Section 4.2 Representing Molecular Compounds

(Student textbook pages 152 to 158)

Specific Expectations

- **C1.1** analyse, on the basis of research, various safety and environmental issues associated with chemical reactions and their reactants and/or product(s)
- **C1.2** analyse how an understanding of the properties of chemical substances and their reactions can be applied to solve environmental challenges
- **C3.1** describe the relationships between chemical formulae, composition, and names of binary compounds
- **C3.2** explain, using the law of conservation of mass and atomic theory, the rationale for balancing chemical equations
- **C3.8** identify simple ionic compounds, simple compounds involving polyatomic ions, molecular compounds and acids using the periodic table and a list of the most common polyatomic ions and write the formulae

In this section, students continue exploring chemical bonds, focusing now on molecular bonds. They practise developing chemical formulas and naming molecular compounds, this time using the prefix method, and examine the electron sharing that forms molecules.

Common Misconceptions

- It is often forgotten that a bond represents one or more electrons being shared. Unlike an ionic bond, the shared electron contributes to the valence shell of both atoms.
- The rules for writing chemical formulas in ionic compounds and molecular compounds may be considered different. However, the same basic rules apply to all binary compounds: that is, the atoms bond with each other until the valence shell is full of electrons.
- Confusion may result from the overlap in nomenclature for ionic and molecular binary compounds. All binary compounds, whether ionic or molecular, end in the suffix *–ide*. Have students note that binary molecular compounds (i.e., those containing only two, non-metal elements) are named using both elements with *prefixes* to indicate the number of each atom that makes up a molecule.
- Unlike ionic compounds, ratios of elements in molecular compounds should not be simplified. For example, N_2O_4 should not become NO_2. Model a molecule to demonstrate the effect of molecular bonds (groups of atoms connected together). Reinforce that ionic compounds contain elements in a certain ratio, not bonded in molecules, so their formulas represent a ratio, not a molecule, and may be simplified. The molecular models created in Activity 4-3 reinforce the reasons for this.
- While it is a good rule of thumb that molecular bonding occurs between non-metals, there are many exceptions. The polyatomic ion "dichromate," for example, involves a molecular bond between oxygen and chromium (a metal). The presence of a metal in a formula (e.g., $K_2Cr_2O_7$) is a good clue that the compound is ionic, but it is not definitive.
- While it is customary to use a different set of naming rules for molecular and ionic compounds, this is not always necessary. For example, NO is correctly named either nitrogen monoxide or nitrogen(II) oxide (following IUPAC rules of nomenclature).
- The order of elements in names or formulas may be mistakenly reversed. Have students note that for molecular compounds, the element with the positive valence always comes first. Positive or negative valence is defined by the number of electrons that it will lose (becoming positive), gain (becoming negative), or share (check the charge balance against the number of protons) when it bonds with other atoms.

Background Knowledge

Any given atom is part of only one specific molecule. For example, in a water molecule, each oxygen atom is connected to two (and only two) hydrogen atoms.

Molecular bonding results when electron transfer is not possible because too much energy would be required to pull the electrons away from the attraction of the protons in their nucleus. Shared electrons complete the valence shell and attract the positive nuclei of the atoms involved, leading to a molecular bond. Binary molecular compounds are those that consist of two non-metal elements bonded together.

Electrons generally pair in single, double, and triple bonds, which involve the sharing of one, two, or three electron pairs between two atoms. Elements in groups 14, 15, and 16 often participate in this form of bonding.

The prefix system is used to indicate the ratios of atoms whenever two or more non-metals share electrons to form a molecular bond (e.g., NO_2 is nitrogen dioxide and N_2O4 is dinitrogen tetroxide).

Diatomic elements are those whose stable form consists of two atoms. These seven elements (H, O, F, Br, I, N, Cl) are named under the Molecules heading of the student textbook (page 153), the term appears in the next section. Some other elements are stable only in multiples, rather than as lone atoms (e.g., sulfur (S_8) and phosphorus (P_4)).

Literacy Support

Using the Text

- Remind students that chemists found a clever and useful way of naming ionic compounds and that the same is true for compounds made up of non-metals.
- Introduce a chemical compound called dihydrogen monoxide. Write it on the board in large letters. Ask students if they have ever heard of this substance. (Accept all logical responses.) Ask students if they would drink the compound without knowing more about it. Then, ask students to refer to the photo and provide the name of the substance in figure 4.12. Although the fact that it is water is obvious, emphasize the need for using a systematic naming approach for even common substances such as water for understanding in all languages. Provide the formula for water and briefly explain how the IUPAC name is generated from the formula to introduce the naming of molecular compounds.

Before Reading

- ELL Review prefixes with students and ask English language learners what the same prefixes are in their language. Provide a connection to the prefixes to help the students remember them: *octa-* octopus (eight legs), *penta-* pentagon (five-sided building in Washington), *tri-* tricycle (three-wheeled bike).
- Have students read the section summary first. Then, use the glossary scan and the section to define the key words (in bold). Post definitions on the word wall.

During Reading

- Have students evaluate their growing understanding of the points in the section summary. What do they now understand? What questions do they have?

After Reading

- ELL Encourage students to keep a vocabulary section in their notebooks where key words are explained in their own words, including examples and illustrations as well as perhaps a translation of the words into their first language.
- Return to the word wall and section summary and have students check that the key words are now understood. Have them list the concepts they need to work on, then have them explain to a classmate in their own words, a concept that partner is struggling with.

- Point out the Study Toolkit in the margin on page 152. Direct students to the Word Study feature on page 138 of the student textbook to reactivate understanding of base words. Group students or work as a class to identify *molecule* as the base word for *molecular* and develop a definition that can be posted on the word wall.

Using the Images

- Before reading the text, have students view Figure 4.12, page 152, and read the caption. As a class, identify the two types of atoms in the dihydrogen monoxide molecule, and from learning in the previous section, evaluate the elements and ratio involved.
- When viewing Figure 4.13 (page 153), have student compare the shared electrons to transferred ones by contrasting this figure to either Figure 4.5 or their work on Activity 4-2 and **BLM 4-7 Take My Electron—Please!** Count the number of electrons being used by each atom and note that every energy level is filled.
- Contrast the molecules of carbon dioxide shown in Figure 4.14 with the arrangement of atoms in ionic compounds shown in Figure 4.6. Note that the molecules exist separately within the compound while all atoms in the ionic compound are bonded together (in a specific ratio).

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Activity 4-3 Electron, Anyone?, page 154	Students show atoms that share electrons, create models that show accurate molecular structure and correctly use language.	Have students complete **BLM 4-13 Electron, Anyone?,** which provides scaffolding for this activity. Have students explain the process verbally or demonstrate without words.
Learning Check question 2, page 156 Section 4.2 Review question 3, page 158	Students name the molecular compound when given the formula or elements involved, and can (oppositely) derive a formula from the name.	Administer a team competition in which you call out names or formulas and teams race to write the corresponding name/formula. You might structure this as a team collaboration, relay, or combination. Or, you could have teams judge each other, verifying each other's answers with points awarded to both. Play a bingo game in which a caller names molecular compounds, which the students must match to the formulas on their bingo cards to win. Have students complete **BLM 4-11 Section 4.1 Review (Alternative Format).**
Practice Problem 1, page 157 Section 4.2 Review question 6, page 158	Non-metals are combined in correct ratios to form molecules. Elements and ratios are correctly identified.	Have students complete **BLM 4-12 Molecular Compounds.** Partner students to verify each other's work, resolving any discrepancies as a team. Have students use a set of nomenclature playing cards to prepare compounds. Have students complete **BLM 4-11 Section 4.1 Review (Alternative Format).**

Instructional Strategies

- DI Have as many models of molecules and crystals around the classroom as possible. Refer to these models often when discussing the theoretical aspects of bond formation.

- ELL Encourage students to note the prefixes (Table 4.9 on page 154 of the student textbook) on an index card for easy reference.
- ELL Post new words and definitions on the classroom word wall. Include reference to any base words contained in the terms.
- Repetition and drill is often the key to mastering chemical nomenclature. Begin each lesson by having students decipher a name, a formula, and a compound's ratio of elements.
- Have students carry out Activity 4–3 Electron, Anyone? to practise and integrate their understanding of electron sharing in molecular bonds. See the notes on Teacher's Resource page TR-2-19.
- Add to the mind map developed in the last section, adding connections between binary ionic and binary molecular compounds.
- Review the properties of the noble gases, in particular their chemical stability, and how this ties in to their full valence electron configurations.
- Have students create a personal set of nomenclature cards to keep the various rules organized. Suggest they use these cards for reference during naming practice, and as flash cards to help them memorize the rules.
- Work through the steps and examples in Tables 4.10 and 4.11 (pages 155 to 156 in the student textbook) as a class. Encourage students to record the steps on note cards for their own reference as they work. Then, have students complete **BLM 4-12 Molecular Compounds** on their own.
- Lead students through the sample problem "Writing the Chemical Formula for a Binary Compound" on page 157 in the student textbook. Then, have them work through the Practice Problems on that page individually or in pairs. Have students check each others' work and address any common misconceptions to the class as a whole.
- Have students work on the Section 4.2 Review questions during class so remediation can be given where necessary, either from a partner or you, the teacher. Additional or alternative questions could be selected from **BLM 4-14 Section 4.2 Review (Alternative Format).**

Activity 4–3 Electron, Anyone? (Student textbook page 154)

Pedagogical Purpose

Students physically manipulate electrons to model the sharing of electrons that occurs in the formation of molecular bonds.

Planning	
Materials	Paper Molecular modelling kits Small circular objects to mimic electrons **BLM 4-13 Electron, Anyone?** One or two days before, prepare small bags with at least 10 objects each.
Time	Approximately 30 min in class
Safety	Remind students to never eat anything in the science classroom.

Background

In a molecular bond, all valence shells are filled with electrons. The valence shell of hydrogen or helium, for example, can hold just two electrons. The second and third energy levels require eight electrons to fill the level. Therefore, oxygen gains two electrons to complete its octet.

Activity Notes and Troubleshooting

- Remind students never to eat in the lab.
- For manipulatives, choose from items such as washers, coloured hole reinforcements, old CDs, wooden beads, or pompoms. Choose inedible items to discourage eating in the classroom.
- Demonstrate the activity and model one example on the board using sticky notes to represent the electrons. Show students how to assemble molecules using the model kits. Refer them to Figure 4.13 in the student textbook for a model of how the diagrams should show electron sharing.
- Alternative: To illustrate electron sharing, cut an overhead into eight and draw a large Bohr-Rutherford diagram on each piece. You will need four hydrogen cards and one card each for nitrogen, oxygen, and carbon. On each valence shell, draw a large coloured circle to show where additional electrons could be held. (For this to work for hydrogen, the circle must be beside the electron, not opposite.) Approaching each molecule in turn, overlap the cards for each molecule until an electron is visible through each hole. As a class, count the electrons that now appear in each valence shell. The circles will make the shared electrons stand out.
- Ensure students have sufficient room to work with the manipulatives.
- Students could work through this activity alone, in pairs, or in small groups. However, it is important that students produce individual diagrams. Provide students with **BLM 4-13 Electron, Anyone?** which includes scaffolding for the diagrams.
- Wrap up the activity by having students compare answers to a partners', working together to resolve any discrepancies.

Additional Support

- DI ELL This is a good hands-on activity for bodily-kinesthetic learners as well as English language learners.
- ELL Encourage English language learners to *describe* the process of molecular bonding.
- Students with motor challenges may benefit from larger manipulatives, such as pompoms or wooden beads. Select materials that respect their age and ability.
- Students who have completed Activity 4-2 Take My Electron—Please! should be able to complete this variation with minimal assistance.

Answers

1. two

2. The number of electrons in the outer level are: oxygen, 6; nitrogen, 5; carbon, 4. In each case, the atom can share electrons until eight are present.

3. Example: Old names become habit and are so widely accepted that they are unlikely to cause confusion.

Learning Check Answers (Student textbook page 156)

1. The prefix beginning each element name tells you how many atoms of each element are found in each molecule of the compound.

2. **a.** carbon disulfide **b.** dinitrogen trioxide
c. carbon monoxide **d.** carbon tetrachloride
e. phosphorus pentafluoride **f.** disilicon hexabromide

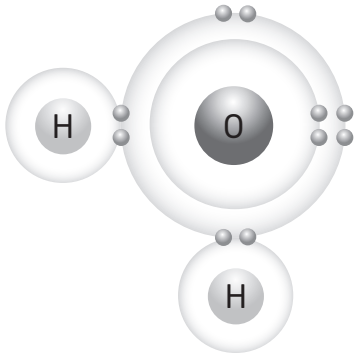
3. The diagram should show: the prefix *di–* means two and phosphorus is the first element in the compound (together meaning there are two phosphorus atoms in the molecule); the prefix *penta–* means five and *ox–ide* means oxygen is the second element in the compound (together meaning there are five oxygen atoms in each molecule).

4. Examples: triathlon (three events), bicycle (two wheels), monopoly (one choice, exclusive).

Section 4.2 Review Answers (Student textbook page 158)

Please see also **BLM 4-14 Section 4.2 Review (Alternative Format).**

1.



2. The end of the name is *–ide*.

3. **a.** carbon monoxide **b.** phosphorus pentachloride **c.** dinitrogen pentoxide

4. methane and ammonia

5. Answers should reflect steps summarized in Tables 4.4, 4.5, and 4.7 in the student textbook.

6. **a.** SF_6 **b.** OF_2 **c.** CBr_4

7. sulfur dichloride, SCl_2

8. Formulas for molecular compounds indicate the number of each atom in the molecule. Since this is a fixed number, rather than a ratio, formulas are not simplified (e.g., N_2O_4).