$$[OH^-_{(aq)}]_{added} = 0.15 \text{ mol/L}$$
$$[HC_2H_3O_{2(aq)}]_{final} = (0.25 - 0.15) \text{ mol/L}$$
$$[HC_2H_3O_{2(aq)}]_{final} = 0.10 \text{ mol/L}$$
$$[C_2H_3O^-_{2(aq)}]_{final} = (0.25 + 0.15) \text{ mol/L}$$
$$[C_2H_3O^-_{2(aq)}]_{final} = 0.40 \text{ mol/L}$$
$$[H^+_{(aq)}] = K_a \frac{[HC_2H_3O_{2(aq)}]}{[C_2H_3O^-_{2(aq)}]}$$
$$= 1.8 \times 10^{-5} \times \frac{0.10}{0.40}$$
$$[H^+_{(aq)}] = 4.5 \times 10^{-6}$$
$$pH = 5.35$$
$$\Delta pH = 5.35 - 4.74$$
$$\Delta pH = 0.61$$

The change in pH is 0.61.

8.6 CASE STUDY: THE SCIENCE OF ACID DEPOSITION

PRACTICE

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Understanding Concepts

1. Acid deposition is suspected as one of the causes of forest decline, particularly in forests at high altitudes and colder latitudes. (Sample table)

Evidence of acid rain damage	Alternative interpretations
The evidence clearly demonstrates that the Black Forest, for example, receives as much as 30 times more acid than if the rain fell through clean air. Damage to the trees includes yellowing, premature needle loss, and eventual death. Study of the tree rings shows that trees grow more slowly in areas subject to acid deposition.	Other scientists question the link between tree growth and acid deposition. They propose conflicting evidence that seedlings actually grow better in an acidic environment. They counter that the reduction in tree growth rate is more directly due to the reduction in mean annual temperature in the regions in question. This hypothesis is supported by empirical data. Other researchers indicate that ground-level ozone, rather than acid deposition, is implicated in the damage to the forests.

2. (a) Scientific research on catalysis assisted the development of catalytic converter technology.
   (b) Sensitive detection devices have helped scientific research in the reduction of sulfur oxide emissions.
   (c) The technology that produces sulfur oxides (smelting and power generating) has a harmful impact on human health.
   (d) Society provides the resources, through government funding, that enable scientific research on the causes and effects of acid deposition.
   (e) Society affects technology by purchasing its products, such as cars with catalytic converters.

Making Connections

3. (a)

ICE Table for the Formation of Carbonic Acid			
	$CO_{2(aq)}$ +	$H_2O_{(l)} \rightleftharpoons$	$H_2CO_{3(aq)}$
Initial concentration (mol/L)	1.2×10^{-5}	–	0.00
Change in concentration (mol/L)	$-x$	–	$+x$
Equilibrium concentration (mol/L)	$1.2 \times 10^{-5} - x$	–	x

$$\frac{x}{1.2 \times 10^{-5} - x} = 3.3 \times 10^{-2}$$

$$x = 4.541 \times 10^{-7} \qquad \text{(extra digits carried)}$$

$$x = [H_2CO_{3(aq)}]$$

ICE Table for the Ionization of Carbonic Acid			
	$H_2CO_{3(aq)} \rightleftharpoons$	$H^+_{(aq)}$ +	$HCO^-_{3(aq)}$
Initial concentration (mol/L)	4.541×10^{-7}	–	0.00
Change in concentration (mol/L)	$-x$	–	$+x$
Equilibrium concentration (mol/L)	$4.541 \times 10^{-7} - x$	–	x

$$\frac{x^2}{4.541 \times 10^{-7} - x} = 4.4 \times 10^{-4}$$

$$x^2 + 4.4 \times 10^{-4}\, x - 2.0 \times 10^{-13} = 0$$

$$x = 2.78 \times 10^{-7}$$

$$x = [H^+_{(aq)}]$$

$$\text{pH} = -\log 2.78 \times 10^{-7}$$

$$\text{pH} = 6.55$$

The pH of natural rain is 6.55.

(b) Carbonate or bicarbonate ions consume hydrogen from the rain, shifting the given equilibria to the right.

(c) (Answers may vary. Answers might include the following:) Some of the effects of acid deposition can be temporarily relieved by adding large quantities of lime, calcium hydroxide, to the lakes. The long-term solution to the problem, of course, is to eliminate the source of the acid.

Explore an Issue: Take a Stand: Acting to Reduce the Effects

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(a) Possible action plans include:

- creating a SO_x tax – industries are taxed on the level of their sulfur emissions.
- increasing the cost of gasoline by $0.10/L.
- These sources of revenue could be used to research cleaner fuels.

(b) Perspectives

Economic

For legislation: Acid deposition is endangering fishing tourism, agriculture, and forestry.
Against legislation: Regulations could severely hinder economic growth.

Social

For legislation: Failure to reduce acid rain will destroy the social fabric of fishing and logging communities.
Against legislation: Shutting down acid-rain-producing industries will severely affect the social fabric of communities depending on these industries.

Legal

For legislation: Both the Canadian and the American governments have passed legislation to reduce the discharge of sulfur and nitrogen oxides.

Against legislation: Passing laws will not solve the problem but only create difficulties for companies.

Ecological

For legislation: Sulfuric and sulfurous acids cause considerable damage when they fall to Earth in the form of acid deposition. Some environmental groups claimed that 14 000 Canadian lakes have been damaged by acid deposition. Acid deposition is also suspected as one of the causes of forest decline, particularly in forests at high altitudes and colder latitudes.

Against legislation: Some researchers report that acid deposition painted on seedlings in soil with inadequate nutrients actually has a beneficial effect on growth.

Scientific

For legislation: Empirical work indicates that the main causes of acid deposition in North America are sulfur dioxide, SO_2, and nitrogen oxides, NO_x. In the atmosphere, SO_2 reacts with water to produce sulfurous acid, $H_2SO_{3(aq)}$.

Against legislation: A 1988 U.S. federal task force maintained that damage to human health, crops, and forests by acid deposition is yet to be proven.

(c) and (d) (Answers will vary widely.)

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Making Connections

1. Many medications require that the **hospital pharmacist** has a thorough knowledge of acids and base chemistry. For example, there are several antacid medications for treating peptic ulcer. Some pain relievers are weak acids that potentially can irritate the stomach of patients. The blood must be maintained within a very narrow pH range for the body to function properly. The pharmacist must be aware of the effects of medication on blood pH.

   The **quality-control chemist** must ensure that product specifications are maintained during the manufacturing process. For example, samples of shampoo are checked regularly during a manufacturing process to ensure that their pH falls within required limits. Many pain relievers are weak acids. The amount of acid in a given tablet can be determined by conducting an acid–base titration to ensure that the tablet contains the required amount.

   The **inorganic laboratory analyst** could design and test specific procedures for handling industrial chemicals and processes. For example, coiled steel is often "pickled" or cleaned using a dip tank of sulfuric acid. The strength of the acid bath needs to be monitored regularly to ensure it can clean the steel effectively. Once the acid has been depleted, the analyst must oversee the proper treatment and disposal of the sludge remaining in a dip tank.

   The **environmental chemist** monitors the testing of samples taken from specific sites. Acids and bases are commonly used in the preparation of samples for analysis. Sometimes the chemist is required to determine the specific concentration of an acid or base spill in the environment and perhaps monitor its cleanup. Knowledge of acid–base properties will help the chemist to determine the best way for containing and treating the spill.

2. (a) The only university in Ontario that has an undergraduate program specifically designed to train analytical chemists is York University.
   (b) At the time of publication of this text, the undergraduate tuition for York University was $915 per full course.
   (c) A variety of scholarships and bursaries is available. Consult the York web site for further details.

CHAPTER 8 LAB ACTIVITIES

ACTIVITY 8.1.1 DETERMINING THE pH OF COMMON SUBSTANCES

(Page 626)

(a) acids: vinegar, soft drinks, shampoo, orange juice, milk
neutral: tap water, milk
basic: antacid, household ammonia, liquid soap

(b) Based on the evidence gathered in this activity, the pH of many foods is generally less than 7 (acidic) and the pH of cleaning solutions is generally greater than 7 (basic). These generalizations are based upon a limited number of foods and cleaners tested.