# THEORIES OF REACTION RATES

## COLLISION THEORY

- for a reaction to occur, reactants must collide with each other

***TO INCREASE*** the number of collisions per second, thus increasing the rate of reaction...

1. **INCREASE** the **CONCENTRATION** of **reactants**
2. **INCREASE** the **SURFACE AREA**

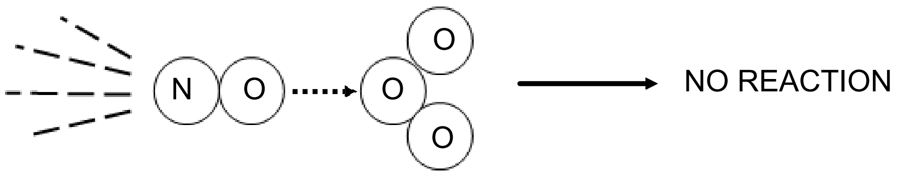
### BEYOND COLLISION THEORY...

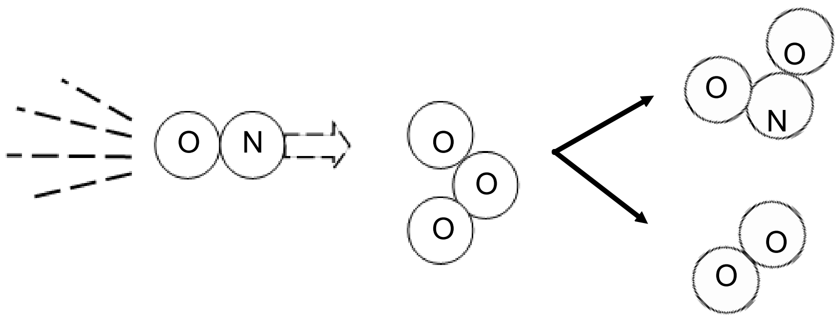
-- not every collision results in a reaction

-- to cause a reaction, **2 CRITERIA** are necessary...

1. **ORIENTATION** of reactants -- proper orientation is necessary for reaction.

$$NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$$



## 2. ACTIVATION ENERGY -- $E_a$

-- sufficient collision **energy** necessary for a successful reaction.

-- minimum energy to break the bonds in the reactants and to begin forming bonds in the products.

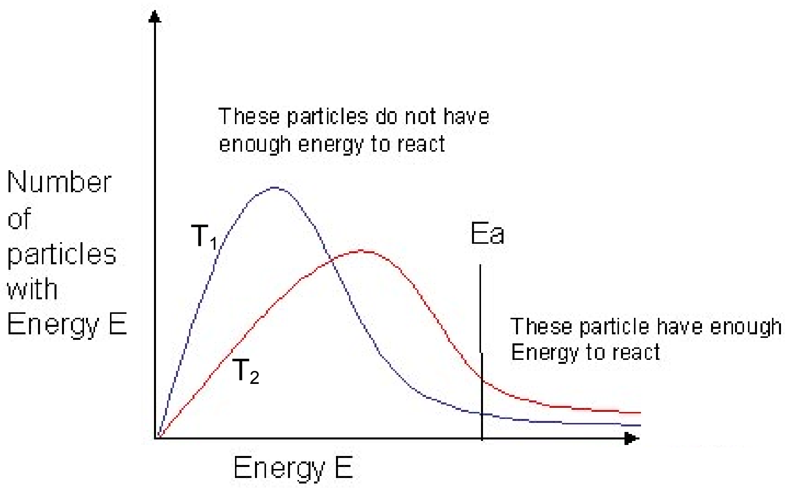
-- depends on the kinetic energy of the colliding particles.

-- recall that the temperature is a measure of the average kinetic energy of the particles in a substance.

-- at a given temperature, the number of collisions versus the kinetic energy of each collision is illustrated by a **Maxwell-Boltzmann Distribution**, as shown below.

-- As the temperature of a sample increases, the fraction of collisions with sufficient energy to react increases.

- In the diagram below: $T_2 > T_1$



# TRANSITION STATE THEORY

$$A + B \xrightarrow{?} C + D$$

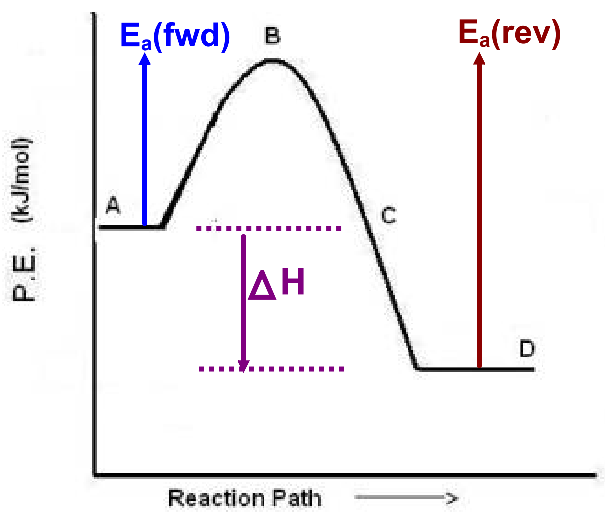
**REACTANTS ⟶ *TRANSITION STATE* ⟶ PRODUCTS**

**K.E. P.E. K.E.**

-- Transition State Theory explains what happens when molecules collide in a reaction.

## POTENTIAL ENERGY DIAGRAMS (P.E.D.):

-- charts the change in Potential Energy against the progress of a reaction.




In the P. E. Diagram,

**A** = reactants

**B** = transition state -- peak of $E_a$ barrier

-- the "species" at B is called the **ACTIVATED COMPLEX** (neither reactant nor product)

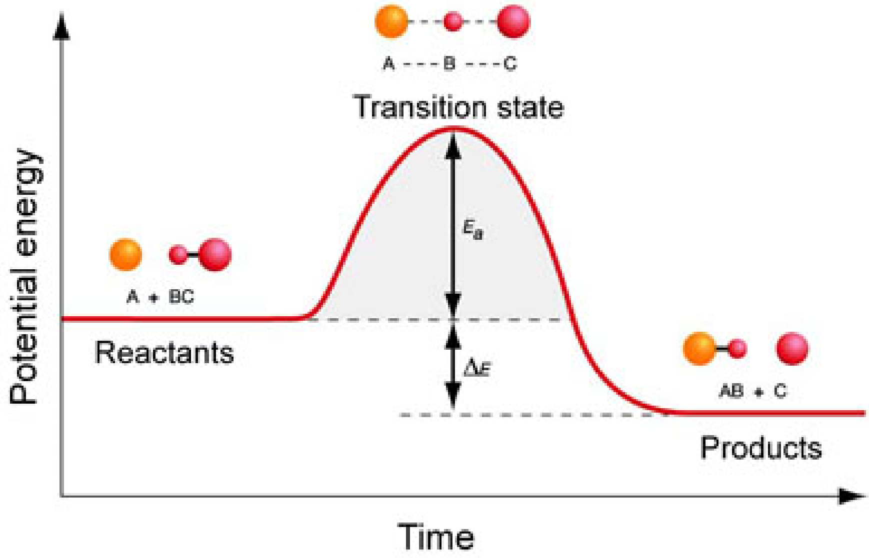
**C** = bond formation of the products

**D** = products

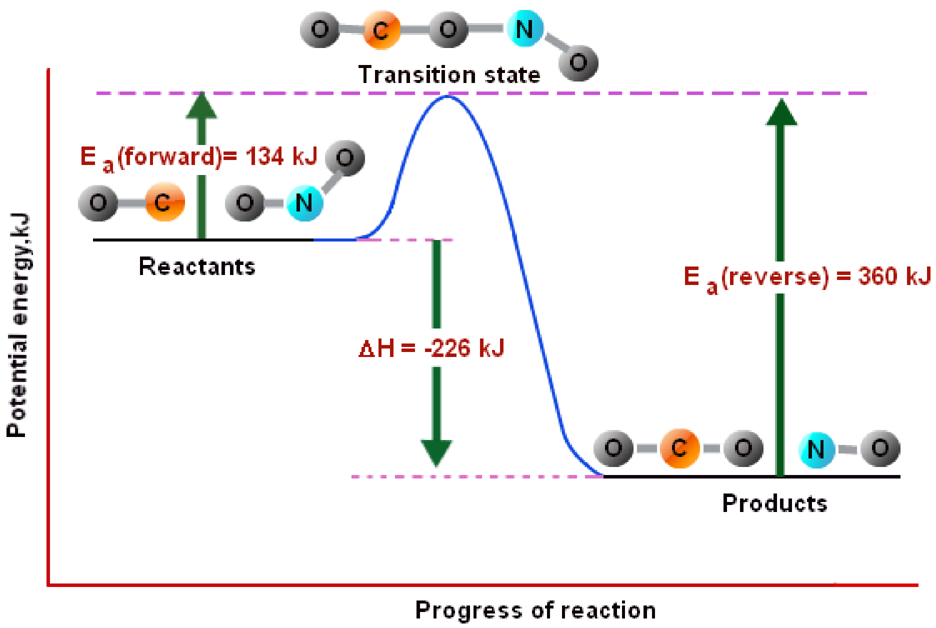
**NOTE:** We cannot predict the activation energy of a reaction from its enthalpy change.

Consider the single displacement reaction: $A + BC \rightarrow AB + C$

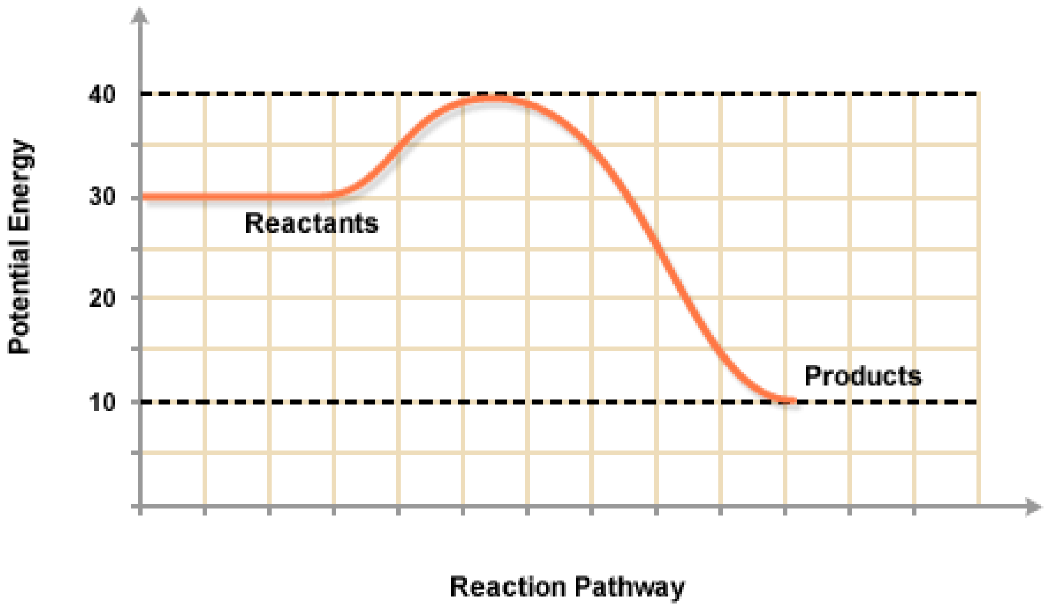
$$A + BC \rightarrow A{-}{-}B{-}{-}C \rightarrow AB + C$$

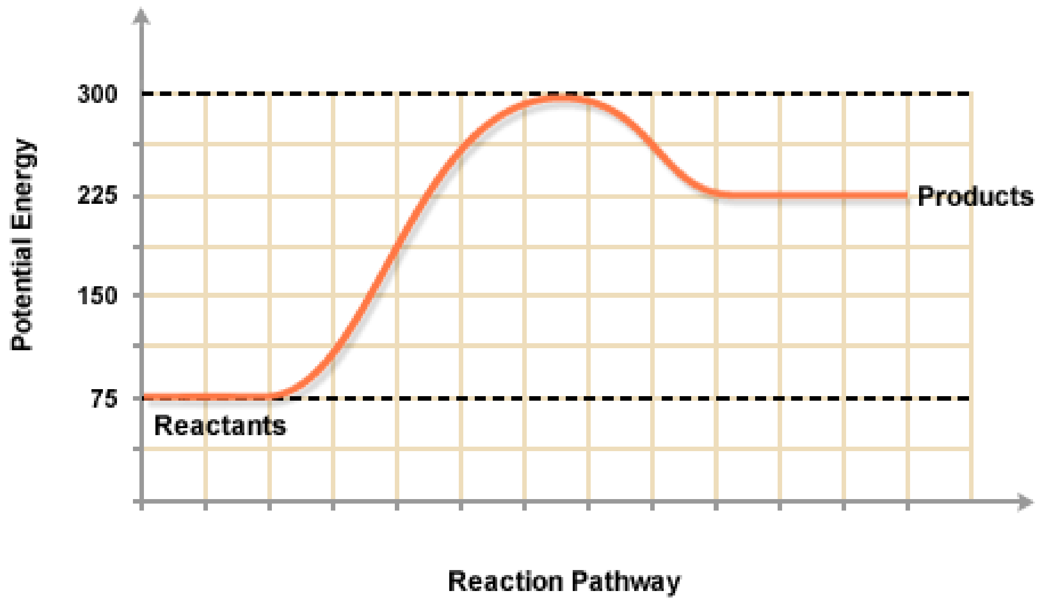



Consider the reaction: $CO_{(g)} + NO_{2(g)} \rightarrow CO_{2(g)} + NO_{(g)}$



**EXERCISE**: State the values of $E_{reac}$, $E_{prod}$, $E_a$, $E_{rev}$, $\Delta H$.



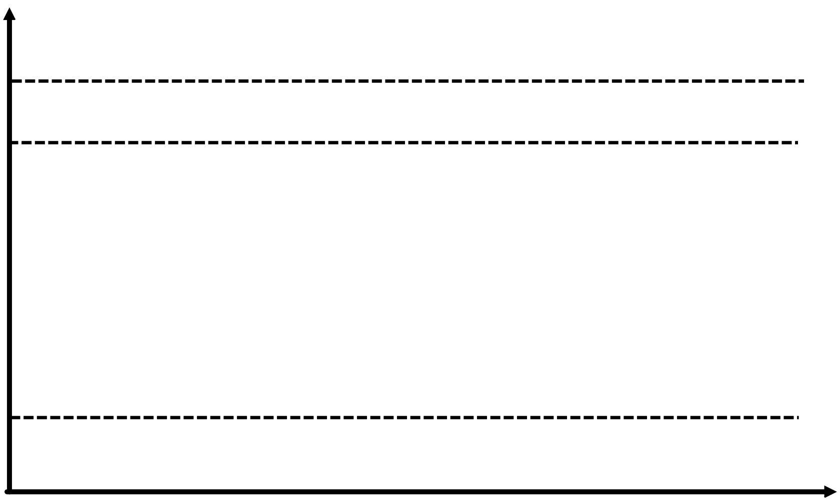
Consider the reaction: $NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$

$\triangle H$ = -200 kJ

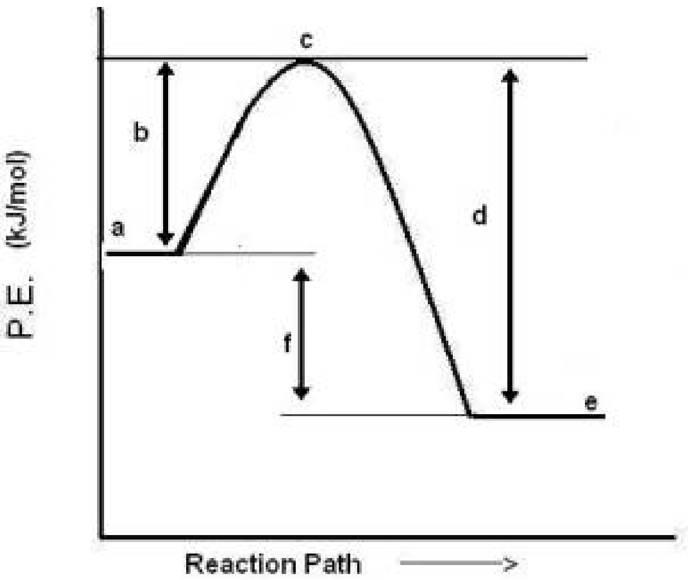
$E_a$ = 10 kJ

P.E. (reactants) = 240 kJ

Draw the P.E. Diagram for the reaction.

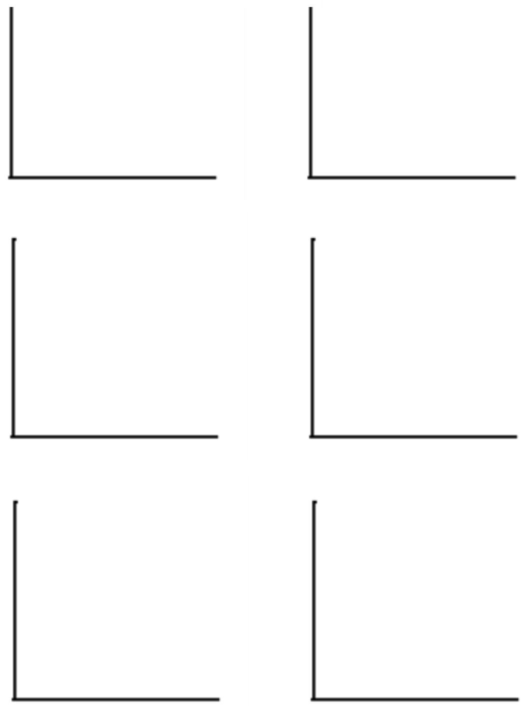


For the P.E. Diagram below, label the parts of the reaction.



1. Sketch the following potential energy diagrams below; label the axes, reactants, products, transition state, $\Delta H$, $E_{a(fwd)}$, and $E_{a(rev)}$:

(a) a highly exothermic, slow reaction
(b) a highly exothermic, fast reaction
(c) a slightly exothermic, slow reaction
(d) a slightly exothermic, fast reaction
(e) a highly endothermic, slow reaction
(f) a slightly endothermic, slow reaction



2. How does the enthalpy of the forward reaction compare to the enthalpy of the reverse reaction?

3. How does the activation energy of the forward reaction compare to the activation energy of the reverse reaction in an exothermic reaction?

4. What is the relationship between the *transition state* and the *activated complex*?

## Attachments

periodic table.docx