Big numbers or little numbers? Do you hate to type subscripts and superscripts? Even with a good word-processing program, having to click on an icon to get a superscript and then remembering to click off after you type the number can be a real hassle. If we did not know about moles and just knew about numbers of atoms or molecules (those big numbers that require lots of superscripts), life would be much more complicated and we would make many more typing errors.

Conversions Between Moles and Atoms (Number of Particles)

Using our unit conversion techniques, we can use the mole label to convert back and forth between the number of particles and moles. It can be done easily by using the Mole Wheel.

When using the mole wheel:

1. Put your finger on the known information

2. Follow with finger to desired information

3. Complete calculations along the path
Sample Problems: Converting Between the Number of Particles and Moles

Problem 1: The element carbon exists in two primary forms: graphite and diamond. How many moles of carbon atoms are in $4.72 \times 10^{24}$ atoms of carbon?

**Step 1: List the known**

- number of C atoms = $4.72 \times 10^{24}$
- 1 mole = $6.02 \times 10^{23}$ atoms

**Unknown**

$4.72 \times 10^{24}$ = ? mol C

One conversion factor will allow us to convert from the number of C atoms to moles of C atoms.

**Step 2: Calculate using dimensional analysis**

$$\frac{4.72 \times 10^{24} \text{ atoms C}}{1} \times \frac{1 \text{ mol C}}{6.02 \times 10^{23} \text{ atoms C}} = 7.84 \text{ mol C}$$

Problem 2: Suppose that you wanted to know how many hydrogen atoms were in a mole of water molecules. First, you would need to know the chemical formula for water, which is $H_2O$. There are two atoms of hydrogen in each molecule of water. How many atoms of hydrogen would there be in two water molecules? There would be $2 \times 2 = 4$ hydrogen atoms. How about in a dozen? In that case a dozen is 12 so $12 \times 2 = 24$ hydrogen atoms in a dozen water molecules. To get the answers, (4 and 24) you had to multiply the given number of molecules by two atoms of hydrogen per molecule. So to find the number of hydrogen atoms in a mole of water molecules, the problem could be solved using conversion factors.

**Step 1: List the known**

- mol $H_2O = 1$ mol
- 1 mol = $6.02 \times 10^{23}$ particles

**Unknown**

atoms of H = ?

The first conversion factor converts from moles of particles to the number of particles (molecules of $H_2O$). The second conversion factor reflects the number of atoms contained within each molecule (how many H atoms per molecule $H_2O$).

**Step 2: Calculate using dimensional analysis**

$$\frac{1 \text{ mol } H_2O}{1} \times \frac{6.02 \times 10^{23} \text{ molecules } H_2O}{1 \text{ mol } H_2O} \times \frac{2 \text{ atoms } H}{1 \text{ molecule } H_2O} = 1.20 \times 10^{24} \text{ atoms } H$$

Two water molecules contain 4 hydrogen atoms and 2 oxygen atoms. A mole of water contains 2 moles of hydrogen atoms and 1 mole of oxygen atoms.
Problem 3: Sulfuric acid has the chemical formula $H_2SO_4$. A certain quantity of sulfuric acid contains $4.89 \times 10^{25}$ atoms of oxygen. How many moles of sulfuric acid is the sample?

**Step 1: List the known**

<table>
<thead>
<tr>
<th>Known</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.89 \times 10^{25} = \text{O atoms}$</td>
<td>mol of $H_2SO_4$ molecules = ?</td>
</tr>
<tr>
<td>$1 \text{ mol} = 6.02 \times 10^{23} \text{ molecules } H_2SO_4$</td>
<td></td>
</tr>
</tbody>
</table>

Two conversion factors will be used. First, convert atoms of oxygen to molecules of sulfuric acid. Then, convert molecules of sulfuric acid to moles of sulfuric acid.

**Step 2: Calculate using dimensional analysis**

\[
\frac{4.89 \times 10^{25} \text{ atoms O}}{1} \times \frac{1 \text{ molecule } H_2SO_4}{4 \text{ atoms O}} \times \frac{1 \text{ mol } H_2SO_4}{6.02 \times 10^{23} \text{ molecules } H_2SO_4} = 20.3 \text{ mol } H_2SO_4
\]

**Step 3: Think about your result.**

The original number of oxygen atoms was about 80 times larger than Avogadro's number. Since each sulfuric acid molecule contains 4 oxygen atoms, there are about 20 moles of sulfuric acid molecules.

**Conversion between mass and number of particles**

How much gas is there? Avogadro was interested in studying gases. He theorized that equal volumes of gases under the same conditions contained the same number of particles. Other researchers studied how many gas particles were in a specific volume of gas. Eventually, scientists were able to develop the relationship between number of particles and mass using the idea of moles.

In conversions between moles and the number of particles, you learned how to convert back and forth between moles and the number of representative particles. In Unit 5.2, you have seen how to convert back and forth between moles and mass of a substance in grams. We can combine the two types of problems into one. In order to convert from mass to number of particles or vice-versa, it will first require a conversion to moles.

**Sample Problem: Converting Mass to Particles**

How many molecules is $20.0 \text{ g}$ of chlorine gas, $Cl_2$?
**Step 1: List the known**  

molar mass Cl\(_2\) = 70.90 g/mol  
mass of Cl\(_2\) = 20.0 g  

number of molecules of Cl\(_2\) = ?

Use two conversion factors. The first converts grams of Cl\(_2\) to moles. The second converts moles of Cl\(_2\) to the number of molecules.

**Step 2: Calculate using dimensional analysis**

The problem is done using two consecutive conversion factors. There is no need to explicitly calculate the moles of Cl\(_2\).

\[
\frac{20.0 \text{ g Cl}_2}{1} \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{6.02 \times 10^{23} \text{ molecules Cl}_2}{1 \text{ mol Cl}_2} = 1.70 \times 10^{23} \text{ molecules Cl}_2
\]

**Step 3: Think about your result.**

Since the given mass is less than half of the molar mass of chlorine, the resulting number of molecules is less than half of Avogadro’s number.

**Summary**

- Methods are described for conversions between moles, atoms, and molecules.
- Calculations are illustrated for conversions between mass and number of particles.

**Review**

1. What is the value of Avogadro’s number?
2. How is the number of particles (atoms, molecules, etc.) converted to the number of moles?
3. Why should I know the formula for a molecule in order to calculate the number of moles of one of the atoms?
4. Why can’t we convert directly from number of particles to grams?
5. The periodic table says the atomic weight of chlorine is 35.5. Why can’t I use that value in my calculations?

**Answers**

1. 6.02 x 10\(^{23}\) - this is the number of particles
2. Divide by 6.02 x 10\(^{23}\)
3. The formula will tell the number of each type of atom in the molecule.
4. Conversion from particle to moles must be done first, then moles to grams.
5. Chlorine is a diatomic molecule. It exists as Cl\(_2\).