UNIT 4 REVIEW

(Pages 363-367)

Understanding Concepts

1. The physical properties of water are:
   - The melting point of water is 0°C and boiling point is 100°C.
   - Water has a unique ability to dissolve a large number of substances.
   - Pure water is clear, colourless, odourless, and tasteless.
   - The density of pure water is 1.0 g/mL.
   - Solid water, or ice, is less dense than liquid water.
   - Water has a very high heat capacity.

   The chemical properties of water are:
   - Water is a polar molecule consisting of an oxygen atom bound to two hydrogen atoms.
   - The large difference between the electronegativity of the hydrogen atom and the electronegativity of the oxygen atom produces a highly polar bond.
   - Water has strong intermolecular forces, called hydrogen bonds, between the positive hydrogen atoms of a water molecule and the negative oxygen atom of a neighbouring water molecule.
2. (a) The large difference between the electronegativity of the hydrogen atoms and the electronegativity of the oxygen atom produces two highly polar bonds in a water molecule. The bonds between the hydrogen and oxygen atoms in a water molecule are polar covalent bonds.
   (b) A water molecule is polar because there is an uneven distribution of electric charge between the oxygen and hydrogen atoms and because of the molecule's bent shape. A region of negative charge surrounds the oxygen atom, while the two hydrogen atoms are regions of positive charge.
   (c) The properties that make water a good solvent are its polarity and its hydrogen bonding capacity. Water dissolves not only ionic compounds, but also covalent compounds. Covalent compounds dissolve in water if they can form hydrogen bonds with water.
   (d) Water exists as a liquid most of the time because the strong hydrogen bonds between water molecules allow water to absorb a large quantity of energy before it changes state. Thus, water has a high boiling point, relative to most other similar substances.
   (e) The ability of large bodies of water to moderate extremes in climate is related to water's high heat capacity. Large bodies of water can hold a lot of heat and, thus, can act as large heat sinks.
   (f) Oils float on the surface of water because they are nonpolar molecules that mix very poorly with the polar molecules of water. Most oils have a density of approximately 0.9 g/mL compared with the 1.0 g/mL density of pure water.
3. Water is known as the universal solvent because of its unique ability to dissolve a large number of substances. Drinking water often has a characteristic taste, and sometimes an odour, caused by substances that have been dissolved in the water. While some of these substances are present in water as a result of natural processes, such as the erosion of soil and rocks, others are contaminants or pollutants.
4. (a) Calcium and magnesium ions are the two ions most responsible for the hardness of water.
   (b) Ground water is hard in some areas because of the amount of dissolved minerals it contains. These minerals are related to the mineral content of the surrounding soil. Ground water from areas that have different soil components may not be hard. For example, areas that border the Great Lakes often have hard water because of the high limestone content of the underlying soil and rock. As slightly acidic water flows through limestone, calcium and magnesium ions become dissolved in the water.
5. Hard water reduces the efficiency of appliances that are used to heat water. Boiling the water causes a scale to form on the bottom of the kettle. This scale reduces the efficiency of heat transfer from the heating element in the appliance to the water.

6. Student answers may vary. Possible answers are shown in **Table 1**.

Table 1 Water contaminants

Physical contaminant	Chemical contaminant	Biological contaminant
• silt • clay • debris • garbage	• metals • fertilizers • petroleum products • pesticides • toxins	• *E. coli* • fecal coliform bacteria • *Cryptosporidium* • *Giardia* • *Campylobacter*

7. 1.55 ppm = 1.55 mg/L
   Therefore, 1.55 mg of nitrate would be in a 1.0-L sample of water.
8. A negative result from a diagnostic test does not prove that a specific ion is absent from a water sample. It means that the ion was not detected in the sample. The ion may be present, but in such small amounts that it does not produce enough colour or solid precipitate to be seen.
9. A qualitative analysis describes a quality or change of matter with no expressed numerical value. Most diagnostic tests are qualitative analyses. A quantitative analysis describes a quantity of matter or degree of change of matter using measurements.
10. (a) An Area of Concern (AOC) is an area in the Great Lakes Basin where pollutants from industrial sources, sewage treatment plants, landfills, and agricultural runoff have entered the waterways, destroyed the quality of the water, and created unsafe situations for people and wildlife.
    (b) A Remedial Action Plan (RAP) is developed and implemented for each AOC, and is designed to restore the ecological health of the area and to make recreational uses possible. The RAP identifies the contaminants in the water and their sources, the treatment required to remove the contaminants, and the preventative measures needed to minimize future contamination.
    (c) The seven objectives of a RAP are:
    - to restore areas of concern
    - to conserve ecologically important areas
    - to control introduction of exotic species
    - to assess and manage ecosystem health
    - to protect and promote human health
    - to reduce harmful pollutants
    - to promote sustainable use of the Great Lakes Basin
11. Student answers may vary. Properties of acids and bases are given in **Table 2**.

Table 2 Properties of Acidic and Basic Solutions

Acids	Acidic Solutions
• are water soluble • are electrolytes	• taste sour* • do not feel slippery* • turn blue litmus red • solutions neutralize basic solutions • react with active metals to produce hydrogen gas
Bases	**Basic Solutions**
• are water soluble • are electrolytes	• taste bitter* • feel slippery* • turn red litmus blue • neutralize acidic solutions

* For reasons of safety, it is not appropriate to use taste or touch as diagnostic tests in the laboratory.

12. (a) The evidence of a strong acid is that, in solution, strong acids exhibit high electrical conductivity. In solution, weak acids of the same concentration exhibit low electrical conductivity.
    (b) According to Arrhenius' theory, acids ionize into positively charged hydrogen ions, $H^+_{(aq)}$, and negatively charged ions when dissolved in water. A strong acid ionizes completely (100%) in solution, while a weak acid only partially (<50%) ionizes when dissolved in water.

13. (a) $NaOH_{(s)}$ base
(b) $HC_2H_3O_{2(aq)}$ acid
(c) $Mg(OH)_{2(s)}$ base
(d) $Ca(OH)_{2(s)}$ base
(e) $NH_{3(aq)}$ base
14. (a) Nitric acid, $HNO_{3(aq)}$, has a lower pH because it is a strong acid, and, thus, ionizes completely in solution compared with acetic acid, $HC_2H_3O_{2(aq)}$, which ionizes only partially.
(b) When using nitric acid, $HNO_{3(aq)}$, greater caution is required than when using acetic acid because a strong acid reacts more quickly with other materials, including human skin or eyes.
(c) $HNO_{3(aq)} \xrightarrow{100\%} H^+_{(aq)} + NO^-_{3(aq)}$
$HC_2H_3O_{2(aq)} \xrightarrow{<50\%} H^+_{(aq)} + C_2H_3O^-_{2(aq)}$
15. (a) Swimming pool water is basic because the correct pH range is 7.2–7.6. pH values greater than 7 are basic and values less than 7 are acidic.
(b) Since the pH of the pool is 7.9, the homeowner may add an acid to the pool to lower the pH to within the acceptable range (7.2–7.6). By adding an acid to a solution, the pH value decreases as the hydrogen ion, $H^+_{(aq)}$, concentration increases.
16. (a) Student answers may vary. Answers could include any household products that contain acids, which can cause the pH of a freshwater source to decrease. For example, muriatic acid cleaner, battery acid (sulfuric acid), vinegar, and CLR cleaner (phosphoric acid) all contain acids.
(b) Student answers may vary. Answers could include household products that contain bases, which can cause the pH of a freshwater supply to increase. For example, lye (NaOH), drain cleaner (NaOH), ammonia solutions, and oven cleaner all contain bases.
17. (a) If a strong acid, with a pH of 4.0, is diluted with a large amount of water, the concentration of hydrogen ions in the solution will decrease.
(b) The pH of the solution will increase. Thus, the pH will be greater than 4.0.
(c) If a basic solution is diluted, the pH will decrease.
18. (a) When a soluble metal oxide reacts with water, a basic solution is formed.
(b) When a nonmetal oxide reacts with water, an acidic solution is formed.
19. $NaHCO_{3(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$
20. Given the evidence from this titration analysis, it would be necessary to conduct a fourth trial because the volume of base used in the trials is not consistent. The average of the three most consistent titrant volumes is used in further calculations. In this titration, the three trials yielded results that spanned 2.1 mL.
21. As the acidity of a lake increases, normally insoluble aluminium hydroxide reacts with hydrogen ions to form soluble aluminium ions.
$Al(OH)_{3(s)} + 3\ H^+_{(aq)} \rightarrow Al^{3+}_{(aq)} + 3\ H_2O_{(l)}$
In similar chemical reactions, acid precipitation also causes an increase in levels of copper, lead, and mercury ions. These metals can accumulate in the tissues of fish and other organisms until a toxic level is reached. Lake trout are susceptible to high levels of toxic metals. Therefore, as the acidity of a lake increases, a large number of trout will die. By measuring the number of trout in a lake, you can make inferences regarding the acidity of the lake.
22. (a) Nitrogen oxides, $NO_{x(g)}$, and sulfur oxides, $SO_{x(g)}$, are major contributors to acid precipitation.
(b) Nitrogen oxide gases are naturally produced by lightning strikes and plant decay. The combustion of fossil fuels in internal combustion engines also contributes to levels of nitrogen oxide gases in the atmosphere. Sulfur oxide gases are naturally produced by volcanic eruptions, or artificially produced by smelting metal ore or burning coal that contain sulfur.
23. (a) A liquid boils when its vapour pressure (pressure exerted by the vapour) is equal to the atmospheric pressure. At a high altitude, the atmospheric pressure exerted on the surface of the liquid is less that the atmospheric pressure exerted at a lower altitude. Thus, a liquid at a high altitude will boil at a lower temperature.
(b) The volume of a gas can be decreased by increasing the external pressure on the container, causing the large spaces between the gas particles to shrink in size. Boyle's law expresses the relationship between the volume of a gas and the pressure exerted on it.
(c) Gas particles move independently of one another in a straight-line motion. This movement results in large spaces between the particles, which makes gases highly compressible. Solids have very little particle motion because of the strong forces of attraction between the particles and the very small spaces between the particles. Thus, many solids are rigid and not compressible. In liquids, the particles remain together, but move around in a jumbled, less orderly, state.

(d) As the air is heated in a hot-air balloon, the gas particles gain kinetic energy. The gas particles move faster, exerting more pressure on the walls of the container, which causes the volume of the balloon to increase. This relationship between the volume and temperature of a gas is described by Charles's law. As the volume of the gas in the balloon increases, the density of the gas decreases and becomes lower than the density of the surrounding air. Therefore, the hot-air balloon rises through the atmosphere until the density of the gas in the balloon equals the density of the air surrounding the balloon.

24. The natural balance of ozone formation and decomposition in the atmosphere has been altered by the introduction of chlorine atoms in the form of chlorinated hydrocarbon molecules (CFCs). Since CFCs are relatively inert, they remain unchanged until they reach the stratosphere. In the stratosphere, they are exposed to ultraviolet radiation, which causes single chlorine atoms to split off from the CFC molecule. The chlorine atoms react with ozone and convert it into oxygen gas. The chlorine atoms regenerate and continue to destroy ozone molecules. The depletion of ozone creates "holes," or areas of decreased ozone concentration, which allow higher levels of UV radiation to reach Earth's surface.
$CCl_3F_{(g)} + \text{UV energy} \rightarrow CCl_2F_{(g)} + Cl_{(g)}$
$Cl_{(g)} + O_{3(g)} \rightarrow ClO_{(g)} + O_{2(g)}$
$ClO_{(g)} + O_{(g)} \rightarrow Cl_{(g)} + O_{2(g)}$

25. Originally, smog was a term used to describe a mixture of smoke and fog. Today, smog refers to a bad air condition that results from a mixture of air pollutants, seen as a haze in the air. Photochemical smog is produced by the reaction between products of fossil fuel combustion in the presence of sunlight. The two main ingredients in smog are ground-level ozone and fine particles. Smog also contains nitrogen dioxide, sulfur dioxide, carbon monoxide, and ammonia. Fine particles and the reddish-brown nitrogen dioxide give smog its colour.

26. It is important to test for air quality on a regular basis because of the serious consequences for people exposed to high levels of airborne toxins. The Air Quality Index (AQI) measures six pollutants: sulfur dioxide, ozone, nitrogen dioxide, total reduced sulfur compounds (TRS), carbon monoxide, and suspended particles (SP). The levels of these air pollutants are measured because they are the most common pollutants and, at high levels, they have adverse effects on humans and the environment.

Applying Inquiry Skills

27. (a) Student answers may vary. Calcium sulfate, $CaSO_{4(s)}$, or sodium sulfate, $Na_2SO_{4(s)}$, may be added to wastewater samples to precipitate lead(II) ions from solution as lead(II) sulfate.
$Pb^{2+}_{(aq)} + CaSO_{4(s)} \rightarrow PbSO_{4(s)} + Ca^{2+}_{(aq)}$
$Pb^{2+}_{(aq)} + Na_2SO_{4(s)} \rightarrow PbSO_{4(s)} + 2\ Na^{+}_{(aq)}$

(b) Student answers may vary. Answers may include the need to do several trials, the need to use precise equipment, and the need to use sufficient amounts of chemical to precipitate all of the lead(II) ions. If insufficient amounts of chemical were added to the wastewater, not all of the lead(II) ions would have precipitated. The technician would need to ensure that the lead(II) ions were the limiting reagent in this reaction. Some of the precipitate may have been lost during the collection, drying, and measuring the mass. In both cases, the concentration of lead(II) ions in the water sample may be underestimated.

28. Using the evidence presented in the table, solution A contains sulfuric acid (acidic solution), solution B contains sugar (molecular solution), solution C contains potassium hydroxide (basic solution), and solution D contains sodium chloride (ionic solution).

29. Student answers may vary. An example of an experiment to test the Prediction that diluting an acid solution by a factor of 10 will change the pH by one is given below.

Materials

eye protection
lab apron
distilled water
10-mL graduated cylinder
pipette bulb
10-mL pipette
0.10-mol/L hydrochloric acid
100-mL volumetric flask with stopper
three 100-mL beakers
pH meter

Procedure

1. Obtain 50 mL of 0.10-mol/L hydrochloric acid in a 100-mL beaker. Measure and record the pH of the solution using a pH meter.

2. Add 40 mL of distilled water to a volumetric flask.
3. Rinse a pipette with distilled water and then with the acid solution. Using the pipette, add 10 mL of 0.10-mol/L hydrochloric acid to the flask. Add distilled water to bring the final volume up to the 100-mL mark. Stopper the flask, and invert it several times to mix the contents.
4. Take about 50 mL of the diluted acid solution from the flask and put it into a 100-mL beaker.
5. Repeat steps 2–4 three times using the diluted acid solution.
6. Wash your hands thoroughly after the experiment. Follow your teacher's instructions for disposing of waste materials.

30. (a) Student answers may vary. One experiment involves burning a small piece of each element in oxygen to produce the oxide of the element and then testing the nature of the solution.

(b) $4\ Na_{(s)} + O_{2(g)} \rightarrow 2\ Na_2O_{(s)}$
$2\ Ba_{(s)} + O_{2(g)} \rightarrow 2\ BaO_{(s)}$
$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$

(c) $Na_2O_{(g)} + H_2O_{(l)} \rightarrow 2\ NaOH_{(aq)}$
$BaO_{(g)} + H_2O_{(l)} \rightarrow Ba(OH)_{2(aq)}$
$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$

(d) $Na_2O_{(g)}$ is basic, $BaO_{(g)}$ is basic, and $SO_{2(g)}$ is acidic.

31. (a) The data table is given below.

Table 4 Titration of 10.0 mL of 0.120-mol/L $Na_2CO_{3(aq)}$ with $HCl_{(aq)}$

Trial	1	2	3	4
Final burette reading (mL)	17.95 mL	35.05 mL	22.95 mL	40.15 mL
Initial burette reading (mL)	0.30 mL	17.90 mL	5.90 mL	22.90 mL
Volume of $HCl_{(aq)}$ added (mL)	17.65 mL	17.15 mL	17.05 mL	17.25 mL

(b) From the titration analysis, an average of 17.15 mL $HCl_{(aq)}$ was added to neutralize the standard $Na_2CO_{3(aq)}$ solution (average of Trials 2, 3 and 4).
$2\ HCl_{(aq)} + Na_2CO_{3(aq)} \rightarrow 2\ NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

$$v_{HCl} = 17.15\text{ mL} = 0.01715\text{ L}$$
$$v_{Na_2CO_3} = 10.0\text{ mL} = 0.0100\text{ L}$$
$$c_{Na_2CO_3} = 0.120\text{ mol/L}$$

$$\begin{aligned} n_{Na_2CO_3} &= v_{Na_2CO_3} c_{Na_2CO_3} \\ &= 0.0100\text{ L} \times 0.120\text{ mol/L} \\ n_{Na_2CO_3} &= 0.0012\text{ mol} \end{aligned}$$

$$n_{HCl} = 0.0012\text{ mol } Na_2CO_3 \times \frac{2\text{ mol HCl}}{1\text{ mol } Na_2CO_3}$$
$$n_{HCl} = 0.0024\text{ mol}$$

$$\begin{aligned} c_{HCl} &= \frac{n_{HCl}}{v_{HCl}} \\ &= \frac{0.0024\text{ mol}}{0.01715\text{ L}} \\ c_{HCl} &= 0.140\text{ mol/L} \end{aligned}$$

The concentration of hydrochloric acid is 0.140 mol/L.

Making Connections

32. (a) Pure water tested with classroom electrical conductivity apparatus would not cause the light bulb to glow because no measurable current would be conducted through the water.
    (b) Electrical current can be conducted by positively and negatively charged ions. Although pure water does not contain dissolved substances, it does contain H^+ and OH^- ions. If the current is high enough, you could be electrocuted if you are standing in pure water.
33. Student answers may vary depending on the sources of water contamination discussed. One possible solution for the contamination of ground water would be to locate landfill sites away from aquifers, or ground water storage locations. Chemical contaminants may leak, run off, or leach into ground water. If landfills are far removed from sources of ground water, the possibility of contamination is reduced.
34. Very precise equipment is required to test drinking water because of the extremely small concentrations of contaminants that may contribute to unsafe conditions. These concentrations are usually measured in parts per million (ppm). Without precise, reliable testing, the maximum acceptable concentration (MAC) of a chemical may be exceeded and yet go unnoticed, posing risk to human health.
35. Student answers will vary depending on the community in which students live. For example, in London, Ontario, the hazardous waste disposal depot is open each Saturday for limited hours. The depot accepts such products as paints, oils, thinners, pesticides, small batteries, cleaners, poisons, medications, and electronics (computers, radios, cameras, VCRs).

    The skills and qualifications of people who work at these depots include training in Emergency Spill Response, Transportation of Dangerous Goods Act, Regulation 347, and WHMIS. Where the hazardous wastes are being produced continually in a region, local people should be trained and provided with the necessary equipment to dispose of them locally. In the case of Nova Scotia, the hazardous waste has been there for some time, and is not being added to by any activity currently happening in the province. Therefore, it is likely cheaper to ship it out of province for disposal than to build a local facility and train local people. Shipping it out of province is contingent, however, on it being done safely.
36. (a) Active game fish prefer cooler water (0°C) because of the increased concentration of oxygen at lower temperatures. According to the kinetic molecular theory, more gas may be dissolved in a liquid at lower temperatures because of the slower movement of both gas and liquid particles. At higher temperatures, particles move more quickly, allowing gas molecules to readily escape from a liquid.
    (b) You would likely catch more fish by casting your lure at a lower depth in a lake. Typically, the water near the surface of a lake is warmer than water at lower depths because the water at the surface absorbs heat from the Sun. Therefore, the deeper, cool water will contain a higher concentration of oxygen gas, which is better suited for fish survival.
37. The dramatic portrayal of extremely corrosive acids is exaggerated in most movies. It is highly unlikely that an aluminum boat would be destroyed by acidic lake water. Although damage to the boat may occur, it would become evident only after extended exposure to an acidic environment. Students' explanations regarding personal experiences may vary. Students may recall that they have not seen acetic acid, or vinegar, eat through any material. Strong acids, such as hydrochloric acid or sulfuric acid, are the most dangerous and should be handled with care.
38. Boric acid has a low degree of ionization, thus resulting in a weak acid. Conversely, strong acids, such as hydrochloric acid and sulfuric acid, have a very high degree of ionization and are highly reactive. Strong acids are very corrosive compared with weak acids.
39. Under normal conditions, coniferous trees prefer acidic soil and are able to tolerate acidic conditions. Since conifer needles are acidic, they leave a layer of black, acidic humus, called peat, on the forest floor after they decompose. Acid rain disrupts the balance of tolerable acidic conditions for coniferous trees. Acid rain causes nutrients in the soil to leach away from the roots. Acid rain also attacks the trees by destroying the waxy coating of needles and lowering disease resistance. It makes some toxic elements, such as aluminum, more soluble. High aluminum concentrations in soil can prevent the uptake and use of nutrients by trees. Thus, while coniferous trees like slightly acidic soil conditions, acid rain makes conditions too acidic.
40. Student answers may vary depending on students' attitudes toward environmental concerns and their waste-disposal habits prior to studying this unit. Most students will likely experience a change in their outlook regarding proper waste disposal.
41. (a) Reverse osmosis is the process in which water is forced through a semi-permeable membrane, which allows some atoms or molecules to pass through but not others. The membrane allows passage of water molecules but not salt ions. In reverse osmosis, the membrane acts like an extremely fine filter to purify seawater. The salty water is put on one side of the membrane and pressure is applied to stop, and then reverse, the osmotic process. It generally takes a lot of pressure and is a fairly slow process.

(b) Although expensive, reverse osmosis is commercially viable in situations where fresh water is required yet no potable (drinkable) water sources are available.

(c) Student answers may vary depending on the facility chosen for study. Some examples of water treatment plants that use reverse osmosis to purify seawater include the Water Desalination Facility in Cape May, New Jersey, which may be built at the existing water treatment plant; and the Bitter End Yacht Club, North Soundings, British Virgin Islands, which produces 6000 L/d.

42. Both chlorine and iodine tablets are effective methods for purifying water. Chlorine tablets are widely available. When used correctly, chlorine destroys most bacteria, but is less effective against viruses and cysts. Chlorine forms by-products (THMs) with organic matter. It also changes the taste of water. Iodine is an effective and convenient method of water purification. It is effective against bacteria and viruses, but some protozoa are highly resistant to iodine. The effectiveness of iodine depends on the temperature of the water and duration: the colder the water, the higher the concentration of iodine and the longer the time needed to purify the water. There may be health risks associated with long-term use of iodine. Some people, such as those with a history of thyroid disease or iodine allergy, pregnant women, and young children should not use iodine for water purification. Iodine also gives water a distinct taste. [This information would be presented in a leaflet using various design formats chosen by the student.]

43. (a) If a chemical or biological water pollutant is extremely dangerous to human health, it may be necessary to set a maximum allowable concentration (MAC) at zero parts per million (ppm).

(b) It may be impossible to set and regulate a zero MAC level for a given contaminant. In many cases, trace amounts of chemicals or biological agents can be found in most water supplies. Additionally, it would be impossible to ensure that a water supply contained a concentration of zero for a given contaminant, due to the limitations of current monitoring equipment.

(c) Federal and provincial water quality agencies research the effects of a variety of chemicals that are found in water. Once the acceptable concentration for each chemical is determined, guidelines listing the MAC levels are published. For example, the MAC levels for Ontario drinking water can be found in the **Ontario Drinking Water Standards (2001)** document.