Synthesis

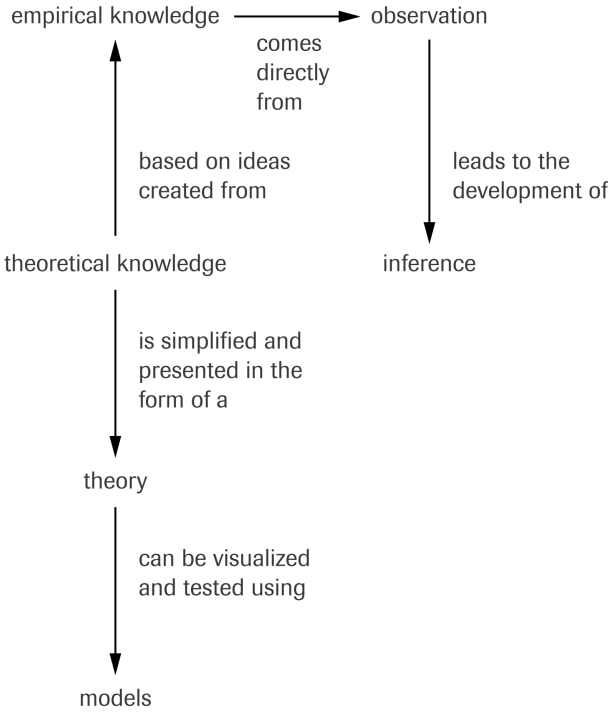
(j) Other tests that could be performed to increase confidence in results include flame emission spectroscopy and thermal emission spectroscopy.

UNIT 1 REVIEW

(Pages 71–73)

Understanding Concepts

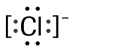
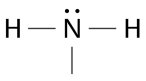
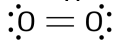
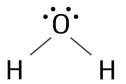
1. (a) An observation is a statement based on what you see, hear, taste, touch, and smell. An inference is a judgment or opinion based on observations and conclusions from testing. An example of an observation is "The water is boiling." An example of an inference is "Since the water is boiling, it must be hot."
   (b) Empirical knowledge comes directly from observations. Theoretical knowledge is based on ideas created to explain observations. An example of empirical knowledge is "Water boils at 100°C." Theoretical knowledge that explains this observation is "When water boils, water molecules have gained enough kinetic energy to escape the liquid state and enter the gaseous state."
   (c) A theory is an explanation of a large number of related observations. A model is a representation of a theory that helps scientists visualize a theory as well as test it. An example of a theory is the kinetic molecular theory. An example of a model is Bohr's model of the atom.

2. 

3. **Table 1** History of Atomic Theory

Scientist	Contribution to atomic theory
John Dalton	Matter consists of particles called atoms that are unique to each element.
J.J. Thomson	The atom is like a raisin bun, with negatively charged electrons scattered within a positively charged sphere.
Ernest Rutherford	The atom contains a dense positive core (the nucleus) that consists of positively charged subatomic particles known as protons. Negatively charged electrons orbit the nucleus like planets around the Sun.

James Chadwick	The atom's nucleus consists of protons as well as particles without electric charge, called neutrons.
Niels Bohr	Electrons spin around the nucleus of an atom in fixed orbits or energy levels. The energy of electrons is quantized.

4. (a) Blue light has a higher frequency. It has a shorter wavelength, therefore more cycles of light energy can pass through a given point in a specific time.
   (b) Blue light has more energy. A higher frequency means more energy.
5. A rainbow is an example of a continuous spectrum because it is an uninterrupted pattern of colours.
6. (a) An electron jumps from the ground state to an excited state by absorbing a quantum of energy; that is, the electron must absorb energy equal to the difference in energy between its ground state and the excited state.
   (b) The electron possesses more energy in the excited state.
   (c) When an electron returns from the excited state to the ground state, it releases the same amount of energy as it absorbed to reach the excited state.
7. The energy of an electron is said to be quantized because an electron must possess a specific amount of energy in order to be in a given energy level. To jump to a higher energy level, it must absorb a specific amount of energy. To drop to a lower energy level, it must release a specific amount of energy.
8. Spectroscopy is the experimental observation of line spectra. Since every element has a characteristic line spectrum, spectroscopy can be used to observe the line spectrum of a gas, and identify the gas by comparing its spectrum to the spectra of identified gases.
9. When a substance is subjected to a flame test, the heat of the flame is a source of energy that can be absorbed by the electrons in the sample. The excess energy causes the electrons to become excited and jump to higher energy levels. When the electrons fall back to their ground state, they release their excess energy in the form of light. If the light released is in the visible spectrum, it will change the colour of the flame.
10. Solutions containing an ionic solute conduct electricity because ionic solutes consist of anions and cations. When an ionic compound is dissolved in water, anions are attracted to the positively charged electrode of a cell, and cations are attracted to the negatively charged electrode. The movement of ions causes current to flow in the circuit.
11. (a) $[Na]^+$
    (b) $[Ca]^{2+}$
    (c) 
    (d) 
    (e) 
    (f) 
12. The chloride ion is negatively charged because it has gained one electron. The sodium ion and the calcium ion are both positively charged. Sodium has lost one electron, while calcium has lost two electrons.
13. Sodium and fluorine in (a) and magnesium and chlorine in (c) form ionic compounds because both pairs of atoms consist of a metal and a nonmetal. The metal loses one or more electrons and becomes a cation, while the nonmetal gains one or more electrons and becomes an anion. The electrostatic force of attraction between cations and anions results in the formation of an ionic bond.
14. Covalent and ionic bonds are formed between atoms in order to satisfy the octet rule. Covalent bonds involve the sharing of electrons between nonmetals, whereas ionic bonds involve the transfer of electrons between metals and nonmetals (cations and anions).
15. (a) 
    (b) 
    (c) 
    (d) 

16. Water is a polar molecule because it consists of two kinds of atoms, one of which—oxygen—has a higher electronegativity than the two hydrogen atoms. The two shared electron pairs between the two hydrogen atoms and the oxygen atom spend more time near the oxygen atom, giving it a slightly negative charge. The two hydrogen atoms therefore have a slight positive charge. Since the water molecule has a bent shape, the oxygen side of the molecule is slightly negatively charged and the hydrogen side is slightly positively charged, resulting in a polar molecule.
17. Carbon tetrachloride is a nonpolar molecule, even though it has four polar covalent bonds, because the four chlorine atoms are arranged symmetrically about the central carbon atom in a tetrahedral shape. As a result, no one end of the molecule is more polar than another end.
18. Nonpolar molecules composed of many atoms have higher melting points than nonpolar molecules composed of fewer atoms because the molecules with many atoms experience more London dispersion forces, and therefore require more energy to break these intermolecular bonds.
19. (a) synthesis
    (b) single displacement
    (c) decomposition
    (d) synthesis
    (e) double displacement
20. (a) could be considered a combustion reaction because oxygen is a reactant.
21. (a) sodium chloride + silver nitrate $\rightarrow$ silver chloride + sodium nitrate
    silver chloride—low solubility
    sodium nitrate—soluble
    aqueous sodium chloride + aqueous silver nitrate $\rightarrow$ solid silver chloride + aqueous sodium nitrate
    $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$
    (b) copper(II) chloride + sodium nitrate $\rightarrow$ sodium chloride + copper(II) nitrate
    sodium chloride—soluble
    copper(II) nitrate—soluble
    aqueous copper(II) chloride + aqueous sodium nitrate $\rightarrow$ no reaction
    (c) sodium sulfide + lead(II) nitrate $\rightarrow$ lead(II) sulfide + sodium nitrate
    lead(II) sulfide—low solubility
    sodium nitrate—soluble
    aqueous sodium sulfide + aqueous lead(II) nitrate $\rightarrow$ solid lead(II) sulfide + aqueous sodium nitrate
    $Na_2S_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow PbS_{(s)} + 2\ NaNO_{3(aq)}$
    (d) potassium hydroxide + ammonium chloride $\rightarrow$ potassium chloride + ammonium hydroxide
    potassium chloride—soluble
    ammonium hydroxide—soluble
    aqueous potassium hydroxide + aqueous ammonium chloride $\rightarrow$ no reaction
22. (a) $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$
    $Na^+_{(aq)} + Cl^-_{(aq)} + Ag^+_{(aq)} + NO^-_{3(aq)} \rightarrow AgCl_{(s)} + Na^+_{(aq)} + NO^-_{3(aq)}$ (total ionic equation)
    $\cancel{Na^+_{(aq)}} + Cl^-_{(aq)} + Ag^+_{(aq)} + \cancel{NO^-_{3(aq)}} \rightarrow AgCl_{(s)} + \cancel{Na^+_{(aq)}} + \cancel{NO^-_{3(aq)}}$
    $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$ (net ionic equation)
    (c) $Na_2S_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow PbS_{(s)} + 2\ NaNO_{3(aq)}$
    $2\ Na^+_{(aq)} + S^{2-}_{(aq)} + Pb^{2+}_{(aq)} + 2\ NO^-_{3(aq)} \rightarrow PbS_{(s)} + 2\ Na^+_{(aq)} + 2\ NO^-_{3(aq)}$ (total ionic equation)
    $\cancel{2\ Na^+_{(aq)}} + S^{2-}_{(aq)} + Pb^{2+}_{(aq)} + \cancel{2\ NO^-_{3(aq)}} \rightarrow PbS_{(s)} + \cancel{2\ Na^+_{(aq)}} + \cancel{2\ NO^-_{3(aq)}}$
    $Pb^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)}$ (net ionic equation)
23. (a) Since different metallic compounds impart a different colour to a flame as a result of the excitation of the electrons in the metal ion within the compound, the presence of a metal ion can be detected using a flame test.
    (b) Since each element has a characteristic line spectrum, spectroscopy can be used to identify a substance by comparing its line spectrum to the line spectra of identified substances.
    (c) The presence of an ion in solution can be detected by adding a compound that causes the ion to precipitate from the solution.

Applying Inquiry Skills

24. Some experimental techniques that may be used to help classify and identify the substance are spectroscopy, precipitation reactions, and flame tests.
25. Student answers will vary. Refer to the solutions for Investigation 1.16 for details.

26. (a) Solid A is an ionic solid because it has a high melting point and boiling point. It also conducts electricity in aqueous solution. Substance B is a molecular solid because it has a low melting point and boiling point and does not conduct electricity when in aqueous solution.
    (b) Other tests that may be performed include solubility in polar and nonpolar solvents as well as testing for hardness and odour.

27. **Analysis**

(a) Substance 1 is an ionic compound: $NaCl_{(aq)}$

Substance 2 is an acid: $HCl_{(aq)}$

Substance 3 is soluble but not ionic: $C_2H_5OH_{(aq)}$

Substance 4 is a base: $Ba(OH)_{2(aq)}$

Synthesis

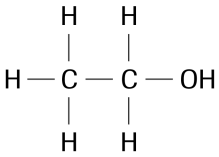
(b) The water is used as a control. The results of the conductivity and litmus tests are the dependent variable. The different substances that are dissolved in water are the independent variables. Since water is used to prepare the solutions for each of the different substances, any change in the dependent variable from the control results can be attributed to the changing independent variable.

(c) Solutions 1, 2, and 4 all have high conductivities, and could have been involved in somebody getting electrocuted. The most likely solution is $NaCl_{(aq)}$.When $NaCl_{(s)}$, $HCl_{(g)}$, and $Ba(OH)_{2(s)}$ are dissolved in water, the positive and negative ions dissociate. The ions can then carry an electric current. The electronegativity difference between the constituent atoms of $C_2H_5OH_{(aq)}$ results in polar covalent bonds—C_2H_5OH is a polar molecule. It does not dissociate into positive and negative ions, so the solution does not conduct electricity and could not have been involved in an electrocution.

$[Na]^+ \quad [:\ddot{\underset{\cdot\cdot}{Cl}}:]^-$

$[H]^+ \quad [:\ddot{\underset{\cdot\cdot}{Cl}}:]^-$

$[Ba]^{2+} \quad 2[OH]^-$



Making Connections

28. (a) $Fe^{3+}_{(aq)} + 3\ OH^-_{(aq)} \rightarrow Fe(OH)_{3(s)}$
    (b) Centrifugation to remove the precipitate is the most likely method.
29. It is safe for patients to drink a wet sample of barium sulfate because it has very low solubility. Barium sulfate does not dissociate into ions in the patient's gastrointestinal tract; therefore, the toxic barium ions are not absorbed by the body.
30. In a court of law, the prosecution or defence must prove, without a reasonable doubt, that the accused is guilty or innocent. Every technique can only test one characteristic of a substance at a time. If evidence that has undergone only one qualitative analysis test is introduced, it may be questioned based on the limits of the technique used, and deemed insufficient. Also, other substances could produce the same result.
31. American currency has many security features that deter counterfeiting. The denomination of the bill is printed in ink that changes colour depending on which way you tilt it. Each banknote has a serial number that starts with a letter. Right below that letter is the corresponding number of that letter in the alphabet. For example, if the serial number starts with a letter B, the number 2 appears right below since the letter B is the second letter of the alphabet. The paper on which American currency is printed is made of a blend of cotton and linen that also has a watermark specific to the denomination of the currency. American currency uses Intaglio printing (raised parts of the currency), has fibres embedded within it that fluoresce, and a vertical insert (slim bar) that has the denomination of the note. You can check some of these features simply by studying and touching the note. You may also use a UV light source, which causes the fibres of genuine notes to fluoresce. Counterfeit notes either fluoresce completely or not at

all. Iodine pens may also be used to check for counterfeit notes. Iodine turns brown in the presence of starch. Since banknote paper is made of cotton and linen fibres, an iodine pen should have no effect on the currency. If a brown colour appears on the bill, the iodine has reacted with starch and the bill is counterfeit. Canadian currency does not have watermarks, nor does it use paper made of cotton and linen. There are no inserts in Canadian currency. Canadian and American banknotes both have microprinting, Intaglio printing, embedded fluorescent fibres, and serial numbers.

32. In order to become an MRI technologist in Canada, you must first have a diploma in radiography, nuclear medicine, or radiation therapy from an accredited technical institution or community college. Two places where you can then obtain your MRI technologist training are the Michener Institute for Health Sciences in Toronto or Red River Community College in Winnipeg. The Michener Institute Program is 15 months long, whereas the Red River Community College Program is 6 months long. Courses offered in these programs include a physics and chemistry review, biochemistry and physiology review, pathology, advanced patient care, computer skills, professional communications, and MRI.

Extension

33. Hard water contains 400–600 mg/L of calcium ions and magnesium ions. Soft water has an ion concentration of less than 50 mg/L. Hard water does not remove soil completely, causing white fabrics to become grayed and dingy. As soil deposits accumulate, fabrics feel harsh and stiff. Zeolites are porous, symmetrical molecular sieves that trap calcium and magnesium ions, thereby reducing the hardness of water and enabling laundry detergents to work better.