11. water sample pH = 5
Thus, $[H^+_{(aq)}] = 10^{-5}$ mol/L
neutral pH = 7
$[H^+_{(aq)}] = 10^{-7}$ mol/L

$$\frac{10^{-5}\ \text{mol/L}}{10^{-7}\ \text{mol/L}} = 100$$

Therefore, to neutralize the water sample, the hydrogen ion concentration must be decreased by a factor of 100.

12. (a) $HBr_{(aq)} \rightarrow H^+_{(aq)} + Br^-_{(aq)}$
1 mol $HBr_{(aq)}$ dissociates to produce 1 mol $H^+_{(aq)}$ ions and 1 mol $Br^-_{(aq)}$ ions.
Therefore, 0.15-mol/L $HBr_{(aq)}$ dissociates to produce 0.15-mol/L $H^+_{(aq)}$ ions and 0.15-mol/L $Br^-_{(aq)}$ ions.
(b) $KOH_{(aq)} \rightarrow K^+_{(aq)} + OH^-_{(aq)}$
1 mol $KOH_{(aq)}$ dissociates to produce 1 mol $K^+_{(aq)}$ ions and 1 mol $OH^-_{(aq)}$ ions.
Therefore, 0.15-mol/L $KOH_{(aq)}$ dissociates to produce 0.15-mol/L $K^+_{(aq)}$ ions and 0.15-mol/L $OH^-_{(aq)}$ ions
(c) $NH_4Cl_{(aq)} \rightarrow NH^+_{4(aq)} + Cl^-_{(aq)}$
1 mol $NH_4Cl_{(aq)}$ dissociates to produce 1 mol $NH^+_{4(aq)}$ ions and 1 mol $Cl^-_{(aq)}$ ions.
Therefore, 0.15-mol/L $NH_4Cl_{(aq)}$ dissociates to produce 0.15-mol/L $NH^+_{4(aq)}$ ions and 0.15-mol/L $Cl^-_{(aq)}$ ions.

13. $[H^+_{(aq)}]$ = 0.2 mg/100 mL = 2 mg/L
$[H^+_{(aq)}]$ = 3 ppm = 3 mg/L
Therefore, the 3-ppm solution has a higher concentration of hydrogen ions than the 0.2-mg/100 mL solution.

Applying Inquiry Skills

14. A litmus paper test would be a simple way to distinguish acidic or basic solutions. Acidic solutions turn blue litmus paper red, while basic solutions turn red litmus paper blue.
15. The chemicals are identified in **Table 1.**

Table 1 Chemical Identification and Explanation

Chemical	Identity	Explanation
1	$HC_2H_3O_{2(l)}$	Acetic acid would turn blue litmus red. Acetic acid has low electrical conductivity because it is a weak acid.
2	$NaOH_{(s)}$	Sodium hydroxide is a strong base that would turn red litmus blue. It has high electrical conductivity because it is a strong base.
3	$Mg_{(s)}$	Solid metals have very low solubility in water.
4	$C_{12}H_{22}O_{11(s)}$	Sucrose is a soluble molecular compound that has low electrical conductivity in solution.
5	$KCl_{(s)}$	Potassium chloride is a soluble ionic compound that has high conductivity in solution.

4.8 EXPLORE AN ISSUE: THE DISPOSAL OF HOUSEHOLD PRODUCTS

CAREER CONNECTION: WASTE TREATMENT ENGINEER

(Page 306)

(i) The types of work that a waste treatment engineer would typically do include designing waste treatment equipment, developing chemical processes for treating waste, assessing existing facilities for efficiency and increases in volume or complexity of waste to be treated, promoting good waste management practices and environmental sustainability, developing residential composting programs, preparing cost estimates, and deciding the most appropriate treatment for different categories of waste.
(ii) There are many programs that prepare students for employment as a waste treatment engineer. For example, the University of Waterloo and the University of Western Ontario both offer programs.

The requirements for Chemical and Environmental Engineering at both universities include the following Grade 12 University level courses: Advanced Functions and Introductory Calculus, Geometry and Discrete Mathematics, Chemistry, Physics, and English. To become a Waste Treatment Engineer, it is beneficial to complete a degree in Chemical or Environmental Engineering.

(iii) Student answers may vary. The following table shows the different classifications of waste.

Table 1 Solid Waste Categories

Type of Waste	Examples	Treatment
household (municipal waste)	• food waste and food containers • packaging	• sent to landfill sites • composted • recycled • flushed down the drain
hazardous waste	• batteries, shoe polish, paint tins, old medicines, medicine bottles • chemical waste, such as formaldehyde and phenols (disinfectants), and mercury • industrial waste such as metal, chemical, paper, pesticide, dye, refining, and rubber goods	• sent to special waste disposal centres • picked up by licensed contractors
infectious waste	• disposable syringes, human waste, body fluids, cultures, medicines	• most hospital waste is sterilized before being sent to landfill sites or incinerated

Understanding the Issue

(Page 307)

1. To determine if household products are potentially toxic or harmful, a consumer should look for the Hazardous Household Products Symbol (HHPS) on the label of the product. Manufacturers are required to convey information regarding the type and degree of hazardous components of a product.
2. (a) The four broad categories of hazardous products are household products, paint products, automobile products, and garden products.
   (b) Student answers may vary. Some examples are given in **Table 2**.

Table 2 Categories and Examples of Household Hazardous Products

Category	Examples
household products	cleaners, disinfectants, household batteries, pharmaceuticals
paint products	latex paint, oil-based paint, stains and finishes, solvents
automobile products	motor oil, antifreeze, transmission fluid, brake fluid, lead–acid batteries
garden products	fungicides, herbicides, poisons, fertilizers

3. Currently, manufacturers are not required to include instructions regarding proper disposal on the labels of hazardous products. Since there is a lack of legislation, most manufacturers do not voluntarily label products with this information.
4. Student answers may vary. Strategies for reducing the quantity of waste batteries in landfills include:
   - buying products that do not need batteries
   - avoiding battery-powered devices that have extra functions
   - buying products that use rechargeable batteries
   - recycling all rechargeable batteries
   - properly disposing of batteries
5. The seven steps involved in the decision-making process are as follows:
   Step 1: Clearly identify and describe the issue or problem.

Step 2: Consider potential solutions to the problem. Consider at least two perspectives that pertain to the issue.
Step 3: Conduct research to learn facts, opinions, and explanations related to the problem.
Step 4: Evaluate the information.
Step 5: Perform a risk–benefit analysis to evaluate the consequences of alternative solutions.
Step 6: Make a well-informed decision based on the analysis of the alternatives. Be prepared to defend your choice.
Step 7: Consider the overall effectiveness of the decision-making process and the final decision.

TAKE A STAND: HOW WILL I DISPOSE OF A HAZARDOUS HOUSEHOLD PRODUCT?

(Page 307)

1. (a) Student answers will vary depending on products chosen for study. Two examples of common hazardous commercial products are given in **Table 3**.

Table 3 Hazardous Household Product Information

Product	Type of hazard	Degree of hazard	Component
Toilet Duck® toilet bowl cleaner	corrosive	caution	sulfamic acid
Easy-Off® Heavy Duty oven cleaner	corrosive explosive	warning caution	sodium hydroxide

Product 1: Toilet Duck®(toilet bowl cleaner)
This product requires careful handling because it contains corrosive components (sulfamic acid). The label states that all contact should be avoided with eyes and skin. The product is disposed of in the sewer or septic system. The empty container should be disposed of at a hazardous waste depot, although the label does not suggest it.

Product 2: Easy-Off® Heavy Duty oven cleaner
This product requires careful handling because of the highly corrosive nature of its active component (sodium hydroxide). Gloves should be worn at all times and skin should be rinsed with water for at least 10 min if it comes into contact with the cleaner. If the cleaner is swallowed or it gets into eyes, a physician should be called immediately. The aerosol can poses an explosion risk, particularly if punctured or heated. The can should be kept away from all heat sources. Since the cleaner is used to clean an oven, used product is most likely washed down the drain into the sewer or septic system. The label encourages consumers to dispose of the empty aerosol can at an appropriate disposal or recycling facility.

(b) Student answers will vary depending on the community in which students live. The waste disposal options available in London, Ontario are presented in **Table 4**.

Table 4 Waste Disposal Options for Hazardous Commercial Products in London, Ontario

Option	Types of waste	Economic perspective	Social perspective	Environmental perspective
curbside garbage pickup	• household garbage in bags or bins	• weekly pickup is expensive • pickup is every 8 days to save on costs	• convenient for citizens • regular pickup reduces accumulation of waste	• regular pickup reduces accumulation of waste • hazardous materials can be hidden in with regular garbage and be sent to the landfill
household special waste drop-off	• paints, oils, thinners, pesticides, small batteries, cleaners, poisons, medications	• open each Saturday for limited hours • low economic expense	• located far from city centre • accessible only by vehicle • location and hours of operation inconvenient	• allows chemicals to be diverted from landfills • reduces contamination of soil and water

(c) Student answers will vary depending on the community in which students live. A risk–benefit analysis of the disposal options available in London, Ontario is shown below.

Risk–Benefit Analysis of Curbside Waste Collection in London, Ontario

Risks				Benefits			
Possible result	**Cost of result (scale of 1 to 5)**	**Probability of result occurring (%)**	**Cost × Probability**	**Possible result**	**Cost of result (scale of 1 to 5)**	**Probability of result occurring (%)**	**Benefit × Probability**
Consumers may put hazardous materials out for pickup.	serious (4)	high (85%)	340	Curbside pickup is established and convenient.	very high (5)	very high (100%)	500
Hazardous chemicals will leach out of land-fills to contaminate water or soil.	very serious (5)	high (90%)	450	Curbside pickup ensures clean homes and neighbourhoods.	very high (5)	very high (90%)	450
Total risk value			**790**	**Total benefit value**			**950**

Risk–Benefit Analysis of Household Special Waste Drop-off in London, Ontario

Risks				Benefits			
Possible result	**Cost of result (scale of 1 to 5)**	**Probability of result occurring (%)**	**Cost × Probability**	**Possible result**	**Benefit of result (scale of 1 to 5)**	**Probability of result occurring (%)**	**Benefit × Probability**
Collecting and storing hazardous materials to take to drop-off is unsafe.	serious (4)	high (75%)	300	Hazardous chemicals are not put in landfills.	very high (5)	very high (100%)	500
Transporting hazardous materials to a drop-off in your family vehicle is unsafe.	serious (4)	high (90%)	360	Proper disposal reduces contamination of soil and water.	very high (5)	very high (90%)	450
Total risk value			**660**	**Total benefit value**			**950**

(d) Student answers may vary. Following the risk–benefit analyses presented above, we can see that disposal at a waste disposal facility may be the best solution since it poses less risk than curbside collection (both solutions have the same benefit). Students may draw different conclusions depending on the risks and benefits they choose for analysis.

Reflection

2. Student answers will vary depending on each student's evaluation of personal water use in section 4.1. Although the decision-making model may be a new concept, it is expected that many students would have intuitively used certain components of the model when making decisions regarding water use. After a more thorough analysis of personal water use by using the decision-making model, students may re-evaluate earlier resolutions.

4.9 INVESTIGATION: DILUTION AND PH

(Pages 308–311)

Prediction

(a) The pH of a solution is defined in terms of the concentration of hydrogen ions in solution. Therefore, a change of one pH unit is equivalent to a 10-fold difference in hydrogen ion concentration. For example, an acidic solution must be diluted by a factor of 10 to raise the pH by one unit.

Part 1: Dilution

Observations

Table 1 pH Values of Dilute Acid Solutions

Solution	1	2	3	4	5	unknown*
(b) pH from meter	1.85	3.25	4.01	4.93	6.05	5.10
(c) Universal indicator colour	dark red	orange red	orange	pale orange	yellow	pale orange
pH from indicator	2	3	4	5	6	5
Concentration of H^+ (mol/L)	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-5}

Analysis

(d) Student answers will depend on the pH values. The concentration of HCl in each flask for the sample data is shown in **Table 1**.
(e) Refer to the $[H^+]$ values in **Table 1**. The concentration of H^+ ions was obtained from the pH value from the universal indicator.
(f) By diluting an acidic solution by a factor of 10, the pH of the solution increases by one pH unit.
(g) Student answers may vary depending on results. Ideally, the pH value obtained using the pH meter should be very similar to the value determined using the pH indicator scale. The pH meter will give a more reliable value than the pH indicator scale.
(h) The 40 mL of distilled water was added to the flask before the hydrochloric acid to reduce the likelihood of excessive heating or splattering as the acid combined with water.
(i) In step 3, 100 mL of water was not put into the flask because doing so would not produce the correct final volume of solution after the acid was added. The final volume of the solution was to be 100 mL. Therefore, by beginning with 100 mL of water, there would be no room to add hydrochloric acid to the flask without exceeding the required final volume.

Evaluation

(j) Student answers will vary. Sources of error for Part 1 include uncertainty of the initial concentration of acid, measurement error for pipette and flask, cross-contamination of solutions from pipettes, and incorrectly interpreting the pH indicator. Using a pH indicator and colorimetric analyses is subject to error during interpretation.

To obtain more accurate results, a new, clean pipette could be used at each step of the investigation to ensure that cross-contamination could not affect the accuracy of the results. Also, more precise evidence may be gathered using a pH meter instead of a pH indicator to determine the final pH value of each solution.
(k) Student answers will vary depending on the depth of the students' initial prediction and the accuracy of results obtained in the investigation.
(l) The pH meter gives the best value because it is the most accurate and precise method of measuring pH.