6.4 on next page

6. **Question**

What is the effect on rate of reaction on the iodine clock reaction?

Prediction

Predict qualitatively what will happen to the time of reaction as the temperature is increased. What will happen to the rate of reaction?

Experimental Design

A series of solutions will be prepared in which the only variable is the temperature. Equal amounts of starch, sodium bisulfite, and hydrochloric acid will be mixed with each of these solutions, so that the time from mixing to formation of a blue-black product can be recorded. The evidence will be analyzed graphically.

Materials

lab apron
eye protection
0.020 mol/L potassium iodate solution (Solution A)
0.001 00 mol/L sodium bisulfite/hydrochloric acid/starch solution (Solution B)
distilled water
3 plastic micropipets, labelled A, B, and H_2O
3 100-mL beakers, labelled A, B, and H_2O
2 large-well microtrays or spot plates, labelled A and B
stopwatch
hot plate
CAUTION:
There are no major safety concerns with this investigation. Follow general lab safety procedures.

Procedure

1. Place a test tube of Solution A and a test tube of Solution B in each of five water baths at different temperatures.
2. Place the two microtrays on clean sheets of white paper. For microtray A, using the appropriate micropipets, place 10 drops of Solution A (at different temperatures) in Wells 1–5. For microtray B, using the appropriate micropipets, place 10 drops of Solution B (at corresponding temperatures) in Wells 1–5.
3. With stopwatch ready, and using the water pipet, transfer the contents of Plate A Well 1 into Plate B Well 1. In doing so, insert the tip of the pipet below the surface of the liquid in Plate B to ensure that the solutions mix thoroughly and keep stirring. Start timing at the moment the pipet is squeezed and stop when the colour first appears. Record your observations.
4. Repeat this process for the other four temperatures of solutions.
5. Dispose of solutions down the drain with lots of running water.

Making Connections

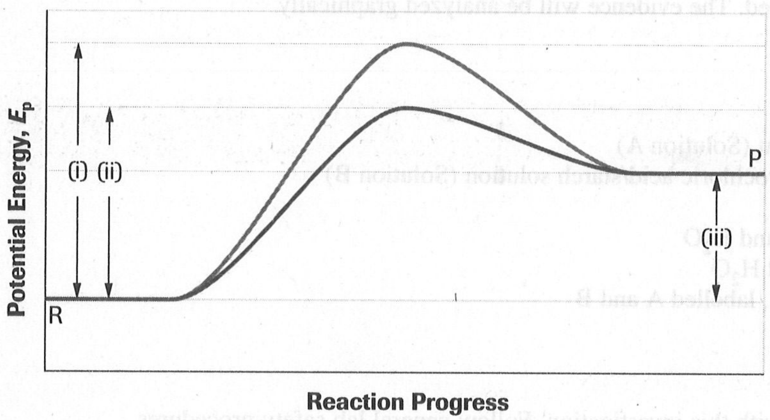
7. (Answers will vary.) Most carbon on Earth is carbon-12. However, the atmosphere contains a small constant percentage of carbon-14, because there is an equilibrium between the rate of its production and its decay. Living animals and plants also contain a constant level of C-14, but at death the organism becomes isolated from the atmosphere and the C-14 starts to decay at a known rate of about 1.2% every century. The remaining percentage of C-14 in artifacts can be used to determine their age. Other radioisotopes used in dating artifacts and soil samples include U-238, Th-232, and K-40.
8. (a) (Answers will vary.) Types of nuclear wastes produced from electricity generation activities can be categorized as low-level wastes and high-level wastes. Low-level wastes are mostly items related to operations, such as mops, plastic sheeting, protective clothing, and paper products. These make up around 1% of the waste and are easily stored in monitored facilities. High-level waste is the used nuclear fuel removed from the reactors. This fuel is in the form of solid ceramic pellets, which must be stored in shielded facilities.
   (b) AECL stores some solid low-level radioactive wastes at its Chalk River Laboratories in Ontario, in above-ground storage buildings. Since used reactor fuel is compact, solid, low in volume, and stable in a water environment, it is initially stored in deep-water pools used for cooling and shielding. After a few years, the used fuel may be moved to above-ground dry storage in concrete canisters.
   (c) Proposed methods include storage deep underground in unused mines.
   (d) Opposition could be based on environmental concerns. Support could be based on economic benefits to the community.

6.4 COLLISION THEORY AND RATE OF REACTION

PRACTICE
(Page 387)

Understanding Concepts

1. (a) **Potential Energy Diagram for System R→P**



   (b) The lower curve represents a catalyzed reaction; the upper curve represents the uncatalyzed reaction.
   (c) The reaction is endothermic so heat flows from the surroundings into the system.
   (d) (i) is the activation energy for the uncatalyzed reaction; (ii) is the activation energy for the catalyzed reaction; (iii) is the enthalpy change.

PRACTICE
(Page 390)

Understanding Concepts

2. (a) When we compare Trials 1 and 2, we see that as $[A_2]$ is doubled, rate is multiplied by 2; therefore, rate depends on $[A_2]^1$.
   When we compare Trials 1 and 3, we see that as [B] is doubled, rate is multiplied by 1; therefore, rate depends on $[B]^0$.
   Overall, rate, $r = k[A_2]^1$
   (b) The rate-determining step is $A_2 \rightarrow$ product.
   (c) $A_2 \rightarrow A + A$ (slow step)
   $2A + 2B \rightarrow 2AB$ (fast step)

SECTION 6.4 QUESTIONS
(Page 391)

Understanding Concepts

1. An elementary step involves one, two, or three molecule collisions in a mechanism. The slowest elementary step in a mechanism is the rate-determining step.
2. (a) $2A + B + E \rightarrow F$
   (b) The first step involves the most molecules and is probably the slowest, or rate-determining, step.
3. (a) 60 kJ (from reactants to highest activated complex)
   (b) –35 kJ
   (c) R → W (biggest individual activation energy)
   (d) exothermic overall
   (e) V, X, Z
   (f) W, Y

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

(Page 396)

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:

   $H_2 + 2\ Pt \rightarrow 2\ Pt\text{–}H$

   $O_2 + 2\ Pt \rightarrow 2\ Pt\text{–}O$

   $Pt\text{–}H + Pt\text{–}O \rightarrow Pt + Pt\text{–}OH$

   $Pt\text{–}OH + Pt\text{–}H \rightarrow 2\ Pt + H_2O$

   (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

(Page 398)

Making Connections

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

PRACTICE

(Page 400)

Understanding Concepts

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

At $T = 20°C$,

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

$$E_a/RT = 82.1$$

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

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

At $T = 25°C$,

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

$$E_a/RT = 80.8$$

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

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

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

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

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

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

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

$$E_a/RT = 73.9$$

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

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

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

$$\frac{k_{20\ 180}}{k_{20\ 200}} = 3636$$

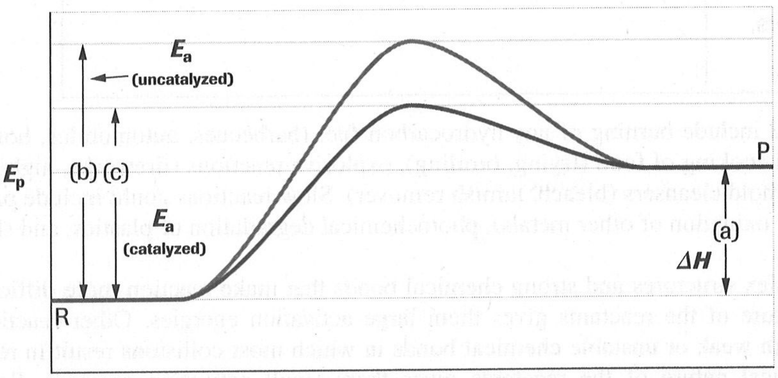
A decrease of activation energy of 10% increases the rate about 3600 times.

SECTION 6.5 QUESTIONS

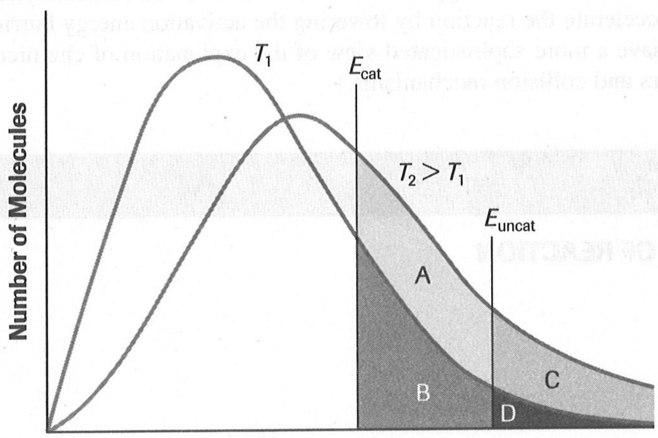
(Page 400)

Understanding Concepts

1. **Potential Energy Diagram of Catalyzed and Uncatalyzed Pathways**



2.



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

(Page 401)

Prediction

(a) (Sample answer)