Name: ______________________ Date: __________

CHALLENGE! 14.1

14.1 The Avogadro Number

READ

Atoms are so small that you could fit millions of them on the head of a pin. As you have learned, the masses of atoms and molecules are measured in atomic mass units. Working with atomic mass units in the laboratory is very difficult because each atomic mass unit has a mass of $^{1}/_{12}$ the mass of one carbon atom.

In order to make atomic mass units more useful, it would be convenient to relate the value of one atomic mass unit to one gram. One gram is an amount of matter we can actually see. For example, the mass of one paper clip is about 2.5 grams. The Avogadro number, 6.02×10^{23}, allows us to convert atomic mass units to grams.

What is a mole?

In chemistry, the term “mole” does not refer to a furry animal that lives underground. In chemistry, a mole is *quantity* of something and is used just like we use the term “dozen.” One dozen is equal to 12. One mole is equal to 6.02×10^{23}, or the Avogadro number. If you have a *dozen* oranges, you have 12. If you have a *mole* of oranges, you have 6.02×10^{23}. This would be enough oranges to cover the entire surface of Earth seven feet deep in oranges!

Could you work with only a dozen atoms in the laboratory? You cannot see 12 atoms without the aid of a very powerful microscope. A mole of atoms would be much easier to work with in the laboratory because the mass of one mole of atoms can be measured in grams. Moles allow us to convert atomic mass units to grams. This relationship is illustrated below:

$$1 \text{ carbon atom} = 12.0 \text{ amu}$$

$$1 \text{ mole of carbon atoms} = 6.02 \times 10^{23} \text{atoms} = 12.0 \text{ grams}$$

To calculate the mass of one mole of any substance (the **molar mass**), you use the periodic table to find the atomic mass (not the mass number) for the element or for the elements that create the compound. You then express this value in grams.

EXAMPLE

Substance	Elements in substance	Atomic mass of element (amu)	No. of atoms of each element	Formula mass (amu)	Molar mass (g)
Na	Na	22.99	1	22.99	22.99
U	U	238.03	1	238.03	238.03
H_2O	H O	1.01 16.00	2 1	18.02	18.02
$CaCO_3$	Ca C O	40.08 12.01 16.00	1 1 3	100.09	100.09
$Al(NO_3)_3$	Al N O	26.98 14.01 16.00	1 3 9	213.01	213.01

CHALLENGE!

14.1

PRACTICE

For the following elements and compounds, complete the following table to calculate the mass of one mole of the substance:

Substance	Elements in substance	Atomic mass of element (amu)	No. of atoms of each element	Formula mass (amu)	Molar mass (g)
Sr					
Ne					
$Ca(OH)_2$					
NaCl					
O_3					
$C_6H_{12}O$					

The molar mass of a substance can be used to calculate the number of particles (atoms or molecules) present in any given mass of a substance. You can determine the number of particles present by using the Avogadro number.

READ

Using the Avogadro number

The Avogadro number states that for one mole of any substance, whether element or compound, there are 6.02×10^{23} particles present in the sample. Those particles are atoms if the substance is an element and molecules if the substance is a compound. If we look again at our previous examples we see that every substance has a different molar mass:

Substance	Elements in substance	Atomic mass of element (amu)	No. of atoms of each element	Formula mass (amu)	Molar mass (g)
Na	Na	22.99	1	22.99	22.99
U	U	238.03	1	238.03	238.03
H_2O	H O	1.01 16.00	2 1	18.02	18.02
CaCO3	Ca C O	40.08 12.01 16.00	1 1 3	100.09	100.09
$Al(NO_3)_3$	Al N O	26.98 14.01 16.00	1 3 9	313.1	313.1

However, one mole of each of these substances contains exactly the same number of fundamental particles, 6.02×10^{23}. The difference is that each of these fundamental particles, atoms, and molecules, has a different mass based on its composition (number of protons and neutrons, numbers and types of atoms). Therefore, the number of particles in one mole of any substance is identical; however, the mass of one mole of substances varies based on the formula mass for that substance.

When a substance's mass is reported in grams and you need to find the number of particles present in the sample, you must first convert the mass in grams to the mass in moles. By using proportions and ratios, you can easily calculate the molar mass of any given amount of substance.

EXAMPLE ▶

How many molecules are in a sample of NaCl that has a mass of 38.9 grams?

First, determine the molar mass of NaCl:

Element	Atomic mass (amu)	No. of atoms	Molar mass (g)
Sodium (Na)	22.99	1	22.99
Chlorine (Cl)	35.45	1	35.45
Molar mass of NaCl			**58.44 g**

Next, determine how many particles are in 38.9 g of NaCl:

We know that 58.44 g of NaCl contains 6.02×10^{23} molecules of NaCl. Therefore, we can set up a proportion to determine the number of molecules in 38.9 g of NaCl:

$$\frac{58.44 \text{ g NaCl}}{6.02 \times 10^{23}} = \frac{38.9 \text{ g NaCl}}{x}$$

Solving for x using cross-multiplication gives us a value of 4.0×10^{23} molecules of NaCl.

CHALLENGE! 14.1

PRACTICE

Complete the following table by determining the molar mass of each listed substance and either providing the number of particles in the given mass of sample or the mass of the sample that contains the given number of particles.

Substance	Molar Mass (g)	Mass of Sample (g)	Number of Particles Present
$MgCO_3$		12.75	
H_2O			296×10^{50}
N_2			7.1×10^{8}
Yb		0.00038	
$Al_2(SO_3)_3$		4657	
K_2CrO_4			0.23×10^{19}