Activation Energy

- During a single chemical reaction, there are several changes in energy that take place during the reaction.

* Important to know!

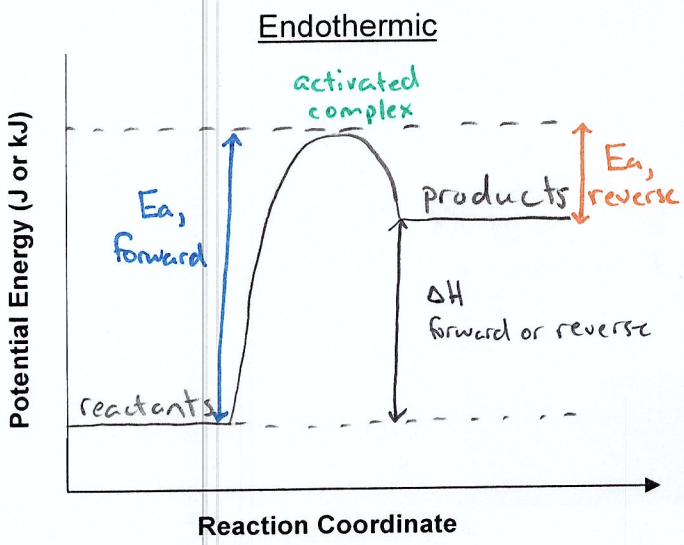
- Consider the energy changes that are involved in any chemical reaction
  - All reactants are in random motion. Therefore, before a reaction, all reactants have *kinetic energy*. All chemicals will also have some type of potential energy due to the bonds that are holding the particle together.
  - A chemical reaction must involve a collision between reactants. When particles collide, they temporarily stop moving and therefore, have no kinetic energy anymore. When all reactants collide and form one entity, this is known as the **activated complex**. The **activated complex** occurs at *maximum potential energy* (all kinetic energy is converted into potential energy stored in chemical bonds needed to hold the complex together momentarily) and is extremely unstable due to its high potential energy.

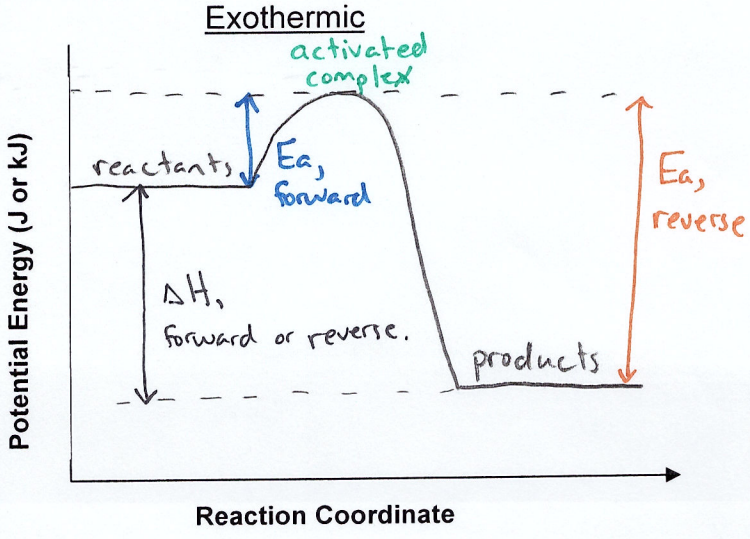
a.k.a transition state

hill top on energy diagram →

  - An effective collision requires sufficient energy before the reaction can occur. This required energy is called the **activation energy (E_a)** and all reactions need to overcome this energy *barrier* before the reaction can occur. The energy required to overcome the *activation energy* is obtained from the kinetic energy of the reactants. Remember that at higher temperatures, molecules have more kinetic energy.
  - After a reaction, the products will have a different potential energy than the reactants due to different bonds. Also, the products will have kinetic energy again as the products go back into random motion.

- An **energy pathway** describes the relative changes in the *potential energy* of the chemical system as the chemical reaction takes place (moves from reactants, to activated complex, to products) and can be represented by a potential energy diagram



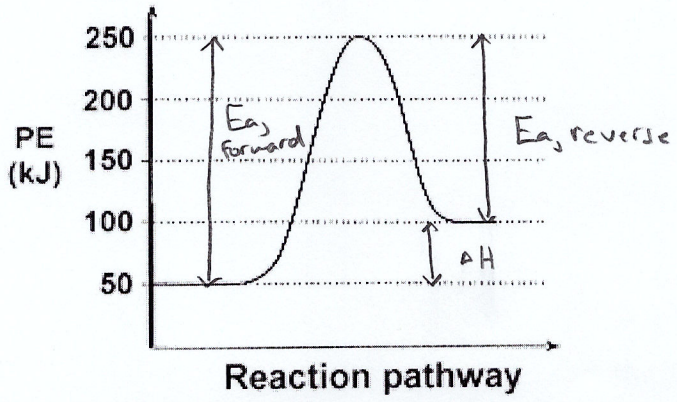


- Remember that endothermic and exothermic reactions can be explained using *bond energy terms*
  - If more energy is released due to bonds forming than the energy required for bond breaking, the reaction is exothermic
  - If more energy is absorbed for bond breaking than the energy released from bond making, the reaction is endothermic

*****Energy Activity*****

EXAMPLES:

1. Use the following potential energy diagram to answer the next few questions.



a. Does the graph represent and endothermic or exothermic reaction?
still a step up

b. Determine the heat of reaction for this reaction.
↳ ΔH = ?

ΔH = 50 kJ

c. Determine the activation energy for this reaction.

Ea = 200 kJ

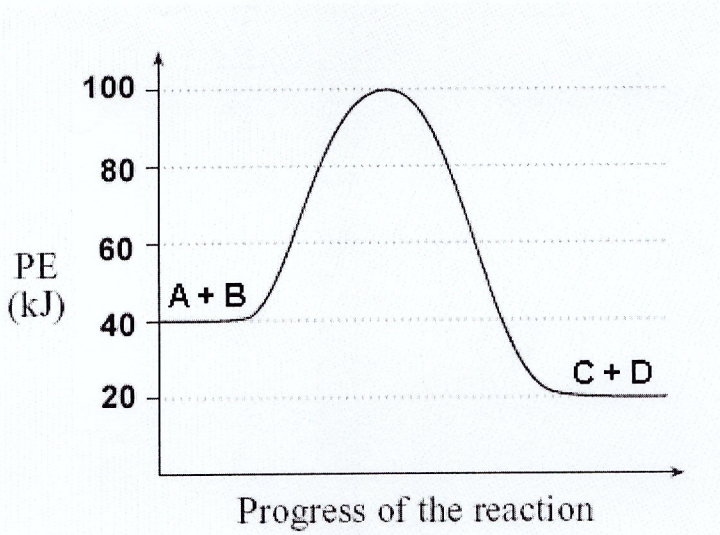
d. Determine the reverse activation energy for this reaction.

Ea = 150 kJ

*****Now try pg. 420 #2-6 (don't need a diagram for #4), 9, 13 & Practice Problems*****

Practice Problems

1. Use the following diagram to answer the next questions.



   a. Does the graph represent and endothermic or exothermic reaction?

   b. Determine the heat of reaction for this reaction.

   c. Determine the activation energy for this reaction.

   d. Determine the reverse activation energy for this reaction.

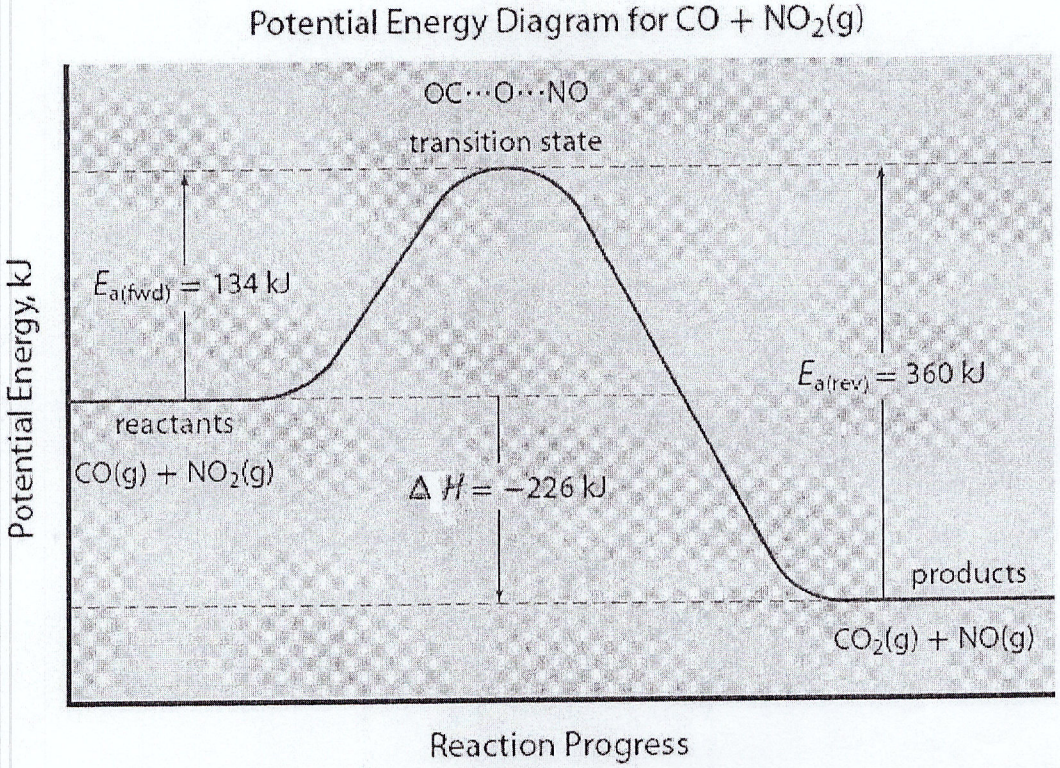
2. Carbon monoxide, $CO_{(g)}$, reacts with nitrogen dioxide, $NO_{2(g)}$. Carbon dioxide, $CO_{2(g)}$, and nitrogen monoxide, $NO_{(g)}$, are formed. Draw a potential energy diagram to illustrate the reaction process. (You do not need to draw your diagram to scale). Label the axes, the transition state, and the activated complex. Indicate on the diagram the activation energy of the forward reaction, $E_{a,for}$=134 kJ, as well as ΔH=-226 kJ. Calculate the activation energy of the reverse reaction, $E_{a,\,rev}$, and show it on the graph.

Solutions

1.

a. Exothermic
b. $\Delta H = -20kJ$
c. 60 kJ
d. 80 kJ

2.

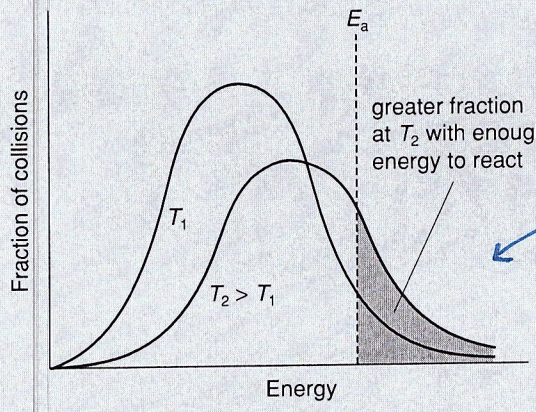


Chapter 11 Review Answers

Student Textbook pages 420–421

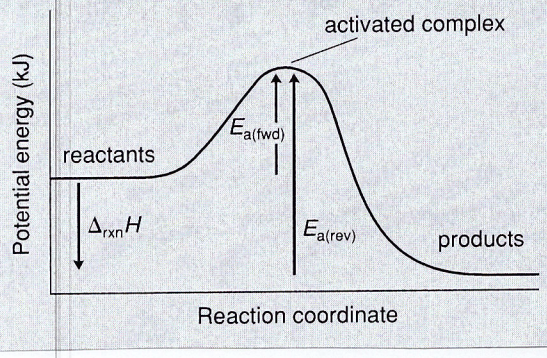
Answers to Understanding Concepts Questions

1. For a reaction to take place, molecules must collide with the correct orientation geometry and with sufficient (activation) energy.
2. A match will not light spontaneously. With the input of the kinetic energy of the strike, the chemicals reach the activation energy and the match will burn completely.
3. The activated complex is a highly unstable species that is neither product nor reactant. It is so unstable because it contains only partial bonds and has the most potential energy of all of the substances found in the reaction since it is at the highest peak of the reaction mechanism.
4. When temperature is increased, the fraction of collisions with sufficient energy to cause a reaction, represented by the area under the curve, increases. If there are more successful collisions, the rate of reaction increases.



graph is not important

5. The energy required to reach activation energy comes from the kinetic energy of the colliding molecules. As they collide, the kinetic energy is converted to potential energy.
6. The reaction is exothermic.



13. **(a)** The reaction is endothermic since the $E_{a(fwd)}$ is larger than the $E_{a(rev)}$.

$\Delta H = E_{a(fwd)} - E_{a(rev)} = 143\text{ kJ} - 75\text{ kJ} = 68\text{ kJ}$; since this is positive we know the reaction is endothermic.

(b)