

# BC SCIENCE 10

## Provincial Exam Study Guide

### Unit 2: Chemical Reactions and Radioactivity

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## ***BC Science 10 Provincial Exam Study Guide***

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## Part A Strategies for Success

# Study Tips for Provincial Exam Preparation

### Introduction

This guide is designed to help you study for the BC Science 10 provincial exam. Completing all the questions in this Study Guide will not guarantee that you will pass the exam, but it will help prepare you for success.

Each unit in this Study Guide matches up to a unit in your *BC Science 10* student book. Each Study Guide unit begins with a checklist of what you should be able to do by the end of that unit. You can use this checklist to help you figure out which concepts you already know and which concepts you need to study further. Each Study Guide unit ends with a checklist of Processes of Science Vocabulary Terms that you should know and a Glossary of terms from the unit that you should understand.

Each section in the Study Guide has the following features.

- **Summary of Key Points**—you must know each of these key points for the exam
- **Study Notes**—these are the key points expanded to include details that may be on the exam
- **Quick Check**—these are questions to check your understanding of the Study Notes. If you cannot answer Quick Check questions, review the material in your student book or talk to your teacher.
- **Sample Exam Questions Explained**—this feature explains in detail the right and wrong answers for questions that are similar in style to the questions that will be on the provincial exam. The feature also describes why each question was asked and where you can get additional help if you did not understand the question. One strategy to help you study is to cover up the right-hand column in the question and try to answer the question first. Then, uncover the column to check your answer or to figure out why an answer is wrong. Figuring out why you got an answer wrong can help you to learn the concept.
- **Practice Questions**—these are questions that are similar in style to the questions that will be on the provincial exam. There are 10 Practice Questions at the end of each section.

### Support for Studying

When you study for the provincial exam, you should have the following materials. If you are missing any of the items below, please see your teacher.

- **BC Science 10 student book** Your student book covers the same curriculum that the provincial exam was developed for. It is an excellent source of information for studying.
- **Your notes** Your teacher has worked the whole semester or school year with you to help you develop the right knowledge, skills, and attitudes. A key part of this work is the notes you have created. Remember to review these notes while you study.
- **BC Science 10 Provincial Exam Data Pages** It is very important that you understand the parts of the Provincial Exam Data Pages and how to use them. Your teacher can answer your questions about these pages.
- **BC Science 10 Provincial Exam Vocabulary List** You should know the meaning of each of these terms. If you are unsure of any of the terms, check the Glossary at the end of each Study Guide unit or at the back of your student book.
- **The BC Science 10 website** You can find practice questions and web links that will help you study the material you have covered in Science 10 this year. Visit [www.bcs10.ca](http://www.bcs10.ca).

## Getting Help

When you study for a year-end test like the provincial exam, it is not uncommon to get stuck on concepts or have questions on material you have previously covered in class. If you are unsure about a concept or something covered in class, check with a classmate first. If both of you cannot figure out the answer, visit your teacher together.

## Tips from Experts

Study experts have a common list of hints they provide to people of all ages. Research has shown that these tips help you study.

- Have a **positive attitude**.
- **Be motivated** and take responsibility for your learning.
- **Attend class** so you do not miss key points about what you are learning. Your friend's notes are not a replacement for being present in class and learning the concepts while they are being taught.
- **Study regularly** to help you identify areas where you need extra help.
- **Get help** when you need it, and do not be afraid to ask questions. There are no bad questions when it comes to figuring something out.
- **Be a good test taker**. Have a good sleep the night before the test and be sure to eat a nutritious breakfast the day of the test. During the test, read each question carefully before selecting your answer.

Here is a list of common hints that science teachers in British Columbia have shared with their students.

- Know how to use your Data Pages.
- Practise reading graphs.
- Practise interpreting illustrations.
- Do not spend extra time studying what you already know.
- When you are writing the exam, read the question first, then read the possible answers. If you do not know the answer, then look at the picture (if there is a picture).
- Take your time when you write the exam. Answer the questions you know first, and then go back to questions that you are not sure of.

## Unit 2 Chemical Reactions and Radioactivity

**By the end of this unit, you should be able to:**

1. Differentiate between atoms, ions, and molecules using knowledge of their structure and components

This includes being able to:

- demonstrate knowledge of the three subatomic particles, their properties, and their location within the atom (e.g., by creating models)
- define and give examples of *ionic bonding* (e.g., metal and non-metal) and *covalent bonding* (e.g., two non-metals, diatomic elements)
- with reference to elements 1 to 20 on the periodic table, draw and interpret Bohr models, including protons, neutrons, and electrons, of
  - atoms (neutral)
  - ions (charged)
  - molecules—covalent bonding (e.g.,  $O_2$ ,  $CH_4$ )
  - ionic compounds (e.g.,  $CaCl_2$ )
- identify valence electrons using the periodic table (excluding lanthanides and actinides)
- distinguish between paired and unpaired electrons for a single atom
- draw and interpret Lewis diagrams showing single bonds for simple ionic compounds (e.g.,  $NaCl$ ,  $MgO$ ,  $BaBr_2$ ) and covalent molecules (e.g.,  $H_2O$ ,  $CH_4$ ,  $NH_3$ )
- distinguish between lone pairs and bonding pairs of electrons and molecules

2. Classify substances as acids, bases, or salts, based on their characteristics, name, and formula

This includes being able to:

- identify acids and bases using indicators (e.g., methyl orange, bromothymol blue, litmus, phenolphthalein, indigo carmine)
  - explain the significance of the pH scale, with reference to common substances
  - differentiate between acids, bases, and salts with respect to chemical formulas and properties
  - recognize the names and formulas of common acids (e.g., hydrochloric, sulfuric, nitric, acetic)
  - use the periodic table to
    - explain the classification of elements as metals and non-metals
    - identify the relative reactivity of elements in the alkali metal, alkaline metal, halogen, and noble gas groups
    - distinguish between metal oxide solutions (basic) and non-metal oxide solutions (acidic)
  - use the periodic table and a list of ions (including polyatomic ions) to name and write chemical formulas for common ionic compounds, using appropriate terminology (e.g., Roman numerals)
  - convert names to formulas and formulas to names for covalent compounds, using prefixes up to “deca”
3. Distinguish between organic and inorganic compounds
- This includes being able to:
- define *organic compounds* and *inorganic compounds*

- distinguish between organic and inorganic compounds, based on their chemical structures
  - recognize a compound as organic or inorganic from its name, from its chemical formula, or from a diagram or model
4. Analyze chemical reactions, including reference to conservation of mass and rate of reaction
- This includes being able to:
- define and explain the law of conservation of mass
  - represent chemical reactions and the conservation of atoms, using molecular models
  - write and balance (using the lowest whole number coefficients) chemical equations from formulae, word equations, or descriptions of experiments
  - identify, give evidence for, predict products of, and classify the following types of chemical reactions:
    - synthesis (combination)
    - decomposition
    - single and double replacement
    - neutralization (acid-base)
    - combustion
- explain how factors such as temperature, concentration, presence of a catalyst, and surface area can affect the rate of chemical reactions
5. Explain radioactivity using modern atomic theory
- define *isotope* in terms of atomic number and mass number, recognizing how these are communicated in standard atomic notation (e.g., uranium-238:  ${}_{92}^{238}\text{U}$ )
  - relate radioactivity decay (e.g., alpha— $\alpha$ , beta— $\beta$ , gamma— $\gamma$ ) to changes in the nucleus
  - relate the following subatomic particles to radioactive decay:
    - proton ( ${}_{1}^{1}p$ )
    - neutron ( ${}_{0}^{1}n$ )
    - electron ( ${}_{-1}^{0}e$ )
    - alpha particle ( ${}_{2}^{4}\alpha$ ) ( ${}_{2}^{4}\text{He}$ )
    - beta particle ( ${}_{-1}^{0}\beta$ )
  - explain half-life with reference to rates of radioactive decay
  - compare fission and fusion
  - complete and balance nuclear equations to illustrate radioactive decay, fission, and fusion

---

**By the end of this unit, you should understand the following key ideas:**

1. Atomic theory explains the formation of compounds.
2. Compounds are classified in different ways.
3. Chemical reactions occur in predictable ways.
4. The atomic theory explains radioactivity.

---

**To help you study you should have the following:**

- *BC Science 10* student book, pages 163 to 337. Note the practice exam questions on pages 336 and 337.
- BC Science 10 Provincial Exam Data Pages, pages 1 to 4.
- BC Science 10 Provincial Exam Vocabulary List, page 2
- Access to [www.bcsience10.ca](http://www.bcsience10.ca).



## Chapter 4 Atomic theory explains the formation of compounds.

### 4.1 Atomic Theory and Bonding

#### I. Summary of Key Points

- Atoms are composed of protons and neutrons, which make up the nucleus, and electrons, which surround the nucleus in patterns.
- Bohr diagrams show the arrangement of protons, neutrons, and electrons in atoms and also in ions.
- Ions are formed from atoms that have lost or gained electrons.
- Compounds can be ionic or covalent.
- Lewis diagrams show the arrangement of bonds within compounds.

#### II. Study Notes

##### Atomic Theory

1. An **atom** is the smallest particle of an element that has the properties of that element.
2. An element is a pure substance that cannot be chemically broken down into simpler substances.  
Example: Oxygen (O) is an element.
3. A **compound** is a pure substance that is made up of two or more different elements that have been combined in a specific way.  
Example:  $\text{H}_2\text{O}$  is a compound made of the elements hydrogen and oxygen.
4. An atom includes smaller particles called protons, neutrons, and electrons
  - **Protons** are subatomic particles that have a  $1+$  (positive) charge.
  - **Neutrons** are subatomic particles that do not have an electric charge.
  - **Electrons** are subatomic particles that have a  $1-$  (negative) electric charge.

##### The Nucleus

1. The nucleus is at the centre of an atom (Figure 4.1).
  - The nucleus is composed of protons and neutrons.
  - Electrons exist in the area surrounding the nucleus.
2. The number of protons = the number of electrons in every atom
3. The nuclear charge = the electric charge on the nucleus = the number of protons
4. The **atomic number** = the number of protons = the number of electrons

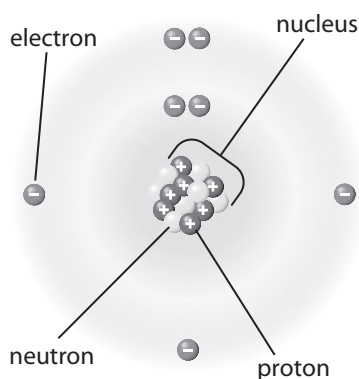


FIGURE 4.1 A model of an atom

## Quick Check

1. Explain how an atom, an element, and a compound are different from each other.

---

---

---

2. What are the electrical properties of the following particles?

(a) protons \_\_\_\_\_

(b) neutrons \_\_\_\_\_

(c) electrons \_\_\_\_\_

3. Where is each particle located in an atom?

(a) proton \_\_\_\_\_

(b) neutron \_\_\_\_\_

(c) electron \_\_\_\_\_

4. What does "atomic number" mean?

---

## Organization of the Periodic Table

Refer to the Periodic Table of the Elements on page 2 of your Data Pages.

1. The periodic table organizes all known elements in order by atomic number.
2. Rows of elements (across) are called **periods**.
3. Columns of elements (down) are called **chemical families** or **groups**.
  - All elements in a family have similar properties and bond with other elements in similar ways.
  - Group 1 = alkali metals
  - Group 2 = alkaline earth metals
  - Group 17 = halogens
  - Group 18 = noble gases
4. Metals are on the left side of the table, non-metals are on the right side, and the metalloids form a "staircase" toward the right side.

## The Periodic Table and Ion Formation

1. Atoms gain and lose electrons to form bonds.
  - When atoms gain or lose electrons, they become electrically charged particles called **ions**.
2. Metals lose electrons and become positive ions.
  - Some metals are multivalent, which means they lose electrons in different ways (Figure 4.2).
    - Iron (Fe) loses either two electrons ( $\text{Fe}^{2+}$ ) or three electrons ( $\text{Fe}^{3+}$ ) as shown in the periodic table.

26	3+
Fe	2+
Iron	
55.8	

FIGURE 4.2 Iron is a multivalent element.

3. Non-metals gain electrons and become negative ions.

## Quick Check

1. What is the difference between a chemical family and a period in the periodic table?

\_\_\_\_\_

2. List the name and group number of four families of elements.

\_\_\_\_\_

\_\_\_\_\_

3. How does an atom become an ion? \_\_\_\_\_

\_\_\_\_\_

4. How do metals become positive ions? \_\_\_\_\_

\_\_\_\_\_

5. How do non-metals become negative ions? \_\_\_\_\_

\_\_\_\_\_

## Bohr Diagrams

1. A **Bohr diagram** is a model of the atom that describes the arrangement of an element's subatomic particles: neutrons and protons in the nucleus and electrons in electron shells (Figure 4.3).
  - Electron **shells** are regular patterns or energy levels around the nucleus.
  - There is a maximum of two electrons in the first shell, eight electrons in the second shell, and eight electrons in the third shell.
  - Electrons in the outermost shell are called **valence electrons**.

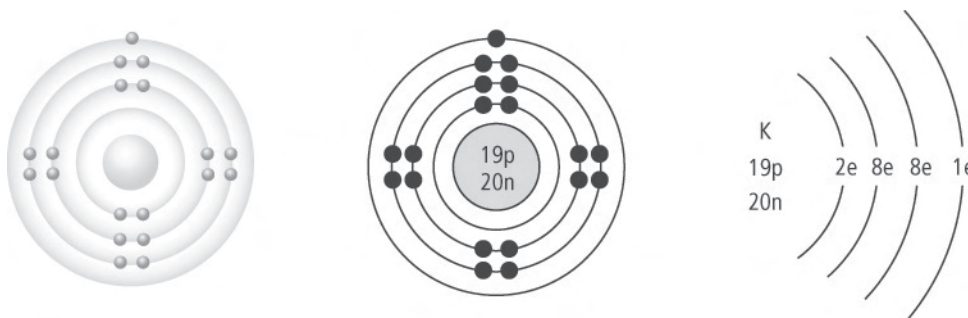


FIGURE 4.3 Bohr diagrams for potassium

2. Patterns of electron arrangements in periods:
  - The period number equals the number of shells in the atom.
  - The valence electrons are in the same shell for all elements in a period.  
Example: The valence electrons for Period 2 elements are found in the second shell for each element.
3. Patterns of electron arrangements in groups:
  - Except for the transition elements (Groups 3–12), the last digit of the group number equals the number of electrons in the valence shell.  
Examples: Group 1 = 1 valence electron, Group 13 = 3 valence electrons

- By losing or gaining electrons, atoms can have the same number of valence electrons as the nearest noble gas.
  - The noble gas elements have full electron shells and are very stable.
- Electrons can exist singly as **unpaired electrons**, or they can be in pairs, called **paired electrons**.

## Quick Check

- Where are valence electrons found? \_\_\_\_\_  
\_\_\_\_\_
- How many electrons can be in each of the first three shells in a Bohr model of an atom?  
Shell 1: \_\_\_\_\_ Shell 2: \_\_\_\_\_ Shell 3: \_\_\_\_\_
- Draw a Bohr diagram showing the number of protons and electrons in an atom of:
  - carbon
  - chlorine
  - aluminum
- Draw a Bohr diagram showing the number of protons and electrons in each of the following ions.
  - $F^-$
  - $Na^+$
  - $Al^{3+}$

## Forming Compounds

- A compound can be formed when the valence electrons of two atoms interact and form a low-energy bond.
  - The most stable (lowest energy) state of a compound occurs when the atoms in the compound have achieved full valence shells.
  - A pair of electrons in the valence shell that is not used in bonding is sometimes called a **lone pair**.
- In **ionic bonding**, the bond forms as a result of the attraction between positively charged ions and negatively charged ions.
  - Metals lose electrons and non-metals gain electrons when forming ions (Figure 4.4).

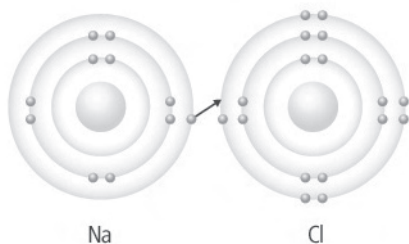


FIGURE 4.4 Sodium (metal) transfers an electron to chlorine (non-metal) to form an ionic bond in the compound sodium chloride, NaCl.

3. In a Bohr diagram of an ionic compound, large square brackets are placed around the diagram with the ion charge shown just outside the end bracket (Figure 4.5).

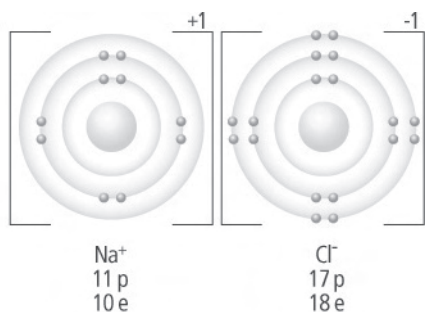


FIGURE 4.5 Bohr diagram of ionic bonding of sodium chloride

4. In **covalent bonding**, the bond forms through the sharing of one or more pairs of electrons.
- Covalent bonds form when electrons are shared between two non-metals.
  - The pair of electrons involved in a covalent bond is sometimes called the **bonding pair**.
  - Electrons are not transferred, but their outer shells overlap.
- Example: Hydrogen and fluorine share valence electrons to form hydrogen fluoride, HF (Figure 4.6).

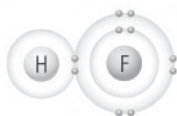


FIGURE 4.6 Bohr diagram of covalent bonding of hydrogen fluoride

5. A **molecule** is a group of atoms in which the atoms are bound together by sharing one or more pairs of electrons.
6. In **diatomic elements**, pairs of electrons are joined by covalent bonds because the two-atom molecules are more stable than the individual atoms.
- Diatomic elements include hydrogen ( $\text{H}_2$ ), nitrogen ( $\text{N}_2$ ), oxygen ( $\text{O}_2$ ), fluorine ( $\text{F}_2$ ), chlorine ( $\text{Cl}_2$ ), bromine ( $\text{Br}_2$ ), and iodine ( $\text{I}_2$ ).

### Lewis Diagrams

1. **Lewis diagrams** represent the atom of an element by showing only the outer valence electrons.
  - Dots representing electrons are placed around the element symbols at the points of the compass (north, east, south, and west).
  - Electron dots are placed singly until the fifth electron is reached, then they are paired.
2. Lewis diagrams of ionic bonding:
  - For positive ions, one electron dot is removed from the valence shell for each positive charge.
  - For negative ions, one electron dot is added to each valence shell for each negative charge of the ion.
  - Square brackets are placed around each ion to indicate transfer of electrons (Figure 4.7).



FIGURE 4.7 Lewis diagram of ionic bonding of sodium chloride

3. Lewis diagrams of covalent bonding:
- Valence electrons are drawn to show sharing of electrons.
  - The shared pairs of electrons are usually drawn as a straight line (Figure 4.8).

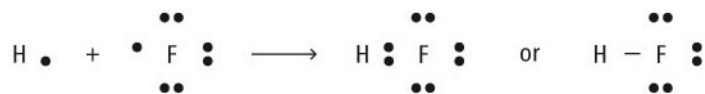


FIGURE 4.8 Lewis diagram of covalent bonding of hydrogen fluoride

## Quick Check

1. Which combinations of elements form ionic bonds in compounds?

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2. Which combinations of elements form covalent bonds?

---

3. Name seven diatomic elements.

\_\_\_\_\_

\_\_\_\_\_

4. Draw Lewis diagrams for the following atoms.

(a) O

(b) F

(c) Na

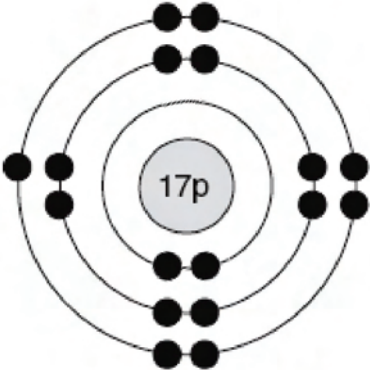
5. Draw Lewis diagrams for the following compounds.

(a) H<sub>2</sub>O

(b) NH<sub>3</sub>

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>Which of the following is an ionic compound?</p> <p>A. <math>N_2</math></p> <p>B. <math>CH_4</math></p> <p>C. <math>NH_4^+</math></p> <p>D. <math>Na_3PO_4</math></p>	<p>A. This is an element, not a compound. A compound must contain two or more elements chemically bonded.</p> <p>B. This is a compound, but it is not ionic. It is a covalent compound because it does not contain a metal in its formula.</p> <p>C. This is ammonium, a positive ion. It is not a compound, even though it possesses more than one element, because it has an overall electric charge. Compounds have an overall charge of zero.</p> <p>D. Correct. This is a compound because it contains more than one element and is electrically neutral. It is ionic because of the presence of the metal sodium (Na) in the formula.</p>
<p>→ Why was this question asked?</p>	
<p>This question was asked to determine if you understand the differences among elements, ions, and compounds. The question requires you to distinguish between ionic and covalent compounds by examining their formulas. Ionic compounds contain more than one element, one of which must be a metal (or the ammonium ion, <math>NH_4^+</math>), whereas covalent compounds have formulas that contain only non-metals.</p>	
<p>→ Where can I get extra practice on this type of question?</p>	
<ul style="list-style-type: none"><li>• Use pages 168 to 197 in <i>BC Science 10</i>.</li><li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li></ul>	

The Question	Why It Is Right/Why It Is Wrong
<p>Use the Bohr diagram below to answer this question.</p>  <p>How many valence electrons are shown in this Bohr diagram?</p> <p>A. 1</p> <p>B. 2</p> <p>C. 7</p> <p>D. 17</p>	<p>A. You may have been counting the number of unpaired electrons. This is not the number of valence electrons.</p> <p>B. You may have been counting the electrons in the innermost electron shell. These are not valence electrons.</p> <p>C. This answer is correct. Valence electrons are the electrons in the outermost occupied electron shell.</p> <p>D. This is the total number of electrons in the atom, not the number of valence electrons.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you understand how electrons are arranged in the shells surrounding the nucleus, including the meaning of terms such as valence electrons, inner electrons, paired electrons, and unpaired electrons.</p> <p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 170 to 175 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	



The Question	Why It Is Right/ Why It Is Wrong
<p>How many bonding pairs and lone pairs of electrons surround the central nitrogen atom in this Lewis structure of ammonia?</p> <div data-bbox="240 352 483 569" style="border: 1px solid black; padding: 10px; margin: 10px auto; width: fit-content;"> </div> <p>A. 1 lone pair and 1 bonding pair</p> <p>B. 2 lone pairs and 3 bonding pairs</p> <p>C. 1 lone pair and 3 bonding pairs</p> <p>D. 3 lone pairs and 1 bonding pair</p>	<p>A. Each pair of dots represents a lone (non-bonding) pair of electrons. Each line represents a pair of bonding electrons.</p> <p>B. Each pair of dots represents a lone (non-bonding) pair of electrons. Each line represents a pair of bonding electrons.</p> <p>C. This answer is correct. Each line represents a pair of bonding electrons. Each pair of dots represents a lone pair.</p> <p>D. You may have reversed the count of bonding pairs and lone pairs.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you understand how electrons are arranged in covalent bonds in which the bonding is affected by the number of shared electrons as well as unshared electrons.</p> <p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 178 to 180 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

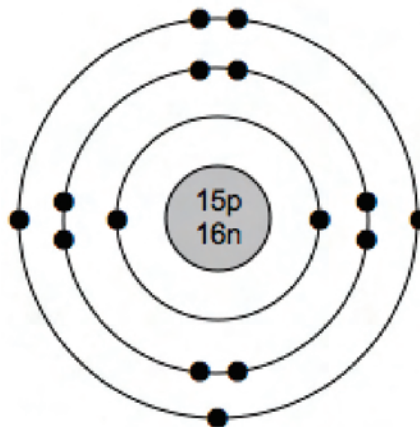
## IV. Practice Questions

### Section 4.1

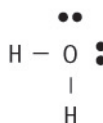
#### Atomic theory explains the formation of compounds: Atomic Theory and Bonding

Circle the letter of the best answer. You can use the Periodic Table of the Elements on page 2 of your Data Pages to help you.

- Which subatomic particles are found in the nucleus of atoms?
  - only protons
  - only electrons
  - protons and neutrons
  - protons and electrons
- When forming ions, elements on the left side of the periodic table tend to behave in which of the following ways?
  - lose protons
  - gain protons
  - lose electrons
  - gain electrons
- What is the name of the reactive family of elements that form  $1-$  ions?
  - halogens
  - noble gases
  - alkali metals
  - alkaline earth metals
- What is the atomic number of an atom with 19 protons, 19 electrons, and 21 neutrons?
  - 19
  - 21
  - 38
  - 39
- Which of the following describes an ion of chlorine?
  - 20 neutrons and 17 electrons
  - 20 neutrons and 18 electrons
  - 37 neutrons and 17 electrons
  - 37 neutrons and 18 electrons

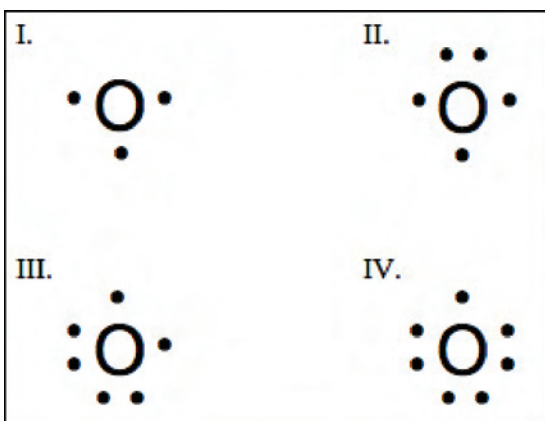


- Identify the atom shown in the Bohr diagram above.
  - gallium
  - sulfur
  - oxygen
  - phosphorus
- How many lone pairs and bonding pairs of electrons appear in the Lewis diagram shown below of water?



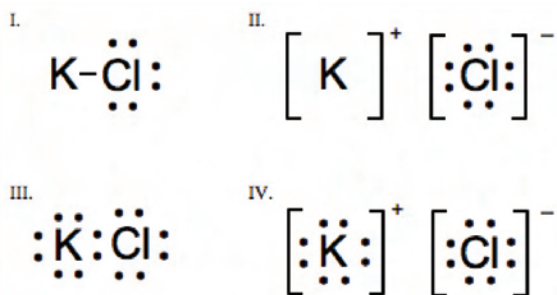
- two lone pairs and no bonding pairs
- two lone pairs and two bonding pairs
- no lone pairs and two bonding pairs
- four lone pairs and four bonding pairs

8. Which of the following Lewis diagrams represents an oxygen atom?



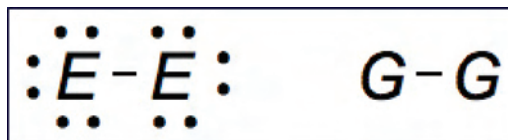
- A. I
- B. II
- C. III
- D. IV

9. Which of the following Lewis diagrams represents KCl?



- A. I
- B. II
- C. III
- D. IV

10. E and G represent unknown elements from the periodic table. What product could be formed from the two molecules shown below?



- A. water
- B. krypton gas
- C. hydrogen chloride
- D. sodium chloride

## 4.2 Names and Formulas of Compounds

### I. Summary of Key Points

- Compounds can be represented with both a name and a chemical formula.
- In an ionic compound, the first part of the name indicates the positive ion and the second part indicates the negative ion.
- In the formula of an ionic compound, the subscripts indicate the ratio in which the positive ions and negative ions are present together in the compound.
- In a binary compound, both the name and the formula indicate the number of each type of atom present in the compound.

### II. Study Notes

#### The Chemical Name of an Ionic Compound

1. The name of an ionic compound always has two parts, one for each type of ion in it.
  - The name of an ionic compound = positive ion + negative ion + *-ide*  
Example: *magnesium* (positive ion) + *oxygen* (negative ion) + *-ide*  
magnesium oxide
2. Ionic formulas are based on the ions of the atoms involved.  
Example: What is the name of  $\text{Ca}_3\text{N}_2$ ?  
Ca, the positive ion, is calcium  
N, the negative ion, is nitrogen  
Drop the end of the negative ion and add *-ide*  
calcium nitride

#### The Chemical Formula of an Ionic Compound

1. In an ionic compound, the positive charges balance out the negatives.
2. The subscript gives the ratio of each type of ion in the compound.
3. The ratio of positive to negative charges gives the proper formula.
4. The ratio is always written in reduced form.  
Example: What is the formula for magnesium phosphide?  
Magnesium is  $\text{Mg}^{2+}$   
Phosphorous is  $\text{P}^{3-}$   
Lowest common multiple of 2 and 3 is 6  
3  $\text{Mg}^{2+}$  ions and 2  $\text{P}^{3-}$  ions  
 $\text{Mg}_3\text{P}_2$

### Quick Check

1. Name the following ionic compounds.
  - (a)  $\text{Li}_3\text{P}$  \_\_\_\_\_
  - (b)  $\text{CaCl}_2$  \_\_\_\_\_
  - (c)  $\text{ZnO}$  \_\_\_\_\_
2. Write the formulas of the following ionic compounds.
  - (a) sodium sulfide \_\_\_\_\_
  - (b) magnesium iodide \_\_\_\_\_
  - (c) aluminum oxide \_\_\_\_\_

## Names and Formulas of Compounds Containing a Multivalent Metal

1. Some metals are multivalent, which means they have more than one ion form.
2. On the periodic table, the most common form of the ion is listed at the top of the element's box.
3. In the name of the compound, Roman numerals are used following the positive ion to indicate which ion was used (Table 4.1).

Example: What is the formula for manganese(III) sulfide?

Manganese (III) is  $\text{Mn}^{3+}$

Sulfur is  $\text{S}^{2-}$

Lowest common multiple of 3 and 2 is 6

2  $\text{Mn}^{3+}$  ions and 3  $\text{S}^{2-}$  ions



TABLE 4.1 Metal Ion Charge and Roman Numeral

Metal Ion Charge	Roman Numeral
1+	I
2+	II
3+	III
4+	IV
5+	V
6+	VI
7+	VII

### Quick Check

1. Write the formulas of the following ionic compounds.
  - (a) copper(I) oxide \_\_\_\_\_
  - (b) lead(IV) iodide \_\_\_\_\_
  - (c) lead(II) chloride \_\_\_\_\_
  - (d) gold(III) sulphide \_\_\_\_\_
2. Name the following ionic compounds containing a multivalent metal ion. Use a Roman numeral in the metal ion's name.
  - (a)  $\text{Cr}_3\text{P}_2$  \_\_\_\_\_
  - (b)  $\text{MnCl}_2$  \_\_\_\_\_
  - (c)  $\text{Co}_2\text{O}_3$  \_\_\_\_\_
  - (d)  $\text{FeN}$  \_\_\_\_\_

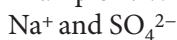
## Polyatomic Ions

Refer to Names, Formulae, and Charges of Some Polyatomic Ions, on page 4 of your Data Pages.

1. **Polyatomic** ions are ions composed of more than one type of atom joined together by covalent bonds.

- The whole group has a + or – charge, not individual atoms.

Example 1: What is the formula of sodium sulfate?



Example 2: What is the name of the compound  $\text{KClO}$ ?

$\text{K}^+$  = potassium

$\text{ClO}^-$  = hypochlorite

potassium hypochlorite

## Quick Check

Refer to Names, Formulae, and Charges of Some Polyatomic Ions, on page 4 of your Data Pages.

1. Write the formulas of the following ionic compounds containing polyatomic ions.
  - (a) cesium sulphate \_\_\_\_\_
  - (b) titanium(IV) hydrogen carbonate \_\_\_\_\_
  - (c) ammonium sulphide \_\_\_\_\_
  - (d) ammonium dichromate \_\_\_\_\_
2. Name the following ionic compounds containing polyatomic ions. The metal ion may need to be written using a Roman numeral.
  - (a)  $\text{NaClO}_4$  \_\_\_\_\_
  - (b)  $\text{Mg}_3(\text{PO}_4)_2$  \_\_\_\_\_
  - (c)  $(\text{NH}_4)_2\text{SO}_3$  \_\_\_\_\_
  - (d)  $\text{CuSO}_4$  \_\_\_\_\_
3. Give the number of each type of atom indicated by the formula, as well as the total number of atoms. (e.g.,  $\text{MgF}_2$  has one Mg and two F for a total of three atoms)
  - (a)  $\text{K}_3\text{PO}_4$  \_\_\_\_\_
  - (b)  $(\text{NH}_4)_2\text{SO}_4$  \_\_\_\_\_
  - (c) nickel(III) carbonate \_\_\_\_\_
  - (d) molybdenum(II) nitrate \_\_\_\_\_

## Names and Formulas of Covalent Compounds and Naming Binary Covalent Compounds

1. Covalent compounds are made up of two or more non-metals, and they may have many or few atoms sharing electrons.
  - The name of a covalent compound may reveal the components, but often it does not.
2. Covalent molecules have subscripts that show the actual number of atoms in the molecule.
3. The names of binary covalent compounds (two non-metal atoms) use a system of prefixes.
  - Prefixes are often used before the atom name to indicate the number of atoms in the molecule. (See page 4 of your Data Pages for a list of prefixes.)
  - Examples: CO = carbon *monoxide*, CO<sub>2</sub> = carbon *dioxide*
4. To name a binary covalent compound:
  - Write the most metallic atom (farthest left in the periodic table) first, and then add *-ide* to the end of the second atom's name.
  - Example: What is the name of the molecule N<sub>2</sub>O<sub>4</sub>?  
There are two (di-) nitrogen atoms and four (tetra-) oxygen atoms.  
dinitrogen tetraoxide

### Quick Check

1. Write the formula of each covalent compound.
  - (a) sulfur trioxide \_\_\_\_\_
  - (b) dinitrogen monoxide \_\_\_\_\_
  - (c) tetraphosphorus decasulfide \_\_\_\_\_
  - (d) phosphorus pentachloride \_\_\_\_\_
2. Write the name of each covalent compound
  - (a) PBr<sub>3</sub> \_\_\_\_\_
  - (b) N<sub>2</sub>S<sub>3</sub> \_\_\_\_\_
  - (c) N<sub>2</sub>O<sub>4</sub> \_\_\_\_\_
  - (d) OF<sub>2</sub> \_\_\_\_\_

## Comparing Ionic Compounds and Covalent Compounds

To determine whether a compound is ionic or covalent:

1. Examine the formula.
  - Ionic compounds start with a metal or the ammonium ion ( $\text{NH}_4^+$ ).
  - Covalent compounds start with a non-metal.
2. If the compound is covalent, use the prefix system of naming if the compound is binary and does not start with hydrogen.
  - If there are more than two different elements, or it starts with H, there is probably a different, simpler name for the covalent molecule.
3. If the compound is ionic, check to see if the metal is multivalent and add a Roman numeral if it is multivalent.
  - The name starts with the name of the metal atom.
  - If the compound ends with a single non-metal, the name will end in *-ide*.
  - If the compound ends in a polyatomic ion, refer to Names, Formulae, and Charges of Some Polyatomic Ions, on page 4 of your Data Pages.

### Quick Check

1. Identify each of the following compounds as either ionic or covalent, and name them.
  - (a)  $(\text{NH}_4)_3\text{P}$  \_\_\_\_\_
  - (b)  $\text{OBr}_2$  \_\_\_\_\_
  - (c)  $\text{FeF}_3$  \_\_\_\_\_
  - (d)  $\text{SnS}_2$  \_\_\_\_\_
2. The compounds below have similar-looking formulas but may have very different names. Classify each compound as ionic or covalent, and then name each compound.
  - (a)  $\text{PbO}_2$  \_\_\_\_\_
  - (b)  $\text{NO}_2$  \_\_\_\_\_
  - (c)  $\text{SO}_2$  \_\_\_\_\_
  - (d)  $\text{SnO}_2$  \_\_\_\_\_



### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>How many atoms of each of the following elements are present in the compound iron(III) nitrate?</p> <p>A. 1 iron, 1 nitrogen, and 3 oxygen</p> <p>B. 3 iron, 1 nitrogen, and 3 oxygen</p> <p>C. 3 iron, 1 nitrogen, and 0 oxygen</p> <p>D. 1 iron, 3 nitrogen, and 9 oxygen</p>	<p>A. The formula is <math>\text{Fe}(\text{NO}_3)_3</math> derived from <math>\text{Fe}^{3+}</math> and <math>\text{NO}_3^-</math>. There is one iron(III) ion and three nitrate ions, for a total of 1 Fe, and 3 N, and 9 O.</p> <p>B. The formula is <math>\text{Fe}(\text{NO}_3)_3</math> derived from <math>\text{Fe}^{3+}</math> and <math>\text{NO}_3^-</math>. There is one iron(III) ion and three nitrate ions, for a total of 1 Fe, and 3 N, and 9 O.</p> <p>C. The formula is <math>\text{Fe}(\text{NO}_3)_3</math> derived from <math>\text{Fe}^{3+}</math> and <math>\text{NO}_3^-</math>. There is one iron(III) ion and three nitrate ions, for a total of 1 Fe, and 3 N, and 9 O.</p> <p>D. This is the correct answer. The formula is <math>\text{Fe}(\text{NO}_3)_3</math> derived from <math>\text{Fe}^{3+}</math> and <math>\text{NO}_3^-</math>. There is one iron(III) ion and three nitrate ions, for a total of 1 Fe, and 3 N, and 9 O.</p>
<p>→ Why was this question asked?</p>	
<p>This question was asked to determine if you can derive a chemical formula for an ionic compound from its name and then count the number of each kind of atom in the compound.</p>	
<p>→ Where can I get extra practice on this type of question?</p>	
<ul style="list-style-type: none"><li>• Use pages 184 to 197 in <i>BC Science 10</i>.</li><li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li></ul>	

The Question	Why It Is Right/Why It Is Wrong
What is the name of the compound $\text{PbS}_2$ ? A. lead sulfide B. lead(II) sulfide C. lead(IV) sulfide D. phosphorus boron sulfide	A. Lead is multivalent with a charge of 4+. This makes the lead ion's name lead(IV). B. Lead is multivalent with a charge of 4+. This makes the lead ion's name lead(IV). C. This answer is correct. Lead is multivalent with a charge of 4+. This makes the lead ion's name lead(IV). D. The symbol for boron is "B," not "b." Pb is the symbol for a single element.
→ Why was this question asked? This question was asked to determine if you understand how ionic compounds are named, given their chemical formula.	
→ Where can I get extra practice on this type of question? <ul style="list-style-type: none"> <li>• Use pages 184 to 193 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

The Question	Why It Is Right/Why It Is Wrong
What is the chemical formula for dinitrogen trioxide? A. NO B. $\text{N}_2\text{O}_3$ C. $\text{N}_3\text{O}_2$ D. $(\text{NO}_3)_2$	A. This formula does not take into account the prefixes di- (two) and tri- (three). B. This answer is correct. Two nitrogen atoms and three oxygen atoms make up the formula. C. The subscripts are reversed. Dinitrogen means two nitrogens. D. Di- refers to two nitrogens, not to two nitrogen trioxides.
→ Why was this question asked? This question was asked to determine if you can write the formula of a covalent compound given the chemical name.	
→ Where can I get extra practice on this type of question? <ul style="list-style-type: none"> <li>• Use pages 193 to 196 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

### Section 4.2

#### Atomic theory explains the formation of compounds: Names and Formulas of Compounds

Circle the letter of the best answer. You can use the Periodic Table of the Elements on page 2 of your Data Pages to help you.

- What is the formula for aluminum sulfide?
  - AlS
  - AlS<sub>3</sub>
  - Al<sub>3</sub>S<sub>2</sub>
  - Al<sub>2</sub>S<sub>3</sub>
- What is the ionic charge of lead in PbO<sub>2</sub>?
  - +1
  - +2
  - +3
  - +4
- Which of the following is the correct name for Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>?
  - iron(II) sulfate
  - iron(II) sulfide
  - iron(III) sulfate
  - iron(III) sulfide
- Which statement best describes the compound N<sub>2</sub>O<sub>3</sub>?
  - It is the ionic compound nitrogen oxide.
  - It is the covalent compound nitrogen oxide.
  - It is the ionic compound dinitrogen trioxide.
  - It is the covalent compound dinitrogen trioxide.
- Which of the following is the correct bond type and name for (NH<sub>4</sub>)<sub>2</sub>S?
  - ionic, ammonium sulfide
  - ionic, nitrogen hydrogen sulfide
  - covalent, ammonium sulfide
  - covalent, dinitrogen monohydrogen sulfide
- What is the formula for diphosphorus pentachloride?
  - PCl
  - PCl<sub>5</sub>
  - P<sub>2</sub>Cl<sub>5</sub>
  - P<sub>5</sub>Cl<sub>2</sub>
- Which of the following is the correct name for SrCl<sub>2</sub>?
  - strontium chloride
  - strontium dichloride
  - strontium(II) chloride
  - monostrontium dichloride
- What is the name for AuBr<sub>3</sub>?
  - gold bromide
  - gold tribromide
  - gold(III) bromide
  - gold(III) bromine
- How many atoms of each of the following elements are present in nickel(III) sulfate?
  - nickel = 2, sulfur = 3
  - nickel = 1, sulfur = 1, oxygen = 4
  - nickel = 3, sulfur = 1, oxygen = 4
  - nickel = 2, sulfur = 3, oxygen = 12
- What is the formula for manganese(II) chloride?
  - MnCl
  - MnCl<sub>2</sub>
  - Mn<sub>2</sub>Cl
  - MgCl<sub>2</sub>

## 4.3 Chemical Equations

### I. Summary of Key Points

- A chemical change is a change in the arrangements and connections between ions and atoms.
- One or more chemical changes that occur at the same time are called a chemical reaction.
- Chemical reactions can be represented using a chemical equation.
- A chemical equation may be written in words or in chemical symbols.
- In a chemical reaction, the reactants are written to the left of an arrow and the products are written to the right.
- The symbols for states of matter may be used to show whether each reactant or product is solid, liquid, gas, or aqueous.
- Chemical reactions obey the law of conservation of mass, and atoms are neither created nor produced in a chemical reaction.
- Chemical equations are balanced using the lowest whole number coefficients, which are numbers written in front of the pure substances in the reaction.

### II. Study Notes

#### Chemical Reactions

1. A chemical change occurs when the arrangement of atoms in compounds changes to form new compounds.
2. One or more chemical changes that happen at the same time are called a chemical reaction.
3. The original substances, called reactants, change into new substances called products.
4. Chemical reactions can be written in different ways.
  - A word equation:  
Example: Nitrogen monoxide + oxygen  $\rightarrow$  nitrogen dioxide
  - A **symbolic equation** is a set of chemical symbols and formulas that identify the reactants and products in a chemical reaction.  
Example:  $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$

#### Conservation of Mass in Chemical Change

1. Chemical change means new compounds are created, but no new matter is created or destroyed; atoms are just rearranged.
  - All of the matter in the reactants = all of the matter in the products
  - Number of each atom in reactants = number of each atom in products
2. The **law of conservation of mass** states that mass is conserved in a chemical reaction; the total mass of the products is always equal to the total mass of the reactants in a chemical reaction.
  - In chemical reactions, atoms are neither created nor destroyed.
  - The law of conservation of mass was formulated by Antoine and Marie-Anne Lavoisier in the 1700s.

#### Quick Check

1. When does a chemical change occur? \_\_\_\_\_  
\_\_\_\_\_
2. What are two ways that a chemical reaction can be written? \_\_\_\_\_  
\_\_\_\_\_
3. State the law of conservation of mass. \_\_\_\_\_  
\_\_\_\_\_

## Writing and Balancing Chemical Equations

1. The simplest form of chemical equation is a word equation.  
Example: Potassium + oxygen  $\rightarrow$  potassium oxide
2. A skeleton equation shows the formulas of the elements/compounds but not quantities of atoms.  
Example:  $K + O_2 \rightarrow K_2O$
3. A balanced chemical equation shows all atoms and their quantities.  
Example:  $4K + O_2 \rightarrow 2K_2O$

## Counting Atoms to Balance an Equation

1. Using the law of conservation of mass, you can count atoms and use math to balance the number of atoms in chemical equations.
  - Balancing ensures that the number of each atom is the same on both sides of the reaction arrow.
2. To balance the compounds, take note of how many atoms of each element occur on each side of the reaction arrow (Figure 4.9).

Skeleton equation:  $CH_4 + O_2 \rightarrow H_2O + CO_2$   
1 C, 4 H, 2 O  $\rightarrow$  1 C, 2 H, 3 O

  - To balance, find values that equate atoms on both sides. Always use the smallest whole number ratio.  
Balanced equation:  $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$   
1 C, 4 H, (2  $\times$  2) O  $\rightarrow$  1 C, (2  $\times$  2) H, (2  $\times$  1) + 2 O

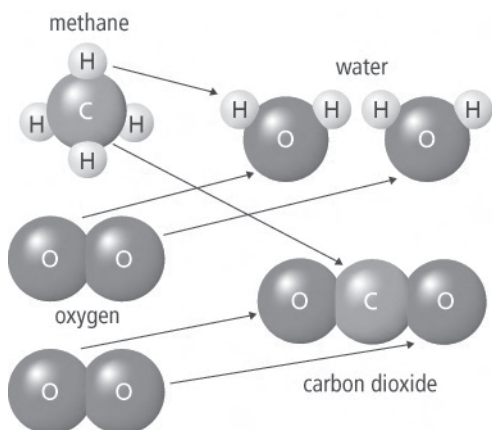


FIGURE 4.9 For an equation to be balanced, the same number of atoms of each element must be present on both sides of the equation.

## Quick Check

1. List the total number of each type of atom in the following reactants.

(a)  $3 Cl_2 + 2 CrI_3$  \_\_\_\_\_

(b)  $Pb(NO_3)_4 + 4 NaI$  \_\_\_\_\_

## Hints for Writing Word Equations

1. Word equations require careful examination to be written correctly.
2. The chemical symbol is used for most elements that are not in a compound
3. Watch for diatomic elements: H<sub>2</sub>, N<sub>2</sub>, O<sub>2</sub>, F<sub>2</sub>, Cl<sub>2</sub>, Br<sub>2</sub>, and I<sub>2</sub>.
4. Watch for polyatomic elements such as P<sub>4</sub> and S<sub>8</sub>.
5. Several common covalent molecules containing hydrogen have common names that do not help in writing chemical formulas.
  - Methane is CH<sub>4</sub>, water is H<sub>2</sub>O, glucose is C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, ethane is C<sub>2</sub>H<sub>6</sub>, and ammonia is NH<sub>3</sub>.

## Strategies for Balancing Equations

1. Balance chemical equations by following these steps.
  - Trial and error will often work for simple equations.
  - Balance compounds first and elements last.
  - Balance one compound at a time.
  - Only add coefficients; NEVER change subscripts.
  - If H and O appear in more than one place, attempt to balance them LAST.
  - Polyatomic ions (such as SO<sub>4</sub><sup>2-</sup>) can often be balanced as a whole group.
  - Always double-check after you think you are finished.

## Quick Check

1. Balance the following skeleton equations.
  - (a)  $\text{___ Al} + \text{___ Cl}_2 \rightarrow \text{___ AlCl}_3$
  - (b)  $\text{___ CH}_4 + \text{___ O}_2 \rightarrow \text{___ CO}_2 + \text{___ H}_2\text{O}$
  - (c)  $\text{___ Ca(NO}_3)_2 + \text{___ Cu}_2\text{SO}_4 \rightarrow \text{___ CaSO}_4 + \text{___ CuNO}_3$
  - (d)  $\text{___ Na}_2\text{CO}_3 + \text{___ Ni(NO}_3)_3 \rightarrow \text{___ NaNO}_3 + \text{___ Ni}_2(\text{CO}_3)_3$
2. Write skeleton equations for the following chemical reactions and then balance them. Be sure to check your formulas carefully before you begin to balance.
  - (a) calcium fluoride + potassium → potassium fluoride + calcium  
\_\_\_\_\_
  - (b) aluminum hydroxide + hydrogen bromide → aluminum bromide + water  
\_\_\_\_\_
  - (c) chromium(III) iodide + potassium carbonate → chromium(III) carbonate + potassium iodide  
\_\_\_\_\_
  - (d) hydrogen nitrate + barium carbonate → barium nitrate + water + carbon dioxide  
\_\_\_\_\_

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>Which set of ordered coefficients correctly balances the following equation?</p> $\text{___ Na}_3\text{PO}_4 + \text{___ MgSO}_4 \rightarrow \text{___ Mg}_3(\text{PO}_4)_2 + \text{___ Na}_2\text{SO}_4$ <p>A. 1, 2, 2, 3</p> <p>B. 2, 1, 2, 3</p> <p>C. 2, 2, 3, 1</p> <p>D. 2, 3, 1, 3</p>	<p>A. Atoms do not balance. For example, there are 3 Na on the left and 6 Na on the right.</p> <p>B. Atoms do not balance. For example, there are 6 Na on the left and 9 Na on the right.</p> <p>C. Atoms do not balance. For example, there are 3 Na on the left and 1 Na on the right.</p> <p>D. This is the correct answer. Each side of the equation gives 6 Na, 2 P, 3 Mg, 3 S, and 20 O.</p>
<p>→ Why was this question asked?</p>	
<p>This question was asked to determine if you can balance an equation by placing coefficients correctly. You need to be able to count the number of each kind of atom present in the reactants and in the products.</p>	
<p>→ Where can I get extra practice on this type of question?</p>	
<ul style="list-style-type: none"> <li>• Use pages 206 to 211 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

The Question	Why It Is Right/Why It Is Wrong
<p><b>Consider the following unbalanced chemical equation.</b></p> $\text{___ NH}_4\text{ClO}_4 \rightarrow \text{___ Cl}_2 + \text{___ N}_2 + \text{___ O}_2 + \text{H}_2\text{O}$ <p>What is the coefficient in front of O<sub>2</sub> when this equation is correctly balanced?</p> <p>A. 1</p> <p>B. 2</p> <p>C. 3</p> <p>D. 4</p>	<p>A. The balanced equation is <math>2\text{NH}_4\text{ClO}_4 \rightarrow \text{Cl}_2 + \text{N}_2 + 2\text{O}_2 + \text{H}_2\text{O}</math></p> <p>B. This is the correct answer.</p> <p>C. The balanced equation is <math>2\text{NH}_4\text{ClO}_4 \rightarrow \text{Cl}_2 + \text{N}_2 + 2\text{O}_2 + \text{H}_2\text{O}</math></p> <p>D. The balanced equation is <math>2\text{NH}_4\text{ClO}_4 \rightarrow \text{Cl}_2 + \text{N}_2 + 2\text{O}_2 + \text{H}_2\text{O}</math></p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you understand how to balance a skeleton chemical equation.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 206 to 211 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li> </ul>	



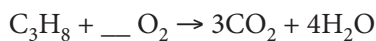
## IV. Practice Questions

### Section 4.3

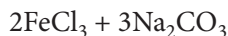
#### Atomic theory explains the formation of compounds: Chemical Equations

Circle the letter of the best answer. You can use the Periodic Table of the Elements on page 2 of your Data Pages to help you.

1. What coefficient is needed in front of  $O_2$  in order to balance the following equation?



- A. 2  
B. 5  
C. 6  
D. 10
2. In a chemical reaction, 40.3 g of magnesium oxide is broken down to yield 24.3 g of magnesium and 16.0 g of oxygen. What is this an example of?
- A. Dalton's atomic theory  
B. the law of constant proportions  
C. the law of conservation of mass  
D. the law of conservation of energy
3. List the total number of each type of atom found in the following reactants:



	Fe	Cl	Na	C	O
I	2	6	6	3	3
II	2	3	6	1	3
III	2	6	6	3	9
IV	1	3	2	1	3

- A. I  
B. II  
C. III  
D. IV

4. Which of the following is the correctly balanced equation for the following skeleton equation?



- A.  $Al + CuCl_2 \rightarrow AlCl_3 + Cu$   
B.  $Al + 3CuCl_2 \rightarrow 2AlCl_3 + Cu$   
C.  $2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$   
D.  $6Al + 3CuCl_2 \rightarrow 2AlCl_3 + 6Cu$
5. Which of the following equations is correctly balanced?
- A.  $Al + Br_2 \rightarrow AlBr_3$   
B.  $Al + 3Br_2 \rightarrow AlBr_3$   
C.  $Al + 3Br_2 \rightarrow 2AlBr_3$   
D.  $2Al + 3Br_2 \rightarrow 2AlBr_3$
6. Rewrite the following word equation as a balanced equation.

Potassium sulfate and lead(II) nitrate react to make potassium nitrate and lead(II) sulfate.

- A.  $K_2S + Pb(NO_3)_2 \rightarrow 2KNO_3 + PbS$   
B.  $K_2SO_4 + Pb(NO_3)_2 \rightarrow 2KNO_3 + PbSO_4$   
C.  $3K_2SO_4 + Pb_3N_2 \rightarrow 2K_3N + 3PbSO_4$   
D.  $3PSO_4 + Pb_3N_2 \rightarrow P_3N + 3PbSO_4$
7. Write the skeleton equation for the following reaction.

Iron(III) bromide reacts with sodium hydroxide to yield iron(III) hydroxide and sodium bromide.

- A.  $FeBr_3 + NaOH \rightarrow Fe(OH)_3 + NaBr$   
B.  $FeBr_3 + SOH \rightarrow Fe(OH)_3 + SBr$   
C.  $FeBr + NaOH \rightarrow FeOH + NaBr$   
D.  $IBr + NaOH \rightarrow IOH + NaBr$

8. Which of the following equations is correctly balanced?
- A.  $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$
  - B.  $C_5H_{12} + 11O_2 \rightarrow 5CO_2 + 6H_2O$
  - C.  $C_5H_{12} + 11O_2 \rightarrow 5CO_2 + 12H_2O$
  - D.  $2C_5H_{12} + 22O_2 \rightarrow 10CO_2 + 24H_2O$
9. In a tightly closed container, a piece of zinc reacts in hydrochloric acid to produce hydrogen gas and a salt solution of zinc chloride. What will happen to the mass of the container?
- A. It will increase.
  - B. It will decrease.
  - C. It will stay the same.
  - D. It will first increase, then decrease.
10. Tom has an open cup of vinegar (acetic acid) and adds some sodium carbonate. The mixture bubbles and fizzes. After the fizzing stops, Tom finds the container is lighter (less mass) than it was originally. He thinks it has broken the law of conservation of mass. His lab partner knows the correct answer and states:
- A. "You must have made a mistake. Try it again."
  - B. "Yes, you found a reaction that breaks the law of conservation of mass!"
  - C. "There is not enough information here. We must do the experiment again."
  - D. "No, the law of conservation of mass is obeyed. Gas was produced, and it escaped into the surrounding air."

## Chapter 5 Compounds are classified in different ways.

### 5.1 Acids and Bases

#### I. Summary of Key Points

- Many common pure substances can be classified according to whether they are acids or bases.
- Some acids and bases are corrosive and poisonous, whereas others add flavour to food or are vitamins.
- Acid-base indicators are chemicals that change colour in response to acidic or basic conditions.
- The pH scale is a number scale for measuring how acidic or basic a solution is.
- A pH value below pH 7 is acidic, pH 7 is neutral, and a pH value above pH 7 is basic.
- Generally, the chemical formula for an acid starts with H (hydrogen) on the left of the formula.
- Bases generally have an OH on the right of the chemical formula.

#### II. Study Notes

##### The pH Scale

1. Many familiar compounds are acids or bases.
2. Classification as acids or bases is based on chemical composition.
  - Both acids and bases can be very corrosive so you should NEVER try to identify an acid or base by taste or touch!
3. The acidity level of solutions of acids and bases is measured on the pH scale.
  - The **pH scale** is a number scale for measuring how acidic or basic a solution is.
  - pH below 7 = **acidic**, pH above 7 = **basic**, pH 7 = neutral
4. Each decrease of 1 on the pH scale indicates 10× more acidic.  
Examples: pH 4 is 10 times more acidic than pH 5.  
pH 3 is 1000× more acidic than pH 6.
5. **Acids** are compounds that produce a solution of less than pH 7 when they dissolve in water.
6. **Bases** are compounds that produce a solution of more than pH 7 when they dissolve in water.
7. If a solution has a pH of 7, it is said to be **neutral**, neither acidic nor basic.

##### Quick Check

1. What is the pH range for each of these solutions?
  - (a) acidic \_\_\_\_\_
  - (b) basic \_\_\_\_\_
2. How many times has the acidity level increased if the pH drops from pH 4 to pH 3? \_\_\_\_\_
3. How many times has the acidity level increased if the pH drops from pH 6 to pH 2? \_\_\_\_\_
4. What is the pH of a solution that is neutral? \_\_\_\_\_

## pH Indicators

- The pH of acids and bases can be measured by pH (acid-base) indicators or by a pH meter that measures the electrical conductivity of the solution.
  - pH indicators**, also called acid-base indicators, are chemicals that change colour based on the solution they are placed in.
- Litmus**, a compound extracted from lichens, is the most common acid-base indicator and is used on litmus paper.
  - There are two colours of litmus paper. Blue indicates basic, pH above 7. Red indicates acidic, pH below 7.
- Acid-base indicators change colour at different pH values, so different indicators are used to identify different pH values. See page 3 of your Data Pages for a chart showing acid-base indicator colour changes.
  - Bromothymol blue** is a type of acid-base indicator that turns yellow when added to an acid.
  - Phenolphthalein** is a type of acid-base indicator that turns pink when added to a base.
  - Other acid-base indicators include **methyl orange**, **methyl red**, and **indigo carmine**.
  - Many natural sources, such as beets and cabbage, are also acid-base indicators.
  - Universal indicator contains many indicators that turn different colours at different pH values.

## Quick Check

Use the acid-base indicator chart on page 3 of your Data Pages to answer the following questions.

- What is the colour of each of these acid-base indicators in the following solutions?
  - methyl orange in stomach acids \_\_\_\_\_
  - methyl orange in tomato juice \_\_\_\_\_
  - bromothymol blue in banana juice \_\_\_\_\_
  - blue litmus in pure water \_\_\_\_\_
  - red litmus in pure water \_\_\_\_\_
  - phenolphthalein in ammonia solution ( $\text{NH}_3$ ) \_\_\_\_\_

## Acids

- If you know a compound's chemical formula, you may be able to identify whether it is an acid.
- Acids often behave like acids only when dissolved in water, so they often are written with the symbol (aq), which means aquatic.
- The chemical formula of an acid usually starts with hydrogen (H).
- Acids with a carbon usually have the C written first.
  - Examples of common acids:  $\text{HCl}(\text{aq})$  = hydrochloric acid; present in stomach
  - $\text{HNO}_3(\text{aq})$  = nitric acid; used to make fertilizers
  - $\text{CH}_3\text{COOH}(\text{aq})$  = acetic acid; present in vinegar
- Names of acids follow these simple rules.
  - Hydrogen + ...-ide = hydro...ic acid  
Example:  $\text{HF}(\text{aq})$  = hydrogen fluoride = hydrofluoric acid
  - Hydrogen + ...-ate = ...ic acid  
Example:  $\text{H}_2\text{CO}_3(\text{aq})$  = hydrogen carbonate = carbonic acid
  - Hydrogen + ...-ite = ...ous acid  
Example:  $\text{H}_2\text{SO}_3(\text{aq})$  = hydrogen sulfite = sulfurous acid

## Quick Check

1. Name the following non-oxygen acids.

(a) HCl(aq) \_\_\_\_\_

(b) HBr(aq) \_\_\_\_\_

(c) HF(aq) \_\_\_\_\_

2. Name the following common acids.

(a) H<sub>2</sub>SO<sub>4</sub> \_\_\_\_\_

(b) HNO<sub>3</sub> \_\_\_\_\_

(c) CH<sub>3</sub>COOH(aq) \_\_\_\_\_

3. Name the following acids containing oxygen and chlorine.

(a) HClO<sub>4</sub>(aq) \_\_\_\_\_

(b) HClO<sub>3</sub>(aq) \_\_\_\_\_

(c) HClO<sub>2</sub>(aq) \_\_\_\_\_

(d) HClO(aq) \_\_\_\_\_

## Bases

1. If you know a compound's chemical formula, you may be able to identify whether it is a base.
2. Bases, like acids, often behave like bases only when dissolved in water so they are often written with the symbol (aq).
3. The chemical formula of a base usually ends with hydroxide (OH).
4. Examples of common bases: NaOH(aq) sodium hydroxide; drain and oven cleaner  
Mg(OH)<sub>2</sub>(aq) magnesium hydroxide; ingredient in some antacids  
Ca(OH)<sub>2</sub>(aq) calcium hydroxide; soil and water treatment  
NH<sub>4</sub>OH(aq) ammonium hydroxide; kitchen cleaner

## Production of Ions

1. Acids and bases can conduct electricity because they release ions in solution (Table 5.1 on the next page).
  - Acids release hydrogen ions, H<sup>+</sup>(aq).
  - Bases release hydroxide ions, OH<sup>-</sup>(aq).
2. The pH of a solution refers to the concentration of hydrogen ions in a solution.
  - **Concentration** means the amount of solute present in a specific volume of solution.
  - High concentration of H<sup>+</sup>(aq) = low pH, very acidic
  - High concentration of OH<sup>-</sup> = high pH, very basic
4. A solution cannot have a high concentration of both H<sup>+</sup>(aq) and OH<sup>-</sup>(aq) because they react with each other and form water.  
Example: H<sup>+</sup>(aq) + OH<sup>-</sup>(aq) → H<sub>2</sub>O(ℓ)
  - This process is called neutralization.

TABLE 5.1 Properties of Acids and Bases

Property	Acids	Bases
Taste ( <i>Never taste chemicals in the laboratory.</i> )	Sour	Bitter
Touch ( <i>Never touch chemicals in the laboratory with your bare skin.</i> )	Will burn skin	Slippery Will burn skin
Indicator tests	Turn blue litmus paper red	Turn red litmus paper blue
Reaction with some metals	Acids corrode metals.	No reaction
Electrical conductivity	Conductive	Conductive
pH	Less than 7	More than 7
Production of ions	Form hydrogen ions ( $H^+$ ) in solution	Form hydroxide ions ( $OH^-$ ) in solution

### Quick Check

- Identify each by their formula as acids, bases, or neither when dissolved in water.
  - HI \_\_\_\_\_
  - KOH \_\_\_\_\_
  - NaCl \_\_\_\_\_
  - $Ca(OH)_2$  \_\_\_\_\_
  - $MgBr_2$  \_\_\_\_\_
  - $H_3PO_4$  \_\_\_\_\_
- Which ion is in high concentration in an acidic solution? \_\_\_\_\_
- Which ion is in high concentration in a basic solution? \_\_\_\_\_
- The concentrations of  $H^+$  and  $OH^-$  cannot both be high at the same time. Why not? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>A mixture of lemon juice, bromothymol blue indicator, and indigo carmine indicator is prepared. What is the colour of this mixture?</p> <p>A. yellow</p> <p>B. blue</p> <p>C. colourless</p> <p>D. green</p>	<p>A. The bromothymol blue is yellow, but it is mixed with blue indigo carmine.</p> <p>B. The indigo carmine is blue, but it is mixed with yellow bromothymol blue.</p> <p>C. The lemon juice is almost colourless, but the presence of the other two indicators makes the solution green.</p> <p>D. This answer is correct. The lemon juice solution is pH 3. At this pH, bromothymol blue is yellow and indigo carmine is blue. A mix of blue and yellow is green.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can make use of the indicator chart on page 3 of your Data Pages.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 220 to 224 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

The Question	Why It Is Right/Why It Is Wrong
<p>What is the name of the compound <math>\text{H}_2\text{SO}_4</math>?</p> <p>A. hydrogen sulfite</p> <p>B. hydrosulfurous acid</p> <p>C. sulfuric acid</p> <p>D. sulfurous acid</p>	<p>A. Hydrogen sulfite is <math>\text{H}_2\text{SO}_3</math>.</p> <p>B. This is not the name of any compound.</p> <p>C. This answer is correct. <math>\text{SO}_4^{2-}</math> is sulfate; “-ate” compounds become “-ic” acids.</p> <p>D. Sulfurous acid is <math>\text{H}_2\text{SO}_3</math>. <math>\text{SO}_3^{2-}</math> is sulphite; “-ite” compounds become “-ous” acids.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can name acids.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 225 and 226 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

### Section 5.1

#### Compounds are classified in different ways: Acids and Bases

Circle the letter of the best answer. Use the charts on page 3 of your Data Pages to help you answer the questions.

1. What is the pH of an acidic substance?
  - A. between 4 and 8
  - B. greater than 7
  - C. less than 7
  - D. equal to 7
2. A sample of grapes is crushed, and the pH is tested using three different indicators. Which set of colours is correct for the grapes?

	Methyl Orange	Bromothymol Blue	Indigo Carmine
I.	yellow	yellow	yellow
II.	red	yellow	blue
III.	red	blue	blue
IV.	yellow	blue	yellow

- A. I
  - B. II
  - C. III
  - D. IV
3. You have a sample to test in a lab. The sample looks like milk. Choose the two best indicators for testing if the sample is in the same pH range as milk.
    - A. litmus and phenolphthalein
    - B. methyl orange and methyl red
    - C. methyl red and bromothymol blue
    - D. phenolphthalein and indigo carmine
  4. A property of acids is that they react with metals. If you placed a cut lemon and a raw egg on two spots on bare metal, which of the following would you observe?
    - A. Only the egg would react.
    - B. Only the lemon would react.
    - C. Both the lemon and the egg would react.
    - D. Neither the lemon nor the egg would react.
  5. What kind of substance feels slippery, turns red litmus blue, and has a pH > 7?
    - A. a base, such as NaOH
    - B. an acid, such as HCl
    - C. a salt, such as MgCl<sub>2</sub>
    - D. a neutral substance, such as HNO<sub>3</sub>
  6. A solution has a pH of 11. Acid is added until pH = 5. Which indicator would be a good choice to know when the solution has reached pH = 5?
    - A. methyl red
    - B. methyl orange
    - C. phenolphthalein
    - D. indigo carmine
  7. A substance used in producing plastic is HCl. It is a(n) \_\_\_ **and** is named \_\_\_.
    - A. salt, hydrogen chlorite
    - B. acid, hydrogen chlorate
    - C. base, hydrogen chloride
    - D. acid, hydrogen chloride



8. Which of the following is the correct formula for sulfuric acid?

- A.  $\text{H}_2\text{S}$
- B.  $\text{HSO}_4$
- C.  $\text{H}_2\text{SO}_3$
- D.  $\text{H}_2\text{SO}_4$

9. Perchloric acid is used in manufacturing explosives and speeding up chemical reactions. What is the formula for perchloric acid?

- A. HF
- B. HBr
- C.  $\text{HClO}_4$
- D.  $\text{H}_2\text{Pe}_3$

10. A sample of bleach was tested with bromothymol blue to determine its pH.

What colour will it be, **and** what does the colour tell you about the pH of bleach?

- A. blue,  $\text{pH} > 7$
- B. blue,  $\text{pH} = 12$
- C. yellow,  $\text{pH} < 7$
- D. yellow,  $\text{pH} = 12$

## 5.2 Salts

### I. Summary of Key Points

- Salts are a class of compounds including ionic compounds that can be produced when an acid and a base react.
- Oxides and carbonates can chemically react with acids and produce salts.
- Salts can also be produced by the chemical reaction of a metal and an acid.
- Metal oxides combine with water to form bases.
- Non-metal oxides combine with water to form acids.

### II. Study Notes

#### Salts

1. **Salts** are ionic compounds formed when acids and bases react.
2. Salts are also produced when oxides or carbonates react with acids, or when metals react with acids.
3. A salt is made up of a positive ion from a base and negative ion from an acid.

#### Acid-Base Neutralization and Metal Oxides and Non-Metal Oxides

1. Neutralization reactions occur when an acid and a base react to produce a salt and water.  
Example:  $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{s}) + \text{H}_2\text{O}(\ell)$   
*acid base salt water*
2. A **metal oxide** is a chemical compound that contains a metal chemically combined with oxygen.
  - Metal oxides react with water to form bases.  
Example:  $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\ell) \rightarrow 2\text{NaOH}(\text{aq})$
3. A **non-metal oxide** is a chemical compound that contains a non-metal chemically combined with oxygen.
  - Non-metal oxides react with water to form acids.  
Example:  $\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\ell) \rightarrow \text{H}_2\text{SO}_3(\text{aq})$
  - Non-metal oxides are formed from the burning of fossil fuels.
  - Non-metal oxides dissolve in rainwater to produce acid precipitation.

#### Quick Check

1. Identify each of the following as an acid, a base, a salt, a metal oxide, or a non-metal oxide.
  - (a)  $\text{Ba}(\text{OH})_2$  \_\_\_\_\_
  - (b)  $\text{H}_2\text{SO}_4$  \_\_\_\_\_
  - (c)  $\text{NaCl}$  \_\_\_\_\_
  - (d)  $\text{K}_2\text{O}$  \_\_\_\_\_
  - (e)  $\text{SO}_2$  \_\_\_\_\_
2. Which kinds of oxides react with water to form acid precipitation? \_\_\_\_\_
3. Complete and balance the following neutralization reactions.
  - (a) \_\_\_\_\_  $\text{HF} +$  \_\_\_\_\_  $\text{KOH} \rightarrow$  \_\_\_\_\_
  - (b) \_\_\_\_\_  $\text{H}_2\text{SO}_4 +$  \_\_\_\_\_  $\text{NaOH} \rightarrow$  \_\_\_\_\_
  - (c) \_\_\_\_\_  $\text{HNO}_3 +$  \_\_\_\_\_  $\text{Mg}(\text{OH})_2 \rightarrow$  \_\_\_\_\_

## Acids and Metals

- The most reactive metals, at the bottom of groups 1 and 2 in the periodic table, react vigorously with water and acids (Figure 5.1).
  - All other metals are less reactive than those in groups 1 and 2.

1 H	
3 Li	4 Be
11 Na	12 Mg
19 K	20 Ca
37 Rb	38 Sr
55 Cs	56 Ba
87 Fr	88 Ra

alkali metals                      alkaline earth metals

FIGURE 5.1 Alkali metals and alkaline earth metals are the most reactive metals.

- When metals react with acids,  $H_2$  gas is usually released.  
Example:  $2 HCl(aq) + Mg(s) \rightarrow MgCl_2(s) + H_2(g)$

## Acids and Carbonates

- Carbonates ( $CO_3$ ) neutralize acids.  
 $H_2SO_4(aq) + CaCO_3(s) \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$   
*sulfuric acid                  calcium carbonate                  calcium sulfate                  water                  carbon dioxide*
  - Calcium carbonate is added to some lakes to help neutralize acid from acid precipitation.

## Quick Check

- Complete and balance the following reactions between an acid and a metal.
  - \_\_\_\_\_ HF + \_\_\_\_\_ Zn  $\rightarrow$  \_\_\_\_\_
  - \_\_\_\_\_  $H_2SO_3$  + \_\_\_\_\_ Mg  $\rightarrow$  \_\_\_\_\_
  - \_\_\_\_\_ HCl + \_\_\_\_\_ Al  $\rightarrow$  \_\_\_\_\_
- Why is calcium carbonate sometimes added to lake water? \_\_\_\_\_  
\_\_\_\_\_

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>Which of the following is a salt?</p> <p>A. <math>\text{CaCl}_2</math></p> <p>B. <math>\text{SCl}_2</math></p> <p>C. <math>\text{Ca}(\text{OH})_2</math></p> <p>D. <math>\text{HCl}</math></p>	<p>A. This answer is correct. Salts contain a positive ion and a negative ion. The positive ion in <math>\text{CaCl}_2</math> is from the base <math>\text{Ca}(\text{OH})_2</math>. The negative ion is from the acid <math>\text{HCl}</math>.</p> <p>B. Salts are ionic. This compound is covalent. Therefore, it is not a salt.</p> <p>C. The presence of <math>\text{OH}</math> indicates that this is a base.</p> <p>D. The presence of <math>\text{H}</math> indicates that this is an acid.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can distinguish among acids, bases, salts, and other compounds.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 234 to 239 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li> </ul>	

The Question	Why It Is Right/Why It Is Wrong
<p><b>Consider the following reaction.</b></p> <p><math>\text{CaO} + \text{H}_2\text{O} \rightarrow \underline{\hspace{2cm}}</math></p> <p>Determine the formula of the product(s) <b>and</b> identify the product(s) as acid, base, or neutral compound.</p> <p>A. <math>\text{Ca}(\text{OH})_2</math>, an acid</p> <p>B. <math>\text{Ca}(\text{OH})_2</math>, a base</p> <p>C. <math>\text{CaO} + \text{H}_2</math>, neutral compounds</p> <p>D. <math>\text{Ca} + \text{H}_2\text{O}_2</math>, neutral compounds</p>	<p>A. <math>\text{Ca}(\text{OH})_2</math> is correct, but it is not an acid.</p> <p>B. This answer is correct. <math>\text{CaO}</math> is a metal oxide, which forms the base <math>\text{Ca}(\text{OH})_2</math> when it reacts with water.</p> <p>C. The product should be a base because it is a metal oxide reacting with water.</p> <p>D. The product should be a base because it is a metal oxide reacting with water.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can distinguish between metal and non-metal oxides and can recall that non-metal oxides form acids while metal oxides form bases when they react with water.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 238 and 239 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

### Section 5.2

#### Compounds are classified in different ways: Salts

Circle the letter of the best answer.

- Which of the following correctly lists, in order, an acid, a base, and a salt?
  - HCl, NaOH, BaCl<sub>2</sub>
  - HNO<sub>3</sub>, CaCl<sub>2</sub>, NaOH
  - NaCl, MgBr<sub>2</sub>, NH<sub>4</sub>OH
  - Ba(OH)<sub>2</sub>, HNO<sub>3</sub>, H<sub>3</sub>PO<sub>4</sub>
- Which reaction is an acid-base neutralization?
  - $\text{HCl} + \text{Ca} \rightarrow \text{CaCl}_2 + \text{H}_2$
  - $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$
  - $\text{HCl} + \text{BaCO}_3 \rightarrow \text{BaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$
  - $\text{HNO}_2 + \text{Ca(OH)}_2 \rightarrow \text{Ca(NO}_3)_2 + \text{H}_2\text{O}$
- Which of the following are produced when Ca + HCl react?
  - CaHCl
  - CaH + Cl<sub>2</sub>
  - CaCl<sub>2</sub> + H
  - CaCl<sub>2</sub> + H<sub>2</sub>
- Which of the following completes the reaction below?  
 $\text{SO}_3(\text{g}) + \text{H}_2\text{O}(\ell) \rightarrow \underline{\hspace{2cm}}$ 
  - H<sub>2</sub>SO<sub>4</sub>(aq)
  - H<sub>2</sub>SO<sub>3</sub>(aq)
  - HSO<sub>4</sub>(aq)
  - HSO<sub>3</sub>(aq)
- Consider the following reaction.  
 $\text{BaO} + \text{H}_2\text{O} \rightarrow \underline{\hspace{2cm}}$   
Determine the formula of the product(s), **and** indicate if the product is an acid, a base, or a neutral compound.
  - Ba(OH)<sub>2</sub>, a base
  - Ba(OH)<sub>2</sub>, an acid
  - BaO + H<sub>2</sub>, neutral compounds
  - Ba + H<sub>2</sub>O<sub>2</sub>, neutral compounds
- Which basic compound could be added to lakes to help deal with acid precipitation?
  - NaCl
  - NaOH
  - CaCO<sub>3</sub>
  - HCl
- Which of the following groups contains only salts?
  - NaCl, HBr
  - NH<sub>4</sub>OH, LiOH
  - NaCl, Ca(NO<sub>3</sub>)<sub>2</sub>
  - NaCl, Ca(NO<sub>3</sub>)<sub>2</sub>, NH<sub>4</sub>OH, LiOH, HBr
- Which of the following is a balanced equation for the reaction between an acid and a carbonate?
  - $2\text{CH}_3\text{COOH} + 2\text{NaOH} \rightarrow 2\text{NaCH}_3\text{COO} + \text{H}_2\text{O}$
  - $2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$
  - $2\text{HCl} + \text{Mg} \rightarrow \text{MgCl}_2 + \text{H}_2$
  - $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$
- Identify the products that complete the following reaction.  
 $\text{H}_3\text{PO}_4 + \text{Ba(OH)}_2 \rightarrow \underline{\hspace{2cm}}$ 
  - BaPO<sub>4</sub> + H<sub>2</sub>O
  - Ba<sub>3</sub>P<sub>2</sub> + H<sub>2</sub>O
  - BaH<sub>2</sub>PO<sub>4</sub> + H<sub>2</sub>O
  - Ba<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> + H<sub>2</sub>O
- Which of the following reactions are written correctly?

I.	$\text{HNO}_3 + \text{Ba(OH)}_2 \rightarrow \text{Ba(NO}_3)_2 + \text{H}_2\text{O}$
II.	$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_2$
III.	$\text{Li}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{LiOH}$

  - I and II
  - I and III
  - II and III
  - I, II, and III

## 5.3 Organic Compounds

### I. Summary of Key Points

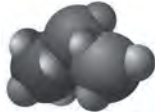
- Organic compounds always contain carbon and almost always contain hydrogen as well.
- Other elements, including metals and non-metals, may also be present.
- Inorganic compounds are all other compounds.
- To recognize a compound as organic, look for an indication of the presence of carbon in its name, chemical formula, or diagram.
- Organic chemistry is the study of compounds that contain carbon.

### II. Study Notes

#### Organic Compounds

1. **Organic** compounds contain carbon and usually contain hydrogen.
  - Organic molecules always have C before H in their formulas.
    - This differentiates organic compounds from acids, which almost always start with H.
  - Carbon has four electrons in its valence shell, which allows for more chemical bonding possibilities than any other element.
2. **Inorganic** compounds are compounds that do not have carbon.
  - Some exceptions to this rule include carbon dioxide and carbon monoxide, which are inorganic compounds even though they contain carbon.
  - Other exceptions to the rule are that carbonates (e.g.,  $\text{CaCO}_3$ ) and carbides (e.g., SiC) are inorganic.
3. Organic compounds can be represented in several different ways as shown in Table 5.2.

TABLE 5.2 Different Ways of Representing Propane

Name	Molecular Formula	Structural Formula	Shortened Structural Formula	Space-Filling Model
propane	$\text{C}_3\text{H}_8$	<pre>  H   H   H             H-C - C - C-H               H   H   H</pre>	$\text{CH}_3\text{CH}_2\text{CH}_3$	

#### Quick Check

1. What element must be present for a compound to be considered organic? \_\_\_\_\_
2. What are three examples of compounds containing carbon that are inorganic?

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## Hydrocarbons

1. A hydrocarbon is an organic compound that contains only carbon and hydrogen.
  - Hydrocarbons are based on a carbon chain, with hydrogen atoms on the sides.
2. The simplest hydrocarbons are methane ( $\text{CH}_4$ ), followed by ethane ( $\text{C}_2\text{H}_6$ ), propane ( $\text{C}_3\text{H}_8$ ), butane ( $\text{C}_4\text{H}_{10}$ ), and pentane ( $\text{C}_5\text{H}_{12}$ ).
3. All hydrocarbons are flammable, and most are liquids at room temperature.

## Alcohols


1. Alcohols are organic compounds with C, H, and O.
2. The simplest alcohols are methanol ( $\text{CH}_3\text{OH}$ ), ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ), and isopropyl alcohol ( $\text{C}_3\text{H}_7\text{OH}$ ).
3. Alcohols are very good solvents (they dissolve other substances), they can be used as fuels and sterilizers, and they are generally very flammable.

## Quick Check

1. The shortened structural formula for pentane, a chemical in gasoline, is  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ .
  - (a) What is pentane's molecular formula? \_\_\_\_\_
  - (b) Draw pentane's structural formula below.

## III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
Which of the following is an organic compound? A. $\text{CaH}_2$ B. $\text{CaCO}_3$ C. $\text{Al}_4\text{C}_3$ D. $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$	A. This compound is inorganic. It does not contain carbon. B. This compound is inorganic. It does contain carbon, but the carbon is in the form of a carbonate. C. This compound is inorganic. It does contain carbon, but the carbon is in the form of a carbide. D. This answer is correct. The presence of C indicates it is organic. Other elements H, N, and O can be present in an organic compound.
→ Why was this question asked?	This question was asked to determine if you distinguish between organic and inorganic compounds.
→ Where can I get extra practice on this type of question?	<ul style="list-style-type: none"><li>• Use pages 244 to 248 in <i>BC Science 10</i>.</li><li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li></ul>

The Question	Why It Is Right/Why It Is Wrong
<p>Consider the following representation of methanol (CH<sub>3</sub>OH).</p>  <p>What type of representation is used in the illustration?</p> <p>A. chemical name</p> <p>B. molecular formula</p> <p>C. shortened structural formula</p> <p>D. space-filling model</p>	<p>A. The chemical name is methanol.</p> <p>B. The molecular formula is CH<sub>4</sub>O.</p> <p>C. The shortened structural formula is CH<sub>3</sub>OH.</p> <p>D. This answer is correct.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you distinguish between different ways of representing organic compounds.</p> <p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 244 to 248 in BC Science 10.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	



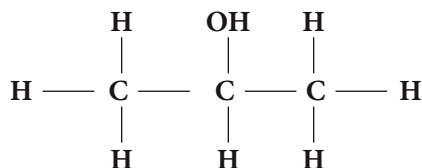
## IV. Practice Questions

### Section 5.3

#### Compounds are classified in different ways: Organic Compounds

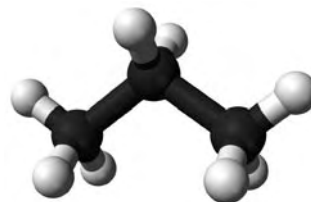
Circle the letter of the best answer.

- Which of the following is **not** an organic compound?
  - CH<sub>4</sub>
  - CO<sub>2</sub>
  - C<sub>6</sub>H<sub>5</sub>COOH
  - K<sub>2</sub>HC<sub>6</sub>H<sub>5</sub>O<sub>7</sub>
- Which of the following best describes organic compounds?
  - almost all compounds that contain carbon
  - compounds made exclusively by living things
  - compounds made of mostly carbon and oxygen, such as oxides and carbonates
  - any compound that does not include carbon, except compounds such as CO<sub>2</sub>, CO, and compounds like Li<sub>2</sub>CO<sub>3</sub>
- What is a hydrocarbon?
  - another name for the acid H<sub>2</sub>CO<sub>3</sub>
  - another name for an organic alcohol
  - one of the products of an acid-base neutralization
  - an organic compound that is made of only carbon and hydrogen
- Which of the following is an inorganic compound?
  - C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>
  - NO<sub>2</sub>
  - CH<sub>3</sub>CH<sub>2</sub>COOH
  - C<sub>4</sub>H<sub>10</sub>
- Consider the following representation of 2-propanol, a kind of rubbing alcohol. What kind of representation is used in the diagram?



- chemical name
- molecular formula
- structural formula
- space-filling model

- Which of the following is an organic compound?
  - CaH<sub>3</sub>
  - H<sub>2</sub>CO<sub>3</sub>
  - C<sub>3</sub>H<sub>8</sub>O
  - Ca<sub>2</sub>CO<sub>3</sub>
- CH<sub>3</sub>(CH<sub>2</sub>)<sub>5</sub>CH<sub>3</sub> is an example of what type of compound?
  - an acid
  - a salt
  - a base
  - an organic compound
- In the following diagram of propane, light-coloured spheres represent hydrogen atoms and dark-coloured spheres represent carbon atoms. What is the chemical formula of propane?



- C<sub>8</sub>H<sub>3</sub>
  - 8C<sub>3</sub>H
  - C<sub>3</sub>H<sub>8</sub>
  - 3C<sub>8</sub>H
- Ethanol (CH<sub>3</sub>CH<sub>2</sub>OH) is used in alcoholic beverages and also as a fuel. What kind of compound is ethanol?
    - inorganic
    - organic
    - ionic
    - multivalent
  - Which of the following is **not** an inorganic compound?
    - methane
    - carbon dioxide
    - barium carbonate
    - ammonium chloride

## Chapter 6 Chemical reactions occur in predictable ways.

### 6.1 Types of Chemical Reactions

#### I. Summary of Key Points

- Chemical reactions can be classified as one of six main types: synthesis, decomposition, single replacement, double replacement, neutralization (acid-base), and combustion.
- You can identify each type of reaction by examining the reactants.
- This makes it possible to classify a reaction and then predict the identity of the products.

#### II. Study Notes

##### Synthesis Reactions

1. **Synthesis** (combination) is a type of chemical reaction in which two or more elements or compounds combine to form a single compound.
  - $A + B \rightarrow AB$  where A and B represent elements
  - The elements may form ionic compounds.  
Example: Sodium metal and chlorine gas combine to form sodium chloride.  
 $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$   
Example: Magnesium metal reacts with oxygen gas to form magnesium oxide.  
 $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
  - The elements may form covalent compounds.  
Example: Nitrogen gas and oxygen gas join to form dinitrogen monoxide.  
 $2\text{N}_2 + \text{O}_2 \rightarrow 2\text{N}_2\text{O}$

##### Quick Check

1. Complete and balance the following synthesis reactions. Remember to consider the chemical formulas of the products carefully before you begin to balance.
  - (a)  $\text{Al} + \text{F}_2 \rightarrow$  \_\_\_\_\_
  - (b)  $\text{K} + \text{O}_2 \rightarrow$  \_\_\_\_\_
  - (c)  $\text{Cd} + \text{I}_2 \rightarrow$  \_\_\_\_\_
2. Identify whether each of the following chemical equations is a synthesis reaction.
  - (a)  $2\text{Fe} + 3\text{CuCl}_2 \rightarrow 2\text{FeCl}_3 + 3\text{Cu}$  \_\_\_\_\_
  - (b)  $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$  \_\_\_\_\_
  - (c)  $2\text{Ni} + 3\text{Cl}_2 \rightarrow 2\text{NiCl}_3$  \_\_\_\_\_

## Decomposition

1. **Decomposition** is a type of chemical reaction in which a compound is broken down into two or more elements or simpler compounds.
  - $AB \rightarrow A + B$  where A and B represent elements
2. Ionic compounds may decompose to produce elements.  
Example: Sodium chloride (table salt) can be broken down into sodium metal and chlorine gas by melting salt at 800°C and running electricity through it.  
 $2\text{NaCl} \rightarrow 2\text{Na} + \text{Cl}_2$
3. Covalent compounds may decompose into elements.  
Example: By running electricity through water, the water molecules decompose into hydrogen and oxygen gases.  
 $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$

## Quick Check

1. Complete and balance the following decomposition reactions. Remember to check for diatomic elements as you write the formulas of the products.
  - (a)  $\text{Na}_2\text{O} \rightarrow$  \_\_\_\_\_
  - (b)  $\text{Mg}_3\text{N}_2 \rightarrow$  \_\_\_\_\_
  - (c)  $\text{CsI} \rightarrow$  \_\_\_\_\_
2. Identify each reaction as synthesis, decomposition, or neither.
  - (a)  $2\text{AgCl} + \text{Cu} \rightarrow \text{CuCl}_2 + 2\text{Ag}$  \_\_\_\_\_
  - (b)  $2\text{Cr} + 3\text{F}_2 \rightarrow 2\text{CrF}_3$  \_\_\_\_\_
  - (c)  $2\text{NaCl} \rightarrow 2\text{Na} + \text{Cl}_2$  \_\_\_\_\_

## Single Replacement

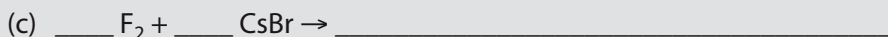
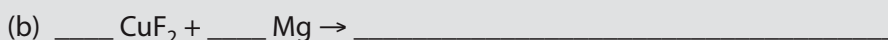
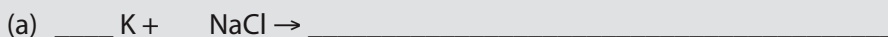
1. **Single replacement** is a type of chemical reaction in which one element replaces another element in a compound.
  - $A + BC \rightarrow B + AC$  where A is a metal, or
  - $A + BC \rightarrow C + BA$  where A is a non-metal
2. Example of when A is a metal:
  - Aluminum foil in a solution of copper II chloride produces solid copper and aluminum chloride.  
 $2\text{Al} + 3\text{CuCl}_2 \rightarrow 3\text{Cu} + 2\text{AlCl}_3$
3. Example of when A is a non-metal:
  - When fluorine is bubbled through a sodium iodide solution, iodine and sodium fluoride are produced.  
 $\text{F}_2 + 2\text{NaI} \rightarrow \text{I}_2 + 2\text{NaF}$

## Double Replacement

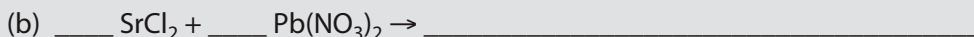
1. **Double replacement** is a type of chemical reaction in which elements in different compounds exchange places.
  - $AB + CD \rightarrow AD + CB$   
Example: When potassium chromate and silver nitrate react, they form silver chromate in a solution of potassium nitrate.  
 $\text{K}_2\text{CrO}_4 + 2\text{AgNO}_3 \rightarrow \text{Ag}_2\text{CrO}_4 + 2\text{KNO}_3$

## Quick Check

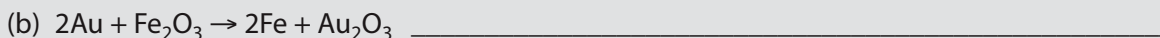
1. Complete and balance the following single replacement reactions.



2. Complete and balance the following double replacement reactions.



3. Classify each reaction as synthesis, decomposition, single replacement, or double replacement.



## Neutralization (acid-base)

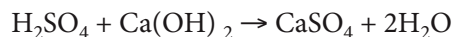
1. **Neutralization (acid-base)** is a type of chemical reaction in which an acid (most compounds starting with H) and a base (most compounds ending in OH, or beginning with  $\text{NH}_4$ ) combine to produce a salt and water.

- Acid + base  $\rightarrow$  salt + water

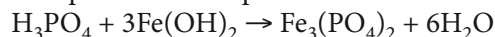


Examples:

- Sulfuric acid is used to neutralize calcium hydroxide.



- Phosphoric acid helps to neutralize the compounds that cause rust, such as iron (II) hydroxide.



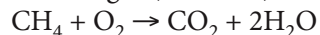
## Combustion

1. **Combustion** is a type of chemical reaction in which oxygen is one of the reactants and where heat is produced.

- $\text{C}_x\text{H}_y + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$  where X and Y represent integers

Examples:

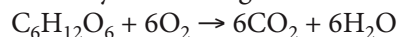
- Natural gas (methane) is burned in furnaces to heat homes.



- An acetylene torch is used to weld metals.



- Carbohydrates like glucose combine with oxygen in our body to release energy.

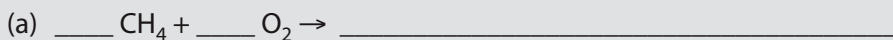


## Quick Check

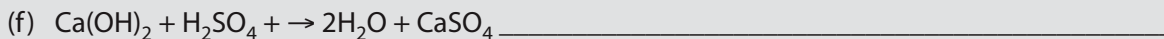
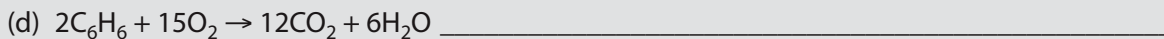
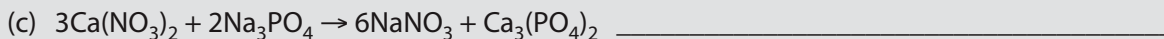
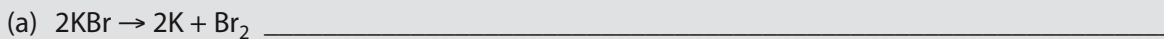
1. Complete and balance the following neutralization (acid-base) reactions.



2. Complete and balance the following combustion reactions.



3. Classify each reaction as synthesis, decomposition, single replacement, double replacement, neutralization, or combustion.



### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>Which of the following reactions is double replacement?</p> <p>A. <math>\text{Pb} + 2\text{CuCl}_2 \rightarrow \text{PbCl}_2 + 2\text{Cu}</math></p> <p>B. <math>\text{Na}_2\text{CO}_3 + \text{CaBr}_2 \rightarrow \text{CaCO}_3 + 2\text{NaBr}</math></p> <p>C. <math>\text{MgCO}_3 + 2\text{HBr} \rightarrow \text{MgBr}_2 + \text{CO}_2 + \text{H}_2\text{O}</math></p> <p>D. <math>\text{Mg}(\text{OH})_2 + 2\text{HBr} \rightarrow \text{MgBr}_2 + 2\text{H}_2\text{O}</math></p>	<p>A. An element reacting with a compound is single replacement. <math>\text{A} + \text{BC} \rightarrow \text{AC} + \text{B}</math></p> <p>B. This answer is correct. Two compounds trade ions. <math>\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}</math></p> <p>C. This does not fit any of the 6 types studied.</p> <p>D. A base and an acid react to make a salt and water. <math>\text{MOH} + \text{HX} \rightarrow \text{MX} + \text{H}_2\text{O}</math></p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can distinguish among the six types of reactions: synthesis, decomposition, single replacement, double replacement, neutralization, and combustion.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 256 and 257 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li> </ul>	

The Question	Why It Is Right/Why It Is Wrong
<p><b>Consider the following balanced equation.</b></p> <p><math>\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}</math></p> <p>What type of reaction is this?</p> <p>A. single replacement</p> <p>B. combustion</p> <p>C. decomposition</p> <p>D. double replacement</p>	<p>A. Although the reaction involves a compound and an element, this is not single replacement. When an organic compound reacts with oxygen (<math>\text{O}_2</math>), it is called combustion.</p> <p>B. This answer is correct. An organic compound is reacting with oxygen (<math>\text{O}_2</math>).</p> <p>C. Decomposition has only one reactant.</p> <p>D. Both reactants in double replacement are compounds.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can distinguish among the six types of reactions: synthesis, decomposition, single replacement, double replacement, neutralization, and combustion.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 256 and 257 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

### Section 6.1

#### Chemical reactions occur in predictable ways: Types of Chemical Reactions

Circle the letter of the best answer.

- What type of reaction is the following?  
$$2\text{Al} + 3\text{CuCl}_2 \rightarrow 2\text{AlCl}_3 + 3\text{Cu}$$
  - synthesis
  - neutralization
  - single replacement
  - double replacement
- Which equation shows a double replacement reaction?
  - $2\text{Mg} + \text{O}_2 \rightarrow \text{MgO}$
  - $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$
  - $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
  - $\text{Na}_2\text{CO}_3 + \text{CaCl}_2 \rightarrow \text{CaCO}_3 + 2\text{NaCl}$
- KCl reacts with  $\text{Pb}(\text{NO}_3)_2$ . What type of reaction is this?
  - combustion
  - neutralization
  - single replacement
  - double replacement
- Solid magnesium reacts with nitric acid to produce hydrogen gas and another product. What is the other product that would be formed in this reaction?  
$$\text{Mg} + 2\text{HNO}_3 \rightarrow \text{___} + \text{H}_2$$
  - $\text{Mg}(\text{NO}_3)_2$
  - $\text{Mg}_3\text{N}_2$
  - MgO
  - $\text{O}_2$
- Which of the following balanced equations represents a synthesis reaction?
  - $2\text{LiF} \rightarrow 2\text{Li} + \text{F}_2$
  - $\text{Ca} + \text{Br}_2 \rightarrow \text{CaBr}_2$
  - $\text{Ba} + \text{CuSO}_4 \rightarrow \text{BaSO}_4 + \text{Cu}$
  - $\text{KOH} + \text{HNO}_3 \rightarrow \text{KNO}_3 + \text{H}_2\text{O}$
- For a neutralization reaction to occur, which of the following should be added to react with NaOH?  
$$\text{NaOH} + \text{___}$$
  - $\text{F}_2$
  - Ca
  - HCl
  - $\text{Mg}(\text{NO}_3)_2$
- What is the missing reactant in this synthesis reaction, **and** what are the coefficients needed to balance this equation?  
$$\text{Na} + \text{___} \rightarrow \text{NaF}$$
  - $\text{Na} + \text{F} \rightarrow \text{NaF}$
  - $\text{Na} + \text{F}_2 \rightarrow \text{NaF}_2$
  - $\text{Na} + \text{F}_2 \rightarrow 2\text{NaF}$
  - $2\text{Na} + \text{F}_2 \rightarrow 2\text{NaF}$
- If  $\text{Na}_2\text{O}$  undergoes decomposition, what will the products be?
  - $\text{Na} + \text{O}$
  - $\text{Na} + \text{O}_2$
  - $\text{Na}_2 + \text{O}$
  - $\text{Na}_2 + \text{O}_2$
- If aluminum bromide decomposes, which of the following is the correct balanced formula equation for the reaction?
  - $\text{AlBr}_3 \rightarrow \text{Al} + \text{Br}$
  - $\text{AlBr}_3 \rightarrow \text{Al} + 3\text{Br}_2$
  - $2\text{AlBr}_3 \rightarrow 2\text{Al} + \text{Br}_2$
  - $2\text{AlBr}_3 \rightarrow 2\text{Al} + 3\text{Br}_2$
- Which of the following balanced equations correctly represents the combustion of butene,  $\text{C}_4\text{H}_8$ ?
  - $\text{C}_4\text{H}_8 + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O}$
  - $\text{C}_4\text{H}_8 + \text{O}_2 \rightarrow 8\text{CO}_2 + 8\text{H}_2\text{O}$
  - $\text{C}_4\text{H}_8 + \text{O}_2 \rightarrow 4\text{CO}_2 + \text{H}_2\text{O}$
  - $\text{C}_4\text{H}_8 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

## 6.2 Factors Affecting the Rate of Chemical Reactions

### I. Summary of Key Points

- Understanding the factors that affect reaction rates helps chemists speed up or slow down chemical reactions.
- Four main factors affect the rate of chemical reactions: temperature (hotter is faster), surface area (the more surface contact between reactants, the faster the reaction), concentration (the greater the concentration, the faster the reaction rate), and the presence of a catalyst (the catalyst helps the reaction go more quickly but is still present in the same amount at the end of the reaction).

### II. Study Notes

#### Temperature

1. In a chemical reaction, how quickly or how slowly reactants turn into products is called rate of reaction.
2. The rate of reaction changes with the temperature.
  - Temperature is a measure of the average energy of molecules.
3. The more energy molecules have, the higher the temperature.
  - When molecules have more energy, they react faster.
  - Higher temperature = faster reaction rate  
Example: We cook food to speed up the chemical reactions.
  - Lower temperature = slower reaction rate  
Example: We refrigerate food to slow down the chemical reactions.

#### Concentration

1. **Concentration** is the amount of solute present in a specific volume of a solution.
  - Concentration is measured in mass per unit volume (g/L).
2. Usually, the higher the concentration of reactants, the faster the reaction occurs.
  - Since there are more molecules per unit volume in high concentrations, there are more opportunities for molecules to collide and react.
  - A splint of wood glows brighter in highly concentrated oxygen than in normal air with a lower concentration of oxygen.

#### Quick Check

1. What happens to the rate of a chemical reaction when the temperature is raised?

\_\_\_\_\_

2. What does cooling do to the frequency at which particles of reactants can collide?

\_\_\_\_\_

3. How does increasing the concentration of an acid result in an increase in reaction rate between the acid and a piece of aluminum metal placed in it? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

4. Why does blowing on a campfire speed the burning process? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



## Surface Area

1. **Surface area** is the extent of a two-dimensional surface enclosed within a boundary. In other words, surface area is the measure of how much area of an object is exposed.
2. Increasing surface area increases the rate of reaction.
  - The more atoms and molecules there are to collide, the higher the reaction rate.
3. Surface area can be increased by creating smaller pieces.
  - A powdered substance has far more surface area than one large chunk.

## Catalysts

1. A **catalyst** is a substance that speeds up a chemical reaction without being changed itself.
  - Catalysts often lower the amount of energy necessary to break the bonds in the reactants.
2. Enzymes are an example of biological catalysts.
  - Saliva has enzymes that help speed up the breakdown of starches in the mouth.
3. A catalytic converter is a device installed in all cars to decrease pollution.
  - Car exhaust passes through the catalytic converter before leaving the car.
  - Catalysts found in the honeycomb-shaped filters in the converter help to change many of the pollutants into less harmful substances.  
Examples: Poisonous carbon monoxide is changed into CO<sub>2</sub>, hydrocarbons are converted into CO<sub>2</sub>, and H<sub>2</sub>O, and nitrogen oxides are changed into N<sub>2</sub> and O<sub>2</sub>.  
$$2\text{N}_2\text{O}_3 \rightarrow 2\text{N}_2 + 3\text{O}_2$$

## Quick Check

1. How does increasing the surface area of a reactant increase reaction rate? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
2. Why does cutting wood into tiny pieces for a campfire speed the burning process? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
3. What happens to the rate of a reaction when a catalyst is added?  
\_\_\_\_\_
4. What is the purpose of a catalytic converter in a car?  
\_\_\_\_\_
5. What is an enzyme? \_\_\_\_\_

### III. Sample Exam Questions Explained

#### The Question

Suppose a chemist performed an experiment by dissolving equal masses of magnesium carbonate in three separate beakers containing hydrochloric acid.

Trial	Hydrochloric Acid	Magnesium carbonate	Temperature
I	Concentrated	Finely ground	50°C
II	Concentrated	Lump	50°C
III	Dilute	Lump	75°C

The magnesium carbonate dissolved the fastest in Trial III and the slowest in Trial II. List concentration, surface area, and temperature in order of most important to least important in increasing the rate of this reaction.

- A. surface area, temperature, concentration
- B. concentration, surface area, temperature
- C. temperature, surface area, concentration
- D. surface area, concentration, temperature

→ Why was this question asked?

This question was asked to see whether you can determine how temperature, concentration, and surface area affect the rate of a reaction by examining experimental data.

→ Where can I get extra practice on this type of question?

- Use pages 272 to 277 in *BC Science 10*.
- Go to [www.bcscience10.ca](http://www.bcscience10.ca) for extra practice.

#### Why It Is Right/Why It Is Wrong

- A. Surface area is less important than temperature in this case because Trial I (higher surface area/lower temperature) was slower than Trial III (lower surface area/higher temperature).
- B. Concentration is less important than temperature in this case because Trial II (higher concentration/lower temperature) was slower than Trial III (lower concentration/higher temperature).
- C. This answer is correct. Trial III is the fastest (high temperature with lower surface area and lower concentration). This series of trials does not demonstrate which of concentration and surface area is more important in this experiment.
- D. Surface area is less important than temperature in this case because Trial I (higher surface area/lower temperature) was slower than Trial III (lower surface area/higher temperature).

The Question	Why It Is Right/Why It Is Wrong
<p>In order to reduce smog emissions from automobiles, exhaust gases are passed through a unit that contains platinum metal. When exhaust gases make contact with the platinum, the rate at which smog decomposes increases several thousand times. What factor is responsible for the increased rate of smog decomposition?</p> <p>A. temperature</p> <p>B. concentration</p> <p>C. surface area</p> <p>D. catalyst</p>	<p>A. Temperature did not change during the process.</p> <p>B. Concentration of smog particles did not change during the process.</p> <p>C. If the surface area of the platinum were increased, the smog decomposition rate would increase. However, the surface area did not change during the process.</p> <p>D. This answer is correct. Platinum metal causes the rate to decomposition of smog to increase. The platinum itself is not changed.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to see whether you can determine how temperature, concentration, surface area, and catalysts affect the rate of a reaction.</p>	
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 272 to 277 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

### Section 6.2

#### Chemical reactions occur in predictable ways: Factors Affecting the Rate of Chemical Reactions

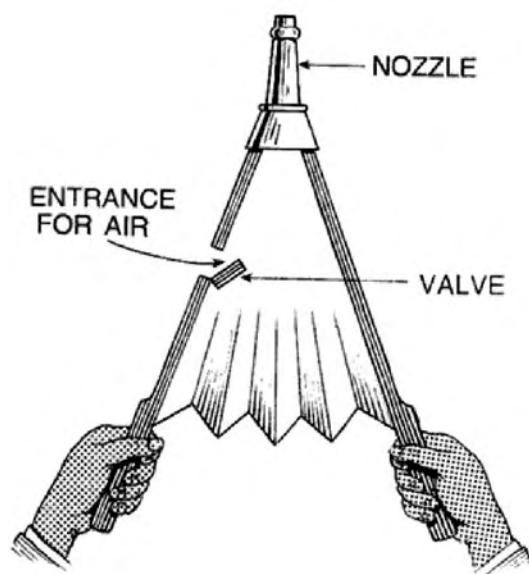
Circle the letter of the best answer.

- When zinc metal is added to hydrochloric acid, it reacts to produce hydrogen gas. Which of the following pairs would react at the greatest rate?
  - a chunk of zinc and dilute HCl
  - a chunk of zinc and concentrated HCl
  - powdered zinc and dilute HCl
  - powdered zinc and concentrated HCl
- Cement is used in many construction projects. When used in building projects, water is sprayed on the surface of the drying cement. This allows the cement to dry evenly both on the surface and in the middle. A strange fact about cement is that, as cement “cures” (what we think of as drying), it undergoes an exothermic reaction. In other words, cement is actually giving off heat energy as it dries, which can speed up drying even more. Which factor affecting the rate of chemical reactions is involved when builders spray water onto drying cement?
  - addition of a catalyst
  - change in temperature
  - change in surface area
  - change in concentration
- Which of the following is an example of decreasing reaction rate?
  - scrambling an egg
  - adding food colouring
  - putting food in a refrigerator
  - cleaning a clogged drain with concentrated vinegar and baking soda
- In order to start a campfire, wood is chopped into many small pieces, called kindling. Which factor makes it easier to light a fire using kindling instead of large pieces of wood?
  - temperature
  - concentration
  - surface area
  - catalyst
- If you have had your gall bladder removed, you may have trouble digesting fats. It is possible in some cases to take an enzyme called lipase, which helps to digest fats.

With respect to rates of reactions, which factor is best illustrated by taking lipase?

  - introducing a catalyst
  - increasing temperature
  - increasing surface area
  - increasing concentration
- Food is digested in your body with the aid of a number of factors that affect the reaction rates. Which of the following affects the rate of food digestion by changing surface area?
  - chewing food
  - a body temperature of 37°C
  - enzymes such as lipase and sucrase
  - the concentration of HCl in the stomach

7. Thinking of factors that affect reaction rate, what first aid treatment should you use when you burn your hand on a hot stove or with hot water?
- Do nothing, as you have already stopped touching the hot object.
  - Cover the burn with moisturizing cream.
  - Cover your burn in butter or margarine.
  - Run your hand under cold water.
8. Blacksmithing is considered to be a fading art. Blacksmiths use heated coal and other materials to work with molten metal to turn the metal into everything from horseshoes to swords and ploughs. Blacksmiths use a tool called a bellows to make the fire hotter. This tool is also often used in homes with fireplaces.



Thinking of factors that affect reaction rate, how do you think the use of bellows affects the temperature of the fire?

- adds a catalyst
- removes carbon dioxide
- increases the surface area of the fire
- increases the concentration of oxygen

9. Why does putting food in a refrigerator slow the spoilage of the food?
- The decreased temperature speeds up the molecules, making the reactions slower.
  - The decreased temperature slows down the molecules making the reactions faster.
  - The decreased temperature slows down the molecules making the reactions slower.
  - Keeping the food in the refrigerator decreases the concentration of oxygen.
10. Which of the following is **not** a factor that affects the rate of reaction?
- changing the temperature
  - changing the colour of the reactants
  - changing the surface area of the reactants
  - changing the concentration of the reactants

## Chapter 7 The atomic theory explains radioactivity.

### 7.1 Atomic Theory, Isotopes, and Radioactive Decay

#### I. Summary of Key Points

- Radiation refers to high-energy rays and particles emitted by radioactive sources.
- Isotopes are atoms of the same element that differ in the number of neutrons in the nucleus.
- Radioisotopes are natural or human-made isotopes that decay into other isotopes, releasing radiation.
- The three major types of radiation are alpha particles, beta particles, and gamma rays.
- A nuclear reaction occurs when radiation is released from the nucleus.
- Radioactivity results when the nucleus of an atom decays.
- If the atom emits one or more protons as it decays, the atom changes into an atom of another element.

#### II. Study Notes

##### Isotopes and Mass Number

1. **Mass number** is the total number of protons and neutrons found in the nucleus of an atom.
  - **Atomic mass** is the average total mass of the protons, neutrons, and electrons that make up an atom.
2. **Isotopes** are atomic nuclei of the same element having the same number of protons but different numbers of neutrons.
  - Isotopes of an element have the same symbol and the same atomic number (number of protons) as each other.
  - Since they have different numbers of neutrons, isotopes have different mass numbers.

##### Representing Isotopes

1. Isotopes are represented using **standard atomic notation** or **isotope notation**, which shows the chemical symbol, the atomic number, and the mass number.
  - The mass number is written above the atomic number.
  - The isotope potassium-39 is written  ${}_{19}^{39}\text{K}$ , which shows that there are a total of 39 protons and neutrons, of which 19 are protons.

##### Radioactive Decay

1. **Radiation** is the high-energy rays and particles emitted by a substance as a result of changes in the nuclei of its atoms.
  - Radioactive atoms emit radiation because their nuclei are unstable. When these nuclei lose energy and break apart, radioactive decay occurs.
  - Radioactive atoms release energy until they become stable, often as different atoms.
  - An element may have only certain isotopes that are radioactive. These are called radioisotopes.
2. **Radioactive decay** is the process in which the nuclei of radioactive parent isotopes emit alpha, beta, or gamma radiation to form decay products.

## Quick Check

1. Complete the following table.

Isotope	Mass Number	Atomic Number (number of protons)	Number of Neutrons
nitrogen-15			
sulfur-30			
neon-22			
		12	13
		4	3
		6	6
	22		12
	19		10

2. An element is analyzed and found to have a mass number of 37. It contains 20 neutrons in its nucleus. State:

- (a) the number of protons \_\_\_\_\_  
(b) the name of the isotope \_\_\_\_\_  
(c) the standard atomic symbol \_\_\_\_\_

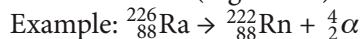
3. For an isotope containing 11 protons and 10 neutrons, state:

- (a) the atomic number \_\_\_\_\_  
(b) the mass number \_\_\_\_\_  
(c) the name of the isotope \_\_\_\_\_  
(d) the standard atomic symbol \_\_\_\_\_

4. What is radioactive decay? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## Alpha Radiation

1. **Alpha radiation**,  $\frac{4}{2}\alpha$  or  $\frac{4}{2}\text{He}$ , is a type of radiation resulting from the emission of helium nuclei from the nuclei of atoms (Figure 7.1).



or

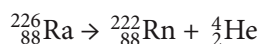
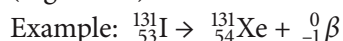


FIGURE 7.1 A radium-226 nucleus undergoes alpha decay to form a different element, radon-222, and an alpha particle.

2. Alpha particles are positively charged with a charge of 2+ because there are two protons.
  - Alpha particles are the most massive of the radiation types.
3. The release of alpha particles is called alpha decay.
4. Alpha particles are slow and penetrate materials much less than the other forms of radiation.
5. A sheet of paper will stop an alpha particle.

## Beta Radiation

1. A **beta particle**,  ${}_{-1}^0\beta$  or  ${}_{-1}^0e$  is a high-speed electron that is emitted by a radioactive nucleus in beta decay (Figure 7.2).



or

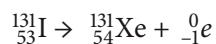


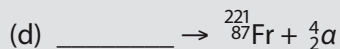
FIGURE 7.2 An iodine-131 nucleus undergoes beta decay to form a different element, xenon-131, and a beta particle.

2. Beta decay occurs when a neutron changes into a proton plus an electron.
  - The proton stays in the nucleus, and the electron is released.
3. Electrons are very tiny, so beta particles are assigned a mass of 0.
4. A beta particle has a charge of 1-.
5. A thin sheet of aluminum foil will stop a beta particle.

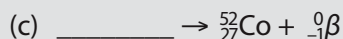
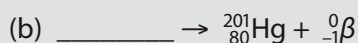
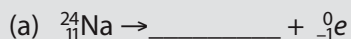


## Quick Check

1. Identify the missing particle in each of these alpha decay equations.



2. Identify the missing particle in each of these beta decay equations.



## Gamma Radiation

1. **Gamma radiation**,  ${}_{0}^0\gamma$ , is a ray of high-energy, short-wavelength radiation, emitted from the nuclei of atoms.



- The \* symbol means that the atom has extra energy.

2. Gamma radiation has no charge and no mass.

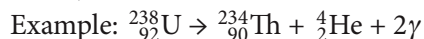
- The release of gamma radiation does not change the atomic number or the mass number of a nucleus.

3. Gamma radiation is the highest-energy form of electromagnetic radiation.

4. It takes thick blocks of lead or concrete to stop gamma rays.

5. Gamma decay results from energy being released from a high-energy nucleus.

- Often, other kinds of radioactive decay will also release gamma radiation.



## Nuclear Equations

1. Nuclear equations are written like chemical equations, with reactants on the left and products on the right, but they represent changes in the nucleus of atoms.

2. The sum of the mass numbers does not change.

3. The sum of the charges in the nucleus does not change.

## Quick Check

1. What is the symbol for a gamma ray in an equation? \_\_\_\_\_
2. Explain the changes that occur in the nucleus during each of the following.
  - (a) alpha decay \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
  - (b) beta decay \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
  - (c) gamma decay \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
3. Classify each of the following as alpha, beta, or gamma decay.
  - (a)  ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\text{He}$  \_\_\_\_\_
  - (b)  ${}_{28}^{60}\text{Ni}^* \rightarrow {}_{28}^{60}\text{Ni} + {}_0^0\gamma$  \_\_\_\_\_
  - (c)  ${}_{11}^{24}\text{Na} \rightarrow {}_{12}^{24}\text{Mg} + {}_{-1}^0e$  \_\_\_\_\_
  - (d)  ${}_{89}^{225}\text{Ac} \rightarrow {}_{87}^{221}\text{Fr} + {}_2^4\alpha$  \_\_\_\_\_
  - (e)  ${}_{91}^{231}\text{Pa}^* \rightarrow {}_{91}^{231}\text{Pa} + {}_0^0\gamma$  \_\_\_\_\_
  - (f)  ${}_{53}^{131}\text{I} \rightarrow {}_{54}^{131}\text{Xe} + {}_{-1}^0\beta$  \_\_\_\_\_

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>The periodic table contains the following information about the element cobalt.</p> <div data-bbox="269 415 548 737" style="border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"> <p style="text-align: center;"> <span style="font-size: 1.2em;">27</span>    <span style="font-size: 1.2em;">2+</span>  <span style="font-size: 1.5em; font-weight: bold;">Co</span>    <span style="font-size: 1.2em;">3+</span>  Cobalt  <span style="font-size: 1.2em;">58.9</span> </p> </div> <p>What can be concluded about the number of subatomic particles in a nucleus of cobalt-57?</p> <p>A. It has 32 protons and 27 neutrons.</p> <p>B. It has 27 protons and 32 neutrons.</p> <p>C. It has 30 protons and 27 neutrons.</p> <p>D. It has 27 protons and 30 neutrons.</p> <p>→ Why was this question asked?</p> <p>This question was asked to see whether you can determine the number of protons, neutrons, the name of the element given in the periodic table, and information about the nucleus of an atom.</p> <p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 286 to 293 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	<p>A. The number 58.9 is not of any use in this problem. The mass number is 57. The atomic number is 27 = number of protons. The number of neutrons is <math>57 - 27 = 30</math>.</p> <p>B. The number 58.9 is not of any use in this problem. The mass number is 57. The atomic number is 27 = number of protons. The number of neutrons is <math>57 - 27 = 30</math>.</p> <p>C. The number 58.9 is not of any use in this problem. The mass number is 57. The atomic number is 27 = number of protons. The number of neutrons is <math>57 - 27 = 30</math>.</p> <p>D. This answer is correct.</p>

The Question	Why It Is Right/Why It Is Wrong		
<p>Consider the following nuclear decay equations.</p>			
<table border="1"> <tr> <td data-bbox="204 302 277 365">I</td> <td data-bbox="277 302 589 365"><math>{}_{80}^{201}\text{Hg} \rightarrow {}_{81}^{201}\text{Tl} + {}_{-1}^0\beta</math></td> </tr> </table>	I	${}_{80}^{201}\text{Hg} \rightarrow {}_{81}^{201}\text{Tl} + {}_{-1}^0\beta$	
I	${}_{80}^{201}\text{Hg} \rightarrow {}_{81}^{201}\text{Tl} + {}_{-1}^0\beta$		
<table border="1"> <tr> <td data-bbox="204 365 277 428">II</td> <td data-bbox="277 365 589 428"><math>{}_{91}^{231}\text{Pa} \rightarrow {}_{89}^{227}\text{Ac} + {}_2^4\text{He}</math></td> </tr> </table>	II	${}_{91}^{231}\text{Pa} \rightarrow {}_{89}^{227}\text{Ac} + {}_2^4\text{He}$	
II	${}_{91}^{231}\text{Pa} \rightarrow {}_{89}^{227}\text{Ac} + {}_2^4\text{He}$		
<table border="1"> <tr> <td data-bbox="204 428 277 491">III</td> <td data-bbox="277 428 589 491"><math>{}_{89}^{225}\text{Ac} \rightarrow {}_{87}^{221}\text{Fr} + {}_2^4\alpha</math></td> </tr> </table>	III	${}_{89}^{225}\text{Ac} \rightarrow {}_{87}^{221}\text{Fr} + {}_2^4\alpha$	
III	${}_{89}^{225}\text{Ac} \rightarrow {}_{87}^{221}\text{Fr} + {}_2^4\alpha$		
<table border="1"> <tr> <td data-bbox="204 491 277 554">IV</td> <td data-bbox="277 491 589 554"><math>{}_{28}^{60}\text{Ni}^* \rightarrow {}_{28}^{60}\text{Ni} + {}_0^0\gamma</math></td> </tr> </table>	IV	${}_{28}^{60}\text{Ni}^* \rightarrow {}_{28}^{60}\text{Ni} + {}_0^0\gamma$	
IV	${}_{28}^{60}\text{Ni}^* \rightarrow {}_{28}^{60}\text{Ni} + {}_0^0\gamma$		
<p>Which equation(s) represent alpha decay?</p> <p>A. I and IV  B. II and III  C. III and IV  D. I and III</p> <p>A. I and IV  B. II and III</p> <p>C. III and IV  D. I and III</p>	<p>A. I is beta and IV is gamma.  B. This answer is correct. Both <math>{}_2^4\text{He}</math> and <math>{}_2^4\alpha</math> represent alpha particles.  C. III is alpha and IV is gamma.  D. I is beta and III is alpha.</p>		
<p>→ Why was this question asked?</p> <p>This question was asked to determine if you can distinguish between alpha, beta, and gamma decay in equations.</p>			
<p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 294 to 298 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>			

## IV. Practice Questions

### Section 7.1

#### The atomic theory explains radioactivity: Atomic Theory, Isotopes, and Radioactive Decay

Circle the letter of the best answer.

- Which of the following shows alpha radioactive decay?
  - ${}^{13}_5\text{B} \rightarrow {}^{13}_6\text{C} + {}^0_{-1}e$
  - ${}^{23}_{11}\text{NaCl} \rightarrow {}^{23}_{11}\text{Na} + {}^{35.5}_{17}\text{Cl}_2$
  - ${}^{60}_{28}\text{Ni}^* \rightarrow {}^{60}_{28}\text{Ni} + {}^0_0\gamma$
  - ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^4_2\text{He}$
- Which of the following shows beta radioactive decay?
  - ${}^{211}_{87}\text{Fr} \rightarrow {}^{207}_{85}\text{At} + {}^4_2\text{He}$
  - ${}^{137}_{55}\text{Cs} \rightarrow {}^{137}_{56}\text{Ba} + {}^0_{-1}e + {}^0_0\gamma$
  - ${}^{60}_{28}\text{Ni}^* \rightarrow {}^{60}_{28}\text{Ni} + {}^0_0\gamma$
  - ${}^1_1\text{H}_2\text{O}_2 \rightarrow {}^1_1\text{H}_2\text{O} + {}^{60}_{28}\text{O}_2$
- Which of the following is an example of gamma radioactive decay?
  - ${}^{42}_{19}\text{K}^* \rightarrow {}^{42}_{19}\text{K} + {}^0_0\gamma$
  - ${}^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + {}^0_{-1}e$
  - ${}^{196}_{79}\text{Au} \rightarrow {}^{192}_{77}\text{Ir} + {}^4_2\alpha$
  - ${}^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^4_2\text{He}$
- What type of decay occurs in the following reaction?
$${}^{24}_{11}\text{Na} \rightarrow {}^{24}_{12}\text{Mg} + {}^0_{-1}e$$
  - alpha
  - beta
  - gamma
  - decomposition
- Which is the correct parent nucleus to give the following products?
$$\text{_____} \rightarrow {}^{227}_{89}\text{Ac} + {}^4_2\text{He}$$
  - ${}^{225}_{85}\text{At}$
  - ${}^{229}_{93}\text{Np}$
  - ${}^{223}_{87}\text{Fr}$
  - ${}^{231}_{91}\text{Pa}$
- How does each of the isotopes of an atom differ?
  - in the number of protons
  - in the number of electrons
  - in the number of neutrons
  - in the number of protons, electrons, and neutrons
- How many protons and neutrons are in the following isotope?
$${}^{37}_{17}\text{Cl}$$
  - 17 protons, 17 neutrons
  - 17 protons, 20 neutrons
  - 17 protons, 37 neutrons
  - 37 protons, 17 neutrons
- If an isotope has 55 protons and 82 neutrons, which of the following correctly represents the isotope?
  - ${}^{55}_{82}\text{Pb}$
  - ${}^{82}_{55}\text{Cs}$
  - ${}^{137}_{55}\text{Cs}$
  - ${}^{137}_{82}\text{Pb}$
- Which of the following correctly completes the following radioactive decay?
$${}^{201}_{80}\text{Hg} \rightarrow {}^{201}_{82}\text{Tl} + \text{_____}$$
  - ${}^0_{-1}e$
  - ${}^0_0\gamma$
  - ${}^1_1\text{H}$
  - ${}^4_2\text{He}$
- Which of the following correctly completes the following radioactive decay?
$${}^{233}_{91}\text{Pa} \rightarrow {}^{229}_{89}\text{Ac} + \text{_____}$$
  - ${}^0_{-1}e$
  - ${}^0_0\gamma$
  - ${}^1_1\text{H}$
  - ${}^4_2\text{He}$

## 7.2 Half-Life

### I. Summary of Key Points

- A half-life can be used to compare the rate of radioactive decay for an isotope.
- The shorter the half-life, the faster the decay rate.
- All radioactive decay rates follow a similar pattern called a decay curve.
- The difference between different isotopes is the length of their half-lives.
- The Common Isotope Pairs Chart identifies the parent isotope (which decays) and the daughter isotope (one of the decay products).
- The chart also shows the half-life of the parent and the dating range the isotope can be used for in radioisotope dating.
- A decay curve can be used to estimate the amount of parent isotope remaining or the amount of daughter isotope produced at any time after the radioactive sample first formed or, in the case of carbon dating, after the organism died.

### II. Study Notes

#### Carbon Dating and The Rate of Radioactive Decay

1. **Half-life** is the amount of time required for half the nuclei in a sample of a radioactive isotope to decay.
  - Strontium-90 has a half-life of 29 years. If you have 10 g of strontium-90 today, there will be 5.0 g remaining in 29 years.
2. The half-life for a radioactive element is a constant rate of decay.
3. Radioactivity provides a method to determine age of objects by measuring relative amounts of remaining radioactive material to stable products formed, such as the ratio of carbon-14 atoms to carbon-12 atoms.

#### Quick Check

Use this information to answer questions 3 and 4:

Suppose a 64 gram sample of a certain isotope has a half-life of 1000 years.

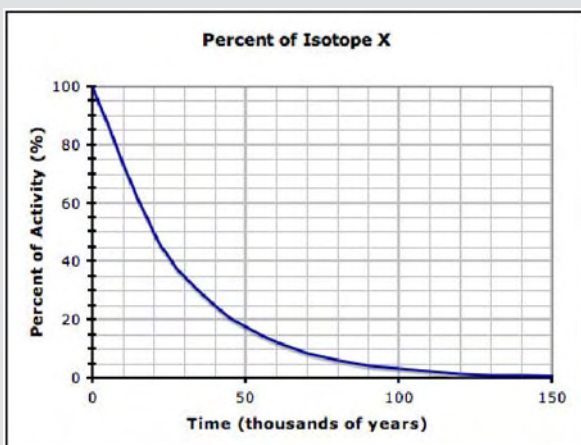
1. What is a half-life? \_\_\_\_\_  
\_\_\_\_\_
2. How does radioactivity provide a method for determining the age of objects? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
3. State what length of time has gone by after:
  - (a) two half-lives \_\_\_\_\_
  - (b) four half-lives \_\_\_\_\_
4. How many grams of the isotope are left after:
  - (a) 1000 years \_\_\_\_\_
  - (b) 2000 years \_\_\_\_\_
  - (c) three half-lives \_\_\_\_\_

## Using a Decay Curve

1. A **decay curve** is a curved line on a graph that shows the rate at which radioisotopes decay.
  - The curve shows the relationship between half-life and the percentage of the original substance that remains.

## Quick Check

1. Use the following decay curve for isotope X.



- (a) Estimate the half-life of isotope X. \_\_\_\_\_
- (b) What percentage of the original isotope remains after 50 000 years? \_\_\_\_\_
- (c) How many years does it take for the isotope to be reduced to about 10 percent of its original quantity? \_\_\_\_\_
- (d) How many half-lives have gone by after 60 000 years? \_\_\_\_\_
- (e) What is the age of volcanic rock containing element X after two half-lives? \_\_\_\_\_

## Common Isotope Pairs

Refer to the Common Isotope Pairs Chart on page 4 of your Data Pages.

1. There are many radioisotopes that can be used for dating.
2. The **parent isotope** is the original, radioactive material.
3. A **decay product** is the product of radioactive decay, which may itself decay to produce another decay product or daughter product.
4. The **daughter product/isotope** is the stable product of the radioactive decay.
  - Example: Carbon-14 (parent) decays into nitrogen-14 (daughter)
  - Example: Uranium-235 (parent) decays into lead-207 (daughter)
5. The rate of decay remains constant, but some elements require one step to decay while others decay over many steps before reaching a stable daughter isotope.

## Quick Check

Refer to the Common Isotope Pairs Chart on page 4 of your Data Pages.

1. Uranium-235 is a radioisotope. What is the daughter in the isotope pair in which uranium is the parent? \_\_\_\_\_
2. What is the half-life of thorium-245? \_\_\_\_\_
3. Which radioisotope decays faster, uranium-238 or rubidium-87? \_\_\_\_\_
4. When a sample of volcanic rock is formed it contains potassium-40 but no argon-40. When the rock is analyzed later, it contains equal amounts of potassium-40 and argon-40. How old is the rock? \_\_\_\_\_

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>Potassium-40 and its daughter isotope argon-40 are used to date a sample of rock. How old is a rock that is found to contain 10 g of potassium-40 and 30 g of argon-40?</p> <p>A. 0.65 billion years old B. 1.3 billion years old C. 2.6 billion years old D. 3.9 billion years old</p>	<p>A. This corresponds to half of a half-life. B. This corresponds to one half-life. C. This answer is correct because the amounts of each isotope indicate that two half-lives have passed. The total mass is 40 g, which started out as potassium-40. After two half-lives the remaining amount is <math>40 \text{ g} \times \frac{1}{2} \times \frac{1}{2} = 10 \text{ g}</math>. This leaves 30 g of daughter isotope. D. This corresponds to three half-lives.</p>
<p>→ Why was this question asked?</p> <p>This question was asked to see whether you can determine the amount of radioisotope left after a given number of half-lives, as well as how much daughter isotope is produced.</p> <p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"><li>• Use pages 302 to 309 in <i>BC Science 10</i>.</li><li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li></ul>	



The Question	Why It Is Right/Why It Is Wrong
<p>A sample of wood from an ancient forest fire is found to contain <math>\frac{1}{8}</math> of the original amount of carbon-14. Estimate the age of the wood.</p> <p>A. 716 years</p> <p>B. 5730 years</p> <p>C. 11 460 years</p> <p>D. 17 190 years</p>	<p>A. This answer corresponds to <math>\frac{1}{8}</math> of a half-life. However, it should correspond to <math>\frac{1}{8}</math> of the original amount of substance, which is three half-lives.</p> <p>B. This answer corresponds to one half-life. However, it should correspond to <math>\frac{1}{8}</math> of the original amount of substance, which is three half-lives.</p> <p>C. This answer corresponds to two half-lives. However, it should correspond to <math>\frac{1}{8}</math> of the original amount of substance, which is three half-lives.</p> <p>D. This answer is correct.  <math>\frac{1}{8}</math> is <math>\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}</math>, which is three half-lives of carbon-14.  Age = <math>3 \times 5730</math> years = 17 190 years</p>
<p>→ Why was this question asked?</p> <p>This question was asked to see whether you can determine the amount of radioisotope left after a given number of half-lives, as well as how much daughter isotope is produced.</p> <p>→ Where can I get extra practice on this type of question?</p> <ul style="list-style-type: none"> <li>• Use pages 302 to 309 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcscience10.ca">www.bcscience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

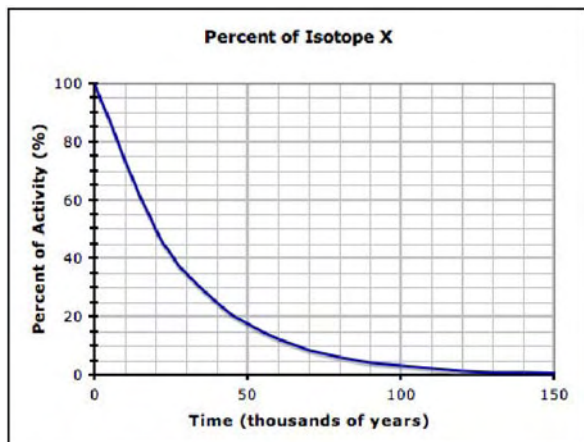
### Section 7.2

#### The atomic theory explains radioactivity: Half-Life

Circle the letter of the best answer. You can use the Common Isotope Pairs chart on page 4 of your Data Pages to help you.

- What is a half-life?
  - the time required for nuclei to undergo nuclear fusion
  - the time required for nuclei to undergo nuclear fission
  - the time required for half the nuclei in a sample to decay
  - the time it takes for an isotope to react with any other substance to produce a new compound
- The carbon-14 isotope has a half-life of 5730 y. What percent of carbon-14 isotope will be present after 17 190 y?
  - 12.5 percent
  - 25 percent
  - 50 percent
  - 100 percent
- A 10 g sample of potassium-40 undergoes radioactive decay until 2.5 g of potassium-40 is present. How many half-lives have occurred?
  - 0
  - 1
  - 2
  - 3
- Suppose a meteorite is analyzed and found to contain equal amounts of uranium-238 and lead-206. How long ago did the meteorite form?
  - 710 million years
  - 1420 million years
  - 4.5 billion years
  - 9 billion years
- What is carbon dating?
  - the exact age of a sample of carbon
  - the process of determining the time required to complete the carbon cycle
  - the process of determining the age of an object by measuring the amount of carbon-14 remaining in that object
  - the process of looking for fossils from specific time periods and determining the age of the carbon sample relative to the fossil
- If a 10 g rock sample of isotope  $^{40}_{19}\text{K}$  undergoes two half-lives to make daughter isotope  $^{40}_{18}\text{Ar}$ , what is the mass of the total sample at the completion of the second half-life?
  - 10 g
  - 5.0 g
  - 2.5 g
  - 1.25 g
- If you start with 100 g of isotope  $^{238}_{92}\text{U}$ , what mass of this parent material will be left after four half-lives?
  - 50 g
  - 25 g
  - 12.5 g
  - 6.25 g
- After three half-lives have passed for carbon-14, a 4.0 g sample remains of the parent isotope. What mass of the parent isotope was originally present?
  - 0.5 g
  - 8.0 g
  - 16 g
  - 32 g

Use the following decay curve to answer question 9.



9. Scientists have discovered a new isotope (X). Using the data they collected, a graph was produced to show the percentage of the isotope remaining over time. Using this information, what is the half-life of this isotope?
- A. 10 000 y
  - B. 20 000 y
  - C. 50 000 y
  - D. 100 000 y
10. A 10 g sample of isotope  $^{14}_6\text{C}$  decays for 17 190 years. Use the Common Isotope Pairs chart on page 4 of your Data Pages to find the half life of this radioactive sample. Determine the total mass of daughter isotope  $^{14}_7\text{N}$  that would be produced.
- A. 8.75 g
  - B. 7.5 g
  - C. 2.5 g
  - D. 1.25 g

## 7.3 Nuclear Reactions

### I. Summary of Key Points

- Fission is a nuclear reaction in which a large nucleus breaks apart, producing two or more smaller nuclei, subatomic particles, and energy.
- Fission is the source of energy for all nuclear power generation used today.
- The daughter products are often radioactive and are a significant waste disposal problem.
- Fusion is a nuclear reaction in which small nuclei combine to produce a larger nucleus.
- Other subatomic particles as well as energy are released in this process.
- Fusion is the source of energy in the Sun.

### II. Study Notes

#### Nuclear Fission

1. **Fission** is the process by which a large nucleus splits into two pieces of roughly equal mass, accompanied by the release of large amounts of energy.
2. Nuclear reactions are different than chemical reactions.
  - In chemical reactions, mass is conserved, energy changes are relatively small.
  - There are no changes to the nuclei in chemical reactions.
3. In nuclear reactions, the nucleus of an atom changes.
  - Protons, neutrons, electrons, and/or gamma rays can be lost or gained.
  - Small changes of mass = huge changes in energy

#### Nuclear Equations for Induced Nuclear Reactions

1. Scientists can induce (force) nuclear reactions by smashing nuclei with alpha, beta, and gamma radiation (Figure 7.3).
2. The rules for writing equations for induced nuclear reactions are:
  - The sum of the mass numbers on each side of the equation stays the same.
  - The sum of the charges (represented by atomic numbers) on each side of the equation stays the same.

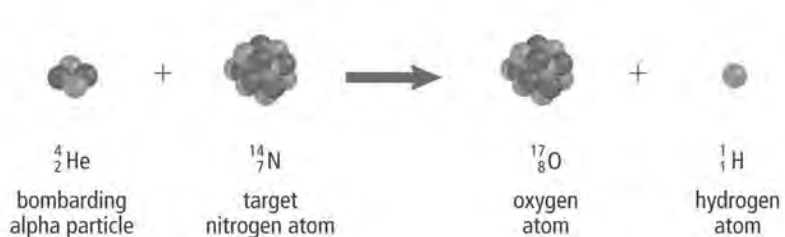


FIGURE 7.3 When a nitrogen-14 nucleus is bombarded by an alpha particle, a fluorine-18 nucleus is produced, which decays into oxygen-17 and a hydrogen atom.

### Quick Check

1. What is a fission nuclear reaction? \_\_\_\_\_  
\_\_\_\_\_
2. What two quantities do not change during a nuclear reaction?  
\_\_\_\_\_

## Nuclear Fission of Uranium-235

1. Most nuclear fission reactors and nuclear weapons use neutrons to smash nuclei (Figure 7.4).

Example:

A neutron,  ${}_0^1n$ , crashes into an atom of stable uranium-235 to create unstable uranium-236, which then undergoes radioactive decay.

After several steps, atoms of krypton and barium are formed, along with the release of three neutrons and huge quantities of energy.

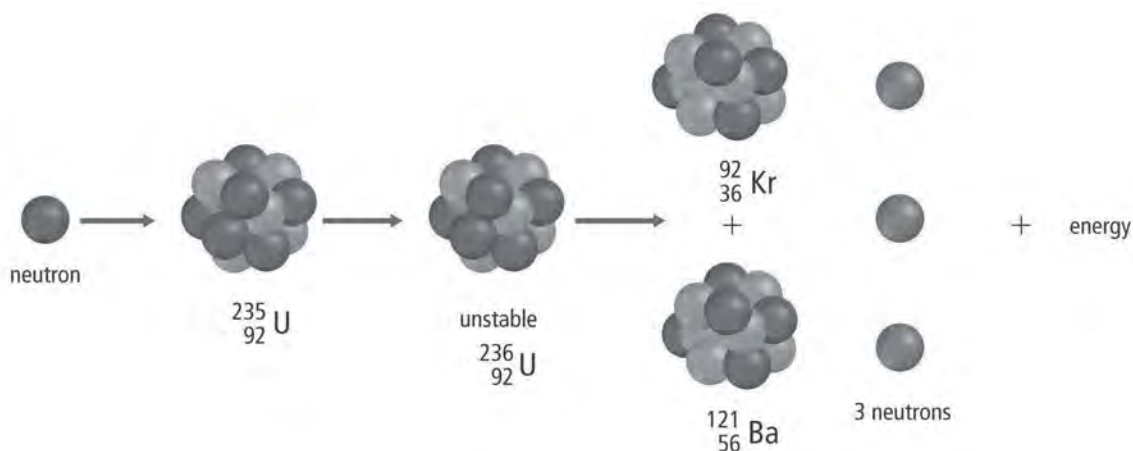
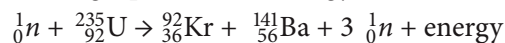


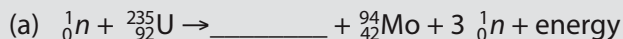
FIGURE 7.4 Nuclear fission of uranium-235

## Chain Reactions

1. Once the nuclear fission reaction has started, it can keep going in a chain reaction.
  - In a chain reaction, each neutron released triggers more reactions on other uranium-235 atoms.
2. Nuclear reactors have complex systems to ensure the chain reaction stays at safe levels.
  - Materials that absorb neutrons, such as cadmium rods, can be inserted into the reactor.
  - An uncontrolled chain reaction can result in a violent nuclear explosion.

## Quick Check

1. Find the indicated daughter nucleus.



2. What happens in a nuclear chain reaction? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## CANDU Reactors and Hazardous Wastes

1. Nuclear power plants can generate large amounts of electricity.
2. Canadian-made nuclear reactors are called CANDU reactors and produce power from fission.
  - CANDU reactors are found in various countries around the world.
  - The reactors are known to be safe and easy to shut down in an emergency.
3. The heat energy produced in a CANDU reactor turns electricity-generating turbines.
4. Hazardous wastes produced by nuclear reactions are problematic.
  - Some waste products, like fuel rods, can be re-used.
  - Some products are very radioactive and must be stored away from living things.
  - Most of this waste is buried underground or stored in concrete.
  - It will take thousands of years before the material reaches safe levels of radioactivity.

## Nuclear Fusion

1. **Fusion** is the joining of two small atomic nuclei to make a larger nucleus, usually involving the release of a large amount of energy.
2. In the core of the Sun, two hydrogen nuclei join under tremendous heat and pressure to form a helium nucleus.
  - When the helium atom is formed, huge amounts of energy are released.
$${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + \text{energy}$$
3. A fusion reaction needs the heat and pressure from a fission nuclear reaction to get it started.
4. Scientists have not yet found a safe, manageable method to harness the energy of nuclear fusion.
  - A fusion reaction is used in nuclear weapons to generate most of the energy in the blast.

## Quick Check

1. Why are hazardous wastes from nuclear reactors an ongoing issue in society? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
2. What is nuclear fusion? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
3. Where does most nuclear fusion occur in our solar system? \_\_\_\_\_

### III. Sample Exam Questions Explained

The Question	Why It Is Right/Why It Is Wrong
<p>Consider the following induced nuclear reaction.</p> ${}_0^1n + {}_{92}^{235}\text{U} \rightarrow \text{---} + {}_{55}^{143}\text{Cs} + 3 {}_0^1n + \text{energy}$ <p>What is the identity of the missing isotope?</p> <p>A. <math>{}_2^4\text{He}</math></p> <p>B. <math>{}_{37}^{90}\text{Sr}</math></p> <p>C. <math>{}_{37}^{92}\text{Sr}</math></p> <p>D. <math>{}_{55}^{143}\text{Cs}</math></p>	<p>A. This fragment is too small.</p> <p>B. This answer is correct. The mass numbers on both sides add up to 236. On the right, <math>90 + 143 + 3 = 236</math>. The atomic numbers on both sides add up to 92. On the right, <math>37 + 55 + 0 = 92</math>.</p> <p>C. The mass number is incorrect.</p> <p>D. Both mass number and atomic number are incorrect.</p>
<p>→ Why was this question asked?</p>	
<p>This question was asked to assess your understanding of nuclear reaction equations.</p>	
<p>→ Where can I get extra practice on this type of question?</p>	
<ul style="list-style-type: none"> <li>• Use pages 312 to 321 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

The Question	Why It Is Right/Why It Is Wrong
<p><math>{}_1^2\text{H} + {}_1^3\text{H} \rightarrow {}_2^4\text{He} + {}_0^1n + \text{energy}</math></p> <p>What does this equation represent?</p> <p>A. a chemical reaction</p> <p>B. a fusion reaction</p> <p>C. a fission reaction</p> <p>D. a decomposition reaction</p>	<p>A. Chemical reactions do not produce new elements.</p> <p>B. This answer is correct. Two small nuclei fuse to form one larger nucleus (as well as a neutron).</p> <p>C. Fission reactions involve a large nucleus splitting into two smaller fragments of nearly equal size.</p> <p>D. This is a nuclear reaction, not a chemical reaction.</p>
<p>→ Why was this question asked?</p>	
<p>This question was asked to assess your understanding of nuclear reaction equations.</p>	
<p>→ Where can I get extra practice on this type of question?</p>	
<ul style="list-style-type: none"> <li>• Use pages 312 to 321 in <i>BC Science 10</i>.</li> <li>• Go to <a href="http://www.bcsience10.ca">www.bcsience10.ca</a> for extra practice.</li> </ul>	

## IV. Practice Questions

### Section 7.3

#### The atomic theory explains radioactivity: Nuclear Reactions

Circle the letter of the best answer.

- What is nuclear fission?
  - the process in which two low mass nuclei join together to make a more massive nucleus
  - the process of cell division that results in two new cells that are identical to their parent cell
  - the splitting of a massive nucleus into two less massive nuclei, subatomic particles, and energy
  - the process in which a parent cell splits into two daughter cells of approximately equal size, often occurring in single celled organisms
- What is nuclear fusion?
  - the process in which two low mass nuclei join together to make a more massive nucleus
  - the process of cell division that results in two new cells that are identical to their parent cell
  - the splitting of a massive nucleus into two less massive nuclei, subatomic particles, and energy
  - the process in which a parent cell splits into two daughter cells of approximately equal size, often occurring in single celled organisms
- Which equation represents nuclear fission?
  - ${}_{19}^{40}\text{K} \rightarrow {}_{20}^{40}\text{Ca} + {}_{-1}^0\text{e} + \text{energy}$
  - $2\text{C}_3\text{H}_7\text{OH} + 9\text{O}_2 \rightarrow 6\text{CO}_2 + 8\text{H}_2\text{O}$
  - ${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + \text{energy}$
  - ${}^1_0\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{92}_{36}\text{Kr} + {}^{141}_{56}\text{Ba} + 3 {}^1_0\text{n} + \text{energy}$
- Which equation represents nuclear fusion?
  - ${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^1_0\beta$
  - ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^4_2\text{He} + 2\gamma$
  - ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + \text{energy}$
  - ${}^1_0\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{114}_{42}\text{Mo} + {}^{119}_{50}\text{Sn} + 3 {}^1_0\text{n} + \text{energy}$
- What is the daughter nucleus to complete the following nuclear fission reaction?
$${}^1_0\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{118}_{43}\text{Tc} + \text{_____} + 3 {}^1_0\text{n} + \text{energy}$$
  - ${}^{114}_{49}\text{In}$
  - ${}^{115}_{49}\text{In}$
  - ${}^{117}_{49}\text{In}$
  - ${}^{118}_{49}\text{In}$
- Which of the following is used to control the rate of the chain reaction that occurs in a nuclear reactor?
  - Add uranium-235 to the reactor.
  - Use fossil fuels (like gas or coal).
  - Insert cadmium rods into the nuclear reactor.
  - Remove cadmium rods from the nuclear reactor.
- Which statement about nuclear fusion is **not** true?
  - Two lightweight nuclei join together to form a heavier nucleus.
  - A typical reaction showing nuclear fusion is:
$${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + \text{energy}$$
  - Lightweight nuclei will not release excess energy if the nucleus generated by fusion is heavier than iron.
  - There are many commercial fusion reactors in the world. Canada has a series of them called CANDU reactors.



8. Which of the following statements applies to nuclear fission?
- A. Nuclear fission produces clean energy with very little waste.
  - B. Unstable nuclei release a huge amount of energy when they split.
  - C. Heavy, unstable nuclei join together into one new, larger nucleus.
  - D. A typical reaction for nuclear fission is:



9. Which of the following statements applies to nuclear fusion?
- A. All fusion reactions release massive amounts of energy.
  - B. Unstable nuclei release a huge amount of energy when they split.
  - C. A typical reaction for nuclear fusion is:
- $${}^1_0n + {}^{235}_{92}\text{U} \rightarrow {}^{92}_{36}\text{Kr} + {}^{131}_{56}\text{Ba} + 3 {}^1_0n + \text{energy}$$
- D. A fusion reaction is used in modern nuclear weapons to generate most of the energy released in the blast.

10. How can a nuclear reaction be induced?
- A. by bombarding a nucleus with alpha particles, beta particles, or gamma rays
  - B. by heating the reaction with your lab Bunsen burner
  - C. by inserting cadmium rods into the nuclear reactor
  - D. by burning the nucleus using oxygen

## Processes of Science Vocabulary Terms

You may encounter the following Processes of Science vocabulary terms on the exam.

- accuracy** the difference between a measurement and its accepted value
- conclusion** the explanation of the results of an experiment as they apply to the hypothesis being tested
- control** a test you carry out with no independent variables so you can observe whether your independent variable in an experiment does indeed cause a change
- controlled experiment** an investigation in which only one variable is changed, and the resulting effect on another variable is observed, while all other variables are held constant
- dependent variable** in an experiment, the factor that changes in response to a change in the independent variable; also called the responding variable
- extrapolation** a prediction that is out of the range of the collected data
- hypothesis** a testable proposal used to explain an observation or to predict the outcome of an experiment; often expressed in the form of an “If ..., then ...” statement
- independent variable** in an experiment, the factor that is selected or adjusted to see what effect the change will have on the dependent variable; also called the manipulated variable
- interpolation** a prediction that is within the range of collected data
- observation** information gathered through one or more senses, including hearing, touch, sight, taste, and smell
- precision** a measure of the detail, such as the number of digits, with which a quantity is expressed
- prediction** a forecast about what you expect to observe when you do an investigation
- principle** a fundamental law, assumption, or fact
- procedure** a specific set of actions which if executed in the same manner under the same circumstances will yield the same results
- scale** ratio between a single unit of distance, such as on a map, model, or drawing, and the corresponding distance in reality
- scientific literacy** an evolving combination of the science-related attitudes, skills, and knowledge necessary to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world
- slope** the direction of a line on a graph, which may be horizontal (zero), slanting up (positive), or slanting down (negative). Slope is calculated by determining the ratio of rise/run.
- uncertainty** a lack of certainty; having limited knowledge to describe a state or outcome, often where more than one outcome is possible
- validity** the degree to which a conclusion is likely to be true
- variable** a factor that can influence the outcome of an experiment
- Venn diagram** a type of graphic organizer that can be used to compare and contrast two or more concepts or objects by using two or more intersecting circles

## Unit 2 Glossary

**acidic** a solution with a pH below 7

**acids** compounds that produce a solution of less than pH 7 when they dissolve in water

**alpha particle** ( $\frac{4}{2}\alpha$ ,  $\frac{4}{2}\text{He}$ ) a positively charged atomic particle that has the same combination of particles as the nucleus of a helium atom

**atom** the smallest particle of an element that has the properties of that element

**atomic mass** the average total mass of the protons, neutrons, and electrons that make up an atom

**atomic number** the number of protons in a nucleus

**bases** compounds that produce a solution of more than 7 when they dissolve in water

**basic** a solution with a pH above 7

**beta particle** ( ${}_{-1}^0\beta$ ,  ${}_{-1}^0e$ ) a high-speed electron that is emitted by a radioactive nucleus in beta decay

**Bohr diagram** a model of an atom that describes the arrangement of an element's subatomic particles with neutrons and protons in the nucleus and electrons in electron shells

**bonding pair** the pair of electrons involved in a covalent bond

**bromothymol blue** a type of acid-base indicator that turns yellow when added to an acid

**catalyst** a substance that speeds up a chemical reaction without being changed itself

**chemical family/group** in the periodic table, columns of elements; all elements in a chemical family or group have similar properties and bond with other elements in similar ways

**combustion** a type of chemical reaction in which oxygen is one of the reactants and where heat is produced

**compound** a pure substance that is made up of two or more different elements that have been combined in a specific way

**concentration** the amount of solute present in a specific volume of a solution

**conservation of mass** the preservation of mass in a chemical reaction; the total mass of the products is always equal to the total mass of the reactants

**covalent bonding** a bond formed through the sharing of one or more pairs of electrons

**daughter product/isotope** the stable product of radioactive decay

**decay curve** a curved line on a graph that shows the rate at which radioisotopes decay

**decay product** the product of radioactive decay, which may itself decay to produce another decay product or daughter product

**decomposition** a type of chemical reaction in which a compound is broken down into two or more elements or simpler compounds

**diatomic element** elements in which pairs of electrons are joined by covalent bonds; examples include hydrogen ( $\text{H}_2$ ), nitrogen ( $\text{N}_2$ ), oxygen ( $\text{O}_2$ ), fluorine ( $\text{F}_2$ ), chlorine ( $\text{Cl}_2$ ), bromine ( $\text{Br}_2$ ), and iodine ( $\text{I}_2$ )

**double replacement** a type of chemical reaction in which elements of different compounds exchange places

**electron** a subatomic particle that has a 1- (negative) electric charge

**fission** the process by which a large nucleus splits into two pieces of roughly equal mass, accompanied by the release of large amounts of energy

**fusion** the joining of two small atomic nuclei to make a larger nucleus, usually involving the release of a large amount of energy

**gamma** ( ${}^0_0\gamma$ ) a ray of high-energy, short-wavelength radiation, emitted from the nuclei of atoms and which has no charge and no mass

**half-life** the amount of time required for half the nuclei in a sample of a radioactive isotope to decay

**hydrocarbon** an organic compound that contains only carbon and hydrogen

**indigo carmine** a pH indicator named after its colour change from blue to yellow over a pH range of 11.2 to 13.0

**inorganic** refers to compounds that generally do not contain carbon; the few exceptions include carbon dioxide, carbon monoxide, and the ionic carbonates

**ionic bonding** a bond formed as the result of the attraction between positively charged ions and negatively charged ions

**ions** electrically charged particles produced when atoms gain or lose electrons

**isotopes** atomic nuclei of the same element having the same number of protons but different numbers of neutrons

**Lewis diagrams** models of the atom that show only the valence electrons

**litmus** a compound extracted from lichens, commonly used as an acid-base indicator called litmus paper

**lone pair** a pair of electrons in the valence shell that is not used in bonding

**mass number** the total number of protons and neutrons found in the nucleus of an atom

**metal oxide** a chemical compound that contains a metal chemically combined with oxygen

**methyl orange** a pH indicator named after its colour change from red to yellow over a pH range of 3.2 to 4.4

**methyl red** a pH indicator named after its colour change from red to yellow over a pH range of 4.8 to 6.0

**molecule** a group of atoms in which the atoms are bound together by sharing one or more pairs of electrons

**neutral** in solutions, a pH of 7; neither acidic nor basic

**neutralization (acid-base)** a type of chemical reaction in which an acid (most compounds beginning with H) and a base (most compounds ending in OH, or beginning with NH<sub>4</sub>) combine to produce a salt and water

**neutron** a subatomic particle that does not have an electric charge

**non-metal oxide** a chemical compound that contains a non-metal chemically combined with oxygen

**organic** refers to almost all carbon-containing compounds; exceptions include carbon dioxide, carbon monoxide, and ionic carbonates

**paired electrons** electrons found in twos

**parent isotope** the original radioactive material that undergoes radioactive decay

**period** in the periodic table, a row of elements

**pH indicators** chemicals that change colour based on the solution they are placed in; also called acid-base indicators

**pH scale** a number scale for measuring how acidic or basic a solution is

**phenolphthalein** a type of acid-base indicator that turns pink when added to a base

**polyatomic** ions that are composed of more than one type of atom joined together by covalent bonds

**proton** a subatomic particle with a 1+ (positive) charge

**radiation** the high-energy rays and particles emitted by a substance as a result of changes in the nuclei of its atoms

**radioactive decay** the process in which the nuclei of radioactive parent isotopes emit alpha, beta, or gamma radiation to form decay products

**salts** ionic compounds formed when acids and bases react

**shell/orbit** regular pattern or energy level around the nucleus

**single replacement** a type of chemical reaction in which one element replaces another element in a compound

**standard atomic notation/isotope notation** a representation of an isotope's chemical symbol, atomic number, and mass number, with the mass number written above the atomic number; for example, the isotope potassium-39 is written  ${}_{19}^{39}\text{K}$

**surface area** the extent of a two-dimensional surface enclosed within a boundary; a measure of how much area of an object is exposed

**symbolic equation** a set of chemical symbols and formulas that identify the reactants and products in a chemical reaction

**synthesis** a type of chemical reaction in which two or more elements or compounds combine to form a single compound

**unpaired electrons** single electrons

**valence electrons** electrons in the outermost shell

## Part C – Unit 2 Answer Key

### Chapter 4

#### Quick Check Answers

page 6

1. An atom is the smallest part of an element that still has the properties of the element. An element is a pure substance that cannot be chemically broken down into simpler substances. A compound is a pure substance that is made up of two or more different elements that have been combined in a specific way.
2. (a) 1+ (positive)  
(b) No electric charge  
(c) 1- (negative)
3. (a) Nucleus  
(b) Nucleus  
(c) Surrounding the nucleus
4. Atomic number is the number of protons in an atom.

page 7

1. A family is a vertical column. A period is a horizontal row.
2. Group 1 is alkali metals, Group 2 is alkaline earth metals, Group 17 is halogens, and Group 18 is noble gases.
3. By losing or gaining electrons
4. Metals lose electrons to form positive ions. Non-metals gain electrons to form negative ions.

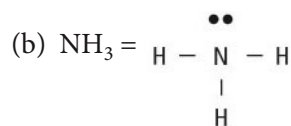
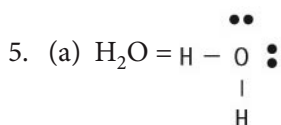
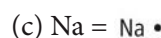
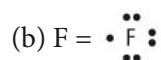
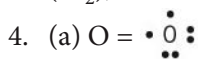
page 8

1. In the outermost shell of an atom
2. 2, 8, 8
3. (a) C 6p 2, 4  
(b) Cl 17p 2, 8, 7  
(c) Al 13p 2, 8, 3
4. (a) F- 9p 2, 8  
(b) Na+ 11p 2, 8  
(c) Al<sup>3+</sup> 13 p 2, 8

page 10

1. An ionic bond is a chemical connection between oppositely charged ions. Metal and non-metals form ionic bonds when they are combined together in a compound.

2. A covalent bond is a chemical connection between two atoms in which a pair of electrons is shared. Non-metals form covalent bonds when they combine chemically with other non-metals.
3. Diatomic elements include hydrogen (H<sub>2</sub>), nitrogen (N<sub>2</sub>), oxygen (O<sub>2</sub>), fluorine (F<sub>2</sub>), chlorine (Cl<sub>2</sub>), bromine (Br<sub>2</sub>), and iodine (I<sub>2</sub>).



page 16

1. (a) lithium phosphide  
(b) calcium chloride  
(c) zinc oxide
2. (a) Na<sub>2</sub>S  
(b) MgI<sub>2</sub>  
(c) Al<sub>2</sub>O<sub>3</sub>

page 17

1. (a) Cu<sub>2</sub>O  
(b) PbI<sub>4</sub>  
(c) PbCl<sub>2</sub>  
(d) Au<sub>2</sub>S<sub>3</sub>
2. (a) chromium(II) phosphide  
(b) manganese(II) chloride  
(c) cobalt(III) oxide  
(d) iron(III) nitride

page 18

1. (a) Cs<sub>2</sub>SO<sub>4</sub>  
(b) Ti(HCO<sub>3</sub>)<sub>4</sub>  
(c) (NH<sub>4</sub>)<sub>2</sub>S  
(d) (NH<sub>4</sub>)<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>
2. (a) sodium perchlorate  
(b) magnesium phosphate  
(c) ammonium sulphite  
(d) copper(II) sulfate

3. (a) 3 K, 1 P, 4 O for a total of 8 atoms
- (b) 2 N, 8 H, 1 S, 4 O for a total of 15 atoms
- (c)  $\text{Ni}_2(\text{CO}_3)_3$ ; 2 Ni, 3 C, 9 O for a total of 14 atoms
- (d)  $\text{Mo}(\text{NO}_3)_2$ ; 1 Mo, 2 N, 6 O for a total of 9 atoms

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1. (a)  $\text{SO}_3$
- (b)  $\text{N}_2\text{O}$
- (c)  $\text{P}_4\text{S}_{10}$
- (d)  $\text{PCl}_5$
2. (a) phosphorus tribromide
- (b) dinitrogen trisulphide
- (c) dinitrogen tetroxide
- (d) oxygen difluoride

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1. (a) Ionic; ammonium phosphide
- (b) Covalent; oxygen dibromide
- (c) Ionic; iron(III) fluoride
- (d) Ionic; tin(IV) sulfide
2. (a)  $\text{PbO}_2$  is ionic: lead(IV) oxide;  $\text{NO}_2$  is covalent: nitrogen dioxide
- (b)  $\text{SO}_2$  is covalent: sulfur dioxide;  $\text{SnO}_2$  is ionic: tin(IV) oxide;  $\text{KClO}_2$  is ionic: potassium chlorite;  $\text{NO}_2$  is covalent: nitrogen dioxide

page 24

1. A chemical change is a process in which the arrangement of atoms changes to form new compounds or substances.
2. Word equation, symbolic (formula) equation
3. Mass is conserved in a chemical reaction; the total mass of the products is always equal to the total mass of the reactants in a chemical reaction.

page 25

1. (a) 6 Cl, 2 Cr, 6 I
- (b) 1 Pb, 4 N, 12 O, 4 Na, 4 I

page 26

1. (a)  $2\text{Al} + 3\text{Cl}_2 \rightarrow 2\text{AlCl}_3$
- (b)  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
- (c)  $\text{Ca}(\text{NO}_3)_2 + \text{Cu}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + 2\text{CuNO}_3$
- (d)  $3\text{Na}_2\text{CO}_3 + 2\text{Ni}(\text{NO}_3)_3 \rightarrow 6\text{NaNO}_3 + \text{Ni}_2(\text{CO}_3)_3$
2. (a)  $\text{CaF}_2 + 2\text{K} \rightarrow 2\text{KF} + \text{Ca}$
- (b)  $2\text{Al}(\text{OH})_3 + 6\text{HBr} \rightarrow 3\text{AlBr}_3 + 6\text{H}_2\text{O}$
- (c)  $2\text{CrI}_3 + 3\text{K}_2\text{CO}_3 \rightarrow \text{Cr}_2(\text{CO}_3)_3 + 6\text{KI}$
- (d)  $2\text{HNO}_3 + \text{BaCO}_3 \rightarrow \text{Ba}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2$

## Practice Questions Answers

### Section 4.1

1. C
2. C
3. A
4. A
5. B
6. D
7. C
8. C
9. B
10. C

### Section 4.2

1. D
2. D
3. C
4. D
5. A
6. C
7. A
8. C
9. D
10. B

### Section 4.3

1. B
2. C
3. C
4. C
5. D
6. B
7. A
8. A
9. C
10. D

## Chapter 5

### Quick Check Answers

page 31

1. (a) below 7 (b) above 7
2. 10 times
3. 10 000 times
4. 7

page 32

- (a) red  
(b) orange (from red + yellow)  
(c) yellow  
(d) blue  
(e) red  
(f) pink

page 33

- (a) hydrochloric acid  
(b) hydrobromic acid  
(c) hydrofluoric acid
- (a) sulfuric acid  
(b) nitric acid  
(c) acetic acid
- (a) perchloric acid  
(b) chloric acid  
(c) chlorous acid  
(d) hypochlorous

page 34

- (a) acid  
(b) base  
(c) neither  
(d) base  
(e) neither  
(f) acid
- H<sup>+</sup>
- OH<sup>-</sup>
- They react together to form water.

page 39

- (a) base  
(b) acid  
(c) salt  
(d) metal oxide  
(e) non-metal oxide
- Non-metal oxides
- (a)  $\text{HF} + \text{KOH} \rightarrow \text{KF} + \text{H}_2\text{O}$   
(b)  $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow 2\text{NaF} + 2\text{H}_2\text{O}$   
(c)  $2\text{HNO}_3 + \text{Mg}(\text{OH})_2 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{H}_2\text{O}$

page 40

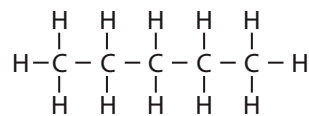
- (a)  $2\text{HF} + \text{Zn} \rightarrow \text{ZnF}_2 + \text{H}_2$   
(b)  $\text{H}_2\text{SO}_3 + \text{Mg} \rightarrow \text{MgSO}_3 + \text{H}_2$   
(c)  $6\text{HCl} + 2\text{Al} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2$
- To help neutralize acid from acid precipitation

page 44

- Carbon
- Carbon oxides (e.g., CO<sub>2</sub>), carbonates (e.g., CaCO<sub>3</sub>), and carbides (SiC)

page 45

- (a) C<sub>5</sub>H<sub>12</sub>  
(b)



### Practice Questions Answers

#### Section 5.1

- C
- B
- C
- B
- A
- A
- D
- D
- C
- A

#### Section 5.2

- A
- D
- D
- A
- A
- C
- C
- B
- D
- B

#### Section 5.3

- B
- A
- D
- B
- C
- C
- D
- C
- B
- A



## Chapter 6

### Quick Check Answers

page 46

- (a)  $2\text{Al} + 3\text{F}_2 \rightarrow 3\text{AlF}_3$   
(b)  $4\text{K} + \text{O}_2 \rightarrow 2\text{K}_2\text{O}$   
(c)  $\text{Cd} + \text{I}_2 \rightarrow \text{CdI}_2$
- (a) Not synthesis  
(b) Not synthesis  
(c) Synthesis

page 47

- (a)  $2\text{Na}_2\text{O} \rightarrow 4\text{Na} + \text{O}_2$   
(b)  $\text{Mg}_3\text{N}_2 \rightarrow \text{N}_2 + 3\text{Mg}$   
(c)  $2\text{CsI} \rightarrow 2\text{Cs} + \text{I}_2$
- (a) Neither  
(b) Synthesis  
(c) Decomposition

page 48

- (a)  $\text{K} + \text{NaCl} \rightarrow \text{Na} + \text{KCl}$   
(b)  $\text{CuF}_2 + \text{Mg} \rightarrow \text{MgF}_2 + \text{Cu}$   
(c)  $\text{F}_2 + 2\text{CsBr} \rightarrow \text{Br}_2 + 2\text{CsF}$
- (a)  $2\text{Na}_3\text{PO}_4 + 3\text{MgI}_2 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 6\text{NaI}$   
(b)  $\text{SrCl}_2 + \text{Pb}(\text{NO}_3)_2 \rightarrow \text{Sr}(\text{NO}_3)_2 + \text{PbCl}_2$   
(c)  $2\text{AgNO}_3 + \text{Na}_2\text{CrO}_4 \rightarrow 2\text{NaNO}_3 + \text{Ag}_2\text{CrO}_4$
- (a) Double replacement  
(b) Single replacement  
(c) Synthesis  
(d) Decomposition

page 49

- (a)  $\text{HF} + \text{NaOH} \rightarrow \text{NaF} + \text{H}_2\text{O}$   
(b)  $2\text{HCl} + \text{Pb}(\text{OH})_2 \rightarrow \text{PbCl}_2 + 2\text{H}_2\text{O}$   
(c)  $\text{Al}(\text{OH})_3 + 3\text{HClO}_4 \rightarrow \text{Al}(\text{ClO}_4)_3 + 3\text{H}_2\text{O}$
- (a)  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$   
(b)  $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$   
(d)  $\text{C}_4\text{H}_8\text{O}_4 + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O}$
- (a) Decomposition  
(b) Single replacement  
(c) Double replacement  
(d) Combustion  
(e) Synthesis  
(f) Neutralization

page 52

- The rate increases
- Cooling decreases the frequency.
- Increasing the concentration of the acid causes more frequent collisions between acid particles and the aluminum.

- Blowing on a camp fire increases the concentration of oxygen ( $\text{O}_2$ ) on the wood. This leads to more frequent collisions between the oxygen molecules and the wood.

page 53

- The greater the surface area, the greater the number of collisions that can happen between reactant particles.
- Cutting wood into small pieces increases the surface area of the wood. This leads to more frequent collisions between the oxygen molecules and the wood.
- The rate increases.
- To convert harmful nitrogen oxides back into harmless  $\text{N}_2$  and  $\text{O}_2$ .
- An enzyme is a biological catalyst.

### Practice Questions Answers

#### Section 6.1

- C
- D
- D
- A
- B
- C
- D
- B
- D
- A

#### Section 6.2

- D
- B
- C
- C
- A
- A
- D
- D
- C
- B

## Chapter 7

### Quick Check Answers

page 59

1.

Isotope	Mass Number	Atomic Number (number of protons)	Number of Neutrons
<b>nitrogen-15</b>	15	7	8
sulfur-30	30	16	14
neon-22	22	10	12
magnesium-25	25	12	<b>13</b>
beryllium-7	7	4	<b>3</b>
carbon-12	12	6	<b>6</b>
neon-22	22	10	12
fluorine-10	19	9	10

2. (a) 17  
(b) chlorine-37  
(c)  ${}_{17}^{37}\text{Cl}$
3. (a) 11  
(b) 21  
(c) sodium-21  
(d)  ${}_{11}^{21}\text{Na}$
4. Radioactive decay is the process in which the nuclei of radioactive parent isotopes emit alpha, beta, or gamma radiation to form decay products.

page 61

1. (a)  ${}_{89}^{227}\text{Ac}$   
(b)  ${}_{82}^{204}\text{Pb}$   
(c)  ${}_{101}^{252}\text{Md}$   
(d)  ${}_{89}^{225}\text{Ac}$
2. (a)  ${}_{12}^{24}\text{Mg}$   
(b)  ${}_{79}^{201}\text{Au}$   
(c)  ${}_{26}^{52}\text{Fe}$   
(d)  ${}_{3}^6\text{Li}$

page 62

1.  ${}_{0}^0\gamma$
2. (a) The nucleus loses an alpha particle, which is the same as a helium nucleus. The mass number drops 4 units and the atomic number drops 2 units.  
(b) The nucleus releases an electron while a neutron turns into a proton. The mass number remains the same while the atomic number increases by one.

(c) The nucleus loses excess energy. The mass number and atomic number remain unchanged

3. (a) Alpha  
(b) Gamma  
(c) Beta  
(d) Alpha  
(e) Gamma  
(f) Beta

page 66

1. Half-life is the amount of time required for half the nuclei in a sample of a radioactive isotope to decay.
2. By measuring relative amounts of remaining radioactive material to stable products formed, such as the ratio of carbon-14 atoms to carbon-12 atoms.
3. (a) 2000 years  
(b) 4000 years
4. (a) 32 g  
(b) 16 g  
(c) 8 g

page 67

1. (a) 20 000 years  
(b) 18 percent  
(c) 65 000 years  
(d) 3  
(e) 40 000 years

page 68

1. lead-207  
2. 14 billion years  
3. uranium-238  
4. 1.3 billion years (or one half-life)

page 72

1. A fission nuclear reaction is the process by which a large nucleus splits into two pieces of roughly equal mass, accompanied by the release of large amounts of energy.
2. The sum of the mass numbers; the sum of the charges (represented by atomic numbers)

page 73

- 1 (a)  ${}_{50}^{139}\text{Sn}$   
(b)  ${}_{37}^{90}\text{Rb}$   
(c)  ${}_{32}^{93}\text{Ge}$
2. A chain reaction is a reaction in which the products of the reaction trigger more reactions in a self-sustaining process.

page 74

1. It takes 20 half-lives (thousands of years) before the material reaches safe levels of radioactivity.
2. Fusion is the joining of two small atomic nuclei to make a larger one, usually involving the release of a large amount of energy.
3. In the Sun

### Practice Questions Answers

#### Section 7.1

1. D
2. B
3. A
4. B
5. D
6. C
7. B
8. C
9. A
10. D

#### Section 7.2

1. C
2. A
3. C
4. C
5. C
6. A
7. D
8. D
9. B
10. A

#### Section 7.3

1. C
2. A
3. D
4. C
5. B
6. C
7. D
8. B
9. D
10. A