Counting Atoms and Molecules, Molar Mass, and Stochiometry

Overview

- Introducing the moles and molar mass.
- Isotopes and Molar Masses
- Determining the Mass from the # of moles and # of moles from Mass
- Stochiometry (Back to Chemical Equations)
- Concentrations of Solutions
    - Molar
    - g/L
    - ppm and ppb

Counting Units

- In daily life we use a few counting units for example
  - 12 eggs in a dozen or a dozen crayons
  - 144 plastic necklaces in 1 gross of plastic necklaces or 144 paper towel rolls in 1 gross of paper towel rolls
  - 500 sheets of paper in a ream of paper
- Counting units are used for convenience. They are all annoying when you don't know them yet

A mole

- The counting unit that chemists use is called a mole.
- It is approximately 6.022×10^{23} of something.
- Most often the something is atoms or molecules.
- But other things could be counting in moles it is just a very big number and not that convenient.

Why this number

- A mole is the number of atoms in 12 grams of carbon -12 (^{12}C). --Remember that carbon-12 is the isotope of carbon that has 6 protons and 6 neutrons.
- This is nice because it gives a ratio that we can use in calculations. 12 grams ^{12}C=1 mole ^{12}C

$$\left(\frac{12\ grams\ ^{12}C}{1\ mole\ ^{12}C}\right) \quad or \quad \left(\frac{1\ mole\ ^{12}C}{12\ grams\ ^{12}C}\right)$$

Mass from Moles and Moles from a Mass

- What if we needed to know how many atoms were in a 4.000 g sample of ^{12}C.

$$4.000\,g\ ^{12}C \times \left(\frac{1\,mole\ ^{12}C}{12.000\,g\ ^{12}C}\right) = 0.3333\,moles\ ^{12}C$$

- Or the mass of 6.000 moles of ^{12}C atoms.

$$6.000\,moles\ ^{12}C \times \left(\frac{12.000\,g\ ^{12}C}{1\,moles\ ^{12}C}\right) = 72.00\,moles\ ^{12}C$$

Why ^{12}C? Why not just C?

- Isotopes of the same element have different masses.
- All natural samples of carbon are mostly carbon atoms with 6 protons and 6 neutrons, but there will also be contain carbon atoms with 6 protons and 7 neutrons, and carbon atoms with 6 protons and 8 neutrons.

Isotopes of carbon.

- The number of moles would depend on the sample taken, and there would be no direct relation to the approximate molar mass of neutrons and protons.

http://earthguide.ucsd.edu/fuels/element.html

A Useful Molar Mass

- The ratio of the grams of carbon to the moles of carbon (12 grams C = 1 mole C for ^{12}C)is called the molar mass of ^{12}C.
- But it would be nice to have a ratio that would give us a mass that could be used to relate the number of carbon atoms in our "normal sample" to the mass of that sample.
- This is achieved by taking an weighted average of the molar masses.

Obtaining a More Useful Molar Mass

- In a natural sample of carbon is
- 98.89% carbon-12
- 1.11% carbon-13
- carbon-14 don't worry it won't be there

$$\left(\frac{?\,grams\,C}{1\,mole\,C}\right) = 0.9889 \times \left(\frac{12\,grams\,^{12}C}{1\,mole\,^{12}C}\right) + 0.0111 \times \left(\frac{13.00335\,grams\,^{13}C}{1\,mole\,^{13}C}\right)$$

$$\left(\frac{?\,grams\,C}{1\,mole\,C}\right) = \left(\frac{12.01\,grams\,C}{1\,mole\,C}\right)$$

Beyond ^{12}C

The periodic table gives you the atomic mass of the various elements. Molar mass and atomic mass are the same number just different units. (grams/mole vs atomic mass units)

In our calculations we will be using molar masses because we will not be concerned with the mass of individual atoms.

Atomic Molar Masses and Molecular Molar Masses

- There are times when we are concerned with atoms in there elemental form and in this form the atoms can be treated as isolated units.
- For Example Helium (He)-Helium is a noble gas. It does not form compounds with other element, or molecules with itself. For Helium the number of moles of helium atoms in a 0.0025 g sample can be calculated as follows.

$$0.0025\,g\,He \times \left(\frac{1\,mole\,He}{4.0026\,g\,He}\right) = 6.2 \times 10^{-4}$$

Molecular Masses

- But we will be dealing with molecular forms of non-metals and compounds.
- The molar masses on the periodic table always refer to the atomic molar masses.
- To get the molar mass of a molecule these masses are added together.
- For Example

$$\left(\frac{?\, grams\, H_2O}{1\, mole\, H_2O}\right) = 2 \times \left(\frac{1.00794\, grams\, H_2}{1\, mole\, H}\right) + \left(\frac{15.9994\, grams\, O}{1\, mole\, O}\right)$$

$$\left(\frac{?\, grams\, H_2O}{1\, mole\, H_2O}\right) = \left(\frac{18.0153\, grams\, H_2O}{1\, mole\, H_2O}\right)$$

- What is the mass of 3 moles of H_2O?

$$3\, moles\, H_2O \times \left(\frac{18.0153\, grams\, H_2O}{1\, mole\, H_2O}\right) = 54.0459\, grams\, H_2O$$

- What is the mass of 6.79 moles of H_2O?

$$6.79\, moles\, H_2O \times \left(\frac{18.0153\, grams\, H_2O}{1\, mole\, H_2O}\right) = 122\, grams\, H_2O$$

Using Molar Masses

- 0.581 grams Sodium reacts with chlorine gas. There is plenty of chlorine gas and all of the sodium reacts to form sodium chloride. How many grams of sodium chloride are formed?

$$2Na + Cl_2 \rightarrow 2NaCl$$

① How many moles of Na react.

② How many moles of NaCl are formed.

③ What is the mass of the NaCl formed.

Example Calculation

① How many moles of Na react.

$$0.518\ grams\ Na \times \left(\frac{1\ mole\ Na}{22.9898\ grams\ Na}\right) = 0.0225\ moles\ Na$$

② How many moles of NaCl are formed.

$$0.0225\ moles\ Na \times \left(\frac{2\ moles\ NaCl}{2\ moles\ Na}\right) = 0.0225\ moles\ NaCl$$

③ What is the mass of the NaCl formed.

$$0.0225\ moles\ NaCl \times \left(\frac{58.442\ grams\ NaCl}{1\ mole\ NaCl}\right) = 1.31\ grams\ NaCl$$

How many grams of O_2 are formed when 2.0 grams of H_2O are broken apart?

- $2H_20 \rightarrow 2H_2 + O_2$

① How many moles of H_2O react.

$$2.0\,grams\,H_2O \times \left(\frac{1\,mole\,H_2O}{18.0153\,grams\,H_2O}\right) = 0.111\,moles\,H_2O$$

② How many moles of O_2 are formed.

$$0.111\,moles\,H_2O \times \left(\frac{1\,mole\,O_2}{2\,moles\,H_2O}\right) = 0.0555\,moles\,O_2$$

③ What is the mass of the O_2 formed.

$$0.0555\,moles\,O_2 \times \left(\frac{31.9988\,grams}{1\,mole\,O_2}\right) = 0.056\,moles\,O_2$$