Teacher's Tools® Chemistry

Prerequisites: Moles and Mass: Student Review Notes

Matter can be measured by counting (moles) or by weighing (mass)

The Mole: This is the basic measuring unit of atoms/molecules.

It is a **counting** unit (like a dozen of something means 12 of the items)

1 mole of atoms = Å atoms

1 mole of molecules = Å molecules

1 mole of elephants = Å elephants

Å = Avagodro's Number = 6.022×10^{23}

The **mole** is also associated with a **mass**. The mass of 1 mole of an element is equal to the atomic mass of the element in grams.

1 mole of Copper (Cu) = 6.022×10^{23} Cu atoms = 63.55 g

You need to get a handle on the fact that 1 mole of something is an **incredibly huge number**

A mole of grains of rice would cover all the land in the world to a depth of 75 meters

A mole of hockey pucks is roughly equal to the mass of the moon

A mole of baseballs would just about fit perfectly into a ball bag the size of the Earth

If one mole of pennies was divided equally between every person on earth, each person could spend a million dollars a day and it would still take just under 3,000 years to spend the money. There would not be much to spend it on though since the surface of the Earth would be buried in copper pennies to a depth of about 420 meters.

If you had a mole of water molecules, could you go swimming? The answer is no, it's not enough water. 1 mole of water molecules is 18.02 grams of water. That's about 18 mL of water since the density of water is roughly 1 g/mL.

The thing to get is that there is no practical way to "count" molecules or atoms. What you do is measure out a mass and then divide by the molar mass (atomic mass) and that tells you the number of moles of the sample. If you then wanted to know the number of molecules or atoms, you'd just multiply by Avagodro's Number.

For elements:

1 mole of element = 6.022×10^{23} atoms of element = X g, where X = Atomic Mass

For compunds:

1 mole of compound= 6.022×10^{23} molecules of compound = Y g, where Y = Molar Mass

Take a look:

Element/Compound	Formula	Formula Mass (no units)	Molar Mass (grams/mole)
Atomic Hydrogen	H	1.01	1.01 g/mol
Molecular Hydrogen	H_2	2.02	2.02 g/mol
Carbon Dioxide	CO_2	1(12.01) + 2(16.00)	44.01 g/mole
Water	H_2O	2(1.01) + 1(16.00)	18.02 g/mol

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Using Molar Mass: mole-to-gram and gram-to-mole conversions

How many moles are in 23 grams of gold?

1. Go to the periodic table and find the atomic mass of gold. AM of Au = 196.97 g/mol.
2. Convert from grams to moles:

$$(23\text{ g Au})\left(\frac{1\text{ mole}}{196.97\text{ g}}\right) = 0.117\text{ mol Au}$$

notice that the units of grams cancel

What is the mass of 54.5 mol of water?

1. Go to the periodic table and calculate the molar mass of water. MM H_2O = 2(1.01) + 1(16.00) = 18.02 g/mol
2. Convert from moles to grams:

$$(54.5\text{ mol }H_2O)\left(\frac{18.02\text{ g}}{1\text{ mol}}\right) = 982\text{ g water (3 sig. figs.)}$$

moles cancel

Take a look at this in the context of a chemical reaction:

$$2N_2H_4 + N_2O_4 \longrightarrow 3N_2 + 4H_2O$$

Mole-mole conversions

1. How many moles of water are formed if 5.65 mol of N_2H_4 react?

$$(5.65\text{ mol }N_2H_4)\left(\frac{4\text{ mole }H_2O}{2\text{ mol }N_2H_4}\right) = 11.3\text{ mol of }H_2O$$

this is called the stoichiometric ratio for the two species

Mole-gram conversion

1. How many grams of N_2 are produced from 4.6 mole N_2H_4?

$$(4.6\text{ mol }N_2H_4)\left(\frac{3\text{ mole }N_2}{2\text{ mol }N_2H_4}\right) = 6.9\text{ mol of }N_2$$

$$(6.9\text{ mol }N_2)\left(\frac{28.02\text{ g }N_2}{\text{mol }N_2}\right) = 1.9 \times 10^2\text{ g of }N_2\text{ (2 sig. figs.)}$$

1. How many moles of H_2O are produced from 5.0 g N_2O_4?

$$(5.0\text{ g }N_2O_4)\left(\frac{1\text{ mol }N_2O_4}{92.03\text{ g }N_2O_4}\right)\left(\frac{4\text{ mole }H_2O}{1\text{ mol }N_2O_4}\right) = 0.22\text{ mol of }H_2O$$

Gram-gram conversion

1. How many grams of N_2O_4 are required produced 85.0 g mole N_2?

$$(85.0\text{ g }N_2)\left(\frac{1\text{ mol }N_2}{28.02\text{ g }N_2}\right)\left(\frac{1\text{ mole }N_2O_4}{3\text{ mol }N_2}\right)\left(\frac{92.02\text{ g }N_2O_4}{1\text{ mol }N_2O_4}\right) = 93.0\text{ g of }N_2O_4$$

Prerequisites: Chemical Formulas: Student Review Notes

Types of formulas:

1. **Empirical or simplest formula:** gives the smallest whole number ratio of atoms

2. **Molecular formula:** indicates the actual number of atoms of each element in the molecule.

Obviously, the molecular formula will be a whole number mulitple of the empirical formula.

Percent composition from formula

The atom ratio, mole fraction or **mole ratio** you get right from the subscripts in the chemical formula.

The **mass percent or mass fraction** requires that you use the subscripts and molar mass of each element in the compound.

$$\text{Mass percent of element X} = \frac{\text{mass of element X in compound}}{\text{total mass of compound}} \times 100\%$$

For example, find the mass percent of C, H and O in $C_6H_{12}O_6$:

In one mole of $C_6H_{12}O_6$ there are:

$$\left.\begin{array}{l} (6 \text{ mole C}) \dfrac{12.01 \text{ g}}{\text{mole C}} = 72.06 \text{ g C} \\ (12 \text{ mole H}) \dfrac{1.01 \text{ g}}{\text{mole H}} = 12.12 \text{ g H} \\ (6 \text{ mole O}) \dfrac{16.00 \text{ g}}{\text{mole O}} = 96.00 \text{ g O} \end{array}\right] \text{Molar Mass of } C_6H_{12}O_6 = 180.2 \text{ g/mol}$$

$$\left.\begin{array}{l} \text{Mass \% C} = \dfrac{72.06}{180.2} \times 100\% = 39.99\% \text{ Carbon} \\ \text{Mass \% H} = \dfrac{12.12}{180.2} \times 100\% = 6.727\% \text{ Hydrogen} \\ \text{Mass \% O} = \dfrac{96.00}{180.2} \times 100\% = 53.28\% \text{ Oxygen} \end{array}\right] \text{mass percents have to sum to 100\%}$$

Chemical formula from percent composition

What you do is find the moles (sometimes grams then moles) of each element in the analysis and then find the lowest integer ratio between them (by dividing through by the smallest number of moles). The ratio for each element will be the subscripts for the empirical formula. If you're given the molecular mass you can divide it by the empirical formula weight to find the molecular formula.

Take a look: Combustion of 5.00 g of ethanol gives 9.55 g CO_2 and 5.87 g H_2O.

	Mass, g	Moles	Whole number ratio
Carbon:	$(9.55 \text{ g } CO_2)\left(\dfrac{12.01 \text{ g C}}{44.01 \text{ g } CO_2}\right) = 2.61$	$(2.61 \text{ g C})\left(\dfrac{1 \text{ mole}}{12.01 \text{ g C}}\right) = 0.217 \text{ mol C}$	2
Hydrogen:	$(5.87 \text{ g } H_2O)\left(\dfrac{2.02 \text{ g H}}{18.02 \text{ g } H_2O}\right) = 0.658$	$(.658 \text{ g H})\left(\dfrac{1 \text{ mole}}{1.01 \text{ g H}}\right) = 0.651 \text{ mol H}$	6
Oxygen:	5.00 g - 2.61 g - 0.658 g = 1.73	$(1.73 \text{ g O})\left(\dfrac{1 \text{ mole}}{16.00 \text{ g O}}\right) = 0.108 \text{ mol O}$	1

Empirical formula = C_2H_6O