Unit 82 – Catalysis

82-1. Account for the increase in reaction rate brought about by a catalyst.

Solution

The general mode of action for a catalyst is to provide a mechanism by which the reactants can unite more readily by taking a path with a lower reaction energy. The rates of both the forward and the reverse reactions are increased, leading to a faster achievement of equilibrium.

82-2. Compare the functions of homogeneous and heterogeneous catalysts.

Solution

Both change the mechanism to one with a lower activation energy, thus producing a faster reaction. Homogeneous catalysts work in the same phase as the reactants; heterogeneous catalysts work in a different phase than the reactants, generally providing a surface upon which the reaction takes place.

82-3. Consider this scenario and answer the following questions: Chlorine atoms resulting from decomposition of chlorofluoromethanes, such as CCl_2F_2, catalyze the decomposition of ozone in the atmosphere. One simplified mechanism for the decomposition is:

$$O_3 \xrightarrow{\text{sunlight}} O_2 + O$$

$$O_3 + Cl \longrightarrow O_2 + ClO$$

$$ClO + O \longrightarrow Cl + O_2$$

(a) Explain why chlorine atoms are catalysts in the gas-phase transformation:

$$2O_3 \longrightarrow 3O_2$$

(b) Nitric oxide is also involved in the decomposition of ozone by the mechanism:

$$O_3 \xrightarrow{\text{sunlight}} O_2 + O$$

$$O_3 + NO \longrightarrow NO_2 + O_2$$

$$NO_2 + O \longrightarrow NO + O_2$$

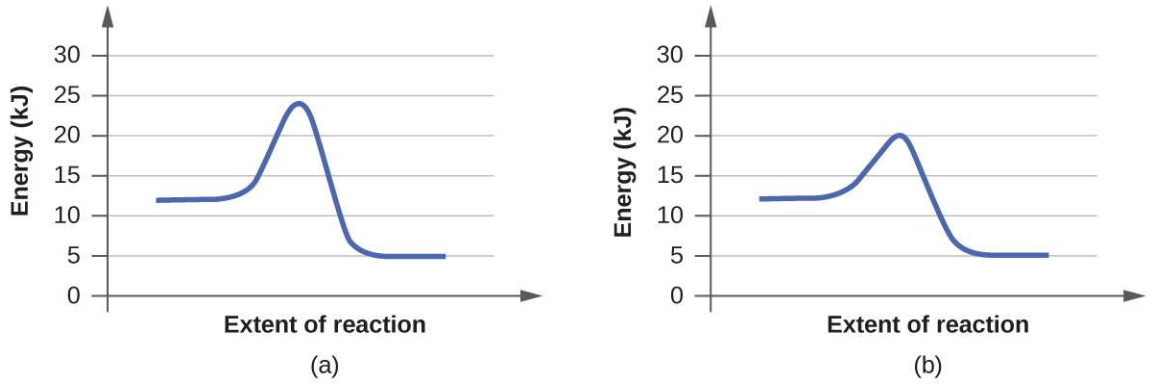
Is NO a catalyst for the decomposition? Explain your answer.

Solution

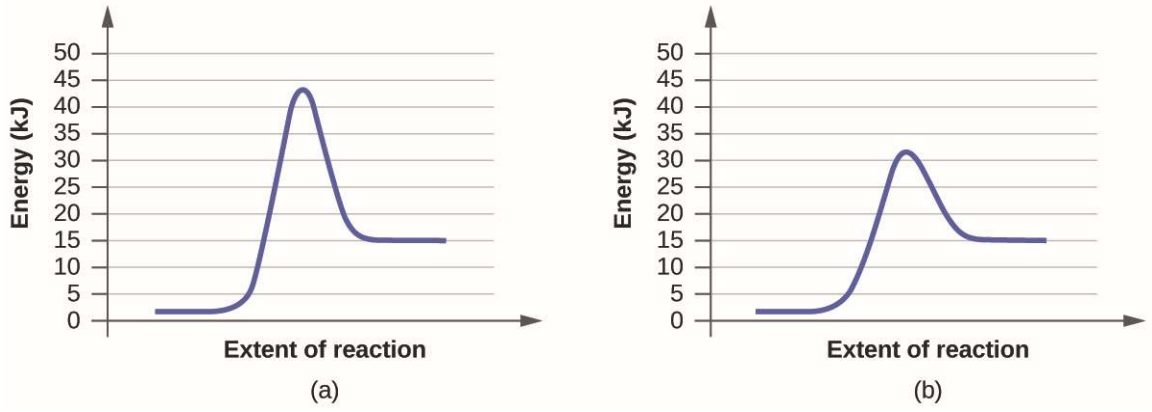
a) Chlorine atoms are a catalyst because they react in the second step but are regenerated in the third step. Thus, they are not used up, which is a characteristic of catalysts. (b) NO is a catalyst for the same reason as in part (a).

82-4. For each of the following pairs of reaction diagrams, identify which of the pair is catalyzed:

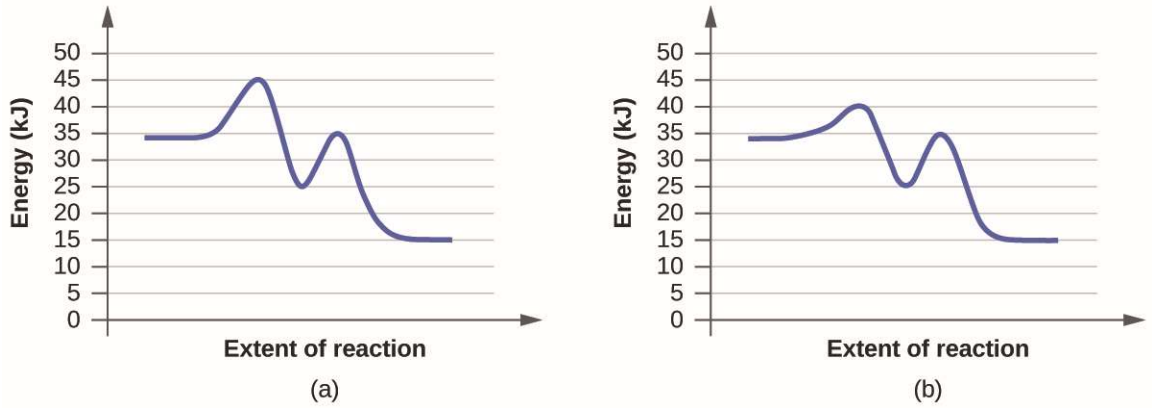
(a)



(b)



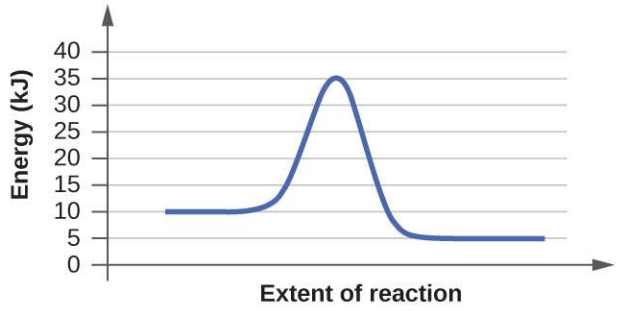
(c)



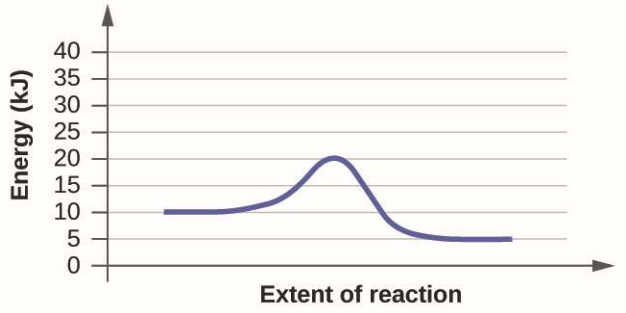
Solution

The lowering of the transition state energy indicates the effect of a catalyst. (a) b; (b) b; (c) b.

82-5. For each of the following reaction diagrams, estimate the activation energy (E_a) of the reaction:
(a)



(b)

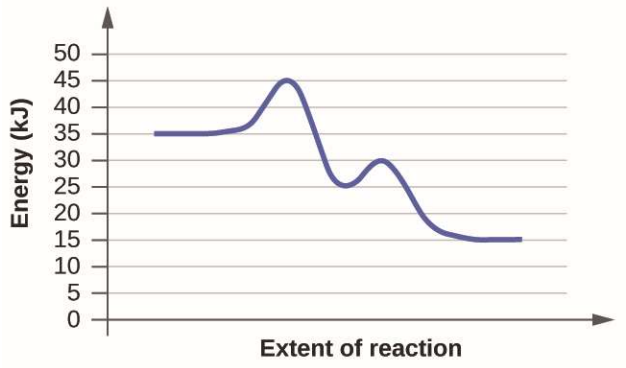


Solution

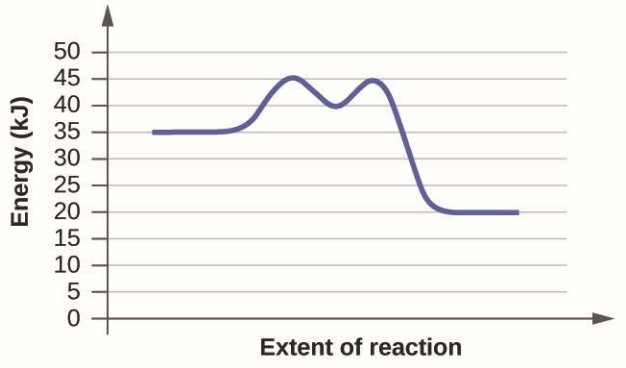
The energy needed to go from the initial state to the transition state is (a) 25 kJ; (b) 10 kJ.

82-6. For each of the following reaction diagrams, estimate the activation energy (E_a) of the reaction:

(a)



(b)



Solution

The energy needed to go from the initial state to the transition state is (a) 10 kJ; (b) 10kJ.

82-7. Assuming the diagrams in Exercise 12.81 represent different mechanisms for the same reaction, which of the reactions has the faster rate?

Solution

The rate of a reaction increases as activation energy decreases. Reaction (b) exhibits a lesser activation energy and will be the faster reaction under a given set of conditions.