KEY

# Chemistry 12
# Review Sheet on Unit 1 -Reaction Kinetics

1. Looking at the expressions for reaction rate on page 1 SW, write similar 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) $Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)}$

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

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

b) $(Ag^+ + NO_3^- + Na^+ + Cl^- \rightarrow Na^+ + NO_3^- + AgCl)$
$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

$r = \frac{\text{decrease } [Ag^+]}{\text{unit time}}$ $r = \frac{\text{decrease } [Cl^-]}{\text{unit time}}$

$r = \frac{\text{increase in mass of } AgCl_{(s)}}{\text{unit time}}$

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

$r = \frac{\text{decrease in mass of } C_{(s)}}{\text{unit time}}$

$r = \frac{\text{decrease in } [O_2]}{\text{unit time}}$ $r = \frac{\text{increase in } [CO_2]}{\text{unit time}}$

2. For each of the following reactions find a ***quantity*** or ***property*** which could be monitored in order to measure the rate of reaction See p. 2-5 in SW. (*"a" is done as an example.*)

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

*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.*

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

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

Total mass of container and contents (open system) will decrease as $CO_{2(g)}$ escapes.
Total pressure will increase (closed system) as $CO_{2(g)}$ is formed.

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

*Two things could be monitored here. One is obvious. Look at*

- Colour will lighten as reaction proceeds
total pressure will decrease (closed system) as 2 moles of gas produce 1 mole of gas

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 *grams of Be consumed per second.*

$r = \frac{0.010\,g}{20\,s} = 5 \times 10^{-4}\,g/s$

Answer $5 \times 10^{-4}$ g of Be/s

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

$$\frac{5\times10^{-4}\text{ g Be}}{\text{s}} \times \frac{\text{mol Be}}{9.0\text{ g Be}} = \frac{6\times10^{-5}\text{ mol Be}}{\text{s}}$$

Answer $6\times10^{-5}$ mol Be/s

c) What will happen to the [HCl] as the reaction proceeds? it will decrease as it is consumed.

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.

$$C_5H_{12} + 8O_2 \longrightarrow 5CO_2 + 6H_2O$$

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

$$\frac{2.16\text{ g } C_5H_{12}}{\text{s}} \times \frac{\text{mol } C_5H_{12}}{72.0\text{ g } C_5H_{12}} = \frac{0.0300\text{ mol } C_5H_{12}}{\text{s}}$$

Answer 0.0300 mol $C_5H_{12}$/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.

$$\frac{0.030\text{ mol } C_5H_{12}}{\text{s}} \times \frac{8\text{ mol } O_2}{1\text{ mol } C_5H_{12}} = \frac{0.24\text{ mol } O_2}{\text{s}}$$

Answer 0.24 mol $O_2$/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.

$$\frac{0.030\text{ mol } C_5H_{12}}{\text{s}} \times \frac{5\text{ mol } CO_2}{1\text{ mol } C_5H_{12}} = \frac{0.15\text{ mol } CO_2}{\text{s}}$$

Answer 0.15 mol $CO_2$/s

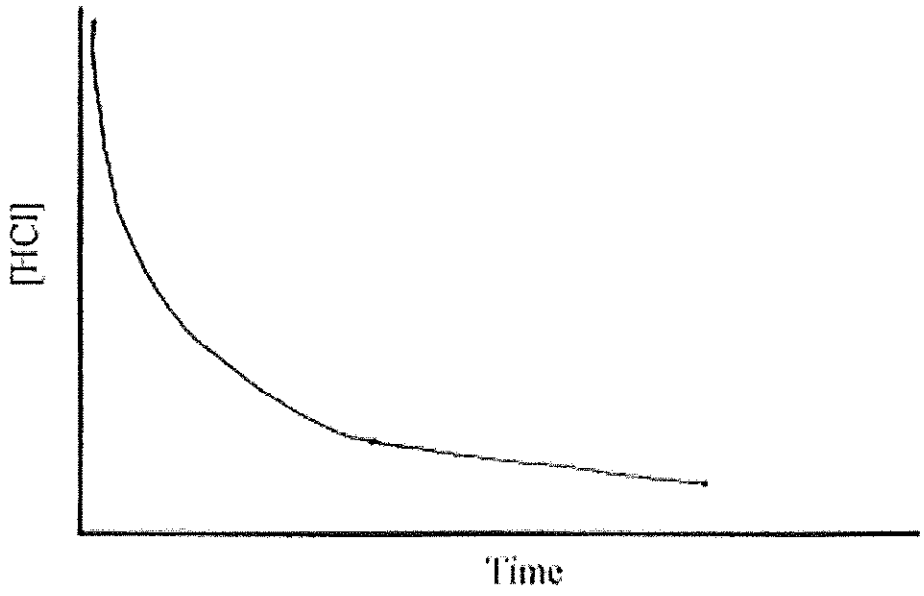
e) If pentane is consumed at an average rate of 0.030 moles/s, determine the rate of production of $CO_2$ in *grams/s*.

$$\frac{0.15\text{ mol } CO_2}{\text{s}} \times \frac{44.0\text{ g } CO_2}{1\text{ mol } CO_2} = \frac{6.6\text{ g } CO_2}{\text{s}}$$

Answer 6.6 g $CO_2$/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:

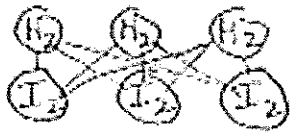
$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$$




Explain how you got that particular shape. Be detailed.

At first rate is high as [HCl] is high so the slope is steeper. As the reaction proceeds HCl is used up so [HCl] decreases. The rate slows down, so the slope $\left(\frac{\Delta[HCl]}{\Delta time}\right)$ gets less steep.

6. How many possible collisions are there between 3 $H_2$ molecules and 3 $I_2$ molecules? *(a diagram may help)* 9 possible collisions




7. a) In a room filled with $H_2$ and $O_2$ there are about $10^{32}$ collisions per second. Explain why the reaction between $H_2$ and $O_2$ at room temperature is so *slow* as to be unnoticeable!

Very, very few of the collisions are successful (energy $\geq E_a$)

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

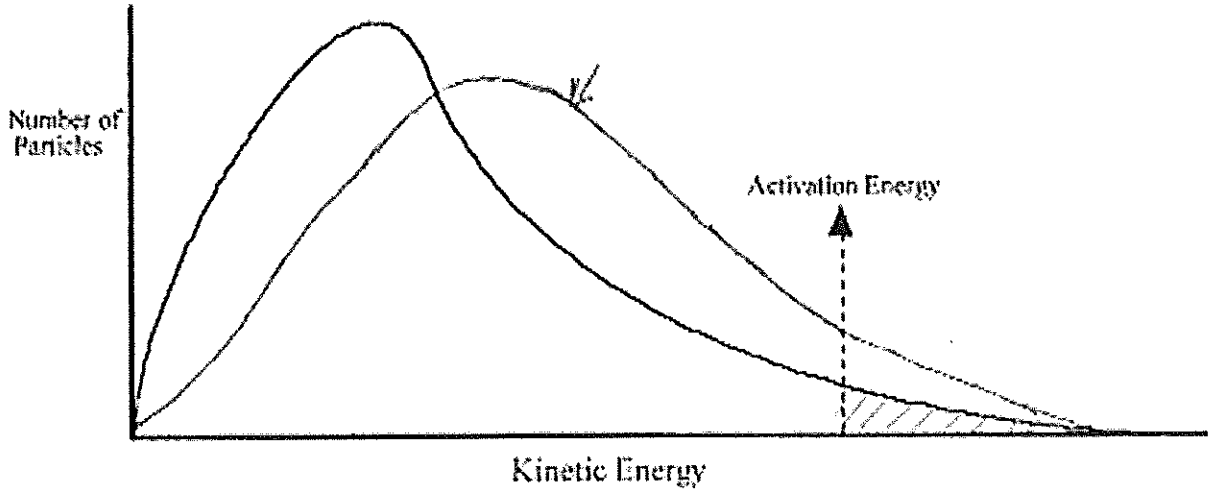
1. increase temperature
2. introduce a catalyst (eg. Platinum)

KEY

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

grind it into powder (inc. surface area)

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?

Answer ~1/10 to 1/15 th

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.

$2A + B \rightarrow 3C \quad \Delta H = -34.5\ kJ$

b) Write a ***thermochemical equation*** for the reaction in (a) *(ie. the Heat Term is right in the equation.)*

$2A + B \rightarrow 3C + 34.5\ kJ$

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")*

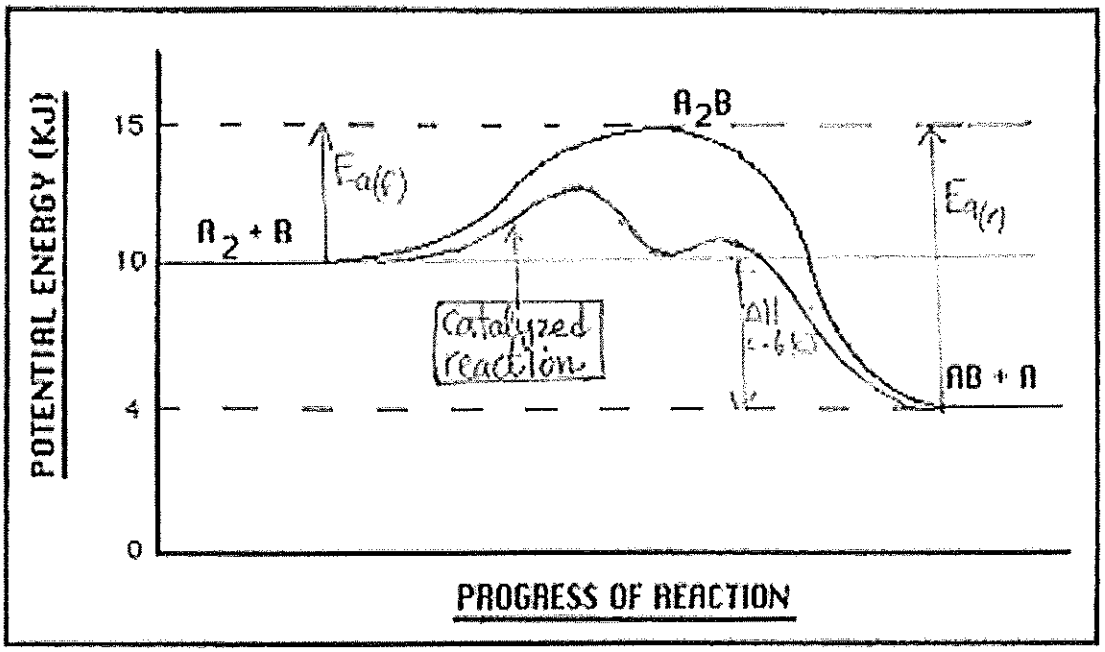
$34.5kJ + 3C \rightarrow 2A + B$

d) What would happen to the *temperature* of the surroundings if the reaction mentioned in "a" was carried out? warmer This type of reaction which ***releases heat*** is called exothermic

e) In the reaction mentioned in question "a" which has *more* ***enthalpy***, the reactants or the products? reactants

f) What is meant by ***enthalpy***? (*Look it up!*) (heat content) the total energy contained in a system

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 ? Answer -6 KJ

b) What is the value of the ***activation energy*** for the *forward* reaction? Answer +5 KJ

c) What is the value of the ***activation energy*** for the *reverse* reaction? Answer +11 KJ

d) Which is a *stronger* bond, A--A or A--B ? Answer A-B

e) Explain your answer to (d)

It takes more energy (11 kJ) to break the bond in A-B than in $A_2$ (5 kJ)

f) Which species is the ***activated complex***? $A_2B$

g) Which set of species has the ***lowest potential energy***? Answer AB + A

h) Is the reaction as written *endothermic* or *exothermic*? Answer exothermic

i) What is the *minimum energy needed* to *start* the reaction $AB + A \rightarrow A_2 + B$?

Answer 11 kJ ($E_{act}$)

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?

Answer the KE increases

k) For $A_2$ and B to form the *activated complex* they must have the proper *energy* and the proper collision geometry

l) If a catalyst C is used in this reaction, it takes place by means of a different

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

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

*Draw another curve on the graph with another colour showing the* ***catalyzed***

m) Which step in question (l) is the rate determining step? Answer step 1

n) Looking at only the equations for the steps in question "l", how could one tell that "C" is a catalyst?

it is introduced (used up) in step 1 and regenerated (given off) in a later step (step 2)

o) What is ΔH for the reverse reaction to what is shown on the graph? Answer +6 KJ

p) What effect did the *catalyst* have on the *activation energy* for the *forward* reaction? decreased the Ea(f)

For the reverse reaction? decreased the Ea(r)

q) What effect did the catalyst have on the ΔH of the forward reaction? no effect

The reverse reaction? no effect

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

$V_2O_5$ used in making sulphuric acid/step $2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$

maltase breaks down maltose to simple sugar (glucose)

nickel used to hydrogenate unsaturated fats

Pt, Pd, Rh used in catalytic converters to break down $NO_2$ in exhaust

13. Describe what happens to the ***kinetic energy***, ***potential energy*** and the ***total energy*** of reactant molecules as they approach each other.

KE decreases PE increases TE remains constant.

14. Explain *why* a lower ***activation energy*** for a reaction leads to a greater reaction rate at a given temperature.

molecular collisions do require as high an energy to be successful so at a particular temp. a greater fraction of the molecules will have enough energy

15. A small piece of zinc react with 2.0 M HCl to produce 12.0 mL of $H_2$ gas in 30.0 seconds. Calculate the ***rate of reaction***

a) In mL of $H_2$/second $\frac{12.0\ mL\ H_2}{30.0\ s} = 0.400\ mL\ H_2/s$

Answer 0.400 mL $H_2$/s

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

$0.400\ mL\ H_2/s \times \frac{1\ L}{1000\ mL} \times \frac{1\ mol}{22.4\ L} = 1.79 \times 10^{-5}\ mol\ H_2/s$

Answer $1.79 \times 10^{-5}$ mol $H_2$/s

KEY

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

Answer a. Explain how you arrived at your answer. both aqueous ions (mobile) - no bonds to break (b & c have covalent bonds, d has solids)

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

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

b) $NO_2 - 33.8$ kJ $\rightarrow 1/2\ N_2 + O_2$ — exo (strange way to write it)

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

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

18. Consider the reaction:

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

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

a) Let the $CaBr_2$ solution evaporate without changing the temperature. — no effect

b) Allow the $H_{2\,(g)}$ to escape ..... — no effect

c) Decrease the temperature. ..... — decrease rate

d) Increase the temperature. ..... — increase rate

e) Increase the [HBr]. ..... — increase rate

KEY

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

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

a) Is it dependent on *temperature*? Yes. Explain your answer.
Mostly all reactions are temperature dependent.

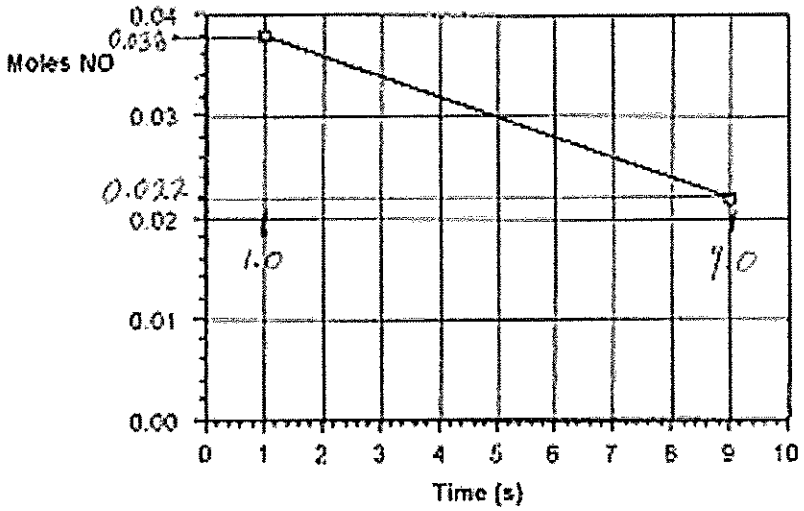
b) Is it dependent on *pressure*? No. Explain your answer.
No gaseous reactants

c) Is it dependent on *surface area*? Yes. Explain your answer.
Heterogeneous reactions. (s) and (aq) reactants

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.*

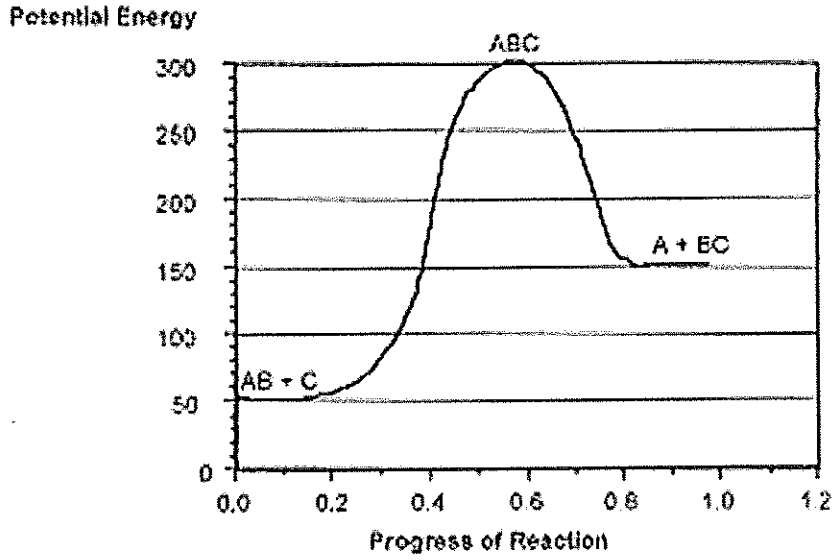
Slope = $-\frac{(0.038 - 0.022)\ mol}{(9.0 - 1.0)\ s} = \frac{0.016\ mol}{8\ s} = -0.002\ mol\ NO/s$

Answer 0.002 mol NO/s

So rate = 0.002 mol NO/s

KEY

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




a) Determine the ***Activation Energy*** for the *forward* reaction... + 250 kJ

b) Determine the ***Activation Energy*** for the *reverse* reaction.... +150 kJ

c) What is the ***Enthalpy Change*** ($\Delta H$) for the *forward* reaction?.. +100 kJ

d) What is the ***Enthalpy Change*** ($\Delta H$) for the *reverse* reaction?.. -100 kJ

e) The *forward* reaction is endo thermic.

f) The *reverse* reaction is exo thermic.

g) Which species or set of species forms the ***Activated Complex?*** ABC

h) Which bond is *stronger*, A--B or B--C? A-B. Give a reason for your answer. It takes more energy (250 kJ) to break A-B than to break B-C (150 kJ)

i) Particles from which species or set of species is moving the *fastest*? AB+C

State how you arrived at your answer. lowest PE = highest KE

KEY

j) Particles from which species or set of species is moving *most slowly*? ABC

State how you arrived at your answer. highest PE = lowest KE

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?

no effect on the graph.

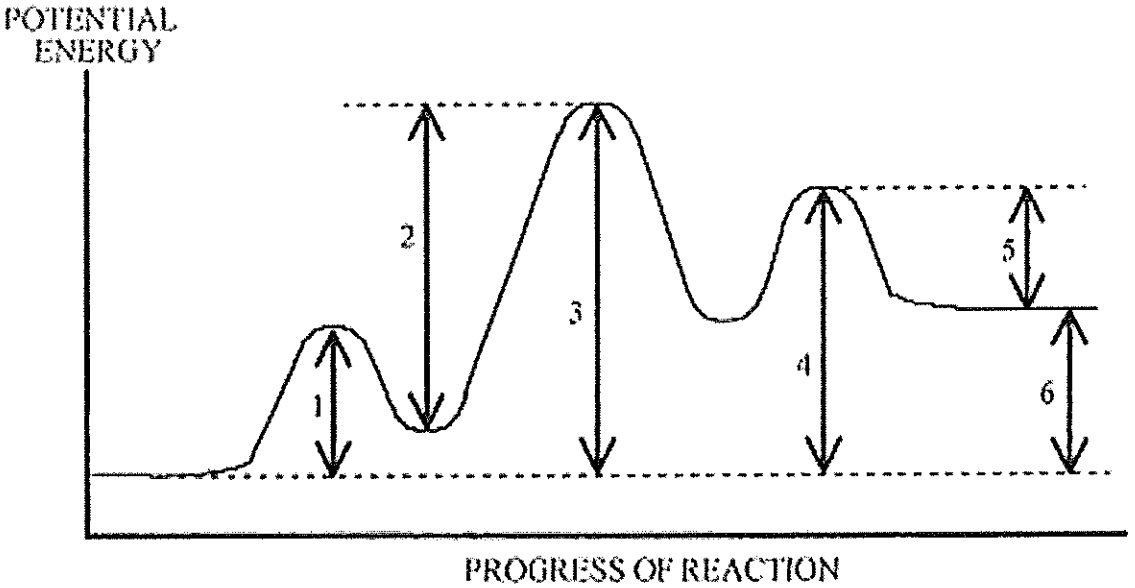
22. What two requirements must be met before a collision between two reactant particles is *effective*?

1. sufficient energy $\geq E_a$
2. proper collision geometry.

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

bounce off each other unchanged

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? 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* ($\Delta H$) *or "heat of reaction"* for the *overall* forward reaction? (6)

e) Which arrow indicates the *enthalpy change* ($\Delta H$) *or "heat of reaction"* 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? Step 2.

25. Given the reaction: $HCOOH \rightarrow CO + H_2O$

a) This reaction, without a catalyst, is *very slow* at room temperature. Suggest why. it has a very high activation energy.

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*** $HCOOH_2^+$ and $HCO^+$

d) Identify the ***catalyst*** in this mechanism $H^+$

e) Another catalyst is discovered which increases the rate of only *Step 1*. How will this affect the rate of the *overall reaction*? no effect.

Explain your answer. Speeding up the RDS (step 2) is

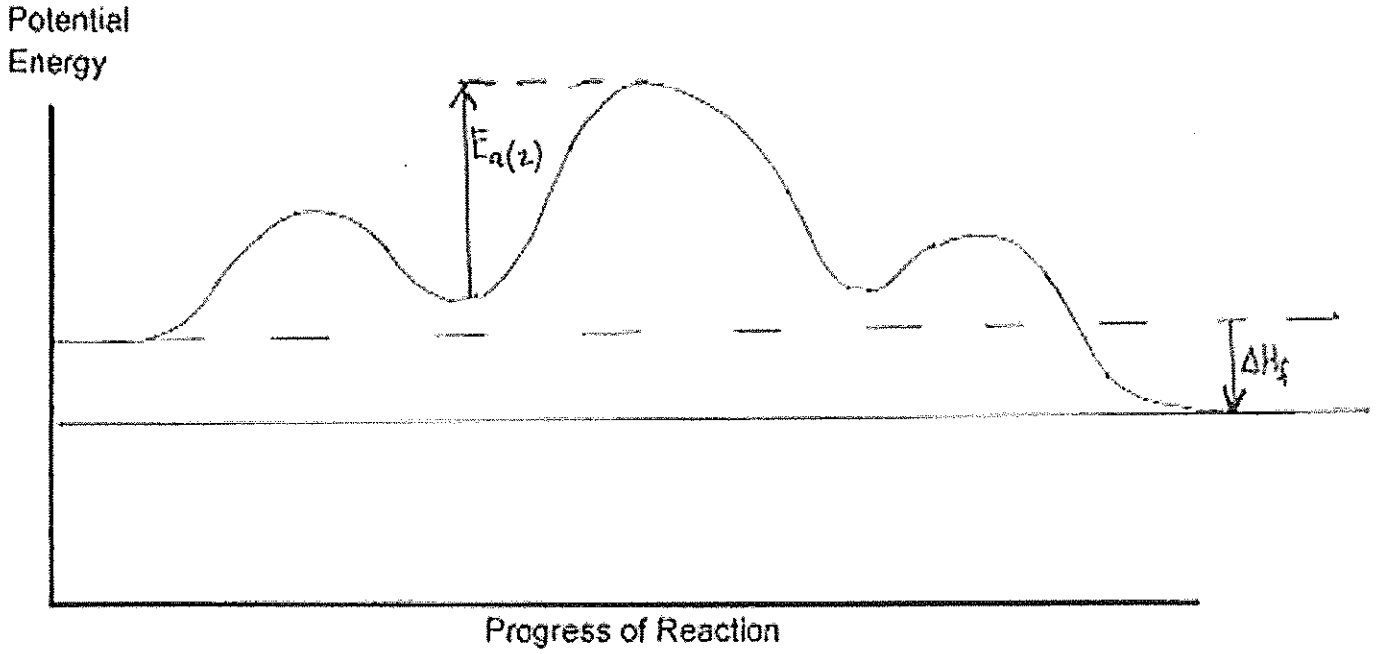
f) Which step has the greatest ***activation energy***? Step 2 (slowest)

g) How many "bumps" will the potential energy diagram for the catalyzed reaction have? 3 bumps.

h) Which step is called the ***rate determining step*** in this mechanism? Step 2.

i) In order to have successful collisions, the colliding particles must have both the proper amount of *energy* and the proper Collision geometry.

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)

$O_3 + O \rightarrow 2O_2$

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? $NO_2$

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: $I^- + \boxed{HOCl} \rightarrow (IOH) + Cl^-$ ( slow )

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

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

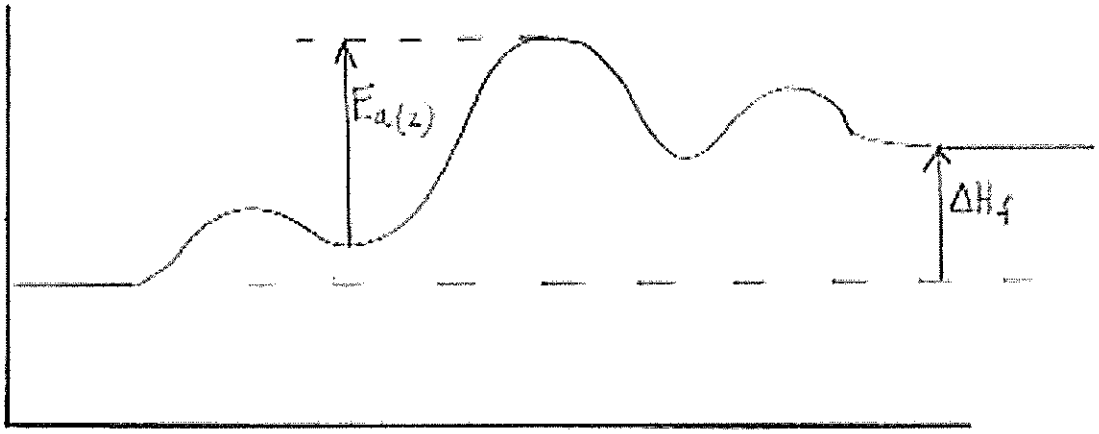
b) Which species in the mechanism above acts as a ***catalyst***? $H_2O$

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