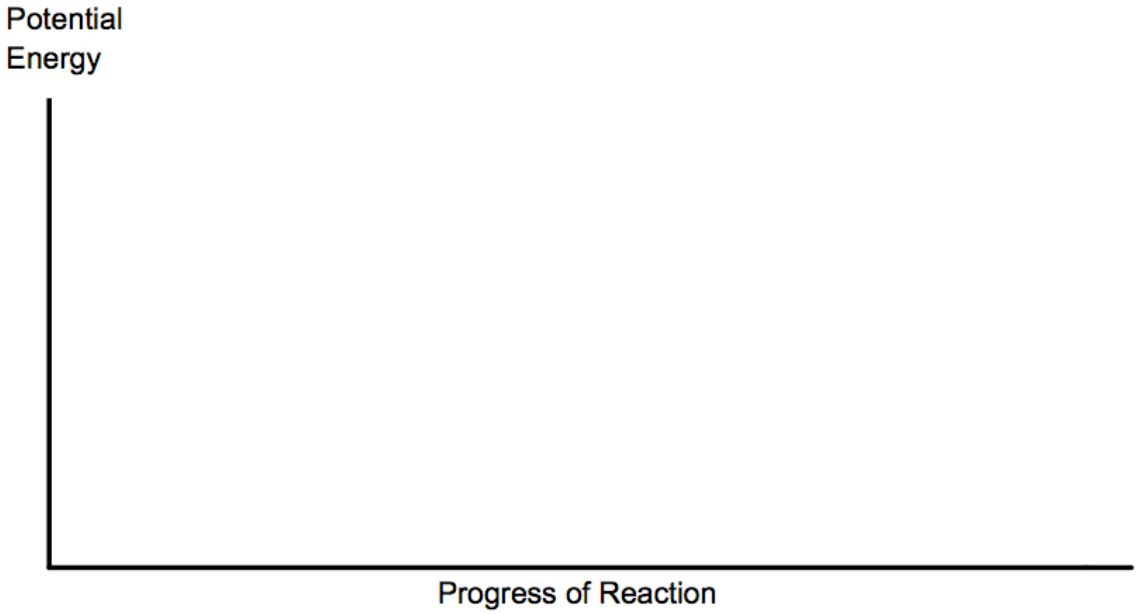
g) How many "bumps" will the potential energy diagram for the catalyzed reaction have?

_____

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.



26. 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***. _____

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!

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

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

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

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.