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Skills to Develop

- Use chemical formulas as conversion factors.

Figure \(\PageIndex{1}\) shows that we need two hydrogen atoms and one oxygen atom to make 1 water molecule. If we want to make two water molecules, we will need four hydrogen atoms and two oxygen atoms. If we want to make five molecules of water, we need 10 hydrogen atoms and 5 oxygen atoms. The ratio of atoms we will need to make any number of water molecules is the same: 2 hydrogen atoms to 1 oxygen atom.

![Water Molecules](image)

*Figure \(\PageIndex{1}\)* Water Molecules. The ratio of hydrogen atoms to oxygen atoms used to make water molecules is always 2:1, no matter how many water molecules are being made.

Using formulas to indicate how many atoms of each element we have in a substance, we can relate the number of moles of molecules to the number of moles of atoms. For example, in 1 mol of water \((H_2O)\) we can construct the relationships given in (Table \(\PageIndex{1}\)).

<table>
<thead>
<tr>
<th>1 Molecule of ((H_2O)) Has</th>
<th>1 Mol of ((H_2O)) Has</th>
<th>Molecular Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2 \text{ H atoms})</td>
<td>(2 \text{ mol of H atoms})</td>
<td>(\text{or}) (\dfrac{2 \text{ mol of H atoms}}{1 \text{ mol of } H_2O \text{ molecules}}) (\text{or}) (\dfrac{1 \text{ mol of } H_2O \text{ molecules}}{2 \text{ mol of H atoms}})</td>
</tr>
<tr>
<td>(1 \text{ O atom})</td>
<td>(1 \text{ mol of O atoms})</td>
<td>(\text{or}) (\dfrac{1 \text{ mol of O atoms}}{1 \text{ mol of } H_2O \text{ molecules}}) (\text{or}) (\dfrac{1 \text{ mol of } H_2O \text{ molecules}}{1 \text{ mol of O atoms}})</td>
</tr>
</tbody>
</table>

The MOle is big
A mole represents a very large number! The number 602,214,129,000,000,000,000,000 looks about twice as long as a trillion, which means it’s about a trillion trillion.

![A mole](image)

Image used with permission (CC BY-SA NC; [https://what-if.xkcd.com/4/](https://what-if.xkcd.com/4/)).

A trillion trillion kilograms is how much a planet weighs. If 1 mol of quarters were stacked in a column, it could stretch back and forth between Earth and the sun 6.8 billion times.

**Table (PageIndex(2)): Molecular and Mass Relationships for Ethanol**

<table>
<thead>
<tr>
<th>1 Molecule of ( C_2H_6O )</th>
<th>1 Mol of ( C_2H_6O )</th>
<th>Molecular and Mass Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 C atoms</td>
<td>2 mol of C atoms</td>
<td>( \frac{2 \text{ mol} \text{ C atoms}}{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}} ) or ( \frac{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}}{2 \text{ mol} \text{ C atoms}} )</td>
</tr>
<tr>
<td>6 H atoms</td>
<td>6 mol of H atoms</td>
<td>( \frac{6 \text{ mol} \text{ H atoms}}{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}} ) or ( \frac{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}}{6 \text{ mol} \text{ H atoms}} )</td>
</tr>
<tr>
<td>1 O atom</td>
<td>1 mol of O atoms</td>
<td>( \frac{1 \text{ mol} \text{ O atoms}}{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}} ) or ( \frac{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}}{1 \text{ mol} \text{ O atoms}} )</td>
</tr>
<tr>
<td>2 (12.01 amu) C</td>
<td>2 (12.01 g) C</td>
<td>( \frac{24.02 \text{ g } C}{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}} ) or ( \frac{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}}{24.02 \text{ g } C} )</td>
</tr>
<tr>
<td>24.02 amu C</td>
<td>24.02 g C</td>
<td></td>
</tr>
<tr>
<td>6 (1.008 amu) H</td>
<td>6 (1.008 g) H</td>
<td>( \frac{6.048 \text{ g } H}{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}} ) or ( \frac{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}}{6.048 \text{ g } H} )</td>
</tr>
<tr>
<td>6.048 amu H</td>
<td>6.048 g H</td>
<td></td>
</tr>
<tr>
<td>1 (16.00 amu) O</td>
<td>1 (16.00 g) O</td>
<td>( \frac{16.00 \text{ g } O}{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}} ) or ( \frac{1 \text{ mol} \text{ } C_2H_6O \text{ molecules}}{16.00 \text{ g } O} )</td>
</tr>
<tr>
<td>16.00 amu O</td>
<td>16.00 g O</td>
<td></td>
</tr>
</tbody>
</table>

The following example illustrates how we can use the relationships in Table (PageIndex(2)) as conversion factors.

**Example (PageIndex(1)): Ethanol**
If a sample consists of 2.5 mol of ethanol (C\(_2\)H\(_6\)O), how many moles of carbon atoms does it have?

**Solution**

**Steps for Problem Solving**

Identify the "given" information and what the problem is asking you to "find."

- Given: 2.5 mol C\(_2\)H\(_6\)O
- Find: mol C atoms

List other known quantities

- 1 mol C\(_2\)H\(_6\)O = 2 mol C

Prepare a concept map and use the proper conversion factor.

\[
\frac{2 \text{ mol C}}{1 \text{ mol } C_2H_6O}
\]

Note how the unit mol C\(_2\)H\(_6\)O molecules cancels algebraically.

Cancel units and calculate.

\[
2.5 \text{ mol C}_2H_6O \times \frac{2 \text{ mol C}}{1 \text{ mol C}_2H_6O} = 5.0 \text{ mol C atoms}
\]

Think about your result.

There are twice as many C atoms in one C\(_2\)H\(_6\)O molecule, so the final amount should be double.

Exercise \(\PageIndex{1}\))

If a sample contains 6.75 mol of Na\(_2\)SO\(_4\), how many moles of sodium atoms, sulfur atoms, and oxygen atoms does it have?

**Answer:**

13.5 mol Na atoms, 6.75 mol S atoms, and 27.0 mol O atoms

The fact that 1 mol equals 6.022 \(\times\) 10\(^{23}\) items can also be used as a conversion factor.

Example \(\PageIndex{2}\)): Oxygen Mass

Determine the mass of Oxygen in 75.0g of C\(_2\)H\(_6\)O.

**Solution**
Steps for Problem Solving

Determine the mass of Oxygen in 75.0g of C\textsubscript{2}H\textsubscript{6}O

Identify the "given" information and what the problem is asking you to "find."

Given: 75.0g C\textsubscript{2}H\textsubscript{6}O
Find: g O

List other known quantities

1 mol O = 16.0g O
1 mol C\textsubscript{2}H\textsubscript{6}O = 1 mol O
1 mol C\textsubscript{2}H\textsubscript{6}O = 46.07g C\textsubscript{2}H\textsubscript{6}O

Prepare a concept map and use the proper conversion factor.

\[
\begin{array}{ccc}
g \text{ C}_2\text{H}_6\text{O} & \xrightarrow{1 \text{ mol C}_2\text{H}_6\text{O}} & 46.07 \text{ g C}_2\text{H}_6\text{O} \\
\times \frac{1 \text{ mol C}_2\text{H}_6\text{O}}{70.98 \text{ g C}_2\text{H}_6\text{O}} & \xrightarrow{1 \text{ mol O}} & 16.00 \text{ g O} \\
& & \xrightarrow{1 \text{ mol O}} \end{array}
\]

Cancel units and calculate.

\[
(75.0 \text{ g C}_2\text{H}_6\text{O}) \times \frac{1 \text{ mol C}_2\text{H}_6\text{O}}{46.07 \text{ g C}_2\text{H}_6\text{O}} \times \frac{1 \text{ mol O}}{1 \text{ mol C}_2\text{H}_6\text{O}} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 26.0 \text{ g O}
\]

Think about your result.

Exercise \(\PageIndex{2}\))

a. How many molecules are present in 16.02 mol of C\textsubscript{4}H\textsubscript{10}? How many C atoms are in 16.02 mol?

b. How many moles of each type of atom are in 2.58 mol of Na\textsubscript{2}SO\textsubscript{4}?

**Answer a:**
9.647 \times 10^{24} \text{ C}_4\text{H}_{10} \text{ molecules and 3.859} \times 10^{25} \text{ C atoms}

**Answer b:**
5.16 \text{ mol Na atoms, 2.58 mol S atoms, and 10.3 mol O atoms}

Summary

In any given formula the ratio of the number of moles of molecules (or formula units) to the number of moles of atoms can be used as a conversion factor.