Making Connections

4. (a) (Answers will vary.) The mechanism of the reaction involves collisions of octane and oxygen molecules in which single carbon–carbon and single carbon–hydrogen bonds are broken in succession down the hydrocarbon chain with reformation of bonds to form carbon dioxide and water molecules at each step.
   (b) (Answers will vary.) Rates can be explained and predicted on the basis of collisions of molecules.
5. (a) (Answers will vary.) Ground-level ozone can damage lung tissue.
   (b) Ground-level ozone is produced in the atmosphere by a photochemical smog mechanism, which involves the oxidations of volatile organic compounds in the presence of nitrogen oxides and sunlight.
   (c) The reaction is catalyzed by the partially combusted hydrocarbon molecules that are produced in automobile exhausts.
6. (Answers will vary, but should include information about award-winning and more recent research and discoveries.)

6.5 EXPLAINING AND APPLYING CHEMICAL KINETICS

PRACTICE

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Understanding Concepts

1. (a) temperature, concentration, surface area
   (b) temperature, catalysis, chemical nature of reactants
2. (a) $2 H_{2(g)} + O_{2(g)} \rightarrow 2 H_2O_{(g)}$

   This reaction is unlikely to occur in a single step because it would involve the collision of three molecules simultaneously.
   (b) (Answers will vary.) The actual mechanism appears to be:

   $H_2 + 2 Pt \rightarrow 2 Pt–H$

   $O_2 + 2 Pt \rightarrow 2 Pt–O$

   $Pt–H + Pt–O \rightarrow Pt + Pt–OH$

   $Pt–OH + Pt–H \rightarrow 2 Pt + H_2O$

   (from http://www.iupac.org/news/prize/2001/michaelides.html)

3. (a) heterogeneous
   (b) homogeneous (all gases)
   (c) homogeneous (all aqueous)
   (d) heterogeneous
4. (a) Oxalate ions are more complex than ferrous ions, requiring more precise collision geometry and a higher activation energy. The fraction of successful collisions is lower.
   (b) Steel wool has a larger surface area than a nail. The collision frequency (i.e., the number of collisions per second among reactant molecules) is higher.
   (c) Nitroglycerin tablets have a much lower concentration. The collision frequency (i.e., the number of collisions per second among reactant molecules) is higher.

Making Connections

5. (a) $Cl_{2(g)} + H_{2(g)} \rightarrow 2 HCl_{(g)}$

   (b) $Cl_{(g)}$ and $H_{(g)}$

   (c) Because a smaller activation energy barrier indicates a faster reaction rate, the collision with atomic chlorine must have a much smaller activation energy than that for molecular chlorine.
6. (Answers will vary, and should include specific reference to industrial applications catalyzed by platinum.) Examples include hydrogenation of ethene to ethane, formation of sulfur trioxide in sulfuric acid production, and even application in setting of dental impression compounds.
7. (Answers might include the following:)
   • addition of chemicals like salt or sugar (somewhat like inhibition or negative catalysis)
   • sealing (reducing concentration of oxygen in air)

- refrigeration (reduction of temperature)
- preserving large blocks of food (reducing surface area)
- choosing foodstuffs that naturally decay more slowly (chemical nature of reactants)

Explore an Issue: Debate: Food Preservation

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(a) (Answers will vary, but should include research from several stated sources, organized into relevant categories (e.g., from the manufacturing industry, from health-watch groups, from the medical community), and used to back up the students' arguments.)

(b) (Answers will vary, but should outline how and possibly why the vote changed.)

PRACTICE

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Making Connections

8. (Answers will vary, depending on career chosen and geographical location.)

PRACTICE

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Understanding Concepts

9. (a) $k = Ae^{-E_a/RT}$

At $T = 20°C$,

$E_a/RT = \dfrac{2.00 \times 10^5}{8.31 \times 293}$

$E_a/RT = 82.1$

$k_{20\ 200} = A \times e^{-82.1}$

$k_{20\ 200} = A \times 2.2 \times 10^{-36}$

At $T = 25°C$,

$E_a/RT = \dfrac{2.00 \times 10^5}{8.31 \times 298}$

$E_a/RT = 80.8$

$k_{25\ 200} = A \times e^{-80.8}$

$k_{25\ 200} = A \times 8.1 \times 10^{-36}$

$\dfrac{k_{25\ 200}}{k_{20\ 200}} = \dfrac{A \times 8.1 \times 10^{-36}}{A \times 2.2 \times 10^{-36}}$

$\dfrac{k_{25\ 200}}{k_{20\ 200}} = 3.7$

An increase in temperature of 5°C increases the rate almost four times.

(b) At $E_a = 180$ kJ/mol

$E_a/RT = \dfrac{1.80 \times 10^5 \text{ J/mol}}{8.31 \times 293}$

$E_a/RT = 73.9$

$k_{20\ 180} = A \times e^{-73.9}$

$k_{20\ 180} = A \times 8.0 \times 10^{-33}$

$\dfrac{k_{20\ 180}}{k_{20\ 200}} = \dfrac{A \times 8.0 \times 10^{-33}}{A \times 2.2 \times 10^{-36}}$
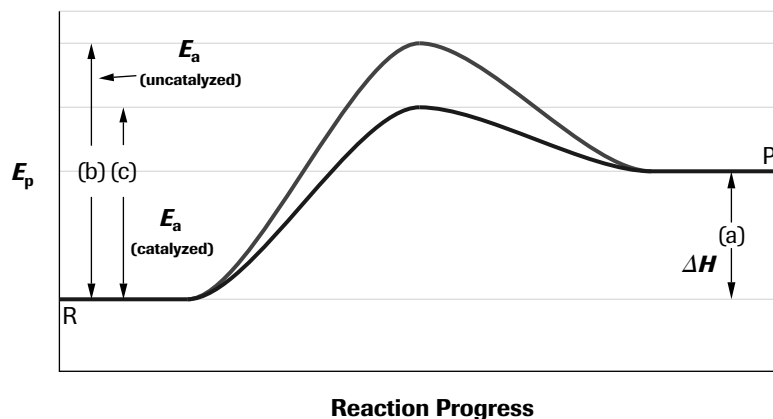
$$\frac{k_{20\ 180}}{k_{20\ 200}} = 3636$$

A decrease of activation energy of 10% increases the rate about 3600 times.
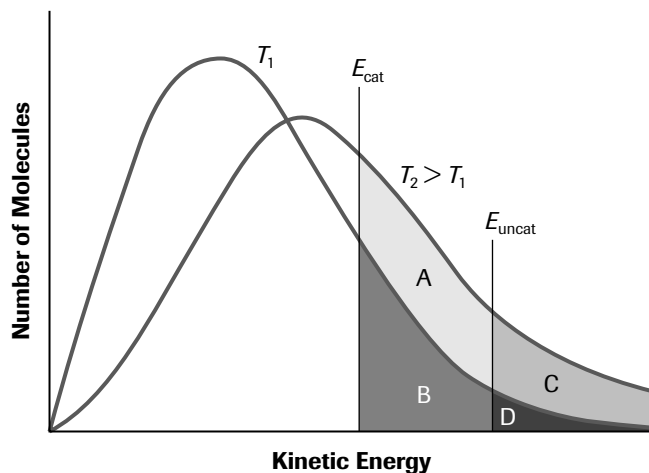
SECTION 6.5 QUESTIONS

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Understanding Concepts

1.

Potential Energy Diagram of Catalyzed and Uncatalyzed Pathways

Reaction Progress

2.

Kinetic Energy

Fraction of molecules able to react
- at T_1 uncatalyzed = D
- at T_1 catalyzed = B + D
- at T_2 uncatalyzed = C + D
- at T_2 catalyzed = A + B + C + D

Making Connections

3. (a) Stratospheric ozone blocks harmful solar ultraviolet radiation, which can cause skin cancer.
   (b) Atomic chlorine is a vastly more effective catalyst than nitric oxide because its activation energy is very much lower. Therefore, a much higher fraction of its collisions with ozone leads to successful reaction.

4. (Partial answer)

Fast reactions	Slow reactions
cooking in the stove or microwave (use temperature to increase the kinetic energy of reacting molecules)	decay of food, perfumes, and pharmaceutical products (controlled by lowering temperature)
contact lens cleaning solutions and meat tenderizers (use catalysts: hydrogen peroxide and papain)	corrosion of garden implements (controlled by painting, which reduces the contact of oxygen with the metal and keeps salt away)
fireworks	
burning of fuels in home heating, lighters, and automobiles	

5. (Answers will vary.) Fast reactions could include burning of any hydrocarbon fuel (barbecues, automobiles, home-heating systems, cigarette lighters), rapid cooking of food (frying, broiling), explosive reactions (fireworks, highway building, mining), and use of some household cleansers (bleach, tarnish remover). Slow reactions could include paint drying, decay of food, corrosion (rusting, oxidation of other metals), photochemical degradation of plastics, and slow bleaching of dyes by the Sun.

6. (a) Some reactant molecules have complex structures and strong chemical bonds that make reaction more difficult. In such situations, the chemical nature of the reactants gives them large activation energies. Other reactions involve simple ions or molecules with weak or unstable chemical bonds in which most collisions result in reaction. In these situations, the chemical nature of the reactants gives them small activation energies. Some exothermic reactions produce large amounts of heat which then accelerate further reaction by giving a larger fraction of molecules sufficient energy to exceed the activation energy barrier. A few reactions are autocatalytic: Their products include catalyst molecules which accelerate the reaction by lowering the activation energy barrier.

   (b) (Answers will vary, but the student should have a more sophisticated view of the explanation of chemical reaction rate in terms of activation energy barriers and collision mechanisms.)

CHAPTER 6   LAB ACTIVITIES

LAB EXERCISE 6.1.1 DETERMINING A RATE OF REACTION

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Prediction
(a) (Sample answer)

Progress of Reaction (x-axis), **Rate of Reaction** (y-axis)