Student Book page 11

A1.1 Check and Reflect

1. Following safety rules maximizes the chances that no one will become injured in the lab.
2. Students' answers should include at least one of the items in each set of responses listed below.
   a) Minimize the chance of poisoning by never eating, drinking, or chewing gum in the lab. Never place your fingers in your mouth or chew on pencils. Wash your hands with soap and water when finished.
   b) Minimize the chance of scalding by boiling small quantities of water. Keep a safe distance away from a beaker full of boiling water in case it shatters. Avoid crowding. Always use the proper kind of beaker tongs to handle a hot container.
   c) Wear safety glasses whenever you are performing a lab or are in a lab where someone is working. Do not put your face close to a beaker into which you are pouring something in case the liquid splashes or spills.
3. a) Caution: corrosive hazard
   b) Danger: toxic hazard
   c) Warning: flammable hazard
   d) Danger: explosive hazard
4. Students' answers will vary but could include the following:
   a) the kitchen: oven cleaner (sodium hydroxide)
   b) the bathroom: tile cleaner (sodium hydroxide or bleach)
   c) the garage: motor oil
   d) the garden: herbicide
   e) an automobile: gasoline
5. Workplace Hazardous Materials Information System
6. An MSDS is a data sheet describing important information about hazardous chemicals. Among the information contained on the data sheet are common names of the substance, physical properties, hazards, exposure limits, safety precautions, and first aid treatments.
7. Students' answers will vary but could include the following steps to take before starting a science activity:
   - make sure that you have permission to do the activity
   - make sure you are not working alone
   - read all the instructions
   - make sure you know about any special safety considerations or rules for the lab
8. A sketch of the lab should show such items as fire exits, fire extinguishers, fire alarms, fire blankets, eye wash station, and safety shower.
9. Students' answers will vary. "Lab safety" could connect to words such as personal responsibility, safety equipment, emergency equipment, rules of conduct, chemicals, procedures, fire exits, eye protection, and WHMIS.
10. Students' answers will depend on the rules you have provided. These could include: policies regarding the use of contact lenses, reporting of accidents, and special routines to accommodate persons with special needs (such as a person who uses a wheelchair).
11. a) An acid splash to the eye should be treated immediately with copious rinsing. Use a prescribed eye wash station or simply place the splashed eye under a tap and turn on the cold water. Speed is most important so that the corrosive substance can be quickly removed.
    b) A fuzzy sweater on fire will spread quickly over the body. Smother the fire immediately with a fire blanket or following the strategy of "stop, drop, and roll" to place someone on the floor and roll them to smother the flames.
    c) A fire alarm calls for an immediate evacuation. Turn the hot plate off by unplugging it. Leave the water to cool in the beaker. If it is in immediate danger of boiling over, use beaker tongs to remove it from the hot plate.
    d) Bleach can react with acids to make chlorine gas. If bleach mixes with something that results in bubble formation, the gas should be considered toxic. Depending on the severity of the chemical reaction, an immediate evacuation may be needed. If possible, place the mixture in a fume hood—but not if it would be too great a risk to personal health. Use beaker tongs to lift up the mixture.
12. Students' answers may vary but could include: First aid treatments explain what to do if the victim is unconscious, and whether to induce vomiting. They will explain how the exposure is to be treated, and whether to call extra help.

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A1.2 Check and Reflect

1. a) The boiling point is the temperature at which a liquid turns into a gas.
   b) Malleability is the ability of material to be hammered without breaking.
   c) Ductility is the ability of a material to be stretched into a wire.
   d) Solubility is a measure of the ability of a substance to dissolve.

2. a) Two solutions mix and a cloudy, opaque material forms.
   b) Bubbling or fizzing occurs.
   c) The container becomes warm to the touch or a thermometer indicates a temperature rise.
3. Water melts and freezes at the same temperature: $0^{o}C$.
4. No chemical reaction takes place when a solid dissolves and then crystallizes during evaporation. These types of changes are considered to be physical changes.
5. All chemical reactions produce new substances with new properties, and also involve the flow of energy into or out of the system.
6. A material that melts over a range of temperatures is a mixture.
7. The black solid is a compound. It cannot be a mixture because it has a constant melting point, rather than a melting range. It is not an element because it breaks down into simpler components, one being a metal and the other being a gas.
8. The combination of diamonds frozen into a block of ice is classified as a mechanical mixture, because it is a heterogeneous mixture of two pure substances.
9. Homogenized milk is heterogeneous. It appears to the naked eye to be homogeneous because the droplets of milk fat are extremely small.
10. Homogenized milk is a colloid. A colloid is intermediate between a true solution, which contains particles smaller than 1 nanometer and a suspension which contains particles larger than 100 nanometers. Unlike a suspension, the milk fat particles will never settle out, and unlike a true solution, the homogenized milk scatters light in all directions (an effect called Tyndall scattering), which a true solution will not do. A true solution does not scatter light to this extent.
11. All liquids have a characteristic boiling point, or boiling range. If the liquid is at normal pressures and below its boiling point, then bubble formation cannot be from boiling. So it is appropriate to assume that a gas is forming from a chemical reaction. If the liquid is hot enough to be at its boiling point, then gas formation is likely due to boiling. (Boiling can occur at lower than expected temperatures if the pressure has been reduced.) If the gas that is produced is collected and then cooled below the boiling point of the liquid, failure to condense shows that the gas must have been a new gas, possibly due to a chemical reaction.

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A1.3 Check and Reflect

1. Students can choose any three of the following:
   Heating—physical process
   Freezing—physical process
   Salting—physical and chemical
   Fermentation—chemical
2. Iron was not found in a metallic state except on the rare occasions when it fell to Earth as a meteorite.
3. When tin ores were added to the smelting of copper, bronze, a new and very useful material, was invented.
4. For example, alchemists discovered elemental mercury, how to make mineral acids, such as hydrochloric acid, and how to perform distillations.
5. Dalton proposed that:
   - all matter is made of small indivisible particles called atoms
   - all the atoms of an element are identical in properties such as size and mass
   - atoms of different elements have different properties
   - atoms can combine in fixed ratios
6. J. J. Thomson discovered the electron. Thomson proposed that an atom was a positive sphere with electrons embedded within it.
7. The scattering pattern of positive high-speed particles that were aimed at a thin sheet of gold foil showed that a tiny fraction of the particles bounced back from the foil. This indicated that atoms have a tiny, massive, positively charged centre.
8. Atoms emit specific colours of light that correspond to the differences in energy between specific energy levels in the atom. As electrons fall from higher energy levels to lower ones, they emit a characteristic energy (and wavelength) that we see as light.
9. First Nations peoples of North America were able to find naturally occurring metallic copper (native copper), and so had no need to develop a smelting technology to produce it.
10. See Figures A1.14 (page 22 of the student book), A1.16 (page 23), A1.18 (page 23), and A1.19 (page 24) in the student book.
11. Electrons in an atom are not in motion. They exist in energy levels in regions near the nucleus and occupy the whole energy level all at once.
12. Students' answers will vary but should reflect the following content. Aristotle might speak about the continuity of matter because, as far as anyone could see, matter could always be broken down

further. He could talk about matter forming out of a combination of fire, water, earth, and air. Democritus could counter that perhaps the smallest part had not yet been discovered, and that recombining atoms could explain how new materials could be produced from other ones.

13. Students' answers will vary but should reflect the following content:
    Dear Professor Thomson, When I was a student in your laboratory you discovered the electron. Because the electron is a negative particle and atoms are electrically neutral, we knew that there must be a positive particle to balance the electron. Well, professor, I think I have found it. I believe that all of the positive charge is concentrated in one tiny place at the centre of the atom. I don't know how several positive particles can be so close to each other without falling apart, but they seem to stay together. I call this region the nucleus. It is like the pit of an apricot.

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A1.0 Section Review

Knowledge

1. Students' answers will depend on the number and location of fire extinguishers in their lab.
2. Standard eye glasses do not have side flaps to prevent spills and splashes from getting to the eyes.
3. The hazard types are flammable, toxic, explosive, irritant, corrosive, biological, and electrical. A yellow triangle means caution; an orange diamond means warning; and a red octagon means danger.
4. Students' answers will vary. For example, they may choose: never work alone and only work with supervision, always wear eye protection, no horseplay in the lab, and wipe up all spills immediately. Other possible rules include those related to responsible behaviour; knowledge of location and use of emergency equipment such as fire extinguishers; knowledge about safety equipment, such as safety glasses; knowledge of escape routes; and rules about the safe handling of potentially toxic or corrosive materials.
5. A chemical reaction is a process in which a substance or substances react to create a different substance or substances. Two characteristics of all reactions are the formation of new substances with new properties, and the flow of energy either into or out of the reaction system.
6. Fermentation is a biochemical preservation technique. One fermentation method uses the bacteria lactobacilli, which produce the chemical lactic acid that acts as a preservative.
7. Bronze is a mixture, or alloy, of copper and tin. It is made by smelting copper with a tin ore. (The tin ore releases tin, which mixes with the copper. It is not necessary to make pure tin metal first.)
8. Antoine Lavoisier discovered the law of conservation of mass.
9. Dalton's model of the atom assumed that atoms were indivisible. J. J. Thomson's discovery of the electron suggested the existence of subatomic particles.
10. Dalton imagined that atoms of different elements would have different sizes, masses, and would also differ in their ability to combine with other atoms.
11. Bohr's model of the atom placed the electrons in energy levels. Although electrons could move between energy levels under the right conditions, they could not exist outside the energy levels.
12. In the modern theory of the atom, any reference to electrons moving within an energy level is abandoned. The electron can be thought to exist by occupying the whole energy level all at once. (Note to teacher: Very specialized experiments can set up certain conditions that can force the electron to be in a very small region of the atom—hence the idea of having a certain quantifiable probability that the electron will be found in a certain location. However, even in this context, the question of how the electron moved to this location is still abandoned—it just has a certain probability that it will be there. Normally, the electron just fills the whole energy level.)

Applications

13. a) bleach—toxic, corrosive
    b) drain cleaner—toxic, corrosive
    c) lube oil—flammable, toxic
    d) pesticide—flammable, toxic, irritant
    e) solid fertilizer—toxic, irritant
    f) gasoline—flammable, explosive, toxic
14. Students' answers will vary. An example is a new kind of drain cleaner, called CleanPiPex, a white crystalline powder that dissolves easily in water and reacts with biological wastes, including hair and grease. The MSDS would describe its state, colour, and appearance, and include warnings about it being corrosive and toxic.
15. a) mixture
    b) compound
    c) mixture
    d) mixture

e) mixture

16. a) Students' answers will vary. They could suggest using photographic film, which would be exposed by radiation coming out of the hole in the lead block. Also a Geiger counter could be used. Rutherford used a scintillation screen, which is a screen made of a chemical that glows when struck by radiation. These materials are used in the screens of today's television sets.
    b) Students' answers will vary. Moving electric charges are influenced by electromagnetic fields. Electromagnets can be placed near the likely path of radioactive particles. Positive and negative particles will be deflected in opposite directions, while neutral particles will pass through the field unaffected.
17. Rutherford was shooting positive particles at the gold foil. Since they bounced off the nuclei of the gold atoms instead of sticking to them, each nucleus must have the same charge as the particles in the beam—positive.
18. Students' answers will vary; the following is just one example.
    Dear Professor Dalton, I am pleased to inform you that your model of the atom has withstood the test of time very well. New discoveries have shown, however, that all atoms are made up of smaller parts. Also, some atoms of the same element are slightly different, with some weighing a little more than others. However, atoms of different elements have different properties, just as you have said, and different elements do combine in specific ratios.

Extensions

19. Students' answers will vary, but should show a positive nucleus and electrons around it in energy levels.
20. Students' answers will vary. The work of Dalton, Thomson, Rutherford, and Bohr should be mentioned.

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A2.1 Check and Reflect

1. Any four of the following:
   - alkali metals: lithium, sodium, potassium, rubidium, cesium
   - alkaline-earth metals: beryllium, magnesium, calcium, strontium, barium, radium
   - transition metals: iron, cobalt, nickel, copper, platinum
   - halogens: fluorine, chlorine, bromine, iodine
   - noble gases: helium, neon, krypton, argon, xenon, radon
2. Protons determine the identity of an element.
3. a) The valence energy level is the outermost (or highest-energy,) occupied energy level in an atom.
   b) Valence electrons are electrons occupying the valence energy level.
4. Isotopes are atoms of the same element with the same number of protons but differing numbers of neutrons.
5. An ion is a charged particle, such as a charged atom or a charged molecule. Positive ions are called cations and negative ions are called anions.
6. The atoms of an element gain or lose the number of electrons that will cause them to have the same number of valence electrons as the nearest noble gas has.
7. The octet rule states that atoms will form stable ions when they have an octet of electrons in their valence energy level. The exceptions are hydrogen, lithium, and beryllium, which have only two electrons in their valence energy level.
8. Students' drawings should show six protons and seven neutrons in the nucleus. The element is carbon. Students' labels should clearly indicate the nucleus in the centre, the neutrons and protons in the nucleus, the inner energy level with two electrons, and the outer, valence energy level with four electrons.
9. Nitrogen-14 and nitrogen-15 have the same number of protons but differ in that nitrogen-14 has 7 neutrons and nitrogen-15 has 8 neutrons.
10. a) phosphorus will gain 3 electrons
    b) sodium will lose 1 electron
    c) chlorine will gain 1 electron
    d) magnesium will lose 2 electrons
    e) iodine will gain 1 electron
11.

Element Name	Mass Number	Number of Protons	Number of Neutrons
calcium	41	***20***	***21***
uranium	238	***92***	***146***
aluminium	***27***	***13***	14
beryllium	9	***4***	5
neon	19	10	***9***
iron	***53***	***26***	27

12.

Atom or Ion Name	Overall Charge	Number of Protons	Number of Electrons	Symbol	Number of Electrons Lost or Gained
oxygen atom	***0***	***8***	***8***	O	***0***
oxide ion	***2−***	***8***	10	O^{2-}	***gained 2***
potassium ion	***1+***	19	***18***	***K^{+}***	***lost 1***
magnesium ion	***2+***	12	10	***Mg^{2+}***	***lost 2***
fluoride ion	***1−***	***9***	***10***	F^{-}	***gained 1***
calcium ion	2+	20	***18***	***Ca^{2}+***	***lost 2***
aluminium ion	3+	***13***	10	***Al^{3+}***	***lost 3***

13. The pattern of ion charges is that elements with similar charges appear in the same column in the periodic table. Using the octet rule, each element in the same column gains or loses the same number of electrons to achieve an octet. For the same reason, each element in the same column gains or loses the same number of electrons to achieve a full valence energy level.

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Practice Problem

Example Problem A2.1

1. a) $MgCl_{2(s)}$
   b) $Na_2S_{(s)}$
   c) $Ca_3P_{2(s)}$
   d) $K_3N_{(s)}$
   e) $CaF_{2(s)}$

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Practice Problem

Example Problem A2.2

2. a) iron(III) chloride
   b) lead(IV) oxide
   c) nickel(III) sulfide
   d) copper(II) fluoride
   e) chromium(III) sulfide

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Practice Problems

Example Problems A2.3, A2.4

3. a) $Ba(OH)_{2(s)}$
   b) $Fe_2(CO_3)_{3(s)}$
   c) $CuMnO_{4(s)}$
4. a) gold(III) nitrate
   b) ammonium phosphate
   c) potassium dichromate

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Practice Problem

Example Problems A2.5

5. a) carbon dioxide
   b) dinitrogen monoxide
   c) phosphorus trichloride
   d) $OF_{2(g)}$
   e) $N_2S_{4(s)}$
   f) $SO_{3(g)}$

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A2.2 Check and Reflect

1. a) An ion is a charged particle, such as a charged atom or molecule. For example, Mg^{2+} is an ion. So is CO_3^{2-}.
   b) A cation is a positively charged ion, such as Li^+ or NH_4^+. (The term cation—pronounced càt-ion—is derived from electrochemistry. It refers to ions that migrate towards the cathode.)
   c) An anion is a negatively charged ion, such as S^{2-}. (The term anion—pronounced àn-ion – is also derived from electrochemistry—it refers to ions that migrate towards the anode.)
   d) A polyatomic ion is a group of atoms covalently bonded that possesses an electric charge, such as NO_3^-.
   e) A multivalent metal is capable of forming more than one kind of stable ion, such as Fe^{2+} and Fe^{3+}.
2. The Greek prefixes are: 1, mono; 2, di; 3, tri; 4, tetra; 5, penta; 6, hexa; 7, hepta; 8, octa; 9, ennea (or nona); 10, deca.
3. a) Na^+
   b) Ca^{2+}

c) Ag^{+}
d) Cu^{2+}
e) Pb^{4+}
f) Cl^{-}
g) ClO_3^{-}
h) ClO_2^{-}
i) CH_3COO^{-}
j) NH_4^{+}

4. a) aluminium ion
   b) potassium ion
   c) zinc ion
   d) nickel(III) ion
   e) iron(II) ion
   f) iron(III) ion
   g) hydrogencarbonate ion
   h) hydroxide ion
   i) thiocyanate ion
   j) sulfite ion
5. a) methane
   b) ammonia
   c) water
   d) hydrogen sulfide
   e) hydrogen fluoride
6. a) ionic
   b) ionic
   c) molecular
   d) ionic
   e) molecular
   f) molecular
   g) ionic
   h) molecular
   i) molecular
   j) ionic
7. a) IUPAC stands for the International Union of Applied Chemistry.
   b) Students' answers will vary but they are likely to use the example of chalk, described at the beginning of section A2.2. The common name "chalk" doesn't provide enough information to differentiate the substances. Another example is the term "salt" which is really a class of ionic compounds. It contains table salt, $NaCl_{(s)}$ and road salt, $CaCl_{2(s)}$. The IUPAC provides a consistent way of naming substances that provides information on their chemical composition. This is useful to chemists and anyone else who uses chemicals.
8. a) aluminium chloride
   b) calcium sulfide
   c) sodium nitride
   d) potassium sulfate
   e) lithium oxide
   f) iron(III) iodide
   g) lead(IV) nitrate
   h) copper(I) phosphate
   i) ammonium nitrite
   j) sodium acetate (or sodium ethanoate)
9. a) $NaOH_{(s)}$
   b) $(NH_4)_2SO_{3(s)}$
   c) $Mg(SCN)_{2(s)}$
   d) $CaHPO_{4(s)}$
   e) $Al(CH_3COO)_{3(s)}$
   f) $CrCl_{3(s)}$
10. a) $N_2O_{4(g)}$
    b) $PCl_{5(g)}$
    c) $NI_{3(s)}$
    d) $CO_{(g)}$
    e) $P_4O_{10(s)}$
    f) $CS_{2(g)}$
    g) $SO_{3(s)}$
    h) $CH_{4(g)}$
    i) $NH_{3(g)}$
    j) $C_6H_{12}O6_{(s)}$
11. a) carbon tetrabromide
    b) nitrogen monoxide
    c) oxygen difluoride
    d) iodine monobromide
    e) selenium dibromide
    f) phosphorus trichloride
    g) dinitrogen trioxide
    h) sulfur dichloride
12. a) hydrogen peroxide
    b) iron(III) thiocyanate
    c) $C_2H_5OH_{(l)}$ or $CH_3CH_2OH_{(l)}$
    d) $Na_2SiO_{3(s)}$
    e) $NH_4ClO_{4(s)}$
    f) sulfur hexafluoride

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A2.3 Check and Reflect

1. The formula of an ionic compound begins with a metallic element or the ammonium ion.
2. An ionic compound is a crystalline solid at room temperature, with a relatively high boiling point (at least several hundred degrees). It has some tendency to dissolve in water, and its aqueous solution conducts electricity.
3. The formula of a molecular compound contains only non-metals.
4. Molecular compounds can be solid, liquid, or gas at room temperature. Their solids are soft and brittle, with low melting points. They tend not to dissolve in water, but those that do, with some exceptions, do not conduct electricity.
5. Water is polar because one part of the molecule is slightly negatively charged while another part of it is positively charged.
6. a) very soluble
   b) slightly souble
   c) very soluble

d) slightly soluble
e) slightly soluble
f) very soluble
g) very soluble

7. Water absorbs and retains heat extremely well. During the summer, land tends to heat up more than the surrounding water. In this case, the water has the effect of cooling the land. In winter, the water remains warm as the land cools. Heat from the water transfers to the land, keeping it warmer than it would otherwise be.
8. a) molecular: low melting point, volatile (has an odour), not crystalline
   b) ionic: high melting point, high solubility, crystalline and most importantly, highly conductive solutions
   c) molecular: despite a somewhat elevated melting point and an ability to dissolve well, the solution is not conductive.
   d) molecular: low melting point
   e) molecular: liquid at room temperature, insoluble
   f) molecular: liquid at room temperature, relatively low boiling point
9. a) bees wax
   b) sodium chloride
   c) table sugar
   d) carbon dioxide (dry ice)
   e) gasoline
   f) water
10. Adding sodium carbonate increases the concentration of carbonate in the water, which helps to precipitate Mg^{2+} and Ca^{2+} ions.

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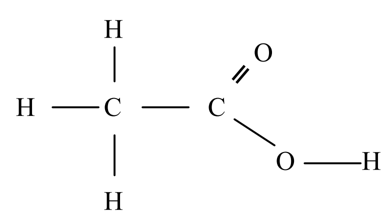
A2.4 Check and Reflect

1. a) basic
   b) acidic
   c) acidic
   d) neutral
   e) acidic
   f) neutral
   g) acidic
   h) basic
   i) neutral
   j) basic
2. An acid-base indicator is a substance that responds to the pH of a solution by changing colour as the pH changes.
3. a) base
   b) acid
   c) neither
   d) acid
   e) acid
   f) base
   g) acid
4. a) $HNO_{3(aq)}$
   b) $CsOH_{(s)}$
   c) $CH_3COOH_{(aq)}$
   d) $Ca(OH)_{2(s)}$
   e) $HCl_{(aq)}$
   f) $H_3PO_{4(aq)}$
   g) potassium hydroxide
   h) hydrobromic acid
   i) sulfuric acid
   j) magnesium hydroxide
5. a) neutral, pH 7; strongly acidic, pH 0; strongly basic, pH 14
   b) In order by decreasing acidity: stomach juices, lemon juice, acid rain, normal rain
   c) In order by decreasing acidity (increasing basicity): human blood, baking soda, window cleaner, oven cleaner
6. Universal indicator changes colour over a range of pH values. Litmus changes colour only at pH 7.
7. a) As $NaOH_{(aq)}$ is added to the hydrochloric acid solution, the pH will rise.
   b) The conductivity will not change much. Both $HCl_{(aq)}$ and $NaOH_{(aq)}$ solutions are highly conductive, as is $NaCl_{(aq)}$ which is produced when they react.
8. a) The solution has changed 4 pH units. Each pH unit represents a 10 times change in acidity. The solution has become 10 000 times more acidic.
   b) The solution has become 10 000 times less basic.
9. Model of ethanoic acid CH_3COOH



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A2.5 Check and Reflect

1. CFCs contains chlorine, which becomes a catalyst in the upper atmosphere, causing the destruction of the ozone layer. CFCs can remain in the atmosphere for as long as two generations or about 50 years.
2. Any chemical that has an affect on the body is considered to be a drug. Alcohol falls into this category.

3. Alcohol abuse can lead to psychological and physical dependence. It can lead to the destruction of the liver, the kidneys, and brain cells. It is toxic at high concentrations.
4. Nicotine's main affect on the body is addiction.
5. Carbon monoxide, benzene, formaldehyde, and tar are all poisonous components of cigarette smoke.
6. Consumer products that are not toxic themselves may have been made from toxic starting materials or have been handled or manufactured using toxic materials.
7. A food technologist might test a food product for nutritional value or to determine which additives should be used to give a food an appealing colour, taste, or texture.
8. Cosmetics formulators must understand the basic properties of materials used in cosmetics, as well as their interactions with each other. They must also know how to make a formulation possible on a large scale and how to test the product for correct chemical and physical properties.
9. Students' answers will vary. One example is nurses. They need to know how medicines affect the body, as well as how to administer them and how to monitor patients to determine if they are having adverse reactions to them.
10. In a physical dependence, the body has become accustomed to the drug and needs it to function. In psychological dependence, the drug is linked to certain moods or feelings, which disappears when the drug wears off.

Student Book pages 76–77

A2.0 Section Review

Knowledge

1. An element is a substance that cannot be broken down into other substances. There are about 90 naturally occurring elements. Students may also mention that an element is composed of atoms that all have the same number of protons.
2. A period is a horizontal row in the periodic table. A family (also known as a group) is a column in the periodic table. The elements in a family have similar chemical and physical properties.
3. Proton: mass of 1.7×10^{-24}g; located in the nucleus; charge of 1+
   Neutron: mass of 1.7×10^{-24}g; located in the nucleus; charge of 0
   Electron: mass of 9.1×10^{-28} g; located in a cloud surrounding the nucleus; charge of 1−
4. An energy level is a region surrounding the nucleus of an atom that may be empty or may contain one or more electrons.
5. The first three energy levels can contain up to 2, 8, and 8 electrons, respectively.
6. Atomic number is the number of protons in the nucleus of an atom.
7. Isotopes are atoms of the same element that have different numbers of neutrons. For example, oxygen-16 has 8 neutrons, while oxygen-18 has 10 neutrons.
8. Mass number is an integer equal to the total number of protons and neutrons in the nucleus of an atom.
9. Valence electrons are electrons in the highest occupied energy level of an atom.
10. Ions are electrically charged atoms or groups of atoms.
11. Ionic compounds are crystalline solids at room temperature. They have relatively high melting points, and many are very soluble in water.
12. An electrolyte is a solution that conducts electricity. Such a solution contains ions. These charged particles move through the solution when electrodes are placed in it. The movement of these ions is an electric current.
13. A precipitate is a solid that forms from a solution. Precipitation is the process of precipitate formation.
14. a) very soluble
    b) slightly soluble
    c) very soluble
    d) very soluble
    e) very soluble
    f) very soluble
    g) slightly soluble
    h) slightly soluble
15. Acids are electrolytes that make litmus red. They form solutions that have a pH less than 7. Metals such as magnesium and zinc react with acids to produce hydrogen gas. Acids taste sour.
16. Bases are slippery electrolytes that make litmus blue. They form solutions that have a pH greater than 7. Bases taste bitter.
17. The pH scale is a numerical measure of the acidity level of a solution. Acidic solutions have a pH less than 7; neutral solutions are pH 7; and basic solutions have a pH greater than 7.
18. Neutralization is a process by which an acid and a base react to make water (and a salt).

Applications

19. helium: 2 electrons
    neon: 10 electrons
    argon: 18 electrons

The valence energy levels of these elements are all full, making them very stable (and unreactive).

20. Mass number is an integer that equals the number of protons and neutrons in the nucleus. Atomic molar mass is the average of the masses of all of an element's isotopes. The atomic molar mass is found in the periodic table.
21. The diagram should show 10 protons and 11 electrons in a nucleus, with 2 electrons in the inner energy level and 8 electrons in the outer energy level. The element is neon.
22. These two isotopes of aluminium both have 13 protons and 13 electrons. However one has 13 neutrons, while the other has 14 neutrons.
23. a) sodium will lose 1 electron
    b) fluorine will gain 1 electron
    c) calcium will lose 2 electrons
    d) nitrogen will gain 3 electrons
    e) oxygen will gain 2 electrons
24. a) cesium chloride
    b) potassium nitride
    c) sodium oxide
    d) aluminium nitride
    e) magnesium sulfide
    f) lithium phosphide
    g) aluminium oxide
    h) silver fluoride
    i) iron(II) bromide
    j) lead(IV) chloride
    k) nickel(III) oxide
    l) gold(III) nitride
25. a) ammonium sulfide
    b) ammonium sulfate
    c) calcium nitrate
    d) aluminium hydrogencarbonate
    e) sodium silicate
    f) chromium(II) chlorite
    g) lead(IV) hydrogenphosphate
    h) potassium permanganate
    i) sodium dichromate
    j) aluminium acetate or ethanoate
    k) cobalt(II) benzoate
    l) ammonium thiocyanate
26. a) $NaBr_{(s)}$
    b) Ca3N2(s)
    c) MgO(s)
    d) AlCl3(s)
    e) RbI(s)
    f) Li3P(s)
    g) FeS(s)
    h) Cr3N2(s)
    i) Cu2O(s)
    j) TiBr4(s)
    k) PbF2(s)
    l) $CoN_{(s)}$
27. a) $Li_2CO_{3(s)}$
    b) Be(NO3)2(s)
    c) Na3PO4(s)
    d) NH4CN(s)
    e) NaHCO3(s)
    f) AlBO3(s)
    g) Mn(ClO4)2(s)
    h) Fe(OH)3(s)
    i) Cu(C6H5COO)2(s)
    j) Au(SCN)3(s)
    k) Pb(CrO4)2(s)
    l) $CrPO_{3(s)}$
28. a) dinitrogen monoxide
    b) sulfur trioxide
    c) phosphorus pentachloride
    d) CBr4(l)
    e) SCl6(g)
    f) OF2(g)
    g) nitrogen triiodide
    h) water
    i) ammonia
    j) CH4(g)
    k) P4O10(s)
    l) $XeF_{2(g)}$
29. A water molecule has a slightly positive side (the positive pole) and a slightly negative side (the negative pole).
30. Ionic solids are composed of ions that are strongly attracted to neighbouring ions of the opposite charge. This holds them tightly in place, making the ionic solid difficult to melt. Molecular solids do not have strong bonds between adjacent molecules, so it takes less heat to break them apart.
31. a) hydrofluoric acid
    b) nitric acid
    c) sodium hydroxide — base
    d) methanoic acid or formic acid
    e) ammonium hydroxide — base
    f) ethanoic acid or acetic acid
    g) phosphoric acid
    h) calcium hydroxide — base
32. A sudden intake of a large amount of alcohol will cause the blood alcohol concentration to become very high. This leads to loss of motor control, and can affect parts of the brain that control breathing and pumping of the heart, leading to unconsciousness and death. Vomiting and then inhaling the vomit can cause suffocation.
33. Long-term use of tobacco products leads to nicotine addition. Smoking damages both the respiratory system and the circulatory system. It also causes cancer.
34. Students' answer will vary. An example: School janitors use solvents to remove pen and felt pen marks. They use bleach, floor-stripping agents, and waxing products, as well as several kinds of

liquid cleaners. Many of these form poisonous gases if mixed. Over a career, chronic exposure to these substances can be harmful to health if they are not handled correctly. All janitorial staff receive WHMIS training and have access to MSDS for the chemicals they use.

Extensions

35. a) Students' diagrams should show 20 protons and 21 neutrons in the nucleus and 2, 8, 8, and 2 electrons in four energy levels.
    b) Students' diagrams should show 20 protons and 21 neutrons in the nucleus and 2, 8, and 8 electrons in three energy levels.
36. a) $Ca(NO_3)_{2(s)}$
    b) $Al(OH)_{3(s)}$
    c) $CH_3OH_{(l)}$
    d) $PBr_{3(g)}$
    e) ammonium carbonate
    f) sulfur dichloride
    g) tin(II) chloride
    h) strontium chloride
    i) $NaCH_3COO_{(s)}$
    j) $Pb(CH_3COO)_{4(s)}$
    k) $H_2O_{2(l)}$
    l) $C_6H_{12}O_{6(s)}$

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A3.1 Check and Reflect

1. Students' answers will vary. In addition to one or more of their own examples, they may use some or all of the examples in the text: the firing of the space shuttle engines, the use of five-minute epoxy, the reaction of ingredients in baking, and the decomposition of sodium azide in an automobile air bag.
2. The symbol *(l)* means liquid, which could be a pure liquid such as water or a homogeneous mixture of two non-water liquids such as oil and benzene. The symbol *(aq)* means aqueous, which is a homogeneous mixture in which water is the solvent, such as alcohol in water, or a brine (salt water solution).
3. The combustion of coal and of hexane both produce the same products: carbon dioxide and water.
4. The law of conservation of mass states that the total mass of a chemical system stays constant during a chemical reaction. Another way to state it is that the mass of the reactants equals the mass of the products.
5. An exothermic reaction releases heat and an endothermic reaction absorbs it.
6. Photosynthesis is a biochemical process that produces glucose from water and carbon dioxide through the input of energy. Cellular respiration is the exact reverse process: when glucose and oxygen react, energy is released and captured by the body to accomplish work.
7. Living systems use enzymes (biological catalysts) extensively to make reactions occur quickly at the temperature of the organism.
8. A rocket propellant needs to react quickly, be exothermic (so as to cause the product gases to expand), and produce gases from solids or liquids (so that the phase change will cause a rapid increase in volume).
9. The full environmental impacts of the combustion of fossil fuels are not yet known. However, it is certain that they release carbon dioxide, a known greenhouse gas. Many fossil fuels also contain sulfur, which, when burned, contributes to acid rain.
10. Using the law of conservation of mass:
    20.0 g carbon dioxide – 5.5 g carbon = 14.5 g oxygen
11. Using the law of conservation of mass:
    100.0 g sugar – 40.0 g carbon – 53.3 oxygen = 6.7 g hydrogen
12. a) The mass of sulfur that combined chemically in the reaction between iron and sulfur was 107.4 g iron sulfide – 50.0 g iron = 57.4 g sulfur.
    b) The mass of sulfur that was burned off was 100.0 g sulfur – 57.4 g sulfur that reacted = 42.6 g sulfur that burned off.
13. An exothermic reaction becomes endothermic when the reaction is reversed and an endothermic reaction becomes exothermic.

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Practice Problem

Example Problem A3.1

1. a) $N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$
   b) $CaC_{2(s)} + 2\ H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + C_2H_{2(g)}$
   c) $SiCl_{4(s)} + 2\ H_2O_{(l)} \rightarrow SiO_{2(s)} + 4\ HCl_{(aq)}$
   d) $2\ H_3PO_{4(aq)} + 3\ CaSO_{4(s)} \rightarrow Ca_3(PO_4)_{2(s)} + 3\ H_2SO_{4(aq)}$

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A3.2 Check and Reflect

1. A chemical equation is a set of words or symbols that records a chemical reaction. It indicates the identity of the reactants and the products in a chemical reaction.
2. Observations that might indicate that a chemical reaction is taking place include:
   - formation of a precipitate
   - formation of a gas
   - colour change
   - temperature change
   - corrosion of a metal
3. A balanced equation provides:
   - the formulas of all the substances involved
   - balancing coefficients
   - state (phase) of each substance
   - possibly information about energy changes
4. A chemical equation does not give information about what is happening during a reaction or about the rate of a reaction.
5. Balancing a chemical equation makes use of the law of conservation of mass.
6. The reactants are the substances that react in a chemical equation. In this example, they are $Zn_{(s)}$ and $HCl_{(aq)}$. The products are the new substances produced in a chemical reaction. In this example, they are $ZnCl_{2(aq)}$ and $H_{2(g)}$. State symbols are used to indicate the state of each reactant and product. In this example, they indicate that $Zn_{(s)}$ is a solid; $HCl_{(aq)}$ and $ZnCl_{2(aq)}$ are aqueous; and $H_{2(g)}$ is a gas. The formulas are symbols that represent each substance. $Zn_{(s)}$, $HCl_{(aq)}$, $ZnCl_{2(aq)}$, and $H_{2(g)}$ are all formulas. The balancing coefficients are numbers placed in front of formulas in chemical equations so that the same number of each element appears on both sides of the equation. In this case, the 2 in front of the $HCl_{(aq)}$ is a balancing coefficient.
7. a) $2\ Al_{(s)} + 3\ F_{2(g)} \rightarrow 2\ AlF_{3(s)}$
   b) $4\ K_{(s)} + O_{2(g)} \rightarrow 2\ K_2O_{(s)}$
   c) $C_6H_{12}O_{6(s)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(g)}$
   d) $H_2SO_{4(aq)} + 2\ NaOH_{(s)} \rightarrow Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$
   e) $Mg(CH_3COO)_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow Mg(NO_3)_{2(aq)} + 2\ AgCH_3COO_{(s)}$
   f) $2\ H_2O_{2(aq)} \rightarrow O_{2(g)} + 2\ H_2O_{(l)}$
8. The skeleton equation in each case is the same as the balanced equation but without the balancing coefficients.
   a) $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$
   b) $2\ NaCl_{(s)} \rightarrow 2\ Na_{(s)} + Cl_{2(g)}$
   c) $Ca(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow 2\ NaNO_{3(aq)} + CaSO_{4(s)}$
   d) $H_{2(g)} + CO_{(g)} \rightarrow C_{(s)} + H_2O_{(g)}$ (balanced)
   e) $2\ Na_{(s)} + 2\ H_2O_{(l)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$
   f) $2\ CaCO_{3(s)} + 2\ SO_{2(g)} + O_{2(g)} \rightarrow 2\ CaSO_{4(s)} + 2\ CO_{2(g)}$
   g) $S_{8(s)} + 8\ O_{2(g)} \rightarrow 8\ SO_{2(g)}$
   h) $Ca_3(PO_4)_{2(s)} + 3\ H_2SO_{4(aq)} \rightarrow 2\ H_3PO_{4(aq)} + 3\ CaSO_{4(s)}$
   i) $2\ KClO_{3(s)} \rightarrow 2\ KCl_{(s)} + 3\ O_{2(g)}$
9. a) $Ca_{(s)} + 2\ HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_{2(g)}$
   b) $Mg_3N_{2(s)} + 6\ H_2O_{(l)} \rightarrow 3\ Mg(OH)_{2(aq)} + 2\ NH_{3(g)}$
   c) $H_2SO_{4(aq)} + 2\ NaOH_{(s)} \rightarrow Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$
   d) $2\ NO_{2(g)} \rightarrow N_2O_{4(g)}$
   e) $CuCl_{2(aq)} + 2\ NaOH_{(aq)} \rightarrow Cu(OH)_{2(s)} + 2\ NaCl_{(aq)}$
10. Students' drawings should illustrate the following reaction:
    $2\ H_2O_{2(aq)} \rightarrow O_{2(g)} + 2\ H_2O_{(l)}$
    Two molecules of hydrogen peroxide should be drawn to the left of an arrow. One molecule of oxygen and two molecules of water should be drawn to the right of the arrow.

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Practice Problems

Example Problems A3.2, A3.3

2. Skeleton: $Li_{(s)} + O_{2(g)} \rightarrow Li_2O_{(s)}$
   Balanced: $4\ Li_{(s)} + O_{2(g)} \rightarrow 2\ Li_2O_{(s)}$
3. Skeleton: $Pb_{(s)} + Br_{2(l)} \rightarrow PbBr_{4(s)}$
   Balanced: $Pb_{(s)} + 2\ Br_{2(l)} \rightarrow PbBr_{4(s)}$

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Practice Problem

Example Problem A3.4

4. a) calcium nitride, $Ca_3N_{2(s)}$
   b) silver oxide, $Ag_2O_{(s)}$
   c) aluminium fluoride, $AlF_{3(s)}$

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Practice Problem

Example Problem A3.5

5. a) $8\ MgS_{(s)} \rightarrow 8\ Mg_{(s)} + S_{8(s)}$

b) $2\ KI_{(s)} \rightarrow 2\ K_{(s)} + I_{2(s)}$
c) $2\ Al_2O_{3(s)} \rightarrow 4\ Al_{(s)} + 3\ O_{2(g)}$
d) $NiCl_{2(s)} \rightarrow Ni_{(s)} + Cl_{2(g)}$

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Practice Problem

Example Problem A3.6

6. a) $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$
b) $2\ C_2H_{6(g)} + 7\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 6\ H_2O_{(g)}$
c) $C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$
d) $2\ C_6H_{6\ (l)} + 15\ O_{2(g)} \rightarrow 12\ CO_{2(g)} + 6\ H_2O_{(g)}$

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Practice Problems

Example Problems A3.7, A3.8

7. Word equation:
chlorine + nickel(III) bromide →
nickel(III) chloride + bromine
Skeleton equation:
$Cl_{2(g)} + NiBr_{3(aq)} \rightarrow NiCl_{3(aq)} + Br_{2(l)}$
Balanced equation:
$3\ Cl_{2(g)} + 2\ NiBr_{3(aq)} \rightarrow 2\ NiCl_{3(aq)} + 3\ Br_{2(l)}$
8. Word equation:
zinc + silver nitrate → zinc nitrate + silver
Skeleton equation:
$Zn_{(s)} + AgNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + Ag_{(s)}$
Balanced equation:
$Zn_{(s)} + 2\ AgNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + 2\ Ag_{(s)}$

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Practice Problem

Example Problem A3.9

9. a) Word equation:
copper(I) nitrate + potassium bromide →
copper(I) bromide + potassium nitrate
Skeleton equation:
$CuNO_{3(aq)} + KBr_{(aq)} \rightarrow CuBr_{(s)} + KNO_{3(aq)}$
Balanced equation:
$CuNO_{3(aq)} + KBr_{(aq)} \rightarrow CuBr_{(s)} + KNO_{3(aq)}$
b) Word equation:
aluminium chloride + sodium hydroxide →
aluminium hydroxide + sodium chloride
Skeleton equation:
$AlCl_{3(aq)} + NaOH_{(aq)} \rightarrow Al(OH)_{3(s)} + NaCl_{(aq)}$
Balanced equation:
$AlCl_{3(aq)} + 3\ NaOH_{(aq)} \rightarrow$
$Al(OH)_{3(s)} + 3\ NaCl_{(aq)}$

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Practice Problem

Example Problem A3.10

10. a) Type of reaction: hydrocarbon combustion
Products: carbon dioxide and water
Skeleton equation:
$C_4H_{10(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$
b) Type of reaction: double replacement
Products: calcium phosphate and sodium nitrate
Skeleton equation:
$Ca(NO_3)_{2(aq)} + Na_3PO_{4(aq)} \rightarrow$
$Ca_3(PO_4)_{2(s)} + NaNO_{3(aq)}$
c) Type of reaction: single replacement
Products: calcium nitrate and silver
Skeleton equation:
$Ca_{(s)} + AgNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + Ag_{(s)}$
d) Type of reaction: formation or synthesis
Products: magnesium oxide
Skeleton equation:
$Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$
e) Type of reaction: decomposition
Products: aluminium and chlorine
Skeleton equation:
$AlCl_{3(s)} \rightarrow Al_{(s)} + Cl_{2(g)}$

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Practice Problems

Example Problem A3.11

11. Word equation:
lead(IV) nitrate + zinc → zinc nitrate + lead
Skeleton equation:
$Pb(NO_3)_{4(aq)} + Zn_{(s)} \rightarrow Zn(NO_3)_{2(aq)} + Pb_{(s)}$
Balanced equation:
$Pb(NO_3)_{4(aq)} + 2\ Zn_{(s)} \rightarrow 2\ Zn(NO_3)_{2(aq)} + Pb_{(s)}$
12. $3\ Ag_{(s)} + Au(NO_3)_{3(aq)} \rightarrow 3\ AgNO_{3(aq)} + Au_{(s)}$

A3.3 Check and Reflect

1. a) Type of reaction: decomposition
   $CaCl_{2(s)} \rightarrow Ca_{(s)} + Cl_{2(g)}$ (balanced)
   b) Type of reaction: single replacement
   $Mg(ClO_4)_{2(s)} + 2\ Na_{(s)} \rightarrow 2\ NaClO_{4(s)} + Mg_{(s)}$
   c) Type of reaction: decomposition
   $2\ NaN_{3(s)} \rightarrow 2\ Na_{(s)} + 3\ N_{2(g)}$
   d) Type of reaction: double replacement
   $Ca(NO_3)_{2(aq)} + Cu_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + 2\ CuNO_{3(aq)}$
   e) Type of reaction: combustion
   $2\ C_5H_{10(l)} + 15\ O_{2(g)} \rightarrow 10\ CO_{2(g)} + 10\ H_2O_{(g)}$
   f) Type of reaction: single replacement
   $Li_4C_{(s)} + 2\ Ca_{(s)} \rightarrow 4\ Li_{(s)} + Ca_2C_{(s)}$
   g) Type of reaction: decomposition
   $PbO_{2(s)} \rightarrow Pb_{(s)} + O_{2(g)}$ (balanced)
   h) Type of reaction: combustion
   $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$
   i) Type of reaction: formation
   $2\ Li_{(s)} + Cl_{2(g)} \rightarrow 2\ LiCl_{(s)}$
   j) Type of reaction: double replacement
   $3\ NaI_{(aq)} + AlCl_{3(aq)} \rightarrow 3\ NaCl_{(aq)} + AlI_{3(s)}$
2. a) Type of reaction: double replacement
   $Na_2SO_{4(aq)} + CaCl_{2(aq)} \rightarrow 2\ NaCl_{(aq)} + CaSO_{4(s)}$
   b) Type of reaction: formation
   $3\ Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$
   c) Type of reaction: double replacement
   $Sr(OH)_{2(aq)} + PbBr_{2(aq)} \rightarrow SrBr_{2(aq)} + Pb(OH)_{2(s)}$
   d) Type of reaction: single replacement
   $2\ Ni(NO_3)_{3(aq)} + 3\ Ca_{(s)} \rightarrow 3\ Ca(NO_3)_{2(aq)} + 2\ Ni_{(s)}$
   e) Type of reaction: combustion
   $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$
   f) Type of reaction: formation
   $4\ Na_{(s)} + O_{2(g)} \rightarrow 2\ Na_2O_{(s)}$
   g) Type of reaction: formation
   $N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$
   h) Type of reaction: decomposition
   $2\ HCl_{(aq)} \rightarrow H_{2(g)} + Cl_{2(g)}$
   i) Type of reaction: single replacement
   $2\ AlI_{3(aq)} + 3\ Br_{2(l)} \rightarrow 2\ AlBr_{3(aq)} + 3\ I_{2(s)}$
   j) Type of reaction: single replacement is the closest but it does not fit the pattern exactly
   $2\ Na_{(s)} + 2\ HOH_{(l)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$
   or
   $2\ H_2O_{(l)} + 2\ Na_{(s)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$
3. a) Type of reaction: formation
   Product: $Li_2O_{(s)}$
   b) Type of reaction: decomposition
   Products: $Cu_{(s)}$ and $Cl_{2(g)}$
   c) Type of reaction: single replacement
   Products: $Cu_{(s)}$ and $Al_2(SO_4)_{3(aq)}$
   d) Type of reaction: double replacement
   Products: $Ca(NO_3)_{2(aq)}$ and $PbBr_{2(s)}$
   e) Type of reaction: combustion
   Products: $CO_{2(g)}$ and $H_2O_{(g)}$
   f) Type of reaction: double replacement
   Products: $AgCl_{(s)}$ and $KNO_{3(aq)}$
   g) Type of reaction: decomposition
   Products: $N_{2(g)}$ and $I_{2(s)}$
   h) Type of reaction: single replacement
   Products: $S_{8(s)}$ and $LiCl_{(aq)}$
   i) Type of reaction: formation
   Product: $Al_2S_{3(s)}$
   j) Type of reaction: combustion
   Products: $CO_{2(g)}$ and $H_2O_{(g)}$
4. $3\ Zn_{(s)} + N_{2(g)} \rightarrow Zn_3N_{2(s)}$
5. $2\ HgO_{(s)} \rightarrow 2\ Hg_{(l)} + O_{2(g)}$
6. $2\ C_6H_{6(l)} + 15\ O_{2(g)} \rightarrow 12\ CO_{2(g)} + 6\ H_2O_{(g)}$
7. $Br_{2(l)} + CaI_{2(aq)} \rightarrow CaBr_{2(aq)} + I_{2(s)}$ (balanced)
8. $Pb(NO_3)_{2(aq)} + 2\ NaI_{(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbI_{2(s)}$
9. $HCl_{(aq)} + NaOH_{(s)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
   This resembles a double replacement reaction because the water could be written as H-OH.
10. $C_{12}H_{22}O_{11(s)} + 12\ O_{2(g)} \rightarrow 12\ CO_{2(g)} + 11\ H_2O_{(g)}$

Practice Problems

Example Problem A3.12

13. Calculate the molar mass of $CH_3OH_{(l)}$:
    Atomic molar mass of C
    = 12.01 g/mol x 1 = 12.01 g/mol
    Atomic molar mass of H
    = 1.01 g/mol x 4 = 4.04 g/mol
    Atomic molar mass of O
    = 16.00 g/mol x 1 = 16.00 g/mol
    Molar mass of $CH_3OH_{(l)}$ = 32.05 g/mol
14. Calculate the molar mass of $Na_2SO_{4(s)}$:
    Atomic molar mass of Na
    = 22.99 g/mol x 2 = 45.98 g/mol
    Atomic molar mass of S
    = 32.07 g/mol x 1 = 32.07 g/mol
    Atomic molar mass of O
    = 16.00 g/mol x 4 = 64.00 g/mol
    Molar mass of $Na_2SO_{4(s)}$ = 142.05 g/mol
15. Calculate the molar mass of $CO_{2(g)}$:
    Atomic molar mass of C
    = 12.01 g/mol x 1 = 12.01 g/mol
    Atomic molar mass of O
    = 16.00 g/mol x 2 = 32.00 g/mol
    Molar mass of $CO_{2(g)}$ = 44.01 g/mol
16. Calculate the molar mass of $(NH_4)_3PO_{4(s)}$:
    Atomic molar mass of N
    = 14.01 g/mol x 3 = 42.03 g/mol

Atomic molar mass of H
= 1.01 g/mol x 12 = 12.12 g/mol
Atomic molar mass of P
= 30.97 g/mol x 1 = 30.97 g/mol
Atomic molar mass of O
= 16.00 g/mol x 4 = 64.00 g/mol
Molar mass of $(NH_4)_3PO_{4(s)}$ = 149.12 g/mol

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Practice Problems

Example Problem A3.13

17. The molar mass of $NaOH_{(s)}$ is 40.00 g/1 mol

$$\text{Therefore} \quad m_{\text{NaOH}} = 5.0\ \cancel{\text{mol}} \times \frac{40.00\ \text{g}}{1\ \cancel{\text{mol}}}$$

$$= 2.0 \times 10^2\ \text{g (or 0.20 kg)}$$

The mass of 5.0 mol of $NaOH_{(s)}$ is 2.0×10^2 g.

18. The molar mass of $C_6H_{12}O_{6(s)}$ is 180.18 g/mol

$$\text{Therefore} \quad n_{\text{C6H12O6}(s)} = 360\ \cancel{\text{g}} \times \frac{1\ \text{mol}}{180.18\ \cancel{\text{g}}}$$

$$= 2.00\ \text{mol}$$

There are 2.00 mol of $C_6H_{12}O_{6(s)}$ in a 360-g sample.

19. The molar mass of $NH_{3(g)}$ = 17.04 g/mol

$$m_{\text{NH3}(g)} = 5.00\ \cancel{\text{mol}} \times \frac{17.04\ \text{g}}{1\ \cancel{\text{mol}}}$$

$$= 85.2\ \text{g}$$

The mass of 5.00 moles of NH_3 is 85.2 g.

20. The molar mass of $Mg(NO_3)_{2(s)}$ is 148.33 g/mol

$$\text{Therefore} \quad n_{\text{Mg(NO3)2}(s)} = 20.0\ \cancel{\text{g}} \times \frac{1\ \text{mol}}{148.33\ \cancel{\text{g}}}$$

$$= 0.135\ \text{mol}$$

There are 0.135 mol of $Mg(NO_3)_{2(s)}$ in a 20.0-g sample.

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A3.4 Check and Reflect

1. There are 6.02×10^{23} particles in one mole.
2. Carbon-12 was chosen as the standard for defining the mole, with 12 g exactly being equal to 1 mole.
3. Molar mass is the mass, in grams, of one mole of any substance.
4. The number of particles in one mole of substance is called Avogadro's number, N_A.
5. a) $N_{\text{gold atoms}}$
   $= 1.0\ \cancel{\text{mol}} \times 6.02 \times 10^{23}$ Au atoms/1 $\cancel{\text{mol}}$
   $= 6.0 \times 10^{23}$ atoms
   There are 6.0×10^{23} gold atoms in 1.0 mol of gold.
   b) $N_{\text{helium atoms}}$
   $= 2.5\ \cancel{\text{mol}} \times 6.02 \times 10^{23}$ $He_{(g)}$ atoms/1 $\cancel{\text{mol}}$
   $= 1.5 \times 10^{24}$ atoms
   There are 1.5×10^{24} helium atoms in 2.5 mol of helium.
   c) $N_{\text{H2 molecules}}$
   $= 10.0\ \cancel{\text{mol}} \times 6.02 \times 10^{23}$ $H_{2(g)}$ molecules/1 $\cancel{\text{mol}}$
   $= 6.02 \times 10^{24}$ molecules
   There are 6.02×10^{24} H_2 molecules in 10.0 mol of $H_{2(g)}$.
   d) $N_{\text{CO2 molecules}}$
   $= 0.628\ \cancel{\text{mol}} \times 6.02 \times 10^{23}$ $CO_{2(g)}$ molecules/1 $\cancel{\text{mol}}$
   $= 3.78 \times 10^{23}$ molecules
   There are 3.78×10^{23} $CO_{2(g)}$ molecules in 0.628 mol of $CO_{2(g)}$.
6. a) $n_{\text{Na}} = 28\ \cancel{\text{g}} \times 1\ \text{mol}/22.99\ \cancel{\text{g}}$
   $= 1.2$ mol
   There are 1.2 mol of sodium in a 28-g sample.
   b) $n_{\text{Fe}} = 28\ \cancel{\text{g}} \times 1\ \text{mol}/55.85\ \cancel{\text{g}}$
   $= 0.50$ mol
   There is 0.50 mol of iron in a 28-g sample.
   c) $n_{\text{Zn}} = 150\ \cancel{\text{g}} \times 1\ \text{mol}/65.39\ \cancel{\text{g}}$
   $= 2.29$ mol
   There are 2.29 mol of zinc in a 150-g sample.
   d) $n_{\text{NaCl}} = 100.0\ \cancel{\text{g}} \times 1\ \text{mol}/58.45\ \cancel{\text{g}}$
   $= 1.711$ mol
   There are 1.711 mol of $NaCl_{(s)}$ in a 100.0-g sample.
   e) $n_{\text{N2}} = 26.0\ \cancel{\text{g}} \times 1\ \text{mol}/28.02\ \cancel{\text{g}}$
   $= 0.928$ mol
   There is 0.928 mol of $N_{2(g)}$ in a 26.0-g sample.
7. a) $m_{\text{Ni}} = 1.0\ \cancel{\text{mol}} \times 58.71\ \text{g}/1\cancel{\text{mol}}$
   $= 59$ g
   The mass of 1.0 mole of nickel atoms is 59 g.
   b) $m_{\text{CO2}} = 1.0\ \cancel{\text{mol}} \times 44.01\ \text{g}/1\ \cancel{\text{mol}}$
   $= 44$ g
   The mass of 1.0 mole of carbon dioxide molecules is 44 g.
   c) $m_{\text{H2O}} = 5.0\ \cancel{\text{mol}} \times 18.02\ \text{g}/1\ \cancel{\text{mol}}$
   $= 90$ g
   The mass of 5.0 moles of water is 90 g.
   d) $m_{\text{MgCl2}} = 36.8\ \cancel{\text{mol}} \times 95.21\ \text{g}/1\ \cancel{\text{mol}}$
   $= 3.50 \times 10^3$ g

The mass of 36.8 moles of $MgCl_{2(s)}$ is 3.50 kg.

e) m_{Al2S3} = 0.00127 ~~mol~~ x 150.14 g/1 ~~mol~~
= 0.191 g
The mass of 0.00127 moles of $Al_2S_{3(s)}$ is 0.191 g.

8. a) 1 mol; b) 6 g; c) 12.0 x 10^{24} molecules
9. n_{Cu} = 3.01 x 10^{23} $Cu_{(s)}$ ~~atoms~~ x 1 mol/6.02 x 10^{23} ~~atoms~~
= 0.500 mol $Cu_{(s)}$
m_{Cu} = 0.500 ~~mol~~ x 63.55 g/1 ~~mol~~
= 31.8 g
The mass of 3.01 x 10^{23} molecules of copper is 31.8 g.
10. n_{H2O} = 1000 ~~g~~ x 1 mol/18.02 ~~g~~
= 55.49 mol $H_2O_{(l)}$
$N_{H2O\ molecules}$
= 55.49 ~~mol~~ x 6.02 x 10^{23} $H_2O_{(l)}$ molecules/1 ~~mol~~
= 3.34 x 10^{25} molecules
There are 3.34 x 10^{25} molecules of water in 1000 g.
11. n_{O2} = 64 ~~g~~ x 1 mol/32.00 ~~g~~
= 2.00 mol $O_{2(g)}$
$N_{O2\ molecules}$
= 2.00 ~~mol~~ x 6.02 x 10^{23} $O_{2(g)}$ molecules/1 ~~mol~~
= 1.204 x 10^{24} molecules
$N_{O\ atoms}$
= 1.204 x 10^{24} $O_{2(g)}$ molecules x 2 O atoms/1 $O_{2(g)}$ molecule
= 2.4 x 10^{24} molecules
There are 2.4 x 10^{24} atoms of oxygen in 64 g of oxygen gas.
12. A mole of oxygen gas contains twice as many atoms as a mole of iron, because each molecule of oxygen contains two atoms.
13. $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$
1 mole of methane produces 2 moles of water, therefore 15 moles of methane produces 30 moles of water.

Student Book page 113

A3.0 Section Review

Knowledge

1. A chemical reaction is a process that occurs when a substance or substances (reactants) react to form a different substance or substances (products). The new substances have different properties from those of the reactants. All reactions are accompanied by energy changes and by the formation of new materials with new properties. All reactions are governed by the law of conservation of mass.
2. Indications that a reaction is taking place could include: colour changes, temperature changes, formation of a precipitate, formation of a gas, and corrosion of a metal.
3. a) Students' answers will vary. One example in the household is the carbon dioxide gas that forms during baking with the reaction of a dry acid with a dry base in baking powder.
   b) Students' answers will vary. An example in a commercial application is the carbonic acid in soft drinks that decomposes to give a "fizzy" taste. In another application, sodium azide decomposes to fill an automobile air bag with nitrogen gas. Students may also mention the use of explosives for road building or mining.
4. a) State symbols present: solid *(s)*, gas *(g)*
   b) The 4 in front of the Na means 4 atoms of sodium or 4 moles of sodium.
   1 is not shown in front of oxygen, meaning 1 molecule of oxygen or 1 mole of oxygen.
   2 in front of the $Na_2O_{(s)}$ means 2 formula units of sodium oxide or 2 moles of sodium oxide.
   c) The reactants are sodium and oxygen and the product is sodium oxide.
   d) The equation is properly balanced because 4 atoms (or moles) of sodium and 2 atoms (or moles) of oxygen are represented on each side.
5. The five reaction types studied are:
formation: A + B → AB
decomposition: AB → A + B
single replacement: A + BC → AC + B where A is a metal
D + BC → BD + C where D is a non-metal
double replacement: AB + CD → AD + CB
hydrocarbon combustion: $C_xH_y + O_2 \rightarrow CO_2 + H_2O$
6. $N_A = 6.02 \times 10^{23}$
7. A mole is 6.02 x 10^{23} particles; more precisely it is an Avogadro's number of particles. It equals the number of atoms in exactly 12 g of carbon-12.
8. Atomic molar mass is the mass in grams of one mole of atoms of a given element.
9. a) n_C = 36.03 ~~g~~ $C_{(s)}$ x 1 mol/12.01 ~~g~~ $C_{(s)}$
   = 3.000 mol $C_{(s)}$
   There are 3.00 mol of methane in 36.03 g of $C_{(s)}$.
   b) n_{H2O} = 1000 ~~g~~ x 1 mol/18.02 ~~g~~
   = 55.49 mol $H_2O_{(l)}$
   There are 55.49 mol of water in 1000 g of water.
   c) n_{CaCO3} = 50.0 ~~g~~ x 1 mol/100.09 ~~g~~
   = 0.500 mol $CaCO_{3(s)}$
   There are 0.500 mol of calcium carbonate in 50.0 g of $CaCO_{3(s)}$.
   d) n_{NH4NO3} = 22.61 ~~g~~ x 1 mol/80.06 ~~g~~
   = 0.2824 mol $NH_4NO_{3(s)}$

There are 0.2824 mol of ammonium nitrate in 22.61 g of $NH_4NO_{3(s)}$.

e) $n_{Al(OH)3} = 0.795\ \cancel{g} \times 1\ mol/78.01\ \cancel{g}$
$= 0.0102\ mol\ Al(OH)_{3(s)}$
There are 0.0102 mol of aluminium hydroxide in 50.0 g of $Al(OH)_{3(s)}$.

10. a) $m_{Au} = 1.0\ \cancel{mol} \times 196.97 g/1\ \cancel{mol}$
$= 2.0 \times 10^2$ g
$= 0.20$ kg
The mass of 1.0 mole of $Au_{(s)}$ is 0.20 kg.

b) $m_{Cu} = 5.6\ \cancel{mol} \times 63.55\ g/1\ \cancel{mol}$
$= 360$ g
$= 0.36$ kg
The mass of 5.6 mole of $Cu_{(s)}$ is 0.36 kg.

c) $m_{H2} = 100\ \cancel{mol} \times 2.02\ g/1\ \cancel{mol}$
$= 202$ g
The mass of 100 mole of $H_{2(g)}$ is 202 g.

d) $m_{NaOH} = 0.918\ \cancel{mol} \times 40.00\ g/1\ \cancel{mol}$
$= 36.7\ g\ NaOH_{(s)}$
The mass of 0.918 mole of $NaOH_{(s)}$ is 36.7 g

e) $m_{Mg(CH3COO)2} = 3.00\ \cancel{mol} \times 142.41\ g/1\ \cancel{mol}$
$= 427$ g
The mass of 3.00 mole of $Mg(CH_3COO)_2$ is 427 g.

Applications

11. In both cases, precipitation refers to substances formed in different states from the original substances. In a single or double replacement reaction, a solid forms from a solution. In weather, rain or snow forms from water vapour in the air.

12. a) $3\ Br_{2(l)} + 2\ Al_{(s)} \rightarrow 2\ AlBr_{3(s)}$

b) $(NH_4)_2CO_{3(s)} + Ca(NO_3)_{2(aq)} \rightarrow$
$2\ NH_4NO_{3(aq)} + CaCO_{3(s)}$

c) $NaOH_{(s)} + HCl_{(aq)} \rightarrow$
$NaCl_{(aq)} + H_2O_{(l)}$ (balanced)

13. a) Type of reaction: decomposition
Balanced equation:
$2\ KBrO_{3(s)} \rightarrow 2\ KBr_{(s)} + 3\ O_{2(g)}$

b) Type of reaction: hydrocarbon combustion
Balanced equation:
$2\ C_2H_{2(g)} + 5\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 2\ H_2O_{(g)}$

c) Type of reaction: single replacement
Balanced equation:
$4\ AuCl_{3(aq)} + 3\ Pb_{(s)} \rightarrow 3\ PbCl_{4(aq)} + 4\ Au_{(s)}$

d) Type of reaction: formation or synthesis
Balanced equation:
$6\ K_{(s)} + N_{2(g)} \rightarrow 2\ K_3N_{(s)}$

e) Type of reaction: double replacement
Balanced equation:
$Sn(NO_3)_{4(aq)} + 2\ Ca(OH)_{2(s)} \rightarrow$
$2\ Ca(NO_3)_{2(aq)} + Sn(OH)_{4(s)}$

14. a) Type of reaction: formation or synthesis
Balanced equation:
$F_{2(g)} + Ca_{(s)} \rightarrow CaF_{2(s)}$ (balanced)

b) Type of reaction: single replacement
Balanced equation:
$3\ Cl_{2(g)} + 2\ NiBr_{3(aq)} \rightarrow 2\ NiCl_{3(aq)} + 3\ Br_{2(l)}$

c) Type of reaction: hydrocarbon combustion
Balanced equation:
$2\ C_5H_{10(g)} + 15\ O_{2(g)} \rightarrow 10\ CO_{2(g)} + 10\ H_2O_{(g)}$

d) Type of reaction: decomposition
Balanced equation:
$2\ KBr_{(s)} \rightarrow 2\ K_{(s)} + Br_{2(l)}$

e) Type of reaction: double replacement
Balanced equation:
$AlF_{3(aq)} + Na_3PO_{4(aq)} \rightarrow AlPO_{4(s)} + 3\ NaF_{(aq)}$

Extensions

15. The law of conservation of atoms is a legitimate way of stating the law of conservation of mass. In balancing equations, we count the number of atoms on both sides of the equation. The law breaks down in nuclear reactions when atoms are created or destroyed and energy/mass conversions occur.

16. $n_{Na} = 1.204 \times 10^{23}\ Na\ \cancel{atoms} \times 1\ mol/6.02 \times 10^{23}\ \cancel{atoms}$
$= 0.200\ mol\ Na_{(s)}$
$m_{Na} = 0.200\ \cancel{mol} \times 22.99\ g/1\ \cancel{mol}$
$= 4.60$ g
The mass of 1.204×10^{23} atoms of $Na_{(s)}$ is 4.60 g.

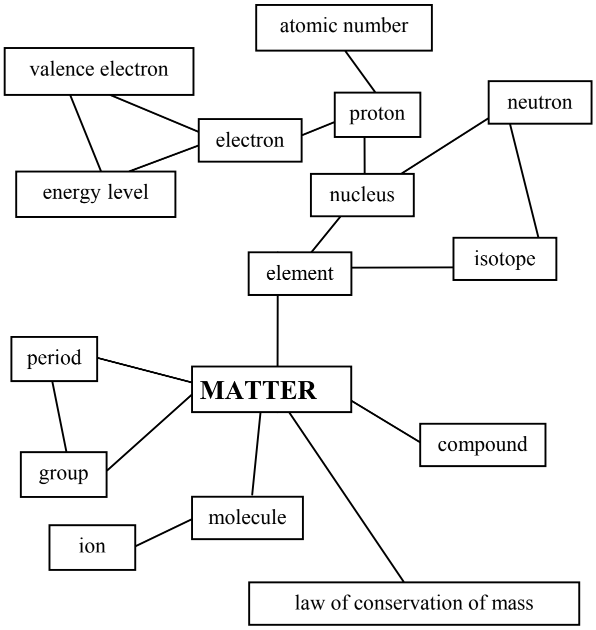
17. $n_{CO2} = 66.0\ \cancel{g} \times 1\ mol/44.01\ \cancel{g}$
$= 1.500\ mol\ CO_{2(g)}$
$N_{CO2\ molecules}$
$= 1.500\ \cancel{mol} \times 6.02 \times 10^{23}\ CO_{2(g)}\ molecules/1\ \cancel{mol}$
$= 9.03 \times 10^{23}$ molecules
There are 9.03×10^{23} $CO_{2(g)}$ molecules in 66.0 g of $CO_{2(g)}$.

Student Book pages 117–121

Unit A Review

Vocabulary

1. Students' answers will vary, but connected words must include the vocabulary terms (example below). To help emphasize the relationships, they could write descriptions on the lines connecting vocabulary terms.



Knowledge

A1.0

2. Students should be able to indicate clearly either in words or drawings where the fire extinguishers, fire alarms, and fire exits are for your science class.
3. Heating food kills micro-organisms, thus sterilizing the food. Freezing prevents micro-organisms from growing and slows chemical reactions that cause food spoilage.
4. Copper has several advantages over gold. It is more common, hence considerably cheaper. It is also harder than gold, so that it is better for tools and implements.
5. Inuit found chunks of native copper, which is copper that is already in metallic form. They used it to make spears, arrows, knife blades, handles for pots, staples, and rivets.
6. Copper is an element. Bronze is an alloy, or mixture, of two elements: copper and tin. Bronze is much harder than copper, so that it makes stronger tools and holds an edge better.
7. J. J. Thomson discovered the electron and determined that it had a negative charge. He described the atom as a sphere of positive charge with the negatively charged electrons buried in it.
8. The law of conservation of mass states that the total mass of a system does not change during a chemical reaction. Students may also describe it in terms of chemical reactions: the total mass of the reactants equals the total mass of the products.
9. Rutherford discovered the nucleus, which he determined to be small and positively charged. He placed the nucleus at the centre of the atom, with electrons surrounding it, occupying most of the volume.

A2.0

10. Five groups in the periodic table include:
    - three groups of metals: the alkali metals, the alkaline-earth metals, and the transition metals, which occupy columns 1, 2, and 3–13 respectively
    - two groups of non-metals: the halogens in column 17 and the noble gases in column 18
11. A period in the periodic table is a row (horizontal). A family in the periodic table is a column (vertical), containing elements that have similar properties.
12. Mass number is an integer that equals the number of protons and neutrons in the nucleus of an element's atom. The atomic number gives the number of protons in the nucleus of an element's atom. It can be used to specify an element. It appears in the periodic table.
13. Cations are positive ions and anions are negative ions.
14.

Element	Mass Number	Protons	Neutrons
carbon	13	***6***	***7***
bromine	79	***35***	***44***
bromine	***81***	***35***	46
chlorine	36	***17***	19
iron	57	26	***31***
sodium	***33***	***11***	22

15.

Atom or Ion	Overall Change	Protons	Electrons	Symbol
sulfur atom	***0***	***16***	***16***	S
sulfide ion	***2−***	***16***	18	S^{2-}
lithium ion	***1+***	3	***2***	Li^{+}
oxide ion	***2−***	8	10	O^{2-}
chloride ion	***1−***	***17***	***18***	Cl^{-}
iron(II) ion	2+	26	***24***	Fe^{2+}
nitride ion	3−	***7***	10	N^{3-}

16. a) very soluble
    b) very soluble
    c) slightly soluble
    d) slightly soluble
    e) very soluble
    f) very soluble
17. $pH < 7$ is acidic
    $pH = 7$ is neutral
    $pH > 7$ basic

18. Acidic solutions turn litmus red, taste sour, and react with some metals to produce hydrogen bubbles.
Basic solutions turn litmus blue, taste bitter, and feel slippery.
19. The IUPAC naming system is important because it provides a clear and consistent way of describing chemicals so that people know the composition of substances. This avoids confusion and improves safety.
20. High risk activities associated with drinking alcohol are drunk driving, over-consumption resulting in a dangerously high level of blood alcohol (alcohol poisoning), and the use of alcohol in combination with other drugs.

A3.0

21. A chemical reaction is a process that occurs when a substance or substances react to form a different substance or substances with new properties. A chemical reaction involves an energy change. A chemical equation is a record of a chemical reaction using chemical symbols and formulas.
22. a) $Cl_{2(g)} + 2\ KBr_{(aq)} \rightarrow 2\ KCl_{(aq)} + Br_{2(l)}$
b) $4\ Li_{(s)} + O_{2(g)} \rightarrow 2\ Li_2O_{(g)}$
c) $2\ C_2H_{6(g)} + 7\ O_{2(g)} \rightarrow 6\ H_2O_{(g)} + 4\ CO_{2(g)}$
d) $6\ Na_{(s)} + N_{2(g)} \rightarrow 2\ Na_3N_{(s)}$
e) $2\ (NH_4)_3PO_{4(aq)} + 3\ Ca(NO_3)_{2(aq)} \rightarrow$
$6\ NH_4NO_{3(aq)} + Ca_3(PO_4)_{2(s)}$
f) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ (balanced)
23. a) hydrocarbon combustion
b) formation
c) single replacement
d) decomposition
e) double replacement
f) double replacement

Applications

24. Students' answers will vary, but rules on behaving safely and responsibly should top the list. Next should be rules on knowledge about the location and use of safety and emergency equipment. Accept all logical answers.
25.

Chemical	Safety Hazard Symbol	WHMIS Symbol
a) bleach bottle	toxic, corrosive	oxidizing material, poisonous (skull), corrosive
b) gasoline can	toxic, flammable	poisonous (skull), flammable
c) spray paint can	explosive, flammable	compressed gas, flammable
d) helium gas bottle	explosive	compressed gas
e) hydrochloric acid bottle	toxic, corrosive	corrosive, poisonous

26. Weapons and tools of all kinds depended on advancements in metallurgy. Copper replaced iron and wood. The process of annealing copper prevented it from breaking easily. Smelting copper with tin ores led to the discovery of bronze, which was harder and held an edge better. Bronze was supplanted by iron and then steel.
27. The octet rule states that an atom will achieve chemical stability when its valence energy level contains eight electrons. Exceptions are elements, such as hydrogen, that require only two electrons in their valence energy level to become stable. A valence energy level containing eight electrons is considered to be filled. From this point of view, hydrogen is not an exception because its valence energy level is full with two electrons.
28. a) Calcium atom: The diagram will show 2, 8, 8, and 2 electrons in four energy levels.
b) Calcium ion: The diagram will show 2, 8, and 8 electrons in three energy levels.
29. a) lose, positively
b) electrons, anions
30. Iron ions have a charge that is determined by comparing the number of protons in the ion with the number of electrons. For example, an iron atom loses two electrons to form the iron(II) ion, giving it two more protons than electrons and an ion charge of +2. Iron can also lose three electrons to form iron(III), giving it an ion charge of +3.
31. An electrolyte is a solution that conducts electricity because of dissolved ions present in the water. Ionic solids exist as a lattice of positive and negative ions. When the ionic solid dissolves, the ions become able to move freely. The movement of ions through a solution creates an electric current. Molecular compounds are not composed of ions, and most do not break apart into ions when they dissolve. With no ions in solution, there can be no movement of charged particles.
32. As solids heat up, the atoms and molecules in them vibrate with increasing energy, tending to make the substance melt. Ionic solids exist as a

lattice of positive and negative ions, in which all the positive charges are attracted to all the negative charges. Neighbouring ions of opposite charge are attracted very strongly to each other. A relatively large amount of energy is required to force the charged particles apart. This keeps the substance a solid even at relatively high temperatures. In molecular solids, there are strong bonds between atoms in the same molecule, but neighbouring molecules do not have strong bonds connecting them. When heating occurs, the molecules easily slide by one another, leading to melting at relatively low temperatures.

33. a) $LiCl_{(s)}$
    b) $Ba_3N_{2(s)}$
    c) $ZnO_{(s)}$
    d) $Ag_2CO_{3(s)}$
    e) $Ca(NO_2)_{2(s)}$
    f) $RbHSO_{4(s)}$
    g) $Cd_3(PO_4)_{2(s)}$
    h) $Co(OH)_{3(s)}$
    i) $Cu(MnO_4)_{2(s)}$
    j) $CrO_{3(s)}$
    k) $Fe(ClO_3)_{3(s)}$
34. a) sodium phosphide
    b) magnesium sulfide
    c) beryllium chloride
    d) ammonium sulfide
    e) cesium nitride
    f) zinc iodide
    g) iron(II) fluoride
    h) iron(III) hydrogen sulfide
    i) gold(I) nitrate
    j) lead(IV) permanganate
    k) sodium acetate or sodium ethanoate
35. a) $N_2S_{(g)}$
    b) $SBr_{2(g)}$
    c) $ClF_{(g)}$
    d) $H_2S_{(g)}$
    e) $CH_{4(g)}$
    f) $PCl_{5(g)}$
36. a) tetraphosphorus decaoxide
    b) nitrogen dioxide
    c) nitrogen trichloride
    d) xenon hexafluoride
    e) hydrogen peroxide
    f) ammonia
37. Because a water molecule is polar it has a slightly positive side (the side with the hydrogen atoms on it) and a slightly negative side (the oxygen side). Water molecules surround a cation, or positive ion, with the negative side closest to the cation. This results in water molecules orienting themselves around the cation with the oxygen atom in each molecule pointing inwards toward the positive charge. Water molecules orient themselves around the anion with the hydrogens in the water molecule pointing inwards toward the negative charge.
38. a) one precipitate, $Fe(OH)_{2(s)}$
    b) one precipitate, $CuOH_{(s)}$
    c) two precipitates, $AgOH_{(s)}$ and $Cd(OH)_{2(s)}$
39. The increase in the pH by adding $NaOH_{(s)}$ shows that the solution has become less acidic. A lower pH indicates a more acidic solution and a higher pH indicates a more basic (and less acidic) solution.
40. Acids have one or more hydrogens on the left side of their formulas (e.g., sulfuric acid, H_2SO_4) or they have a –COOH group (e.g., ethanoic acid, CH_3COOH) on the right. Bases are ammonium or metal compounds that have an OH group on their right side (e.g., sodium hydroxide, NaOH, or ammonium hydroxide, NH_4OH).
41. Both alcohol and nicotine are addictive. However, studies have shown that nicotine is much more addictive than alcohol. Nicotine creates both psychological and physical dependence. Most people are not aware of their addiction until they try to stop smoking.
42. Students will probably use the example of benzene, described on pages 73 and 74 in the student book. Regulations for transporting benzene include limits on the amount that can be shipped at one time, and the type of transportation that can be used, such as rail or truck. Exposure limits for people working with benzene dictate average concentrations that are acceptable and the kinds of masks or breathing apparatus that must be used.
43. Students will probably use the example described in the text. In living things, photosynthesis and cellular respiration are examples of reactions that are a reverse of each other. The reaction for photosynthesis is:
    $$\text{energy} + 6\ CO_{2(g)} + 6\ H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6\ O_{2(g)}$$
    An example of a reversible reaction in a non-living system is a rechargeable dry cell, which produces electricity through a chemical reaction. When the dry cell is recharged, the chemical reaction is reversed.
44. The reaction is exothermic. The beaker became warmer, indicating that the chemical system was releasing energy to the environment in the form of heat.
45. In a chemical change, new substances with new properties are produced. In a physical change, no new substances are formed, although a change of state may occur.

46. a) $I_{2(s)} + Hg_{(l)} \rightarrow HgI_{2(s)}$ (balanced)
b) $2\ K_3PO_{4(aq)} + 3\ Sr(OH)_{2(aq)} \rightarrow$
$6\ KOH_{(aq)} + Sr_3(PO_4)_{2(s)}$
c) $Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

47. a) Type of reaction: double replacement
Balanced equation:
$CaI_{2(s)} + 2\ AgNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2\ AgI_{(s)}$
b) Type of reaction: hydrocarbon combustion
Balanced equation:
$2\ C_6H_{14(l)} + 19\ O_{2(g)} \rightarrow 12\ CO_{2(g)} + 14\ H_2O_{(g)}$
c) Type of reaction: decomposition
Balanced equation:
$MgCO_{3(s)} \rightarrow MgO_{(s)} + CO_{2(g)}$ (balanced)
d) Type of reaction: double replacement
Balanced equation:
$3\ Li_2SO_{3(aq)} + 2\ Au(NO_3)_{3(aq)} \rightarrow$
$6\ LiNO_{3(aq)} + Au_2(SO_3)_{3(s)}$
e) Type of reaction: formation
Balanced equation:
$16\ Cs_{(s)} + S_{8(s)} \rightarrow 8\ Cs_2S_{(s)}$
f) Type of reaction: single replacement
Balanced equation:
$2\ Al_{(s)} + 3\ CuSO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 3\ Cu_{(s)}$

48. For the following reactions, the skeleton equations have the same reactants and products but no balancing coefficients.
a) Type of reaction: single replacement
Balanced equation:
$CaF_{2(aq)} + I_{2(s)} \rightarrow CaI_{2(aq)} + F_{2(g)}$ (balanced)
b) Type of reaction: decomposition
Balanced equation:
$2\ RbI_{(s)} \rightarrow 2\ Rb_{(s)} + I_{2(s)}$
c) Type of reaction: hydrocarbon combustion
Balanced equation:
$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$
d) Type of reaction: double replacement
Balanced equation:
$3\ Cu(ClO_4)_{2(aq)} + 2\ Li_3PO_{4(aq)} \rightarrow$
$6\ LiClO_{4(aq)} + Cu_3(PO_4)_{2(s)}$
e) Type of reaction: single replacement
Balanced equation:
$3\ Zn_{(s)} + 2\ FeBr_{3(aq)} \rightarrow 3\ ZnBr_{2(aq)} + 2\ Fe_{(s)}$

49. a) $n_{He(g)} = 8.00\ \cancel{g} \times 1\ mol/4.00\ \cancel{g}$
$= 2.00\ mol$
The 4.00 g sample of $He_{(g)}$ contains 2.00 moles.
b) $n_{Na(s)} = 11.50\ \cancel{g} \times 1\ mol/22.99\ \cancel{g}$
$= 0.5002\ mol$
The 11.50 g sample of $Na_{(s)}$ contains 0.5002 mol.
c) $n_{H2O(l)} = 72.08\ \cancel{g} \times 1\ mol/18.02\ \cancel{g}$
$= 4.000\ mol$
The 72.08 g sample of $H_2O_{(l)}$ contains 4.000 mol.
d) $n_{Na2SO4(s)} = 0.251\ \cancel{g} \times 1\ mol/142.05\ \cancel{g}$
$= 0.00177\ mol$
The 0.251 g sample of $Na_2SO_{4(s)}$ contains 0.00177 mol.
e) $n_{KCl(s)} = (6.2 \times 10^3\ g)(1\ mol/74.55)$
$= 83\ mol$
The 6.2×10^3 g sample of $KCl_{(s)}$ contains 83 mol.

50. a) $m_{Ag(s)} = 2.00\ \cancel{mol} \times 107.87\ g/1\ \cancel{mol}$
$= 216\ g$
The mass of 2.00 moles of $Ag_{(s)}$ is 216 g.
b) $m_{Pb(s)} = 0.50\ \cancel{mol} \times 207.19\ g/1\ \cancel{mol}$
$= 1.0 \times 10^2\ g$
$= 0.10\ kg$
The mass of 0.50 moles of $Pb_{(s)}$ is 1.0×10^2 g.
c) $m_{O2(g)} = 10\ \cancel{mol} \times 32.00/1\ \cancel{mol}$
$= 3.2 \times 10^2\ g$
$= 0.32\ kg$
The mass of 3.2×10^2 moles of $O_{2(g)}$ is 3.2×10^2 g.
d) $m_{CS2(g)} = 9.67\ \cancel{mol} \times 76.15\ g/1\ \cancel{mol}$
$= 736\ g$
The mass of 9.67 moles of $CS_{2(g)}$ is 736 g.
e) $m_{CaCO3(s)} = 0.832\ \cancel{mol} \times 100.09\ g/1\ \cancel{mol}$
$= 83.3\ g$
The mass of 0.832 moles of $CaCO_{3(s)}$ is 83.3 g.

Extensions

51. Antoine Lavoisier made careful measurements of the masses of the chemicals he used and produced in his reactions. Earlier researchers had not made such careful measurements.
52. Atomic number is defined as the number of protons because the number of protons in an atom does not vary, except in some nuclear reactions. The number of electrons in an atom can change. Although this affects its chemistry, it does not change the identity of the element.
53. Mass number is an integer that equals the number of protons and neutrons in the nucleus. Atomic molar mass is the average of the masses of all of an element's isotopes. The atomic molar mass is found in the periodic table.
54. a) sodium oxide
b) aluminium oxalate
c) methanol
d) $NH_4HOOCCOO_{(s)}$
e) $C_3H_{8(g)}$
f) $Ru(H_2PO_4)_{4(s)}$
g) dinitrogen tetraoxide
h) tungsten(VI) dichromate
i) osmium(VIII) oxide
j) $C_6H_{12}O_{6(s)}$
k) $Pt(CN)_{4(s)}$
l) $Na_2S_2O_{3(s)}$

55. Pressurized oxygen tanks have to be heavy, so they would increase the amount and cost of fuel needed to operate planes. They are more awkward to load and store. They would require space for storage. There are also safety issues associated with carrying pressurized gas on board, including the potential for oxygen leaks, and explosion if the tank fails.

56. a) $N_{\text{Al}(s)\text{ atoms}}$ = (2.0 mol)(6.02 x 10^{23} $Al_{(s)}$ atoms)/1 mol
= 1.2 x 10^{24} atoms
There are 1.2 x 10^{24} $Al_{(s)}$ atoms in 2.0 mol of $Al_{(s)}$ atoms.
b) $N_{\text{SO3}(g)\text{ molecules}}$ = 36.0 ~~mol~~ x 6.02 x 10^{23} $SO_{3(g)}$ molecules/~~mol~~
= 2.17 x 10^{25} molecules
There are 2.17 x 10^{25} $SO_{3(g)}$ molecules in 36.0 mol of $SO_{3(g)}$ molecules.
c) $N_{\text{helium atoms}}$ = 0.023 ~~mol~~ x 6.02 x 10^{23} $He_{(g)}$ atoms/~~mol~~
= 1.4 x 10^{22} atoms
There are 1.4 x 10^{22} $He_{(g)}$ atoms in 0.023 mol of $He_{(g)}$ atoms.

57. a) n_{NH3} = (9.31 x 10^{22} $NH_{3(g)}$ ~~molecules~~) (1 mol)/6.02 x 10^{23} ~~molecules~~
= 0.155 mol $NH_{3(g)}$
There are 0.155 mol of $NH_{3(g)}$ molecules in 9.31 x 10^{22} molecules of $NH_{3(g)}$.
b) n_{Cu} = (1.63 x 10^{24} $Cu_{(s)}$ ~~atoms~~)(1 mol)/6.02 x 10^{23} ~~atoms~~
= 2.71 mol $Cu_{(s)}$
There are 2.71 mol of copper in 1.63 x 10^{24} atoms of $Cu_{(s)}$.
c) n_{H2} = (3.91 x 10^{23} $H_{2(g)}$ ~~molecules~~)(1 mol)/6.02 x 10^{23} ~~molecules~~
= 0.65 mol $H_{2(g)}$
There are 0.65 mol of $H_{2(g)}$ in 3.91 x 10^{23} molecules of $H_{2(g)}$.

Skills Practice

58. When the sodium carbonate and calcium chloride reacted, all the products remained in the beaker. In effect, even though the beaker had no lid, the system was closed, because nothing got in or out (neglecting evaporation). In the second case, the acid and metal reacted to produce a gas, which escaped, because the system was open. Although the law of conservation of mass appears to be obeyed in all chemical reactions, it can only be verified in closed systems.

59. Students' answers will vary in presentation but should include the following information:
Here's a procedure for testing the acid-base nature of a solution. Before working with an unknown solution, take safety precautions. Use approved safety eyewear and keep the solution off the skin. Don't eat anything during the testing. Take a sample of the solution and test it with both red and blue litmus paper. If the red turns blue, the solution is basic. If the blue turns red, then the solution is acidic. If the red remains red, and the blue remains blue, then the solution is neutral. Instead of using litmus paper, you could use pH paper or a pH meter. If the pH is 7, then the solution is neutral. If it is less than 7, it is acidic; and if it is greater than 7, it is basic.

Self Assessment

60. Students' answers will vary but should reflect the content of the unit.

61. Students' answers will vary but could include the following information. The use of potentially toxic industrial chemicals is widespread in our society, and very important economically. A toxic substance is not a hazard until it is released into the environment or someone is exposed to it. Determining how to use such a material depends on a balanced risk-versus-benefit assessment and on many factors, such as available technology to transport, use, and dispose of such materials.

62. Students' answers will vary. One example is returning aluminium cans for deposit instead of throwing them away. The cans can be recycled, which means that the environmental costs associated with smelting aluminium for all new cans can be reduced.