

## 6.3 Modelling Compounds

The Michael Lee-Chin Crystal at the Royal Ontario Museum in Toronto, shown in **Figure 6.26**, is an impressive accomplishment. Architects and designers, with a wide variety of knowledge and artistic abilities, relied on models throughout the design and construction process. Two-dimensional models, in the form of floor plans, blueprints, and drawings, helped to show how spaces would be arranged within the building and how the building would look from the outside. Three-dimensional models were also used to get a different perspective. These models showed how the building would fit on the available land and what the relative scale of the components would be when the construction was complete. Each type of model has its benefits and its limitations. Like architecture and design, science relies on two-dimensional and three-dimensional models, which can be used to illustrate the important features of compounds.

**Figure 6.26** To build the Michael Lee-Chin Crystal at the Royal Ontario Museum, models were used at different stages to convey different types of information.

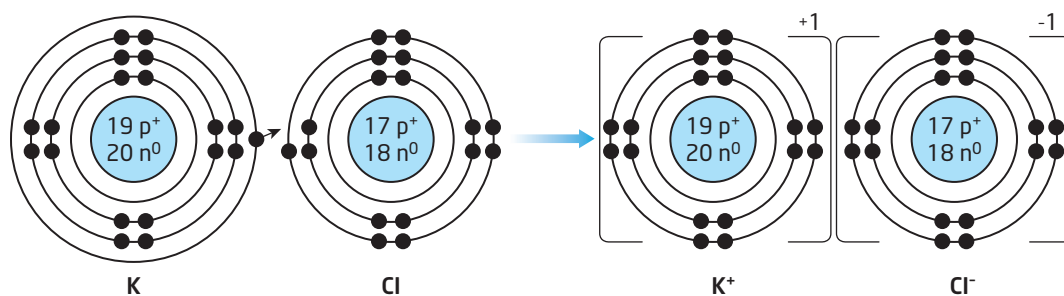


## Two-dimensional Models: Bohr-Rutherford Diagrams

The simplest models of compounds are models that can be drawn on paper. These are two-dimensional models, which indicate height and width. Two-dimensional models are useful for showing what happens during the formation of ionic and molecular compounds.

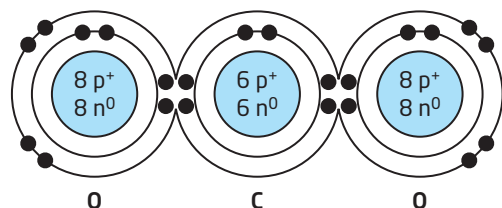
In the previous chapter, you learned how to draw Bohr-Rutherford models of atoms. You also saw examples of Bohr-Rutherford models for compounds earlier in this chapter, when you learned about the formation of ionic and molecular compounds. These models are helpful for understanding how ions form and how atoms share electrons.

The Bohr-Rutherford model in **Figure 6.27** represents the formation of potassium chloride, KCl. The single electron in the fourth energy level of the potassium atom transfers to the chlorine atom, to fill chlorine's third energy level. After the transfer, the potassium ion has a positive charge, the chloride ion has a negative charge, and both ions have full outer energy levels of electrons.



**Figure 6.27** The single valence electron of the potassium atom transfers to the chlorine atom. The resulting ions form the ionic compound potassium chloride.

The Bohr-Rutherford model for the molecular compound carbon dioxide ( $\text{CO}_2$ ) is shown in **Figure 6.28**. Notice that each oxygen atom shares two pairs of electrons with the carbon atom. This sharing of electrons results in full outer energy levels for the oxygen atoms and the carbon atom. When two atoms share two pairs of electrons, the covalent bond between them is called a *double bond*. You will learn more about this type of bond in future chemistry courses. You will practise drawing Bohr-Rutherford models for ionic and covalent compounds in Activity 6-4.



**Figure 6.28** Each oxygen atom shares two of its electrons with the carbon atom to form a molecule of carbon dioxide.



## Activity 6-4

### Representing Compounds Using Bohr-Rutherford Models

Bohr-Rutherford models can be used as two-dimensional representations of how ionic and molecular compounds form. How do Bohr-Rutherford models depict the difference between ionic compounds and molecular compounds?

#### Materials

- Bohr-Rutherford models of NaCl, H<sub>2</sub>O, KCl, and CO<sub>2</sub> (in **Figures 6.4, 6.18, 6.27, and 6.28**).
- periodic table

#### Procedure

1. Examine the Bohr-Rutherford models for ionic and molecular compounds in **Figures 6.4, 6.18, 6.27, and 6.28**. Use these models to help you draw models of the compounds in this activity. In your models, be sure to show the following details:
  - In your models for ionic compounds, be sure to show the transfer of electrons, the formation of ions, and the joining of oppositely charged ions to form ionic bonds.
  - In your models for molecular compounds, be sure to show the electrons that are shared between atoms, creating a covalent bond.

2. Using a periodic table, draw Bohr-Rutherford models for the compound formed from each of the following pairs of elements.
  - a. sodium and fluorine
  - b. nitrogen and three hydrogens
  - c. sulfur and two hydrogens
  - d. lithium and chlorine

#### Questions

1. If a non-metal has six electrons in its outer energy level, how many single electrons from other atoms does it have room for?
2. A certain non-metal consistently forms three covalent bonds. How many single electrons does it have in its outer energy level?
3. What part of a Bohr-Rutherford model of an atom illustrates the difference between how ionic compounds form and how molecular compounds form?

### Three-dimensional Models

A two-dimensional model does not show the three-dimensional characteristics of a compound, such as the spacial arrangement of each atom in the molecule. Three-dimensional models indicate height, width, and depth. There are a variety of three-dimensional models, ranging from ball-and-stick models to computer-generated images, that can show what a compound looks like. These types of models are analogous to three-dimensional models used by architects, such as the one shown in **Figure 6.29**.

**Figure 6.29** This three-dimensional model of the Lee-Chin Crystal at the Royal Ontario Museum provided a more realistic view of what the extension would look like.

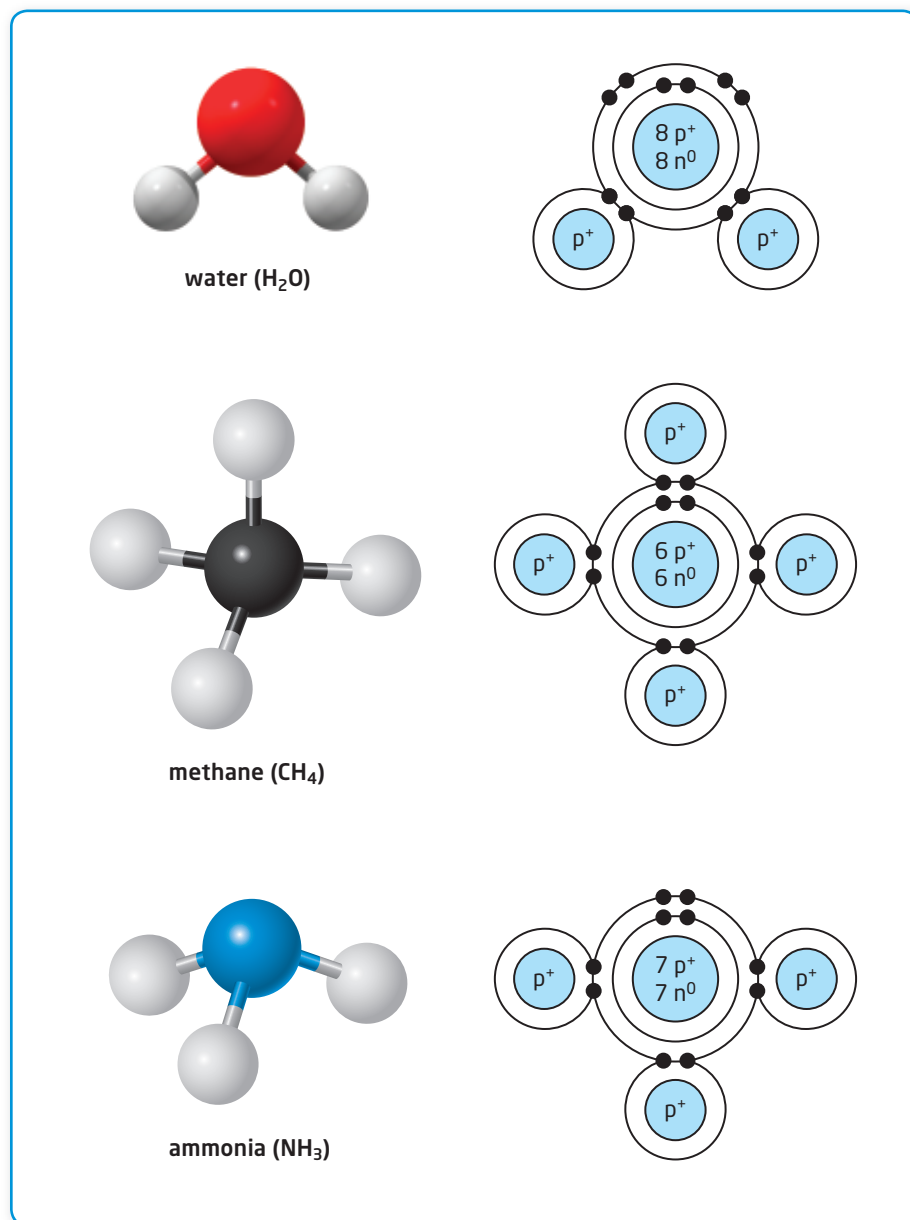


## Ball-and-Stick Models

Although simple craft materials can be used to model molecular compounds, model kits are available. One benefit of using a model kit is that the balls representing the atoms of different elements have holes in the correct positions and at the proper angles for joining them. This helps to show how the atoms in a molecule are arranged in three-dimensional space. The shape of a molecule has a strong influence on the properties of the compound, so being able to see the shape is important. Compare the Bohr-Rutherford model and the ball-and-stick model of each molecular compound in **Figure 6.30** to see how the models convey different information. In Activity 6-5, you will use a model kit to build ball-and-stick models for several molecular compounds.

### Study Toolkit

**Making Inferences** Read the paragraph on this page. Draw a table like the one on page 220 to make an inference about three-dimensional models of compounds. This will help you gain a better understanding of the information that three-dimensional models can provide.



**Figure 6.30** The three-dimensional ball-and-stick models better reflect the true shapes of these molecules.

### Learning Check

1. Why is a Bohr-Rutherford model considered a two-dimensional model?
2. Draw a Bohr-Rutherford model for  $\text{CH}_4$ .
3. What information does a ball-and-stick model of a molecule provide that a Bohr-Rutherford model does not?
4. Think of a model you have made or used, and describe it. Use a two-column table to summarize how well the model represented the object, as well as the limitations of the model.

## Activity 6-5

### Ball-and-Stick Models

Two-dimensional models, such as Bohr-Rutherford models, provide helpful information about the bonds between atoms. This information can be used to make three-dimensional models. What information do you think three-dimensional models can provide?

#### Safety Precautions

- Be careful when joining the pieces in the model kit. Excessive force could break them.
- Make sure that you keep track of all the pieces in the model kit, so that none are lost.

#### Materials

- molecular model kit



Molecular model kits contain pieces that represent atoms (balls) and bonds (sticks).

#### Procedure

1. Create a table to place the sketches of Bohr-Rutherford models and ball-and-stick models that you will make in this activity.
2. Sketch Bohr-Rutherford models for each of the following compounds:  $\text{H}_2\text{O}$ ,  $\text{O}_2$ ,  $\text{CO}_2$ ,  $\text{NH}_3$ , and  $\text{CH}_4$ . Have your teacher check your models. You will refer to your models as you build your three-dimensional models.
3. Your teacher will give you a molecular model kit. The ball-shaped pieces in the model kit represent the atoms. The stick-like pieces represent the electron pairs or covalent bonds between the atoms. Place the stick-like pieces between the atoms, using your Bohr-Rutherford model as a guide for how the atoms are connected.
4. Draw a quick sketch of your three-dimensional model, and label it with the chemical formula of the molecule.
5. Build a model of every compound listed in step 2. Remember to sketch each model that you build.

#### Questions

1. What information does the ball-and-stick model provide that the two-dimensional model does not?
2. Compare and contrast ball-and-stick models with Bohr-Rutherford models.

## Space-Filling Models

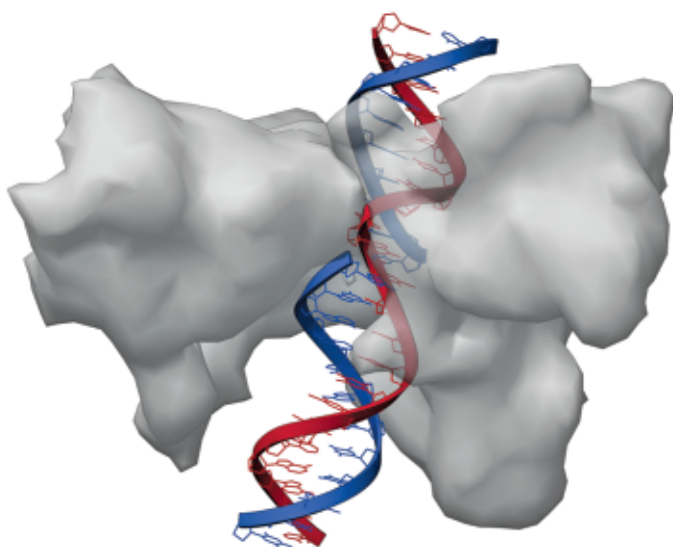
The relative sizes of atoms can be used to create more accurate three-dimensional models of atoms, ions, and molecules. The space-filling model in **Figure 6.31** is one example of a three-dimensional model that shows the relative sizes of the atoms.

Computer-generated three-dimensional models, like the one in **Figure 6.32**, are extensively used to study large, complex biological molecules, such as proteins and DNA. By building and studying three-dimensional models, scientists can learn more about how these molecules carry out life's essential processes and how chemicals can interact with them and interfere with their activities.



**Figure 6.31** This space-filling model of water is a more accurate representation of the relative sizes of the oxygen (red) atom and hydrogen (grey) atoms than a Bohr-Rutherford model or a ball-and-stick model would be.

Go to **scienceontario**  
to find out more



**Figure 6.32** Being able to view DNA as a three-dimensional structure allows scientists to speculate on how other molecules can interact with it. This model shows a molecule, called a protein (in grey), interacting in a specific way with DNA.

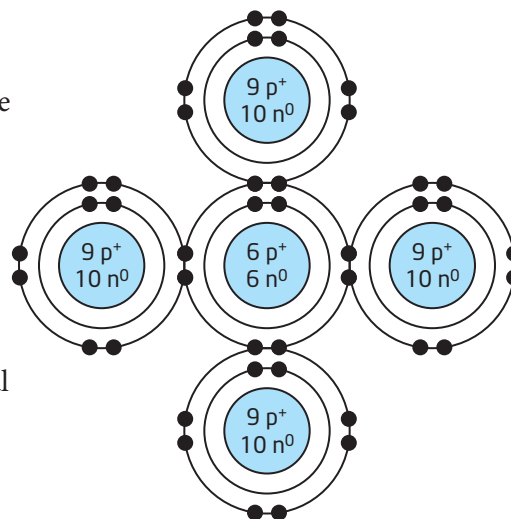
## Section 6.3 Review

### Section Summary

- Bohr-Rutherford models are two-dimensional models of compounds. A Bohr-Rutherford model shows the electron arrangement within each atom of a compound.
- Three-dimensional models provide valuable information about compounds, including the spatial arrangement of the atoms or ions.
- Two types of three-dimensional models are ball-and-stick models and space-filling models. Ball-and-stick models show the overall shape of a molecule, and space-filling models emphasize the relative sizes of the atoms or ions.

### Review Questions

- K/U** 1. What type of model shows all the electrons in each atom of a compound?
- T/I** 2. Examine the Bohr-Rutherford model of carbon tetrafluoride on the right. How many electrons are used in covalent bonds in the molecule? How many electrons in the outer energy levels of the atoms are not in bonds?
- K/U** 3. What are two ways to model compounds in three dimensions?
- A** 4. What three-dimensional model can you easily make using materials you can find at home?
- T/I** 5. Compare and contrast the usefulness of the two-dimensional models and three-dimensional models in **Figure 6.30**.
- C** 6. Write an argument for why there is not one best way to model compounds.
- T/I** 7. You could make a ball-and-stick model of a compound from a model kit or from gumdrops and toothpicks. Analyze the benefits and limitations of each of these materials for making a model of a compound.
- A** 8. Which type of model would be best to use to determine if a new pain medicine is the correct size and shape to bind to a particular location on a nerve cell? Explain your reasoning.



This Bohr-Rutherford model represents carbon tetrafluoride.