SECTION 6.1

Chemical Proportions and Percentage Composition

Key Terms

law of definite proportions
mass percent
percentage composition

Figure 6.1 NASA discovered water on the Moon in 2009 by intentionally crashing a rocket into the lunar crater Cabeus A and then analyzing the debris and dust from the impact.

law of definite proportions a law stating that a chemical compound always contains the same proportions of elements by mass

On October 9, 2009, an extraordinary mission to find a life-sustaining substance on the Moon occurred. Hoping to find traces of water on the Moon, National Aeronautics and Space Administration's (NASA) Lunar Crater Observation and Sensing Satellite (LCROSS) mission sent a rocket hurtling into the crater Cabeus A, shown in **Figure 6.1**. Cabeus A, which is 100 km wide, is found near the south pole of the Moon. The impact tossed debris and dust over the lunar surface. Using special instruments, scientists found evidence that this lunar material contained significant amounts of water.

Compounds That Contain the Same Elements in the Same Proportions

Does lunar water have the same formula as water on Earth? It turns out that the answer to this question is yes. More than 200 years ago, scientists discovered that compounds contain elements with fixed mass proportions. It does not matter where water is found. Whether it comes from the moon, a lake, snow, or ice, as shown in **Figure 6.2**, a molecule of water always contains two hydrogen atoms and one oxygen atom. It also does not matter how large the sample is. The discovery that elements in the same compound are always found in fixed mass proportions was accepted as a law approximately 100 years after the initial discovery.

The Law of Definite Proportions

Around the turn of the 19th century, French chemist Joseph Louis Proust analyzed samples of copper(II) carbonate, $CuCO_3(s)$, from both natural and synthetic sources. He discovered that all the samples contained the same proportions of copper, carbon, and oxygen by mass, no matter what their source. Based on his discovery, Proust developed the **law of definite proportions** (also known as the law of definite composition or the law of constant composition).

Law of Definite Proportions
The elements in a chemical compound are always present in the same proportions by mass.

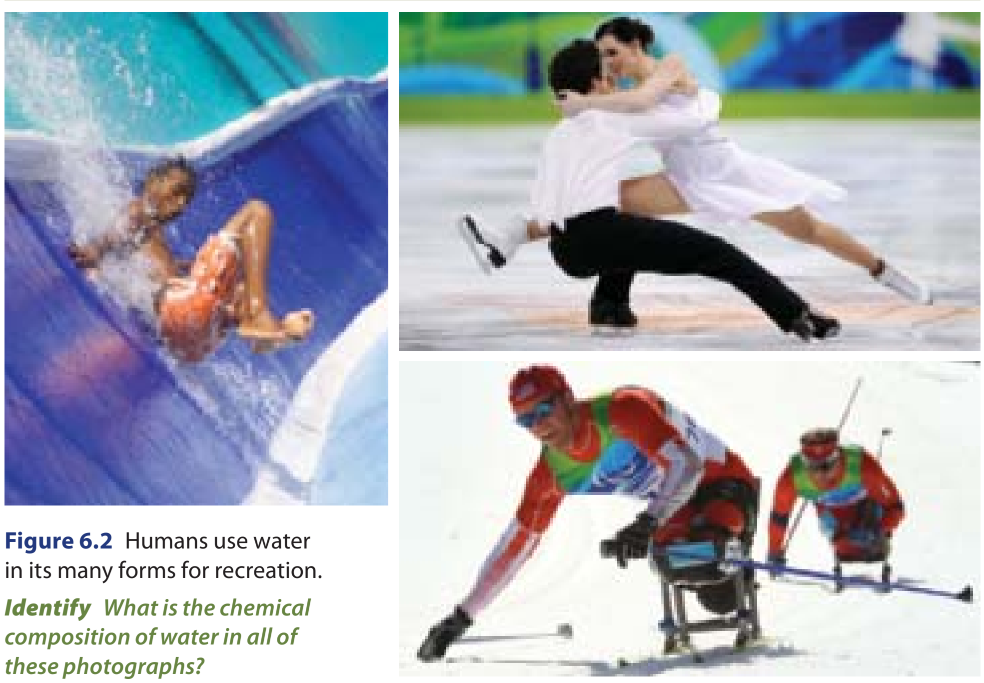


Figure 6.2 Humans use water in its many forms for recreation.

Identify *What is the chemical composition of water in all of these photographs?*

Mass Percent

According to the law of definite proportions, all water molecules have the same chemical composition. The average atomic mass of water molecules is 18.02 u (2.02 u of hydrogen plus 16.00 u of oxygen). Translated into moles, 1 mol of water has a mass of 18.02 g, which consists of 2.02 g of hydrogen and 16.00 g of oxygen. Note, however, that the law of definite proportions deals with the proportion of each element in a compound by mass, rather than the mass of each element. As a result, the proportion of each element is usually expressed as a percentage of the total mass of the compound. This is known as a **mass percent**. To determine the mass percent of each element in the compound, divide the mass of each element by the mass of the compound and multiply by 100 percent. As shown in the calculations below, the mass percent of hydrogen in water is 11.2 percent.

mass percent the mass of an element in a compound, expressed as a percentage of the total mass of the compound

$$\begin{aligned} \text{mass percent of H} &= \frac{\text{mass of H}}{\text{mass of } H_2O(\ell)} \times 100\% \\ &= \frac{2.02 \cancel{g}}{18.02 \cancel{g}} \times 100\% \\ &= 11.2\% \end{aligned}$$

This example for the hydrogen in water shows how the mass percent of an element can be calculated using the chemical formula for the compound. Mass percent can also be calculated using the results from an experiment. The following Sample Problem shows how mass percent can be calculated based on mass data obtained from an experiment. The Practice Problems and activity that follow will give you the opportunity to practise determining mass percent using the chemical formula for a compound and using experimental mass data.

Sample Problem

Determining the Mass Percent of an Element in a Compound

Problem

A 13.8 g sample of a compound contains 8.80 g of iron. Determine the mass percent of iron in the sample.

What Is Required?

You need to find the mass percent of iron in the sample.

What Is Given?

You know the mass of the sample: 13.8 g

You also know the mass of iron in the sample: 8.80 g

Plan Your Strategy	Act on Your Strategy
Divide the mass of iron by the mass of the sample, and then multiply by 100%.	$\text{mass percent of Fe} = \frac{\text{mass of Fe}}{\text{mass of sample}} \times 100\%$ $= \frac{8.80 \cancel{g}}{13.8 \cancel{g}} \times 100\%$ $= 63.8\%$ The mass percent of iron in the sample is 63.8%.

Check Your Solution

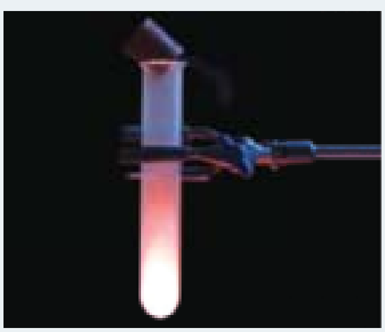
The mass of iron is about 9 g of the approximately 14 g sample, or about 64%, so the answer is reasonable.

Practice Problems

1. Calculate the mass percent of oxygen in iron(II) oxide, FeO(s).
2. Calculate the mass percent of oxygen in dinitrogen tetroxide, N_2O_4(g).
3. A 650 mg sample is analyzed and found to contain 51.0 mg of hydrogen. What is the mass percent of hydrogen in the sample?
4. Calculate the mass percent of oxygen in acetic acid, CH_3COOH(ℓ).
5. Potassium dichromate, $K_2Cr_2O_7$(s), is used in the production of safety matches. A 50.0 g sample of potassium dichromate contains 12.8 g of potassium. What is the mass percent of potassium in the potassium dichromate sample?
6. A 30.0 g sample of a compound contains 8.2 g of carbon. What is the mass percent of carbon in the sample?
7. Which substance has the greater mass percent of chromium: chromic acid, H_2CrO_4(aq), or dichromic acid, $H_2Cr_2O_7$(aq)?
8. Which substance has the greater mass percent of sulfur: sulfurous acid, H_2SO_3(aq), or peroxodisulfuric acid, $H_2S_2O_8$(aq)?
9. Calcium chloride, $CaCl_2$(s), is used as a de-icer. Calculate the mass percent of chlorine in calcium chloride.
10. Many metals are refined from sulfide mineral deposits that were laid down by volcanoes billions of years ago. List the following sulfide compounds in order, from greatest to least mass percent of sulfur: lead(II) sulfide, PbS(s): zinc sulfide, ZnS(s): copper(I) sulfide, Cu_2S(s).

Activity 6.1 Mass Percent of Oxygen

Imagine that you are an early chemist, studying compounds that contain one atom of potassium, one atom of chlorine, and varying numbers of atoms of oxygen. You are testing one compound to experimentally determine the mass percent of oxygen so you can calculate the relative number of oxygen atoms in the compound. You know that your compound will decompose when heated, losing the oxygen as a gas and leaving potassium chloride as a solid. You first measure the mass of your empty test tube. You then place some of the compound in the test and again measure the mass. You heat the test tube and then measure the mass of the test tube with the potassium chloride residue. Use the observations in the table below to determine the mass percent of oxygen in potassium chlorate.



Data Table

Mass of test tube	19.85 g
Mass of test tube + original compound	24.62 g
Mass of test tube + potassium chloride residue	22.83 g

Procedure

1. Calculate the mass of your original compound.
2. Calculate the mass of potassium chloride residue that was produced.
3. Calculate the mass of oxygen that was lost as a gas.
4. Calculate the mass percent of oxygen in your original compound, based on the experimental data.
5. Determine whether your compound contains one, two, three or four oxygen atoms by calculating the mass percent of oxygen for each of the possible compounds.
6. Calculate the percentage error in the experiment, using the difference between the theoretical mass percent of oxygen (expected value for the compound that you determined in step 5) and the mass percent of oxygen measured by experiment. Go to Measurement in Appendix A for help with percentage error.

Questions

1. How does the law of conservation of mass allow you to calculate the mass of oxygen that was produced?
2. Why do you think chemists use mass percent rather than a percent of the number of atoms in a compound?
3. Write the chemical formula for your original compound. State the name of the compound.
4. Write the balanced chemical equation for the decomposition reaction that occurred when you heated your compound.

Compounds That Contain the Same Elements in Different Proportions

Whether you take a sample of water from a glacier, the Moon, or your own tap, the mass percent of hydrogen and oxygen atoms always are the same. Each unique compound contains the same percent by mass of each of its elements. However, there are numerous compounds that have the same elements in different proportions.

Different Proportions, Different Properties

If you completed the Launch Lab at the beginning of this chapter, you saw how different compounds with the same elements in different proportions—salicylic acid and acetylsalicylic acid—have different properties. Two other compounds with the same elements but very different properties are nitrogen dioxide, $NO_2(g)$, and dinitrogen monoxide, $N_2O(g)$, shown in **Figure 6.3**. Nitrogen dioxide, which is emitted from combustion engines, is highly toxic. In comparison, dinitrogen monoxide, a chemical with a similar formula, is used to calm patients during dental procedures.

Figure 6.3 The car exhaust **(A)** contains nitrogen dioxide, a toxic brown gas that contributes to pollution. The dental patient **(B)** is receiving dinitrogen monoxide, commonly known as "laughing gas." Dinitrogen monoxide is a helpful compound, when used properly, with completely different properties than nitrogen dioxide. Both of these compounds contain nitrogen and oxygen, but in different proportions.

Similarly, water, $H_2O(\ell)$, and hydrogen peroxide, $H_2O_2(\ell)$, contain the same elements but in different proportions. Their properties differ greatly. Water is generally stable, whereas hydrogen peroxide is quite reactive. Carbon dioxide, $CO_2(g)$, and carbon monoxide, $CO(g)$, are another example. Both contain carbon and oxygen. But whereas carbon dioxide is a gas you breathe out, carbon monoxide can be a deadly poison.

Learning Check

1. The launch of the rocket that NASA intentionally crashed into the Moon burned hydrogen and formed water as the main product. Was this water the same as the water that is found naturally on Earth and the Moon? Explain.
2. Explain how nitrogen and oxygen can combine to form two different compounds, as shown in **Figure 6.3**.
3. Why do you think the law of definite proportions is also known as the law of definite composition or the law of constant composition?
4. Can the mass percent of carbon in carbon dioxide, $CO_2(g)$, change? Explain.
5. Can the mass percent of carbon in different compounds be different? Explain.
6. The mass percent of carbon in carbon monoxide, CO(g), is 42.9%.
   a. What is the mass percent of oxygen?
   b. Why is the mass percent of carbon atoms different from the mass percent of oxygen atoms, even though they are in the same ratio in the formula CO?

Percentage Composition

percentage composition the percent by mass of each element in a compound

When you combine the mass percent for all of the elements in a compound, you have the **percentage composition** of the compound. Two examples are shown below.

Percentage composition of $NO_2(g)$		*Percentage composition of $N_2O(g)$*	
mass percent of N =	30.45%	mass percent of N =	63.65%
mass percent of O =	69.55%	mass percent of O =	36.25%
Total	100%	Total	100%

Determining Percentage Composition from Mass Data

Knowing the percentage composition of a compound can help scientists determine the identity and composition of newly discovered chemical compounds. For example, vitamin C, an important molecule for human health, was first discovered in the early 1900s. Humans cannot synthesize their own vitamin C. Most people get the vitamin C they require from their diet, mainly from fruits and vegetables, such as the oranges shown in **Figure 6.4**. Because some people do not get enough vitamin C from their diet, synthetic vitamin C is produced and sold as a dietary supplement. In order for manufacturers to produce a synthetic copy of a molecule, however, scientists must first determine the composition and structure of the original molecule.

Figure 6.4 Vitamin C is a complex organic molecule that comes from plant sources. Some foods, such as citrus fruits, strawberries, and rosehips, are especially rich in this molecule.

Explain *How might knowledge of the percentage composition of vitamin C help scientists produce it synthetically in a laboratory?*

An Application of Percentage Composition

Vitamin C, also known as ascorbic acid, $C_6H_8O_6(s)$, was first produced synthetically in a laboratory in 1933. This was such an important accomplishment that one of the scientists involved, Sir Walter Norman Haworth, received the Nobel Prize in Chemistry for his part in this achievement. Determining the proportions of the different elements in ascorbic acid was a crucial part of the process. The Sample Problem below shows how to calculate the percentage composition of elements in a simpler compound. Study this problem, and then complete the Practice Problems that follow.

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Sample Problem

Determining Percentage Composition from Mass Data

Problem

A sample of a compound that is found in gasoline has a mass of 35.8 g. The sample contains 30.10 g of carbon and 5.70 g of hydrogen. What is the percentage composition of the compound?

What Is Required?

You need to calculate the mass percent of carbon and hydrogen in the compound.

What Is Given?

You know the mass of the compound sample: 35.8 g
You know the mass of carbon in the sample: 30.10 g
You know the mass of hydrogen in the sample: 5.70 g

Plan Your Strategy	Act on Your Strategy
Find the mass percent of carbon. To do this, divide the mass of carbon by the mass of the sample and then multiply by 100 to get the percent.	$\text{mass percent of C} = \frac{\text{mass of C}}{\text{mass of sample}} \times 100\%$ $= \frac{30.10\ \cancel{g}}{35.8\ \cancel{g}} \times 100\%$ $= 0.8407 \times 100\%$ $= 84.1\%$
Find the mass percent of hydrogen. Divide the mass of hydrogen by the mass of the sample, and then multiply by 100 to get the percent.	$\text{mass percent of H} = \frac{\text{mass of H}}{\text{mass of sample}} \times 100\%$ $= \frac{5.70\ \cancel{g}}{35.8\ \cancel{g}} \times 100\%$ $= 0.1592 \times 100\%$ $= 15.9\%$ Therefore, the percentage composition of the compound is 84.1% carbon and 15.9% hydrogen.

Alternative Solution

Because there are only two elements in the compound, the mass percent of hydrogen can also be found by subtracting the mass percent of carbon from 100%.

$$\begin{aligned}\text{Mass percent of H} &= 100\% - 84.1\% \\ &= 15.9\%\end{aligned}$$

Check Your Solution

The sum of the calculated percentages is 100%, so the answers are reasonable.

Practice Problems

11. A 19.6 g sample of compound A contains 16.1 g of nitrogen and 3.5 g of hydrogen. Determine the percentage composition of the compound.

12. A 304 g sample of compound B contains 207.9 g of chromium and 96.1 g of oxygen. Determine the percentage composition.

13. A 60.0 mg sample of compound C contains 24.0 mg of carbon, 4.0 mg of hydrogen, and 32.0 mg of oxygen. Determine the percentage composition.

14. A 15 g sample of compound D contains 7.22 g of nickel, 2.53 g of phosphorus, and 5.25 g of oxygen. Determine the percentage composition.

15. A sample of an unknown compound contains 84.05 g of carbon, 5.00 g of hydrogen, 42.02 g of nitrogen, and 96.08 g of oxygen. Determine the percentage composition of the compound.

16. What is the percentage composition of a compound with a mass of 48.72 g, if it contains 32.69 g of zinc and 16.03 g of sulfur?

17. The percentage composition of a compound is 79.9% copper and 20.1% sulfur. The mass of a sample of the compound is 160.0 g. What are the masses of the copper and sulfur in the sample?

18. A chemist analyzed a sample of a compound that was known to contain potassium, manganese, and oxygen. She obtained the following results:
Total mass of sample = 316.08 g
Mass of potassium = 78.20 g
Mass of manganese = 109.88 g
Determine the percentage composition of the compound.

19. A volatile chemical was removed from a crime scene. Analysis of a 35.20 mg sample of the chemical showed that it contained 3.56 mg of carbon and 0.28 mg of hydrogen. Later, investigators learned that the chemical was chloroform, $CHCl_3(\ell)$. What is the percentage composition of chloroform?

20. A 68.2 g sample of an unknown alcohol was tested by a student and found to contain 44.2 g of carbon, 9.3 g of hydrogen, and 14.7 g of oxygen. The student concluded that the unknown alcohol was ethanol, $C_2H_5OH(\ell)$, which contains 52.1% carbon, 13.2% hydrogen, and 34.7% oxygen. Was the student correct? Explain, using percentage composition calculations.

Percentage Composition in Industry

It is important to be able to calculate percentage composition from mass values. However, it is more common to calculate percentage composition from a chemical formula and molar masses. There are many applications of the latter type of calculation in industry, such as in metal refining.

For example, copper is a valuable metal with a wide range of uses, such as in coins (pennies), computer circuit boards, and electrical wiring. In nature, copper is found mainly in the form of ores, which are ionic compounds. One example of a copper ore is chalcocite, or copper(I) sulfide, $Cu_2S(s)$, which is shown in **Figure 6.5**.

Figure 6.5 Chalcocite is a copper ore. Most metals are found in impure rocks and mineral ores, which must be refined to obtain the pure metals. Knowledge of percentage composition is necessary for metallurgists who want to assess the values of ores and mineral deposits.

Determining Percentage Composition from a Chemical Formula

Metallurgists need to know the percentage composition of different metal ores so they can determine the amount and value of the metal that can be extracted from an ore. To determine the percentage composition of copper(I) sulfide from its chemical formula, $Cu_2S(s)$, a sample mass must be chosen. Recall that the law of definite proportions states that the proportions of the elements in a compound remain the same, no matter what their size or source. Therefore, any mass could be picked for the sample size. The most convenient sample size, however, is equivalent to the molar mass of the compound or, in other words, 1 mol of the compound. This allows the masses of the elements in the sample to be determined directly from the periodic table.

Thus, the mass percent of copper in copper(I) sulfide can be calculated as follows:

$$\begin{aligned}\text{mass percent of Cu} &= \frac{\text{mass of Cu in 1 mol of } Cu_2S}{\text{mass of 1 mol of } Cu_2S} \times 100\% \\ &= \frac{(2 \times 63.55\ \cancel{g})}{159.17\ \cancel{g}} \times 100\% \\ &= 0.798517 \times 100\% \\ &= 79.9\%\end{aligned}$$

Because there are only two elements in the compound, the mass percent of sulfur can be found by subtracting the mass percent of Cu(s) from 100.

$$\begin{aligned}\text{mass percent of S} &= 100\% - 79.9\% \\ &= 20.1\%\end{aligned}$$

Therefore, the percentage composition of copper(I) sulfide is 79.9 percent copper and 20.1 percent sulfur.

The following flowcharts illustrate the steps needed to calculate percentage composition from the chemical formula and the steps needed to calculate percentage composition from mass data. Note that most chemical compounds are composed of more than two elements. The Sample Problem on the following page shows you how the percentage composition of a larger compound is determined.

Suggested Investigation

Inquiry Investigation 6-A, Determining the Percentage Composition of Magnesium Oxide

Determining Percentage Composition

From Mass Data

Measure the masses of the elements in the sample and the mass of the entire sample.

↓

Calculate the mass percent of the elements in the compound sample using mass data.

From Chemical Formula

Confirm the chemical formula.

↓

Calculate the molar mass of the compound. This becomes the sample mass.

↓

Use the periodic table to determine the mass of each element in 1mol of the compound.

↓

Calculate the mass percent of the elements in the compound. Use the mass of each element in 1 mol of the compound and the molar mass of the compound (sample mass).

Sample Problem

Determining Percentage Composition from a Chemical Formula

Problem

The most common copper ore comes from the mineral chalcopyrite, $CuFeS_2(s)$. Determine the percentage composition of chalcopyrite.

What Is Required?

To determine the percentage composition of chalcopyrite, you need to calculate the mass percents of copper, iron, and sulfur in the compound.

What Is Given?

You know the formula for chalcopyrite: $CuFeS_2(s)$

Plan Your Strategy	Act on Your Strategy
Calculate the molar mass of chalcopyrite. This becomes your sample mass.	$M_{CuFeS_2} = 1M_{Cu} + 1M_{Fe} + 2M_S$ $= 1(63.55 \text{ g/mol}) + 1(55.85 \text{ g/mol}) + 2(32.07 \text{ g/mol})$ $= 183.54 \text{ g/mol}$ The molar mass of $CuFeS_2(s)$ is 183.54 g/mol.
Calculate the mass percents of copper, iron, and sulfur. For each calculation, use the mass of the element in 1 mol of the compound and the mass of 1 mol of the compound (the sample mass).	$\text{mass percent of Cu} = \frac{\text{mass of Cu}}{\text{mass of } CuFeS_2} \times 100\% = \frac{63.55 \cancel{g}}{183.54 \cancel{g}} \times 100\% = 34.62\%$ $\text{mass percent of Fe} = \frac{\text{mass of Fe}}{\text{mass of } CuFeS_2} \times 100\% = \frac{55.85 \cancel{g}}{183.54 \cancel{g}} \times 100\% = 30.43\%$ $\text{mass percent of S} = \frac{\text{mass of S}}{\text{mass of } CuFeS_2} \times 100\% = \frac{2(32.07 \cancel{g})}{183.54 \cancel{g}} \times 100\% = 34.95\%$ Therefore, the percentage composition of chalcopyrite is 34.62% copper, 30.43% iron, and 34.95% sulfur by mass.

Check Your Solution

The masses of the three elements in $CuFeS_2(s)$ are very similar. Therefore, each mass is about $\frac{1}{3}$ of the total mass of the sample and the three mass percents add to 100%.

Practice Problems

21. What is the percentage composition of manganese sulfide, $MnS(s)$?

22. What is the percentage composition of silver oxide, $Ag_2O(s)$?

23. Calculate the percentage composition of sulfuric acid, $H_2SO_4(\ell)$.

24. What is the percentage composition of aluminum hydroxide, $Al(OH)_3(s)$?

25. Calculate the percentage composition of strontium nitrate, $Sr(NO_3)_2(s)$.

26. Indigo, $C_{16}H_{10}N_2O_2(s)$, is a blue dye. Determine the percentage composition of indigo.

27. Manganese can be extracted from pyrolusite ore, $MnO_2(s)$. Calculate the mass of manganese that can be extracted from 325 kg of pyrolusite ore.

28. What mass of pure silver is contained in 2.00×10^2 kg of silver nitrate, $AgNO_3(s)$?

29. An 18.4 g sample of silver oxide, $Ag_2O(s)$, is decomposed into silver and oxygen by heating. What mass of silver is produced in the reaction?

30. An industrial chemist is testing some iron ore samples that contain iron(III) oxide, $Fe_2O_3(s)$. The chemist needs to determine if the ore has a high enough mass percent of iron to be suitable for mining. Calculate the mass of iron that could be refined from a sample that contains 355 kg of iron(III) oxide.

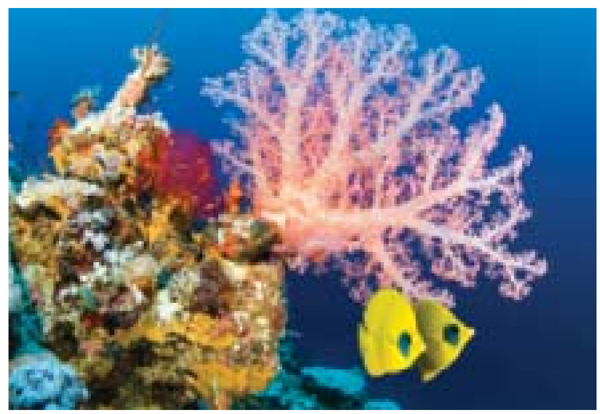
Section 6.1 REVIEW

Section Summary

- The law of definite proportions states that the elements in a chemical compound are always present in the same proportions by mass.
- The same elements can form different compounds when combined in different whole-number ratios.
- The mass percent of an element in a compound is the mass of the element expressed as a percentage of the total mass of the compound.
- The percentage composition of a compound is the percent by mass of each element in a compound.
- Percentage composition can be calculated using either mass data for a substance or the chemical formula for the substance.

Review Questions

1. K/U Samples of carbon dioxide are taken from the atmosphere and from a block of dry ice. Are the chemical formulas for the carbon dioxide in the two samples different? Explain.
2. K/U When determining the percentage composition of a compound from its formula, the calculations are usually based on 1 mol of a sample. Explain why this is the most convenient amount to use.
3. K/U Acetylene, $C_2H_2(g)$, is made up of two carbon atoms and two hydrogen atoms. Explain why acetylene does not contain 50% of each element by mass.
4. T/I What is the mass percent of each element in sucrose, $C_{12}H_{22}O_{11}(s)$?
5. C Draw a flowchart that shows the steps needed to determine the percentage composition of a compound, using the masses of the elements in the compound.
6. T/I A sample of an unknown compound is analyzed and found to contain 0.90 g of calcium and 1.60 g of chlorine. The sample has a mass of 2.50 g. Determine the percentage composition of the compound.
7. T/I A 19.00 kg sample of an unknown compound contains 0.06 kg of hydrogen, 11.01 kg of gold, and 7.93 kg of chlorine. Determine the percentage composition of the compound.
8. K/U In your own words, explain the difference between mass percent and percentage composition.
9. T/I Phosphoric acid, $H_3PO_4(\ell)$, is used in some carbonated beverages to give them a tangy flavour. Determine the percentage composition of phosphoric acid.
10. T/I Determine the percentage composition of magnesium phosphate, $Mg_3(PO_4)_2(s)$.
11. T/I What mass of boron would be in a 35.0 g sample of sodium tetraborate, $Na_2B_4O_7(s)$?
12. A Calcium carbonate, $CaCO_3(s)$, can have many different forms. Coral, shown below, as well as marble and chalk, are substances that have $CaCO_3(s)$ as a principal component.



    a. Determine the percentage composition of this compound.
    b. When acid rain reacts with the marble in a statue, carbon dioxide gas is formed. What does this do to the mass percent of carbon and oxygen in the statue?
13. A Washing soda is the common name for a compound that is used to make soap and glass. Washing soda contains 43.4% sodium by mass and 45.3% oxygen by mass, as well as one other element. If the molar mass of washing soda is 105.99 g/mol, identify the other element.
14. A A typical soap molecule is made up of a polyatomic anion associated with a cation. The polyatomic anion contains hydrogen, carbon, and oxygen. One soap molecule has 18 carbon atoms and contains 70.5% carbon, 11.5% hydrogen, and 10.4% oxygen by mass. It also contains one alkali metal ion. Identify this alkali metal ion.