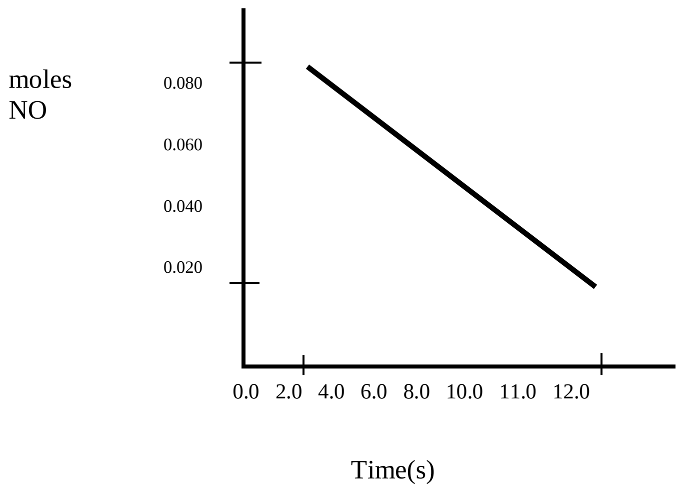
CHEMISTRY 12 – Reaction Kinetics Problem Set **Name:**

1. Given the following reaction, and the corresponding graph:

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



a) What is the rate in moles NO per second?

b) What is the rate in moles N_2 per second?

c) What is the rate in grams NO per min?

d) What is the rate in grams N_2 per hour?

2. a) Define the term "homogeneous reaction".

b) List the factors that will increase the rate of a chemical reaction that is homogeneous.

c) Define the term "heterogeneous reaction".

d) List the factors that will increase the rate of a chemical reaction that is heterogeneous.

3. Which factor will only increase the rate of a gaseous reaction? Explain.

4. State two examples of chemical reactions that are desired to be slow.

5. Give two examples of chemical reactions that are desired to be fast.

6. For each reaction specifically describe all of the ways to increase the reaction rate.

(i). $H_{2\,(g)} + F_{2\,(g)} \rightarrow 2\,HF_{(g)}$

(ii). $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

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

(iv) $H_2O_{2\,(aq)} \rightarrow H_{2\,(g)} + O_{2\,(g)}$

7. Homogeneous reactions are generally (faster/slower) than heterogeneous because the reactants are more adequately __________ and, as a result, there are more __________ between reactant particles.

8. Simple ionic reactions are generally (faster/slower) than more complex ionic reactions because there are no ___________ to break.

9. Indicate the faster and slower reaction and **explain why**.

a) $2Al_{(s)} + 3I_{2\,(s)} \rightarrow 2AlI_{3\,(s)}$ **OR** $2Na^{+}_{(aq)} + 2ClO^{-}_{(aq)} \rightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + O_2$

b) $3Ba^{+2}_{(aq)} + 2PO_4^{-3}{}_{(aq)} \rightarrow Ba_3(PO_4)_{2(aq)}$ **OR** $Cu_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Cu^{+2}_{(aq)} + 2Ag_{(s)}$

c) $2Al_{(s)} + 3I_{2\,(s)} \rightarrow 2AlI_{3\,(s)}$ **OR** $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

Given the following reactions, clearly explain the statements given using collision theory.

10. $H_2O_{2\,(aq)} \rightarrow H_2O_{(l)} + O_{2(g)}$

- H_2O_2 decomposes slowly at 20^{o} C.
- KI is added and rapid decomposition begins.

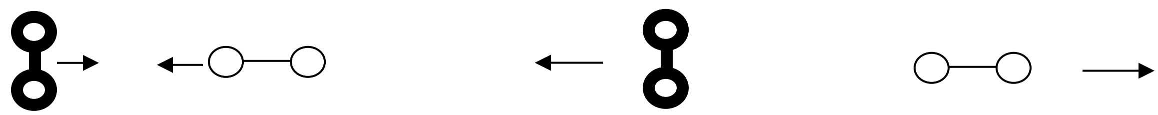
11. $H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$

- $H_{2(g)}$ and $O_{2(g)}$ in a balloon do not react.
- A spark violently ignites the balloon.

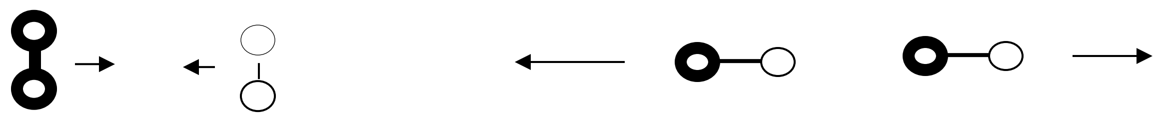
12. Both collisions A and B have the same KE. Which collision is successful and explain why.

<u>Before Collision</u> <u>After Collision</u>

A)



B)

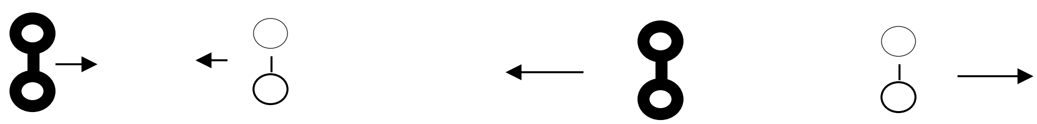


13. Explain why collision A was successful while collision B was unsuccessful.

<u>Before Collision</u> <u>After Collision</u>

A)

B)



14. Describe the PE and KE changes as reactant molecules approach each other.

15. Consider the following reaction:

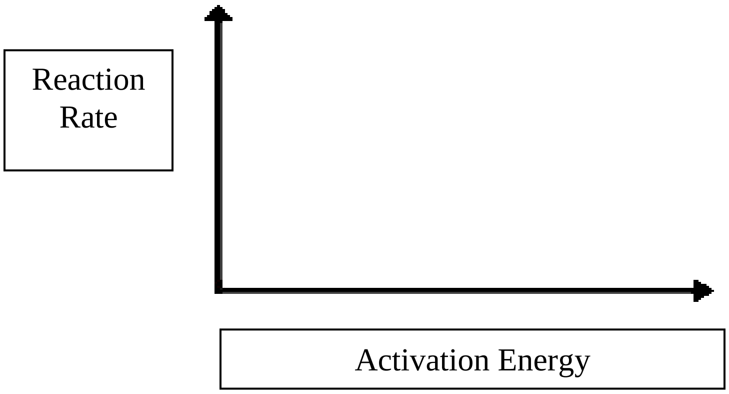
$$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$

Even though there are more than four billion collisions per second between N_2 and O_2, the amount of product after a year in our atmosphere is too small to detect. Using collision theory, give two reasons why this reaction might be slow.

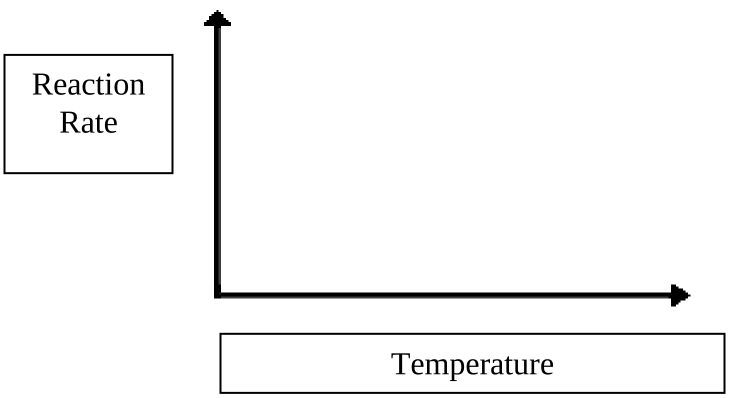
i)

ii)

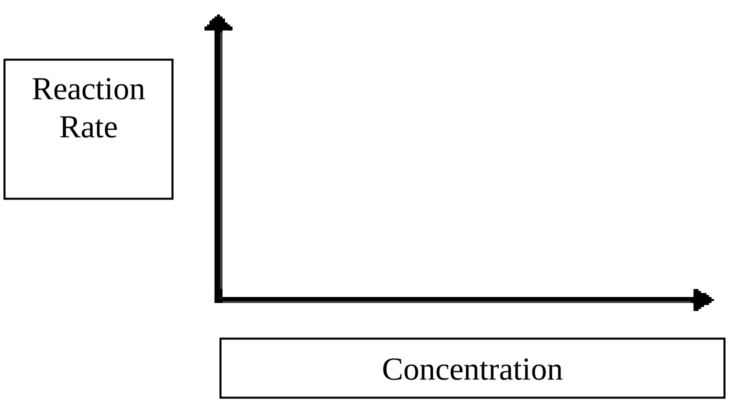
16. State the relationship between activation energy and the rate of a reaction. Sketch a graph of reaction rate vs activation energy.



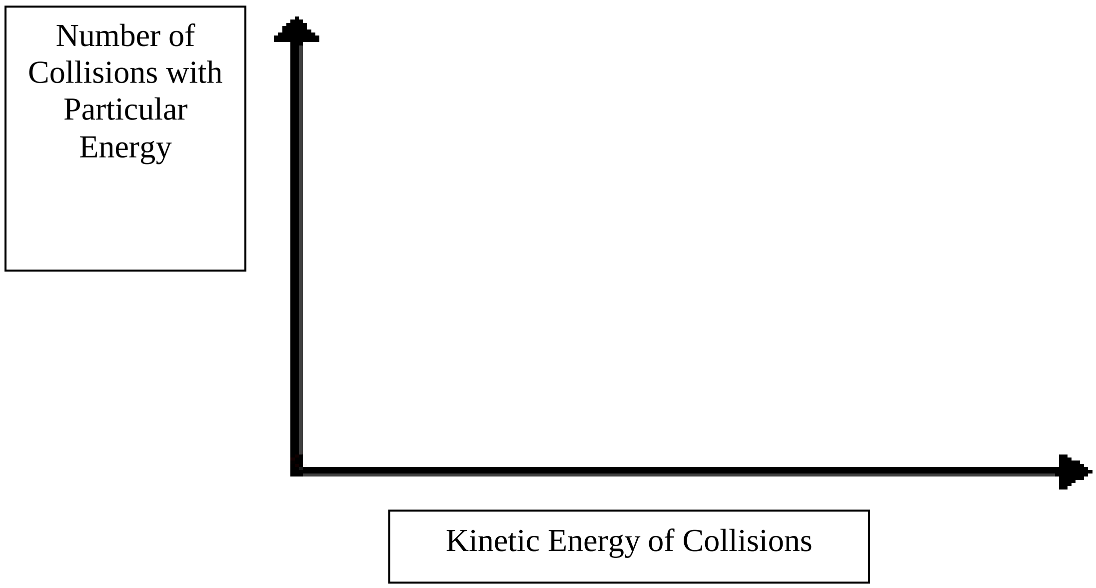
17. State the relationship between temperature and the rate of a reaction. Sketch a graph of reaction rate vs temperature



18. State the relationship between concentration and the rate of a reaction. Sketch a graph of reaction rate vs concentration.



21. (a) Draw a kinetic energy distribution curve for a reaction where the y-axis is number of collisions with a particular energy and the x-axis is the K.E. of the collision. Draw the Ea line showing about 10% of the collisions having sufficient energy. Draw the Ea line for the catalyzed reaction where 20% have sufficient energy (after the addition of a catalyst).

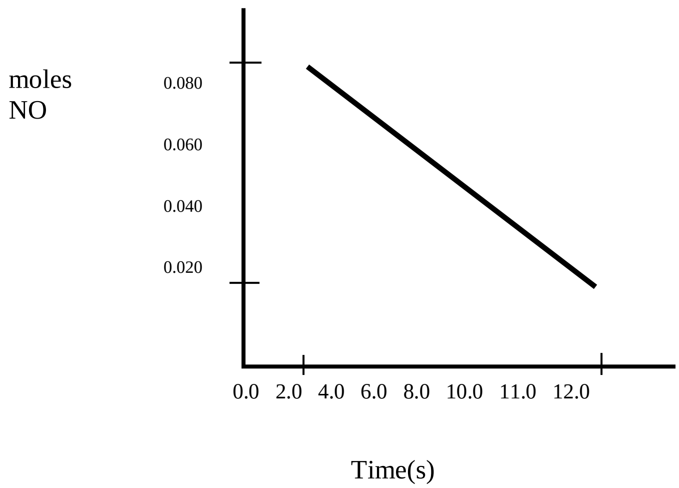


(b) Now, on the graph above, shade in the area of the collision energy distribution diagram showing those collisions that do NOT have the required energy to be successful at the temperature depicted by the graph.

CHEMISTRY 12 – Reaction Kinetics Problem Set **Name:**

1. Given the following reaction, and the corresponding graph:

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



a) What is the rate in moles NO per second?

(0.020 mol – 0.080 mol) / (12.0 s – 2.0 s) = 0.0060 mol NO/s

b) What is the rate in moles N_2 per second?

(0.0060 mol NO/s)(1 mol N_2/2 mol NO) = 0.0030 mol N_2/s

c) What is the rate in grams NO per min?

(0.0060 mol/s)(30.0g/mol)(60s/min) = 11 g/min

d) What is the rate in grams N_2 per hour?

(0.0030 mol N2/s)(28.0 g/mol)(3600s/h) = 3.0 x 10^2 g/h

2. a) Define the term "homogeneous reaction".

Reactants in the same phase (aq, l,g) and are thoroughly mixed.

b) List the factors that will increase the rate of a chemical reaction that is homogeneous.

Increase temperature, increase concentration, increase pressure or decrease volume for gaseous reactants, catalyst, nature of the reactants

c) Define the term "heterogeneous reaction".

Reactants are in 2 or more phases, and are not thoroughly mixed

d) List the factors that will increase the rate of a chemical reaction that is heterogeneous.

Same as for homogeneous reactions as well as increasing surface area and agitation (mixing)

3. Which factor will only increase the rate of a gaseous reaction? Explain.

Pressure (volume) because molecules can be compressed.

4. State two examples of chemical reactions that are desired to be slow.

Food spoiling, metal corrosion, rusting

5. Give two examples of chemical reactions that are desired to be fast.

Combustion of gasoline, digestion of food, production of chemicals (industrial processes), cooking food

6. For each reaction specifically describe all of the ways to increase the reaction rate.

(i). $H_{2\,(g)} + F_{2\,(g)} \rightarrow 2\,HF_{(g)}$

Homogeneous reaction, reactants in gas phase

- **Increase temperature**
- **Increase pressure (decrease volume)**
- **Increase concentration of a reactant, either H_2 or F_2**
- **Add a catalyst**

(ii). $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Homogeneous reaction

- **Increase temperature**
- **Increase concentration of NaOH**
- **Increase concentration of HCl**
- **Add a catalyst**

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

Heterogeneous reaction

- **Increase temperature**
- **Increase concentration of HCl**
- **Increase surface area of solid zinc**
- **Add a catalyst**
- **Stir /agitate reaction mixture**

(iv) $H_2O_{2\,(aq)} \rightarrow H_{2\,(g)} + O_{2\,(g)}$

Homogeneous reaction

- **Increase temperature**
- **Increase concentration of H_2O_2**
- **Add a catalyst**

7. Homogeneous reactions are generally (**faster**/slower) than heterogeneous because the reactants are more adequately **MIXED** and, as a result, there are more **COLLISIONS** between reactant particles.

8. Simple ionic reactions are generally (**faster**/slower) than more complex ionic reactions because there are no **BONDS** to break.

9. Indicate the faster and slower reaction and **explain why**.

a) $2Al_{(s)} + 3I_{2(s)} \rightarrow 2AlI_{3(s)}$ **OR** $\mathbf{2Na^{+}_{(aq)} + 2ClO^{-}_{(aq)} \rightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + O_2}$

Reactants are in the aqueous phase, it is a homogeneous reaction (no phase boundary) and reactants are therefore mixed better resulting in more collisions per unit time.

b) $\mathbf{3Ba^{+2}_{(aq)} + 2PO_4^{-3}{}_{(aq)} \rightarrow Ba_3(PO_4)_{2(aq)}}$ **OR** $Cu_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Cu^{+2}_{(aq)} + 2Ag_{(s)}$

Reactants are in the aqueous phase, it is a homogeneous reaction (no phase boundary) and therefore reactants are mixed better resulting in more collisions per unit time. As the reactants are both ions, there are no bonds to break making for a faster reaction.

c) $2Al_{(s)} + 3I_{2(s)} \rightarrow 2AlI_{3(s)}$ **OR** $\mathbf{Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}}$

Homogeneous, fully mixed, no bonds to break

Given the following reactions, clearly explain the statements given using collision theory.

10. $H_2O_{2(aq)} \rightarrow H_2O_{(l)} + O_{2(g)}$

- H_2O_2 decomposes slowly at 20^o C.
- KI is added and rapid decomposition begins.

Activation energy is too high. The catalyst lowers Ea resulting in a greater proportion of collisions having sufficient energy to react. This is an exothermic reaction, releasing energy resulting in reactants having more energy, moving faster, colliding more frequently and colliding more energetically resulting in even more successful collisions.

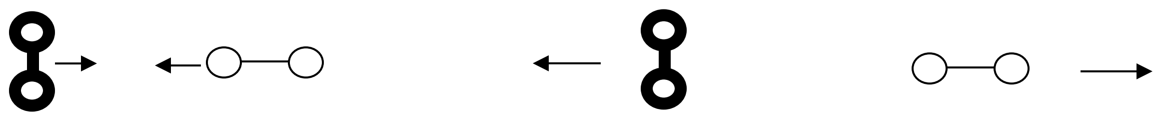
11. $H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$

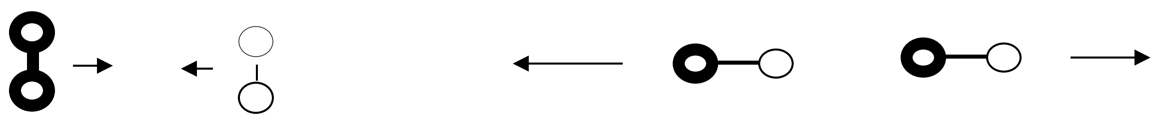
- $H_{2(g)}$ and $O_{2(g)}$ in a balloon do not react.
- A spark violently ignites the balloon.

Activation energy is too high but the spark provides the energy required to overcome the barrier (Ea). This is an exothermic reaction releasing lots of energy in the form of an explosion.

12. Both collisions A and B have the same KE. Which collision is successful and explain why.

Before Collision After Collision

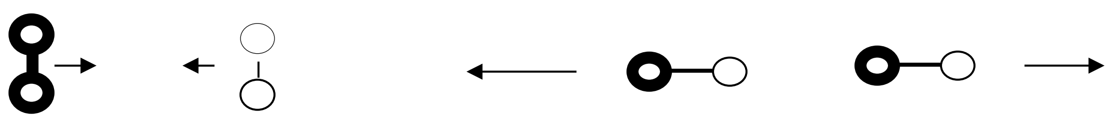
A) 

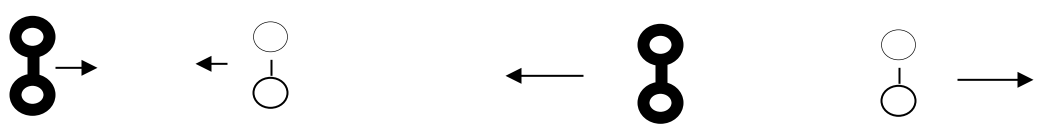
B) 

Collision B is successful due to favourable geometry.

13. Explain why collision A was successful while collision B was unsuccessful.

Before Collision After Collision

A) 

B) 

Collision A is successful because it had sufficient energy.

14. Describe the PE and KE changes as reactant molecules approach each other.

Potential energy increases and kinetic energy decreases due to repulsion from electron clouds.

15. Consider the following reaction:

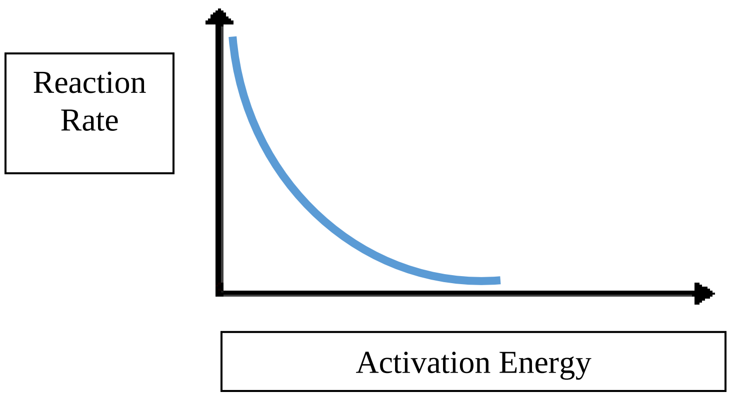
$$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$

Even though there are more than four billion collisions per second between N_2 and O_2, the amount of product after a year in our atmosphere is too small to detect. Using collision theory, give two reasons why this reaction might be slow.

i) **Low temperature, collisions are unsuccessful**

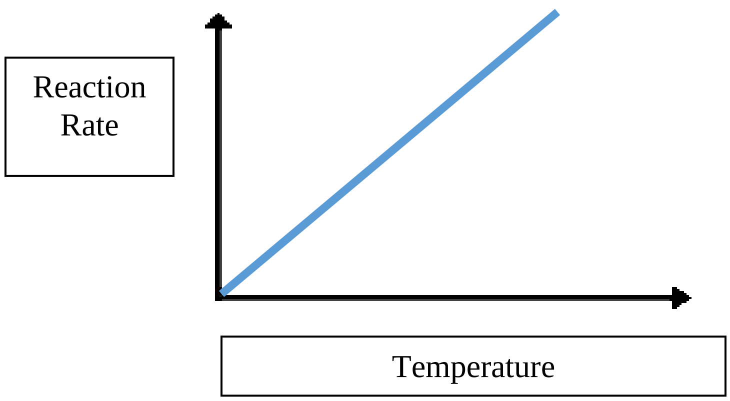
ii) **High activation energy**

16. State the relationship between activation energy and the rate of a reaction. Sketch a graph of reaction rate vs activation energy.



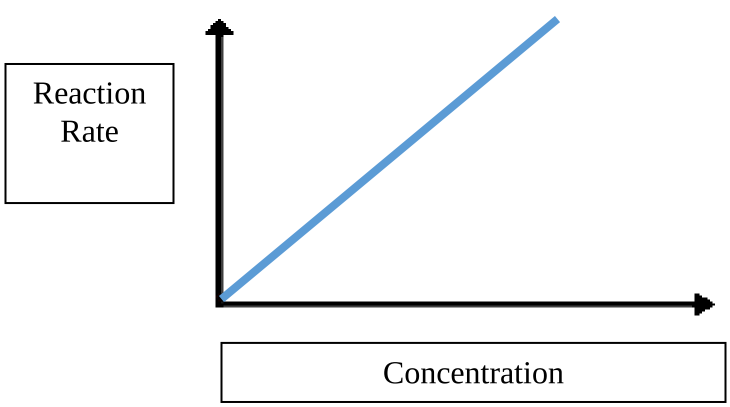
INVERSE relationship because a decrease in Ea increases the rate

17. State the relationship between temperature and the rate of a reaction. Sketch a graph of reaction rate vs temperature



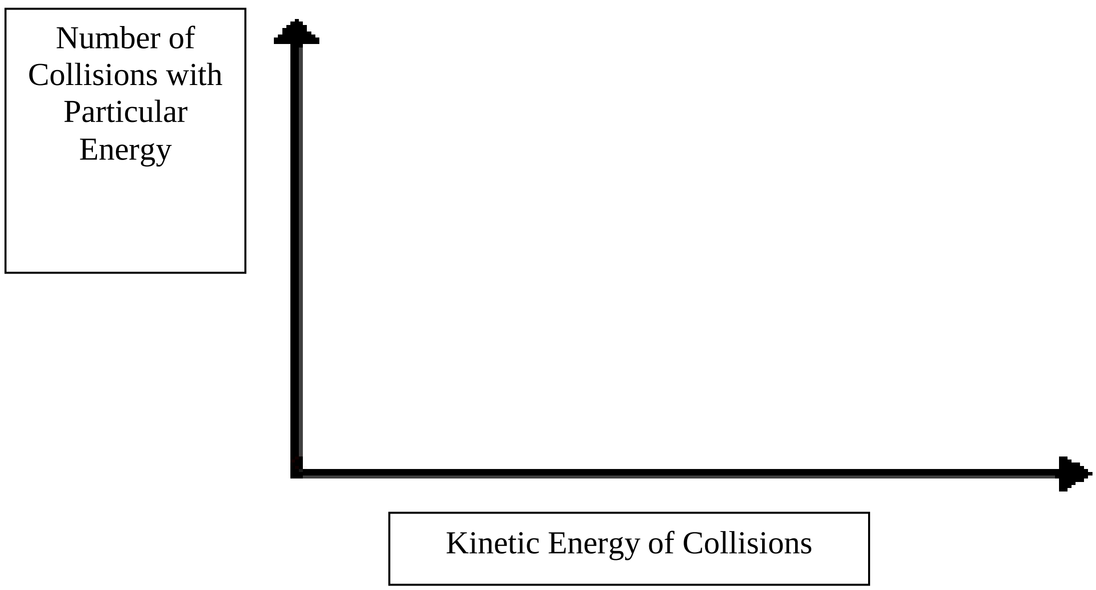
DIRECT

18. State the relationship between concentration and the rate of a reaction. Sketch a graph of reaction rate vs concentration.



DIRECT

21. (a) Draw a kinetic energy distribution curve for a reaction where the y-axis is number of collisions with a particular energy and the x-axis is the K.E. of the collision. Draw the Ea line showing about 10% of the collisions having sufficient energy. Draw the Ea line for the catalyzed reaction where 20% have sufficient energy (after the addition of a catalyst).



(b) Now, on the graph above, shade in the area of the collision energy distribution diagram showing those collisions that do NOT have the required energy to be successful at the temperature depicted by the graph.