UNIT 1 MATTER AND QUALITATIVE ANALYSIS WORKBOOK

1.1 EXTENSION EXERCISE

(Pages 1–3)

ACTIVITY: IDENTIFYING A MYSTERY POWDER

(j) In this test, the scientist collects information about the physical and chemical properties of the new drug using different diagnostic tests. These properties can later be used to identify the drug. Similarly, a forensic investigator trying to identify a substance collects information on the physical and chemical properties of the substance in order to identify it by comparing its properties to the properties of identified substances. The scientist is establishing criteria for identifying a new substance. The forensic investigator is using these criteria to identify the substance.

1.2 ALTERNATIVE EXERCISE

(Page 6)

TRY THIS ACTIVITY: DANCING RAISINS

Table 1 Observations versus Inferences

Observations	Inferences
• The raisins are bouncing up and down in the liquid. • The raisins are brown in colour. • The water is bubbling. • The bubbles originate from the bottom of the glass. • Some bubbles attach to the raisins. • The bubbles pop.	• The bubbles cause the raisins to bounce around. • The raisins expel air bubbles, which causes them to bounce around. • The bubbles attach to the raisins, causing the raisins to float around in the liquid.

(a) It is important that scientists make many observations before making inferences because inferences are judgements or opinions based on observations. The larger the number of observations, the more information exists from which to draw inferences.
(b) The bubbles in carbonated water are carbon dioxide bubbles. When a carbon dioxide bubble attaches to a raisin, the density of the raisin plus the bubble becomes collectively less than that of water, causing the raisin to rise in the solution. When the bubble bursts, the density of the raisin is greater than the density of water, so the raisin sinks.
(c) Student answers will vary. The explanation in (b) is similar to the inference "The bubbles attach to the raisins, causing the raisin to float around in the liquid." The explanation provides more scientific detail, taking density into consideration, whereas the inference provides a general idea.

1.2 EXTENSION EXERCISE

(Pages 7–10)

BUILDING SCIENTIFIC KNOWLEDGE—ADDITIONAL PRACTICE

1. (a) E (d) T
   (b) E (e) T
   (c) T (f) E

2. (a) Observation: The back wall of the room is completely burnt, whereas the side walls are still intact.
Inference: The fire started near the back wall since it is burnt completely, and then spread to the side walls of the room.
(b) Observation: The cashier is short $20.00 at the end of his shift.
Inference: A customer received two $20.00 bills stuck together when he received change. The customer did not mention this oversight.
(c) Observation: Sally received a grade of 88% on her last test.
Inference: Sally was well prepared for her unit test.
3. (b) All the observations are highlighted.
(c) A possible cause for the space shuttle accident suggested in this article is that the thermal tiles, designed to protect the shuttle during re-entry into Earth's atmosphere, were damaged or missing. The thermal tiles may have been damaged when a piece of insulation broke off from the big external fuel tank during lift off. At the time of the writing of this article, this suggestion is an inference.
(d) Investigators will gather further evidence and information, including retrieving 32 seconds of additional data from the flight computers; collecting bits of metal, ceramic tile, computer chips, and insulation scattered on Earth from the shuttle's break-up; recording the exact landing position of every piece of debris; and microscopically examining the debris to determine how hot it became and how it twisted in order to learn which parts flew off first. The Toledo Blend Reservoir will be searched for a large piece of the shuttle.
(e) Gathering as much empirical knowledge as possible before formulating a theory ensures that the theory is highly probable since it is supported by lots of evidence. Formulating a theory too early can cause us to ignore or miss other important observations that may lead to new theories.
(f) To determine what happened in the space shuttle *Columbia* accident, forensic investigators collect information to come up with a model of how the shuttle broke up. They will develop a timeline of which piece flew off first, second, etc. With this information, they can then propose a theory to explain the cause of the accident.

The Globe and Mail

Posted at 7:45 PM EST Sunday February 2 [2003]

NASA Launches *Columbia* probe

Associated Press

Cape Canaveral, Fla.—Just before it disintegrated, the space shuttle *Columbia* experienced a sharp and sudden rise in temperature on its fuselage, NASA said Sunday.

The sharp rise was followed by increased drag on the spacecraft that caused its flight system to adjust its path.

NASA space shuttle program manager Ron Dittemore cautioned that the information was preliminary but said it could suggest that the thermal tiles that are designed to protect the shuttle from burning up during re-entry into Earth's atmosphere were damaged or missing, possibly from an episode earlier in the shuttle's flight.

"We've got some more detective work. But we're making progress inch by inch," Mr. Dittemore said.

Mr. Dittemore said the engineering data showed a temperature rise of 20°F to 30°F in the left wheel well of the shuttle about 7 min before communication was lost with the spacecraft. There was an even more significant temperature rise—about 60°F over 5 min—in the middle left side of the fuselage, he said.

The drag on the left wing began a short while later, causing the shuttle's automated flight system to start making adjustments.

Across Texas and Louisiana, meanwhile, officials were marking the exact satellite measures of the locations where debris was found in hopes it would help reconstruct the accident.

Mr. Dittemore said NASA engineers are still trying to recover 32 s worth of additional data from the flight computers. But he said the combination of new engineering data and an observer who reported seeing debris from the shuttle while it was still passing over California may create "a path that may lead us to the cause."

The shuttle broke up shortly before landing Saturday, killing all seven astronauts. Most of its debris landed in eastern Texas and Louisiana.

Earlier Sunday, NASA administrator Sean O'Keefe named a former Navy admiral to oversee an independent review of the accident, and said investigators initially would focus on whether a broken-off piece of insulation from the big external fuel tank caused damage to the shuttle during liftoff

January 16 that ultimately doomed the flight 16 days later.

Mr. O'Keefe emphasized that the space agency was being careful not to lock onto any one theory too soon. He vowed to "leave absolutely no stone unturned."

For a second day, searchers scoured forests and rural areas for over 800 km^2 of East Texas and western Louisiana for bits of metal, ceramic tile, computer chips, and insulation from the shattered spacecraft.

State and federal officials, treating the investigation like a multicounty crime scene, were protecting the debris until it can be catalogued, carefully collected, and then trucked to Barksdale Air Force Base in Louisiana.

The effort to reconstruct what is left of *Columbia* into a rough outline of the shuttle will be tedious and painstaking.

When any shuttle piece was located this weekend, searchers left it in place until a precise global position satellite reading could be taken. Each shuttle part is numbered; NASA officials say experts hope to trace the falling path of each recovered piece.

The goal is to establish a sequence of how parts were ripped off *Columbia* as it endured the intense heat and pressure of the high-speed re-entry into the atmosphere.

As engineers pinpointed the exact satellite location of debris, NASA said it had found remains from all seven astronauts who perished.

At least 20 engineers from United Space Alliance, a key NASA contractor for the shuttle program, were dispatched to Barksdale for what is expected to be a round-the-clock investigation.

Other experts, including metallurgists and forensic medicine specialists, are expected to join the investigation. Their focus will be on a microscopic examination of debris and remains that could elicit clues such as how hot the metal became, how it twisted, and which parts flew off first.

In addition to NASA's investigation, Mr. O'Keefe named an independent panel to be headed by retired Navy admiral Harold Gehman Jr., who previously helped investigate the 2000 terrorist attack on the *USS Cole*.

Mr. Gehman's panel will also examine the *Columbia* wreckage, and come to its own conclusions about what happened. Mr. O'Keefe described Mr. Gehman as "well-versed in understanding exactly how to look at the forensics in these cases and coming up with the causal effects of what could occur."

Joining Mr. Gehman on the commission are four military officers and two federal aviation safety officials.

Officials used horses and four-wheel-drive vehicles to find and recover the shuttle pieces. Divers were being called in to search the floor of Toledo Blend Reservoir, on the Texas-Louisiana line, for a car-sized piece seen slamming into the water.

Some body parts from the seven-member astronaut crew have been recovered and are being sent to a military morgue in Dover Air Force Base in Delaware.

Columbia came apart 61 km over Texas while it was streaking at more than 19 500 km/h toward the Kennedy Space Center. A long vapour trail across the sky marked the rain of debris.

1.3 SELF QUIZ

(Page 11)

Completion

						1 P	R	O	T	O	2 N						
											U						
	3 N	4 E	U	T	R	O	N				C						
		M									L						
5 A		P		6 A	7 T	O	M		8 R		E		9 D				
L		E			H				U		U		A				
C		10 D	E	M	O	C	R	I	T	U	S		L				
H		O			M				H				T				
E		C			S		11 E	L	E	C	T	R	O	N			
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I		E			N				12 F	I	R	E					
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14 S	U	B	D	I	V	I	D	E	D								

1.3 EXTENSION EXERCISE

(Pages 14–15)

CASE STUDY: RUTHERFORD'S GOLD FOIL EXPERIMENT—EXTRA CHALLENGE

Prediction

(a) Based on Thomson's raisin bun model, in which the atom is a positively charged sphere embedded with negatively charged electrons, and on the theory that positive and negative charges are distributed evenly within the atom, Rutherford predicted that all the alpha particles would travel through the gold foil.

Analysis

(b) From the data, most of the particles are deflected by 5°, while smaller and smaller numbers of particles are deflected at large angles. If the positive and negative charges were distributed evenly within the atom, there would not be such a wide range of angle deflection or of the number of particles deflected. The numbers would be uniform.

(c) Since most of the alpha particles were only slightly deflected, the atom must consist mostly of empty space. Most of the alpha particles travelled right through the gold foil. A small number of particles bounced back at an angle greater than 105°. Since like charges repel, Rutherford concluded that the atom has a dense positive core, with electrons orbiting it.

(d) Alpha particles are deflected since an atom contains positively charged particles called protons. Since like charges repel, a positively charged alpha particle repels a positively charged proton.

(e) Most of the alpha particles had small angles of deflection because the atom is mostly empty space: the positive electrostatic charge of the nucleus exerted little influence on the alpha particle, resulting in a small angle of deflection.

Evaluation

(f) Since most of the deflected alpha particles had small angles of deflection, Rutherford concluded that the atom is mostly empty space. The nucleus at the atom's centre must have the same charge as the alpha particles because only a like charge would cause the alpha particles to be reflected. The atom's nucleus must therefore be made up of positively charged particles. These particles were later named protons.

(g) Rutherford set out to test Thomson's raisin bun model of the atom, which consisted of a positively charged sphere embedded with negatively charged particles. After performing his gold foil experiment, Rutherford came up with a new atomic model, consisting of a positively charged nucleus with negatively charged electrons orbiting around it. This example illustrates that theories and models are modified based on new knowledge gained; therefore, scientific knowledge is tentative.

1.1–1.3 SELF QUIZ

(Pages 16–17)

Matching

1. B
2. D
3. E
4. C
5. F
6. A

Completion

7. Earth, air, water, fire, Empedocles, Democritus, atoms, empirical, alchemists, gold, John Dalton
   (a) Matter consists of definite particles called atoms.
   (b) Each element is made up of its own type of atom.
   (c) Atoms of different elements have different properties.
   (d) Atoms of two or more elements can combine in constant ratios to form new substances.
   (e) Atoms cannot be created, destroyed, or subdivided in a chemical change.
   subatomic, electron, J.J. Thomson, raisin bun, Rutherford, nucleus, protons, neutrons, neutrons, Chadwick
8. (a) Atoms of different elements have different properties.
   (b) Atoms of two or more elements can combine in constant ratios to form new substances.
   (c) Each element is made up of its own type of atom.
   (d) Atoms cannot be created, destroyed, or subdivided in a chemical change.
9. Both physical and chemical properties are used in qualitative analysis to identify matter.

1.4 EXTENSION EXERCISE

(Pages 18–19)

THE ELECTROMAGNETIC SPECTRUM—ADDITIONAL PRACTICE

1. wavelength of (i): 6 mm; wavelength of (ii): 10 mm
   (b) The wave with the higher frequency is wave (i) because it has the shorter wavelength. More cycles will pass a point in a given time.
   (c) The wave with the most energy is (i). The higher the frequency of a wave, the more energy it possesses.
   (d) (i) 6 mm = 0.006 m × 1 nm/1 × 10^{-9} m = 6.0 × 10^{6} nm
   (ii) 10 mm = 0.01 m × 1 nm/1 × 10^{-9} m = 1.0 × 10^{7} nm
2. (a) microwave
   (b) infrared light
   (c) ultraviolet light
   (d) visible light
3. (a) infrared light
   (b) visible light
   (c) X ray
   (d) ultraviolet light
4. Different types of matter are composed of different elements or compounds. Each element possesses a different number of electrons. Since each element has a different electron configuration, its line spectrum is also unique. For this reason, line spectra can be used in qualitative analysis to identify matter.
5. The spectrum in **Figure 2** is discontinuous: it consists of distinct lines separated by dark bands.

6. (a) UVA and UVB rays have different wavelengths. The wavelength of UVA rays is 320 to 400 nm, whereas the wavelength of UVB rays is 290 to 320 nm.
   (b) Both UVA and UVB rays penetrate Earth's atmosphere. Excessive absorption of these rays leads to wrinkles, photoaging, and cancer. UVA and UVB light penetrates the skin and can damage the DNA in skin cells. DNA damage can lead to uncontrolled cell replication, which can cause skin cancer.
   (c) Sunscreen protects the skin from UVA and UVB light by blocking and preventing this light from penetrating the skin. Some chemicals, such as titanium dioxide, scatter UV light so it is not absorbed. Other chemicals, such as para amino benzoic acid (PABA), absorb the light and then release its energy in the form of heat.
7. The retina of the eye contains two different types of cells that allow us to see: rods and cones, named because of their shapes. Rods and cones absorb incoming light and convert its energy into electrical impulses that the brain interprets as images. The rods allow us to see shades of gray and images in dim light. The cones allow us to see sharp images in colour and in bright light. There are three different types of cones that are sensitive to blue, green, and red light, respectively. Only 2% of cones are sensitive to blue light, 32% are sensitive to green light, and the remaining 64% are sensitive to red light. Colour blindness occurs when one type of cone does not absorb the wavelengths of light it should absorb, or when it absorbs light of a slightly shorter or longer wavelength.

1.5 EXTENSION EXERCISE

(Pages 20–21)

ACTIVITY: IDENTIFYING GASES USING LINE SPECTRA

(k) Currently, more than 150 colours of "neon" lights can be produced by combining different gases and coatings inside glass tubes. A colourless glass tube filled with neon gas produces a red colour. If argon and helium are combined in a colourless tube, a dim blue light ensues. Tangerine and pink lights are produced by coating a tube with phosphor and filling it with neon. Shades of blue come from using various phosphor coatings along with argon and helium. White light is produced using argon in a phosphor-coated tube.

1.5 ALTERNATIVE EXERCISE

(Pages 22–23)

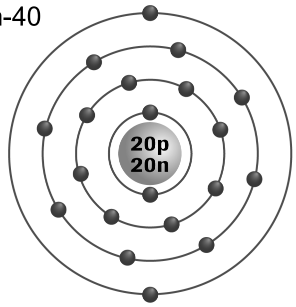
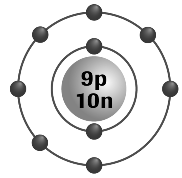
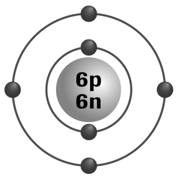
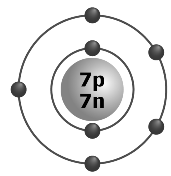
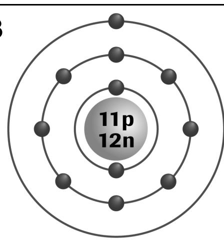
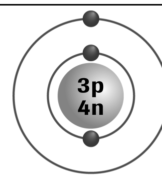
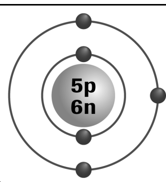
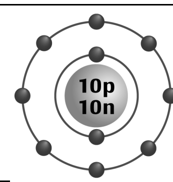
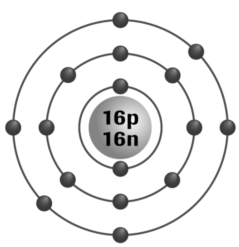
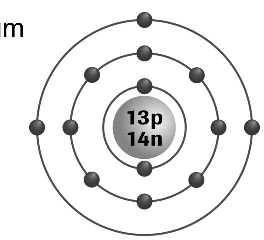
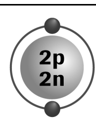
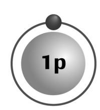
CASE STUDY: DETERMINING THE COMPOSITION OF A STAR

1. Astronomers use spectroscopy, that is, a telescope with a diffraction grating. The telescope is pointed at a star, and the light emitted by the star is separated into its component wavelengths. The spectrum produced is then analyzed by comparing it to the spectra of known gases.
2. The starlight that we see comes from gases on a star's surface. There may be gases within the star whose light cannot escape. Since astronomers cannot detect this light, they cannot analyze it. Therefore, elements may exist that have not been detected.
3. Starlight comes from exothermic (energy-releasing) nuclear reactions within the star. During these reactions, the electrons of the gases in the star are promoted to higher energy levels. When the electrons return to their ground states, they emit energy in the form of light, which astronomers can detect.
4. Qualitative analysis is the identification of a substance by investigating its physical and chemical properties and then comparing them to the same properties of identified substances. The composition of a star is determined from its line spectrum, which is then compared to the line spectra of different elements. Since this method involves the comparison of properties of different substances in order to identify a substance, it is a qualitative analysis technique.
5. The elements found in this star may be hydrogen, sodium, and calcium.

1.6 EXTENSION EXERCISE

(Pages 24–26)

BOHR–RUTHERFORD DIAGRAMS—ADDITIONAL PRACTICE

(a) calcium-40 	(b) fluorine-19 
(c) carbon-12 	(h) nitrogen-14 
(d) sodium-23 	(i) lithium-7 
(e) boron-11 	(j) neon-20 
(f) sulfur-32 	(k) aluminum 
(g) helium-4 	(l) hydrogen-1 

1.6 EXTENSION EXERCISE

(Pages 27–28)

THE BOHR MODEL OF THE HYDROGEN ATOM—ADDITIONAL PRACTICE

1. The Bohr atomic model places the protons and neutrons in the nucleus of the atom, resulting in a dense positive core. The electrons are found in distinct energy levels orbiting the nucleus. Each energy level is associated with a specific

energy value and can contain a maximum number of electrons. The first energy level can contain a maximum of two electrons, and the second energy level can hold a maximum of eight electrons. The third energy level can hold 18 electrons, but is stable with eight electrons.

2. Bohr chose to study the line spectrum of hydrogen because it is the simplest element.
3. (a) 2 (b) 8 (c) 8
4. (a) A spectroscope is an optical scientific instrument.
   (b) A spectroscope separates light into its component colours, producing a line spectrum.
   (c) Since each element has a characteristic line spectrum, a spectroscope can be used to identify elements. For this reason, it is a qualitative analysis tool.
5. An electron must absorb a fixed amount of energy in order to jump from its ground state to an excited state because, according to the Bohr model of the atom, the energy of electrons is quantized. In order for an electron to be promoted from a lower energy level to a higher energy level, it must absorb a specific amount of energy. By analogy, if a ball is to be kicked from a lower step to a higher step, it must be given a specific amount of energy. If the ball is kicked too hard, it will jump too high. If it is kicked too softly, it will not jump high enough and will fall back down.
6. The ground state of an electron is its lowest possible energy level, where it is the most stable. Each electron possesses one ground state. Electrons have the ability to absorb various specific amounts of energy. Depending on which specific amount they absorb, they can be excited to different energy levels. As a result, electrons have more than one excited state. For example, an electron in the first energy level can be promoted to the second, third, fourth, and higher energy levels, but it cannot move lower than its most stable position.
7. If the energy of electrons were not quantized, the line spectra of atoms would be continuous because electrons would not require specific amounts of energy to jump to higher energy levels, nor would they release specific amounts of energy when falling to lower energy levels.
8. The hydrogen atom's line spectrum is composed of more than one line even though the hydrogen atom has only one electron because the lone electron may be promoted to more than one energy level. Since the electron absorbs different values of energy when it jumps to higher energy levels, it releases different values of energy when it falls back down to its ground state, resulting in more than one line in its spectrum.

1.7 ALTERNATIVE EXERCISE

(Page 31)

INVESTIGATION: MAKING FIRE LOGS

Prediction

(a) Lithium chloride will produce a bright red flame, sodium chloride will produce a yellow flame, potassium chloride will produce a violet flame, strontium chloride will produce a bright red flame, and copper(II) chloride will produce a blue flame.

Observations

Table 1 Colours of Burning Fire Logs and Corresponding Metallic Compounds

Colour	Metallic compound
bright red	lithium chloride and strontium chloride
yellow	sodium chloride
violet	potassium chloride
blue	copper(II) chloride

Analysis

(b) Student answers will vary depending on the colours they observe. **Table 1** above may be used as a guide.

Evaluation

(c) One source of error in this investigation is the masking of colours. If a greater amount of one metallic compound is present on the fire log, it may mask the colour of another metallic compound. To avoid this source of error, the students should soak each fire log in the different solutions for equal amounts of time. Also, two colours could combine to produce a flame colour that does not represent either compound, making it difficult to identify the compounds present. This error cannot be avoided.

(d) Student answers will vary depending on their observations. If all the colours in **Table 1** are observed, the Prediction is valid.
(e) It is difficult to distinguish between two compounds that produce the same flame colour using a flame test because a flame test is used to identify metallic compounds by the colour of their flames. If two compounds produce the same colour of flame, another test must be used in order to distinguish them.

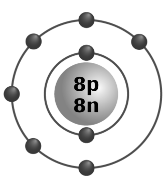
Synthesis

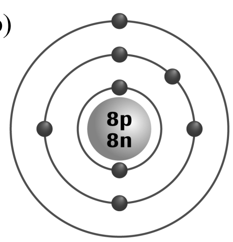
(f) Using a flame test key, we know that copper compounds that are not halides produced a green colour during a flame test. Therefore, an emerald green flame colour indicates that the metallic compound contains copper.
(g) The metal cations in metallic compounds emit a characteristic colour when subjected to a flame test. Therefore, a metal in a metallic compound may be identified based on its flame colour.

1.4–1.7 SELF QUIZ

(Page 32)

Completion

1. (a) Ultraviolet light has the shorter wavelength.
   (b) Ultraviolet light has a higher frequency.
   (c) Infrared light has the lower energy.
2. A continuous spectrum has an uninterrupted pattern of colours; exact distinctions cannot be made with respect to where one colour ends and a different colour starts. A line spectrum is composed of distinct coloured lines of light, alternating with dark bands. A rainbow is an example of a continuous spectrum, whereas hydrogen's line spectrum is an example of a line spectrum.
3. (a) A line spectrum is a pattern of distinct coloured lines alternating with dark bands.
   (b) A line spectrum is produced when electrons of atoms absorb energy, jump to higher energy levels, then release this energy when they drop back down to lower energy levels. We can observe a line spectrum by using a spectroscope. Light is passed through a diffraction grating or prism and is separated into its component wavelengths. Each wavelength corresponds to a different band of light on the spectrum.
   (c) Each element has a unique line spectrum. In qualitative analysis, a sample of matter can be identified by comparing its line spectrum to the line spectra of identified samples.
4. The ground state of an electron is its lowest possible energy level, in which the electron is most stable. An electron in the excited state has absorbed a specific amount of energy and has jumped to a higher energy level.
5. (a)


   (b)


6. (a) Elements emit different colours when subjected to a flame test because each element is composed of a different number of electrons found in different energy levels. When subjected to a flame, the electrons absorb the energy and are promoted from the ground state to the excited state. When they return to their ground states, they release this energy in the form of light characteristic to that element. As a result, during a flame test, metal compounds change the flame to a characteristic colour.
   (b) Since different samples of matter produce different flame colours when burned, a sample can be identified by observing the colour of its flame and comparing it to the flame colours of identified samples.

1.8 ALTERNATIVE EXERCISE

(Pages 33–35)

INVESTIGATION: WATER CONTENT AND THE STRENGTH OF CONCRETE

Prediction

(a) If the quantity of water added to a cement mixture is too high, the hardness of the dried concrete will be less than it should be.

Observations

(b)

	Mould				
	1	2	3	4	5
Mass of empty beaker (g)	66.98	66.98	66.98	66.98	66.98
Mass of beaker with dry cement mixture (g)	304.29	304.29	304.29	304.29	304.29
Mass of dry cement mixture (mass of dry cement mixture minus mass of empty beaker) (g)	237.31	237.31	237.31	237.31	237.31

(c) **Mould 1 (Steps 1 and 13)**
volume of water remaining in graduated cylinder: 63.50 mL
volume of water poured into cement mixture: 36.50 mL
(100 mL minus volume of water remaining in graduated cylinder)
Mould 2 (Step 9)
36.50 mL × 0.8 = 29.20 mL
Mould 3 (Step 10)
36.50 mL × 0.6 = 21.90 mL
Mould 4 (Step 11)
36.50 mL × 1.2 = 43.80 mL

Table 1 Observations of Dried Concrete Samples of Varying Water Composition

Mould	Description of surface	Observations after surface scratched with nail file	Height of steel ball bounce (cm)
1	light grey, smooth	surface hard, difficult to scratch	2.0
2	light grey, smooth	surface hard, difficult to scratch	3.5
3	dark grey, grainy	surface scratches to produce grains of concrete	4.0
4	light grey, smooth	thin film on surface scratches off easily	0.5
5	light grey, rough	surface hard, difficult to scratch	2.5

Analysis

(d) From hardest to softest, the order of the concrete samples is 3, 2, 5, 1, 4. Adding less water produces the hardest concrete.

Evaluation

(e) Measure the depth a nail will penetrate the dried concrete when hit with the same force.
(f) When measuring the mass of cement mixture in step 3, calculation error occurs because the mass of cement mixture used is calculated by subtracting the mass of the beaker from the mass of the beaker and its contents. This source of error could be avoided by taring the mass of the beaker on an electronic balance, adding cement until the beaker is half-full, and reading the mass of the cement mixture directly on the digital readout.

Synthesis

(g) Eight percent water was used in my optimum mixture. This quantity of water is half the optimum 16% given in the introduction.
(h) Less water appears to make concrete harder.

(i) Covering the concrete with plastic wrap results in a smoother surface on the dried concrete.
(j) Since we were testing the effect of varying volumes of water on the hardness of concrete, other variables like the quantity of cement mixture must be kept constant so that valid comparisons may be made.
(k) Pockets of unmixed cement mixture change the proportion of water that actually mixes with the cement mixture powder, causing comparisons to be invalid.
(l) I would choose a lower percentage of water because it results in harder concrete.

1.9 EXTENSION EXERCISE

(Page 36)

TECH CONNECT: DETECTING COUNTERFEIT CANADIAN CURRENCY—EXTRA CHALLENGE

1. The Bank of Canada is sometimes called the banker's bank because it does not deal with individual customers, but rather with banking institutions in Canada. Each day, in every bank across the country, people make deposits and withdrawals from different banks and institutions. For example, someone may deposit a TD-Canada Trust cheque into an account at the Bank of Montreal. Funds must therefore be transferred from TD-Canada Trust to the Bank of Montreal. At the end of each business day, the Bank of Canada transfers money from one banking institution to another based on the day's transactions.
2. The objective of the program is to raise awareness of security features on Canadian currency. The currency education program is for people who handle large sums of money.
3. Counterfeiting activity was low in the 1980s due to the comparatively low level of technology that was available. With the introduction of high-quality colour copiers and desktop publishing software, counterfeiting has increased.
4. It is important to check more than one security feature because you may be checking a security feature that the counterfeiter has done a good job of counterfeiting. It is less likely that the counterfeiter would be able to fake two or more security features successfully.
5. In order to help the visually impaired identify the denomination of a bank note, the denomination of a note is indicated by a large dark number on a white background and a large white number on a dark background. Also, each denomination has a different set of raised dots. These dots are not Braille since not every blind person can read Braille. Also, every note has a bar code that can be read by a portable note reader that tells a blind person the denomination of the bill.
6. Counterfeiting in Canada is relatively rare but is on the rise. There is a 1/10 000 chance that you will ever receive a counterfeit note. There are approximately 35 billion notes in circulation, and about 130 000 of them may be counterfeit.
7. If you suspect you have been passed a counterfeit note, try to retain the note or record its details, try to obtain details of the person who passed you the note (licence plate, description etc.) if you can do so safely, and contact the police. If you surrender the note to the police, obtain a receipt.

1.8–1.10 SELF QUIZ

(Page 39)

Completion

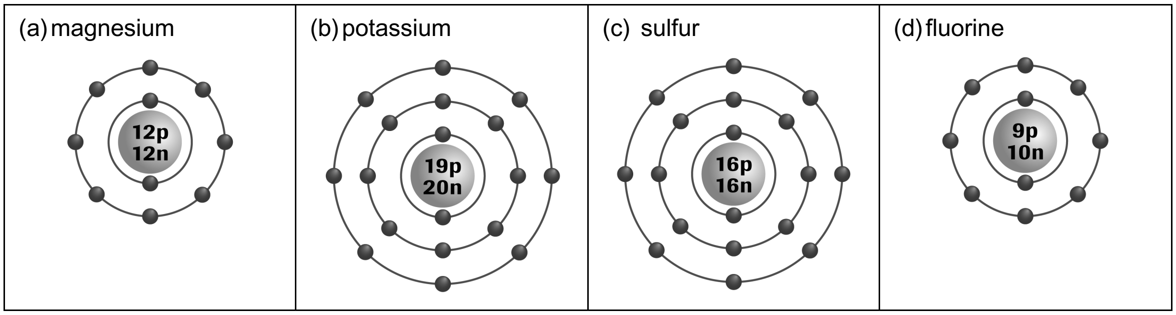
1. magnetic resonance imaging, radio, magnets, hydrogen, radio-wave, release, 43, medical MRI technologist
2. (a) Some areas of a banknote fluoresce because they are made of ink or fibres that are sensitive to UV light. Since this ink or fibre is not found throughout the note, only certain areas of the note fluoresce.
   (b) The ink or fibre that fluoresces consists of atoms that absorb UV light. The absorption of energy causes the electrons within the atoms to jump from the ground state to the excited state. When they return to the ground state, the electrons release this excess energy in the form of visible light.
   (c) Other security features of Canadian currency include intaglio (raised) printing, microprinting, an optical security device, and serial numbers.
3. (a) Two processes that can weaken a concrete structure are carbonation and the alkali-aggregate reaction.
   (b) The damage done by carbonation is detected by using the acid–base indicator phenolphthalein. If the indicator remains colourless, carbonation has taken place. The presence of alkali compounds is detected using flame emission spectroscopy. If the colour of the flame is identical to the colour that the alkali ion produces, then the alkali compound is present.

1.11 EXTENSION EXERCISE

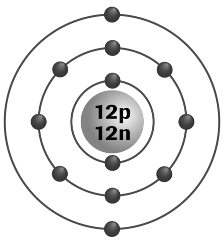
(pages 40-41)

THE FORMATION OF IONIC COMPOUNDS—ADDITIONAL PRACTICE

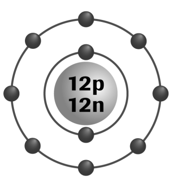
1.



2. (a) neon
   (b) argon
   (c) argon
   (d) neon
3. The octet rule is used to predict the number of electrons that must be lost or gained in order to achieve stability.
4.



In the above example, magnesium has two electrons in its outermost shell. In order to become stable, it can either lose these two electrons, leaving behind a full second shell with eight electrons, or gain six electrons to fill its third shell, for a total of eight electrons. It is easier to lose two electrons than to gain six electrons in order to satisfy the octet rule. The result is a magnesium ion with a 2+ charge.



5. (a) two electrons lost
   (b) one electron lost
   (c) two electrons gained
   (d) one electron gained
6. (a) 2+
   (b) 1+
   (c) 2–
   (d) 1–
7.

(a) magnesium ion	(b) potassium ion	(c) sulfide ion	(d) fluoride ion
$[Mg]^{2+}$	$[K]^{+}$	$[:\ddot{\underset{..}{S}}:]^{2-}$	$[:\ddot{\underset{..}{F}}:]^{-}$

8. (a) $\overset{\times}{Ca}{}^{\times} + \cdot\ddot{\underset{\cdot}{O}}: \rightarrow [Ca]^{2+}\ [\times\ddot{\underset{\times}{O}}:]^{2-}$ + energy

   (b) $Li^{\times} + \cdot\ddot{\underset{..}{F}}: \rightarrow [Li]^{+}\ [\times\ddot{\underset{..}{F}}:]^{-}$ + energy

   (c) $\overset{\times}{Mg}{}^{\times} + \cdot\ddot{\underset{..}{Br}}: + \cdot\ddot{\underset{..}{Br}}: \rightarrow [\ddot{\underset{..}{Br}}\times]^{-}\ [Mg]^{2+}\ [\times\ddot{\underset{..}{Br}}:]^{-}$ + energy

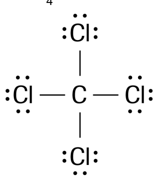
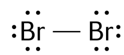
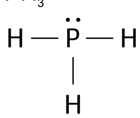
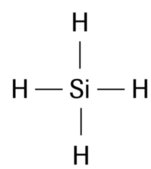
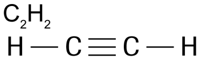
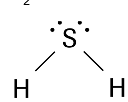
9. The type of bond that occurs in the compounds in question 8 is an ionic bond.
10. The compounds formed in question 8 are considered electrolytes because, when placed in water, they dissolve and dissociate into their respective ions and conduct electricity.
11. In order to experimentally verify whether the compounds in question 8 are electrolytes, you could test for conductivity. Dissolve a small amount of the compound in a beaker of water, then apply a low-voltage conductivity apparatus. If a current registers, the compound is an electrolyte.

1.12 EXTENSION EXERCISE

(Pages 42–43)

COVALENT BONDING—ADDITIONAL PRACTICE

1.

(a) CCl_4 	(d) Br_2 
(b) PH_3 	(e) SiH_4 
(c) C_2H_2 	(f) H_2S 

2. (a) Sulfur has a higher electronegativity than magnesium because sulfur has more protons in its nucleus and therefore a stronger nuclear pull on any shared pair of electrons.
   (b) Bromine has a higher electronegativity than potassium because bromine has more protons in its nucleus and hence has a stronger nuclear pull on a shared pair of electrons.
   (c) Oxygen is more electronegative than hydrogen because oxygen has more protons in its nucleus than hydrogen and therefore has a stronger nuclear pull on a shared pair of electrons.
3. The bond arrangement from most polar to least polar is: S—O, Cl—O, Cl—Cl. Sulfur and oxygen have the greatest difference in electronegativity (3.5 – 2.5 = 1.0), followed by chlorine and oxygen (3.5 – 3.0 = 0.5). They are both polar covalent bonds, with sulfur and oxygen exhibiting the greatest degree of polarity. Since there is no difference in electronegativity between the two chlorine atoms, the covalent bond between them is nonpolar.
4. (a) H—O
   (b) H—O
   (c) N—F

5.

Table 1 Shape and Polarity of Molecules

Molecule	Polar or nonpolar?
CCl_4	nonpolar
PH_3	polar
C_2H_2	nonpolar
Br_2	nonpolar
SiH_4	nonpolar
H_2S	polar

1.11–1.13 SELF QUIZ

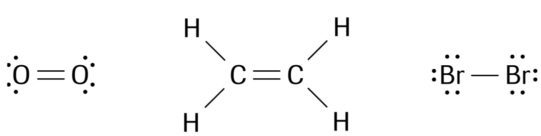
(Pages 47–48)

Matching

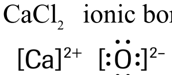
1. J
2. F
3. A
4. B
5. L
6. D
7. E
8. N
9. M
10. K
11. G
12. O
13. I
14. H
15. C

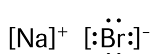
Completion

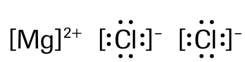
16.

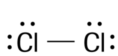


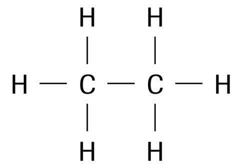
17. (a) LiCl ionic bond
    (b) MgO ionic bond
    (c) N_2 covalent bond
    (d) CO_2 covalent bonds
    (e) $CaCl_2$ ionic bonds

18. (a) 

    (b) 

    (c) 

19. (a) 

(b) 

(c) $:N \equiv N:$

20. Some physical properties that can be used to determine whether a substance is ionic or molecular include hardness, solubility in water, conductivity, and melting and boiling points. To test for hardness, place a small sample of the substance onto a watch glass or other hard surface, and press it with a scoopula to see how easily it breaks apart. To test for solubility, place a small amount of the substance in water and see if it dissolves. To test for conductivity, use a low-voltage conductivity apparatus to see if the solution of the dissolved substance conducts electricity. The melting point may be obtained by using a melting point apparatus or research. From the results of these tests, you can infer whether the substance is ionic or molecular.
21. Solids that consist of cations and anions (e.g., metals and nonmetals) are ionic compounds. Solids composed of nonmetals bonded covalently are molecules.

1.14 EXTENSION EXERCISE

(Pages 49–50)

CHEMICAL REACTIONS—ADDITIONAL PRACTICE

1. (a) synthesis—two elements combine to form a compound
   (b) double displacement—two compounds react to form two new compounds
   (c) decomposition—water (a compound) is being broken down into its component elements
   (d) decomposition—a compound is being broken down into its component elements
   (e) single displacement—an element and a compound react to produce a new element and a new compound
   (f) double displacement—two compounds react to form two new compounds
   (g) single displacement—an element and a compound react to produce a new element and a new compound
   (h) decomposition—a compound is broken down into simpler substances
   (i) single displacement—an element and a compound react to produce a new element and a new compound
   (j) synthesis—two simple substances combine to form a more complex substance
   (k) decomposition—a compound is broken down into its component elements
   (l) decomposition—a compound is broken down into simpler substances
2. (a) $4\ Na_{(s)} + O_{2(g)} \rightarrow 2\ Na_2O_{(s)}$
   This reaction is a combustion reaction because oxygen is one of the reactants.
3. (a) $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2\ NaCl_{(aq)}$
   (b) $2\ MgO_{(s)} \rightarrow 2\ Mg_{(s)} + O_{2(g)}$
   (c) $Cu_{(s)} + 2\ AgNO_{3(aq)} \rightarrow 2\ Ag_{(s)} + Cu(NO_3)_{2(aq)}$
   (d) $Pb(NO_3)_{2(aq)} + 2\ NaCl_{(aq)} \rightarrow PbCl_{2(s)} + 2\ NaNO_{3(aq)}$
   (e) $2\ K_{(s)} + Cl_{2(g)} \rightarrow 2\ KCl_{(s)}$
   (f) $H_{2(g)} + I_{2(g)} \rightarrow 2\ HI_{(s)}$
   (g) $3\ Na_{(s)} + AlCl_{3(aq)} \rightarrow Al_{(s)} + 3\ NaCl_{(aq)}$
4. The solvent is the substance in a solution that is in greater quantity and that dissolves the other components of the solution. The solute is the substance in a solution that is in lesser quantity and that is dissolved by the solvent.
5. (a) air—oxygen gas dissolved in nitrogen gas
   (b) 14 K gold—copper dissolved in gold
   (c) salt water—salt dissolved in water
6. Measure 2 g of the solid and place it in 20 mL of water that has been heated to approximately 85°C. Stir using a stirring rod. Measure the initial temperature of the water, then allow the solution to cool. As soon as you observe that the solid is precipitating from the solution, measure the temperature of the solution again. Record this temperature. Repeat the procedure, this time using only 18 mL of water. For the next four trials, use 16 mL, 14 mL, 12 mL, and 10 mL of water, respectively. Plot a graph of the concentration of the solid versus temperature.

1.15 EXTENSION EXERCISE

(Pages 51–52)

PREDICTING PRECIPITATE FORMATION—ADDITIONAL PRACTICE

1. (a) calcium sulfate—low solubility
   (b) hydrogen sulfide—soluble
   (c) sodium nitrate—soluble
   (d) copper(II) chloride—soluble
   (e) magnesium carbonate—low solubility
   (f) sodium hydroxide—soluble
2. (a) magnesium nitrate + lithium sulfate $\rightarrow$ magnesium sulfate + lithium nitrate
   magnesium sulfate—soluble
   lithium nitrate—soluble
   $MgNO_{3(aq)} + LiNO_{3(aq)} \rightarrow$ no reaction
   (b) lead(II) acetate + silver nitrate $\rightarrow$ silver acetate + lead(II) nitrate
   silver acetate—low solubility
   lead(II) nitrate—soluble
   aqueous lead(II) acetate + aqueous silver nitrate $\rightarrow$ solid silver acetate + aqueous lead(II) nitrate
   $Pb(C_2H_3O_2)_{2(aq)} + AgNO_{3(aq)} \rightarrow AgC_2H_3O_{2(s)} + Pb(NO_3)_{2(aq)}$
   $Pb(C_2H_3O_2)_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow 2\ AgC_2H_3O_{2(s)} + Pb(NO_3)_{2(aq)}$
   (c) sodium bromide + sodium nitrate $\rightarrow$ sodium bromide + sodium nitrate
   Since the products are the same as the reactants, there is no reaction.
   sodium bromide + sodium nitrate $\rightarrow$ no reaction
   (d) silver nitrate + ammonium phosphate $\rightarrow$ silver phosphate + ammonium nitrate
   silver phosphate—low solubility
   ammonium nitrate—soluble
   aqueous silver nitrate + aqueous ammonium phosphate $\rightarrow$ solid silver phosphate + aqueous ammonium nitrate
   $AgNO_{3(aq)} + (NH_4)_3PO_{4(aq)} \rightarrow Ag_3PO_{4(s)} + NH_4NO_{3(aq)}$
   $3\ AgNO_{3(aq)} + (NH_4)_3PO_{4(aq)} \rightarrow Ag_3PO_{4(s)} + 3\ NH_4NO_{3(aq)}$
   (e) magnesium hydroxide + calcium nitrate $\rightarrow$ calcium hydroxide + magnesium nitrate
   calcium hydroxide—low solubility
   magnesium nitrate—soluble
   aqueous magnesium hydroxide + aqueous calcium nitrate $\rightarrow$ solid calcium hydroxide + aqueous magnesium nitrate
   $Mg(OH)_{2(aq)} + Ca(NO_3)_{2(aq)} \rightarrow Ca(OH)_{2(s)} + Mg(NO_3)_{2(aq)}$
   (f) potassium carbonate + barium chloride $\rightarrow$ barium carbonate + potassium chloride
   barium carbonate—low solubility
   potassium chloride—soluble
   aqueous potassium carbonate + aqueous barium chloride $\rightarrow$ solid barium carbonate + aqueous potassium chloride
   $K_2CO_{3(aq)} + BaCl_{2(aq)} \rightarrow BaCO_{3(s)} + KCl_{(aq)}$
   $K_2CO_{3(aq)} + BaCl_{2(aq)} \rightarrow BaCO_{3(s)} + 2\ KCl_{(aq)}$
   (g) silver nitrate + potassium chloride $\rightarrow$ silver chloride + potassium nitrate
   silver chloride—low solubility
   potassium nitrate—soluble
   aqueous silver nitrate + aqueous potassium chloride $\rightarrow$ solid silver chloride + aqueous potassium nitrate
   $AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$
   (h) lead(II) nitrate + potassium sulfide $\rightarrow$ lead(II) sulfide + potassium nitrate
   lead(II) sulfide—low solubility
   potassium nitrate—soluble
   aqueous lead(II) nitrate + aqueous potassium sulfide $\rightarrow$ solid lead(II) sulfide + aqueous potassium nitrate
   $Pb(NO_3)_{2(aq)} + K_2S_{(aq)} \rightarrow PbS_{(s)} + KNO_{3(aq)}$
   $Pb(NO_3)_{2(aq)} + K_2S_{(aq)} \rightarrow PbS_{(s)} + 2\ KNO_{3(aq)}$

3. (b) $Pb(C_2H_3O_2)_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow 2\ AgC_2H_3O_{2(s)} + Pb(NO_3)_{2(aq)}$
$Pb^{2+}_{(aq)} + 2\ C_2H_3O^-_{2(aq)} + 2\ Ag^{2+}_{(aq)} + 2\ NO^-_{3(aq)} \rightarrow 2\ AgC_2H_3O_{2(s)} + Pb^{2+}_{(aq)} + 2\ NO^-_{3(aq)}$ (total ionic equation)
$\cancel{Pb^{2+}_{(aq)}} + 2\ C_2H_3O^-_{2(aq)} + 2\ Ag^+_{(aq)} + \cancel{2\ NO^-_{3(aq)}} \rightarrow 2\ AgC_2H_3O_{2(s)} + \cancel{Pb^{2+}_{(aq)}} + \cancel{2\ NO^-_{3(aq)}}$
$\cancel{2}\ Ag^+_{(aq)} + \cancel{2}\ C_2H_3O^-_{2(aq)} \rightarrow \cancel{2}\ AgC_2H_3O_{2(s)}$
$Ag^+_{(aq)} + C_2H_3O^-_{2(aq)} \rightarrow AgC_2H_3O_{2(s)}$ (net ionic equation)

(d) $3\ AgNO_{3(aq)} + (NH_4)_3PO_{4(aq)} \rightarrow Ag_3PO_{4(s)} + 3\ NH_4NO_{3(aq)}$
$3\ Ag^+_{(aq)} + 3\ NO^-_{3(aq)} + 3\ NH^+_{4(aq)} + PO_4^{3-}{}_{(aq)} \rightarrow Ag_3PO_{4(s)} + 3\ NH^+_{4(aq)} + 3\ NO^-_{3(aq)}$ (total ionic equation)
$3\ Ag^+_{(aq)} + 3\ \cancel{NO^-_{3(aq)}} + 3\ \cancel{NH^+_{4(aq)}} + PO_4^{3-}{}_{(aq)} \rightarrow Ag_3PO_{4(s)} + \cancel{3\ NH^+_{4(aq)}} + \cancel{3\ NO^-_{3(aq)}}$
$3\ Ag^+_{(aq)} + PO_4^{3-}{}_{(aq)} \rightarrow Ag_3PO_{4(s)}$ (net ionic equation)

(e) $Mg(OH)_{2(aq)} + Ca(NO_3)_{2(aq)} \rightarrow Ca(OH)_{2(s)} + Mg(NO_3)_{2(aq)}$
$Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)} + Ca^{2+}_{(aq)} + 2\ NO^-_{3(aq)} \rightarrow Ca(OH)_{2(s)} + Mg^{2+}_{(aq)} + 2\ NO^-_{3(aq)}$ (total ionic equation)
$\cancel{Mg^{2+}_{(aq)}} + 2\ OH^-_{(aq)} + Ca^{2+}_{(aq)} + 2\ \cancel{NO^-_{3(aq)}} \rightarrow Ca(OH)_{2(s)} + \cancel{Mg^{2+}_{(aq)}} + 2\ \cancel{NO^-_{3(aq)}}$
$Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$ (net ionic equation)

(f) $K_2CO_{3(aq)} + BaCl_{2(aq)} \rightarrow BaCO_{3(s)} + 2\ KCl_{(aq)}$
$2\ K^+_{(aq)} + CO_3^{2-}{}_{(aq)} + Ba^{2+}_{(aq)} + 2\ Cl^-_{(aq)} \rightarrow BaCO_{3(s)} + 2\ K^+_{(aq)} + 2\ Cl^-_{(aq)}$ (total ionic equation)
$\cancel{2\ K^+_{(aq)}} + CO_3^{2-}{}_{(aq)} + Ba^{2+}_{(aq)} + \cancel{2\ Cl^-_{(aq)}} \rightarrow BaCO_{3(s)} + \cancel{2\ K^+_{(aq)}} + \cancel{2\ Cl^-_{(aq)}}$
$Ba^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow BaCO_{3(s)}$ (net ionic equation)

(g) $AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$
$Ag^+_{(aq)} + NO^-_{3(aq)} + K^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)} + K^+_{(aq)} + NO^-_{3(aq)}$ (total ionic equation)
$Ag^+_{(aq)} + \cancel{NO^-_{3(aq)}} + \cancel{K^+_{(aq)}} + Cl^-_{(aq)} \rightarrow AgCl_{(s)} + \cancel{K^+_{(aq)}} + \cancel{NO^-_{3(aq)}}$
$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$ (net ionic equation)

(h) $Pb(NO_3)_{2(aq)} + K_2S_{(aq)} \rightarrow PbS_{(s)} + 2\ KNO_{3(aq)}$
$Pb^{2+}_{(aq)} + 2\ NO^-_{3(aq)} + 2\ K^+_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)} + \cancel{2\ K^+_{(aq)}} + 2\ NO^-_{3(aq)}$ (total ionic equation)
$Pb^{2+}_{(aq)} + 2\ \cancel{NO^-_{3(aq)}} + \cancel{2\ K^+_{(aq)}} + S^{2-}_{(aq)} \rightarrow PbS_{(s)} + \cancel{2\ K^+_{(aq)}} + 2\ \cancel{NO^-_{3(aq)}}$
$Pb^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)}$ (net ionic equation)

4. (b) $Pb^{2+}_{(aq)} + 2\ C_2H_3O^-_{2(aq)} + 2\ Ag^+_{(aq)} + 2\ NO^-_{3(aq)} \rightarrow 2\ AgC_2H_3O_{2(s)} + Pb^{2+}_{(aq)} + 2\ NO^-_{3(aq)}$
(d) $3\ Ag^+_{(aq)} + 3\ NO^-_{3(aq)} + 3\ NH^+_{4(aq)} + PO^{3-}_{4(aq)} \rightarrow Ag_3PO_{4(s)} + 3\ NH^+_{4(aq)} + 3\ NO^-_{3(aq)}$

1.15 EXTENSION EXERCISE

(Pages 53–54)

INVESTIGATION: PRECIPITATION REACTIONS IN SOLUTION—EXTRA CHALLENGE

Prediction

(a) According to the solubility rules, when a solution of cobalt(II) chloride is combined with solutions of sodium hydroxide and sodium carbonate, respectively, precipitates will form. When a solution of silver nitrate is combined with solutions of sodium hydroxide, potassium iodide, and sodium carbonate, respectively, precipitates will form. Finally, when a solution of aluminum nitrate is combined with a solution of sodium hydroxide, a precipitate will form.

Observations

Table 1 Record of Precipitate Formation

	$NaOH_{(aq)}$	$KI_{(aq)}$	$Na_2CO_{3(aq)}$
$CoCl_{2(aq)}$	P	NP	P
$AgNO_{3(aq)}$	P	P	P
$Al(NO_3)_{3(aq)}$	P	NP	NP

Analysis

(b) The pairs of solutions that produced precipitates are cobalt(II) chloride and sodium hydroxide, cobalt(II) chloride and sodium carbonate, silver nitrate and sodium hydroxide, silver nitrate and potassium iodide, silver nitrate and sodium carbonate, and aluminum nitrate and sodium hydroxide.

(c) $CoCl_{2(aq)} + 2\ NaOH_{(aq)} \rightarrow Co(OH)_{2(s)} + 2\ NaCl_{(aq)}$

$Co^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)} + 2\ Na^{+}_{(aq)} + 2\ OH^{-}_{(aq)} \rightarrow Co(OH)_{2(s)} + 2\ Na^{+}_{(aq)} + 2\ Cl^{-}_{(aq)}$ (total ionic equation)

$Co^{2+}_{(aq)} + \cancel{2\ Cl^{-}_{(aq)}} + \cancel{2\ Na^{+}_{(aq)}} + 2\ OH^{-}_{(aq)} \rightarrow Co(OH)_{2(s)} + \cancel{2\ Na^{+}_{(aq)}} + \cancel{2\ Cl^{-}_{(aq)}}$

$Co^{2+}_{(aq)} + 2\ OH^{-}_{(aq)} \rightarrow Co(OH)_{2(s)}$ (net ionic equation)

$CoCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CoCO_{3(s)} + 2\ NaCl_{(aq)}$

$Co^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)} + 2\ Na^{+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow CoCO_{3(s)} + 2\ Na^{+}_{(aq)} + 2\ Cl^{-}_{(aq)}$ (total ionic equation)

$Co^{2+}_{(aq)} + \cancel{2\ Cl^{-}_{(aq)}} + \cancel{2\ Na^{+}_{(aq)}} + CO3^{2-}_{3(aq)} \rightarrow CoCO_{3(s)} + \cancel{2\ Na^{+}_{(aq)}} + \cancel{2\ Cl^{-}_{(aq)}}$

$Co^{2+}_{(aq)} + CO^{2\ -\ \ -}_{3\ (aq)\ (aq)} \rightarrow CoCO_{3(s)}$ (net ionic equation)

$AgNO_{3(aq)} + NaOH_{(aq)} \rightarrow AgOH_{(s)} + NaNO_{3(aq)}$

$Ag^{+}_{(aq)} + NO^{-}_{3(aq)} + Na^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow AgOH_{(s)} + Na^{+}_{(aq)} + NO^{-}_{3(aq)}$ (total ionic equation)

$Ag^{+}_{(aq)} + \cancel{NO_{3(aq)}} + \cancel{Na^{+}_{(aq)}} + OH^{-}_{(aq)} \rightarrow AgOH_{(s)} + \cancel{Na^{+}_{(aq)}} + \cancel{NO_{3(aq)}}$

$Ag^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow AgOH_{(s)}$ (net ionic equation)

$AgNO_{3(aq)} + KI_{(aq)} \rightarrow AgI_{(s)} + KNO_{3(aq)}$

$Ag^{+}_{(aq)} + NO^{-}_{3(aq)} + K^{+}_{(aq)} + I^{-}_{(aq)} \rightarrow AgI_{(s)} + K^{+}_{(aq)} + NO^{-}_{3(aq)}$ (total ionic equation)

$Ag^{+}_{(aq)} + \cancel{NO_{3(aq)}} + \cancel{K^{+}_{(aq)}} + I^{-}_{(aq)} \rightarrow AgI_{(s)} + \cancel{K^{+}_{(aq)}} + \cancel{NO_{3(aq)}}$

$Ag^{+}_{(aq)} + I^{-}_{(aq)} \rightarrow AgI_{(s)}$ (net ionic equation)

$2\ AgNO_{3(aq)} + Na_2CO_{3(aq)} \rightarrow Ag_2CO_{3(s)} + 2\ NaNO_{3(aq)}$

$2\ Ag^{+}_{(aq)} + 2\ NO^{-}_{3(aq)} + 2\ Na^{+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow Ag_2CO_{3(s)} + 2\ Na^{+}_{(aq)} + 2\ NO^{-}_{3(aq)}$ (total ionic equation)

$2\ Ag^{+}_{(aq)} + 2\ \cancel{NO_{3(aq)}} + 2\ \cancel{Na^{+}_{(aq)}} + CO^{2-}_{3(aq)} \rightarrow Ag_2CO_{3(s)} + 2\ \cancel{Na^{+}_{(aq)}} + 2\ \cancel{NO_{3(aq)}}$

$2\ Ag^{+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow Ag_2CO_{3(s)}$ (net ionic equation)

$Al(NO_3)_{3(aq)} + 3\ NaOH_{(aq)} \rightarrow Al(OH)_{3(s)} + 3\ NaNO_{3(aq)}$

$Al^{3+}_{(aq)} + 3\ NO^{-}_{3\ (aq)} + 3\ Na^{+}_{(aq)} + 3\ OH^{-}_{(aq)} \rightarrow Al(OH)_{3(s)} + 3\ Na^{+}_{(aq)} + 3\ NO^{-}_{3\ (aq)}$ (total ionic equation)

$Al^{3+}_{(aq)} + 3\ \cancel{NO_{3\ (aq)}} + 3\ \cancel{Na^{+}_{(aq)}} + 3\ OH^{-}_{(aq)} \rightarrow Al(OH)_{3(s)} + \cancel{3\ Na^{+}_{(aq)}} + \cancel{3\ NO^{-}_{3\ (aq)}}$

$Al^{3+}_{(aq)} + 3\ OH^{-}_{(aq)} \rightarrow Al(OH)_{3(s)}$ (net ionic equation)

Evaluation

(d) One source of error is cross contamination of reactants. To avoid this source of error, we should clearly label which eyedroppers we are using with which solutions, and use each eyedropper for that solution only. Another possible source of error is that the precipitate may not be clearly visible. To reduce this source of error, we could continue adding drops of solution until we detect a precipitate.

(e) Student answers will vary depending on their predictions. If students used the solubility rules to make their predictions, their results should validate their predictions.

1.14–1.17 SELF QUIZ

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Completion

1. (a) synthesis
   (b) double displacement
   (c) synthesis
   (d) decomposition
   (e) synthesis
   (f) single displacement
   (g) decomposition
   (h) decomposition
   (i) single displacement
   (j) double displacement
   (k) single displacement
2. (a) $AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$

   $Ag^{+}_{(aq)} + NO^{-}_{3\,(aq)} + K^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + K^{+}_{(aq)} + NO^{-}_{3\,(aq)}$ (total ionic equation)

   $Ag^{+}_{(aq)} + \cancel{NO^{-}_{3\,(aq)}} + \cancel{K^{+}_{(aq)}} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + \cancel{K^{+}_{(aq)}} + \cancel{NO^{-}_{3\,(aq)}}$

   $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$ (net ionic equation)

   (b) $Pb(NO_3)_{2(aq)} + K_2S_{(aq)} \rightarrow PbS_{(s)} + 2\ KNO_{3(aq)}$

   $Pb^{2+}_{(aq)} + 2\ NO^{-}_{3\,(aq)} + 2\ K^{+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)} + 2\ K^{+}_{(aq)} + 2\ NO^{-}_{3\,(aq)}$ (total ionic equation)

   $Pb^{2+}_{(aq)} + \cancel{2\ NO^{-}_{3\,(aq)}} + \cancel{2\ K^{+}_{(aq)}} + S^{2-}_{(aq)} \rightarrow PbS_{(s)} + \cancel{2\ K^{+}_{(aq)}} + \cancel{2\ NO^{-}_{3\,(aq)}}$

   $Pb^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)}$ (net ionic equation)
3. (a) solute—the part of a solution that is in lesser quantity
   (b) solvent—the part of a solution that is in greater quantity
   (c) solubility—a measure of the extent to which a solute dissolves in a solvent at a given temperature and pressure
   (d) spectator ion—an ion that is present during a chemical reaction but that does not participate in the reaction
   (e) precipitate—a solid formed from a reaction that takes place in solution
   (f) supernate—the part of a solution that remains in a centrifuge tube once the precipitate has been removed

UNIT 1 SELF QUIZ

Multiple Choice

1. (d)
2. (c)
3. (a)
4. (a)
5. (d)
6. (d)
7. (a)
8. (d)
9. (a)
10. (c)
11. (b)
12. (d)
13. (c)

Completion

14. J.J. Thomson worked with cathode ray tubes. He suggested that the atom is not the smallest unit of matter, but that there are negatively charged particles within the atom. Thomson's raisin bun model of the atom consists of a positively charged sphere embedded with negatively charged particles.

15. (a) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

$Ag^{+}_{(aq)} + NO^{-}_{3(aq)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + Na^{+}_{(aq)} + NO^{-}_{3(aq)}$ (total ionic equation)

$Ag^{+}_{(aq)} + \cancel{NO^{-}_{3(aq)}} + \cancel{Na^{+}_{(aq)}} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + \cancel{Na^{+}_{(aq)}} + \cancel{NO^{-}_{3(aq)}}$

$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$ (net ionic equation)

(b) $Na_2CO_3 + Zn(NO_3)_2 \rightarrow NaNO_3 + ZnCO_3$

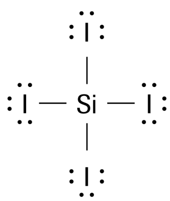
$Na_2CO_{3(aq)} + Zn(NO_3)_{2(aq)} \rightarrow 2\ NaNO_{3(aq)} + ZnCO_{3(s)}$

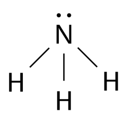
$2\ Na^{+}_{(aq)} + CO^{2-}_{3(aq)} + Zn^{2+}_{(aq)} + 2\ NO^{-}_{3(aq)} \rightarrow 2\ Na^{+}_{(aq)} + 2\ NO^{-}_{3(aq)} + ZnCO_{3(s)}$ (total ionic equation)

$\cancel{2\ Na^{+}_{(aq)}} + CO^{2-}_{3(aq)} + Zn^{2+}_{(aq)} + \cancel{2\ NO^{-}_{3(aq)}} \rightarrow \cancel{2\ Na^{+}_{(aq)}} + \cancel{2\ NO^{-}_{3(aq)}} + ZnCO_{3(s)}$

$Zn^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow ZnCO_{3(s)}$ (net ionic equation)

16.

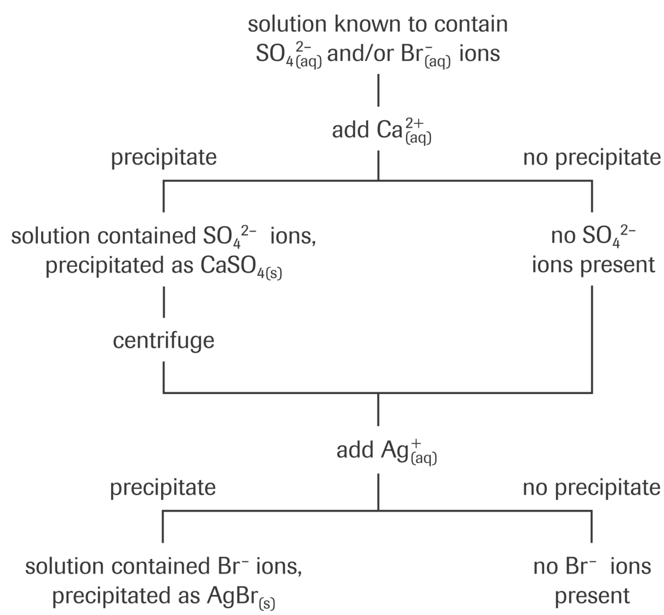




17. (a) If sodium chloride is added to the solution and a precipitate forms, it will indicate the presence of $Pb^{2+}_{(aq)}$ ions.
(b) A centrifuge could be used to separate the precipitate from the supernate.
(c) If sodium sulfate is added first, then both the $Pb^{2+}_{(aq)}$ and $Sr^{2+}_{(aq)}$ ions will precipitate as $PbSO_{4(s)}$ and $SrSO_{4(s)}$, respectively. By adding sodium chloride first, only the $Pb^{2+}_{(aq)}$ ion will precipitate as $PbCl_{2(s)}$. The $Sr^{2+}_{(aq)}$ ion will not precipitate when sodium chloride solution is added because $SrCl_{2(s)}$ is soluble in water.

18. Three situations in which spectroscopy can be used to perform a qualitative analysis test are (a) determining the mineral content of a geological sample using thermal emission spectroscopy, (b) determining the presence of alkali compounds in concrete, and (c) determining the composition of a star.

19. The following experimental design may be followed to test for the presence of sulfate ions and/or bromide ions.



20. The metallic ion that produces a yellow-green flame in a flame test is the barium ion, $Ba^{2+}_{(aq)}$. When sodium sulfate is added to a solution containing barium ions, a precipitate of barium sulfate, $BaSO_{4(s)}$, is formed. Given that the original solution is basic, you can infer that barium hydroxide, $Ba(OH)_{2(aq)}$, is the solute. A solution of barium hydroxide conducts electricity.

21. **Analysis**

Solution A contains potassium ions, $K^{+}_{(aq)}$.

Solution B contains copper(II) ions, $Cu^{2+}_{(aq)}$.

Solution C contains sodium ions, $Na^{+}_{(aq)}$.

Solution D contains calcium ions, $Ca^{2+}_{(aq)}$.

Solution E contains strontium ions, $Sr^{2+}_{(aq)}$ or lithium ions, $Li^{+}_{(aq)}$.

22. During a fireworks display, we observe many different colours. Fireworks are composed of different metallic ions that produce different colours when ignited. Every metallic ion gives off different wavelengths of light when the electrons in its atoms are excited by the addition of energy. The colour of light produced depends on the atomic structure of the ions in the compounds. Every ion has a different electron configuration. According to the Bohr model of the atom, the energy of electrons is quantized. When energy, such as heat, is applied to an element, the electrons in the ground state enter the excited state. When they return to the ground state, they emit the absorbed energy in the form of light that is characteristic to that element. The characteristic flame colours of metallic ions can be observed during a flame test. Therefore, the excitation of different chemical compounds within a fireworks display leads to different colours of light.