Lab 5 – Gram to Mole Conversions

This week we will look at some calculations that involve moles. **Moles** are the unit that chemists use to describe the **amount of a substance.**

Let's start by looking at the definition of a mole:

$$1 \text{ mole} = 6.022 \times 10^{23} \text{ particles}$$

For this class, the particles that we are interested in are going to be **atoms or molecules**. For example:

$$1 \text{ mole of sodium} = 6.022 \times 10^{23} \text{ sodium atoms}$$

$$1 \text{ mole of water} = 6.022 \times 10^{23} \text{ water molecules}$$

So, what's special about the number 6.022×10^{23}? This number is Avogadro's Constant. It's special to chemists because it allows us to relate **the mass of a substance in grams to the relative atomic mass** (also called atomic weight) **of the substance**. Let's look at this relationship:

Imagine we have a cast iron pan like the one shown to the right. It is made entirely from the element iron (Fe) and we want to know how many moles of Fe it contains.

The nucleus of any atom is comprised of protons and neutrons that **each** weigh 1.661×10^{-24} grams.

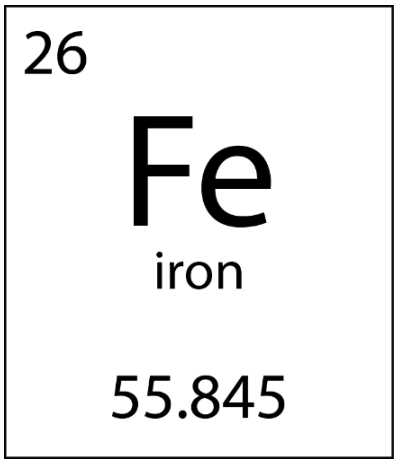
If we were to look closely at an atom of Fe, we would see that it has 26 protons and (on average) 29.845 neutrons. Using this information, we can calculate the mass of an iron atom in grams:

$$1.661 \times 10^{-24} \text{ grams} \times (26 + 29.845) = 9.27 \times 10^{-23} \text{ grams}$$

Now we know the mass for a single atom of Fe, we can calculate the mass for one mole of Fe using Avogadro's constant:

$$1 \text{ mole of Fe} = 6.022 \times 10^{23} \text{ Fe atoms}$$

$$6.022 \times 10^{23} \times 9.27 \times 10^{-23} \text{ grams} = 55.845 \text{ grams}$$



If we look at the periodic table entry for iron, we can see that it has a relative atomic mass of 55.845. Looking back to our calculations, we see that **the numerical value for 1 mole of iron in grams is the same as the value for the relative atomic mass of iron.**

****In fact: the numerical value for 1 mole of <u>any</u> substance in grams is equal to the value for the relative atomic/molecular mass of that substance****

Once we know this, it is easy to calculate how many moles of Fe are in the pan by weighing it, then dividing by the relative atomic mass of Fe. So if the pan weighs 820.5 grams, our answer is:

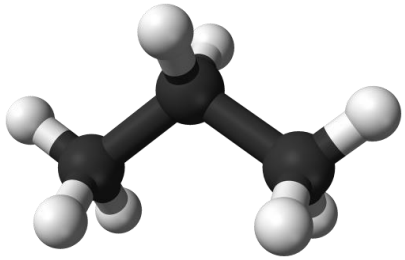
820.5 / 55.845 = 14.69 moles

You can see from the previous page that the values involved when we don't use moles are either very large or very small (e.g., 10^{23}, 10^{-24}). Moles let us work in more convenient units and, as you might see later, are important when performing many calculations in thermodynamics.

Let's look at another example:

Propane is commonly used in gas barbeques and has the chemical formula C_3H_8. Unlike our last example, propane is a molecule. So, 1 mole of propane contains 6.022 x 10^{23} **molecules** of C_3H_8.

Propane molecule:



We can see from the formula for propane, that each propane molecule contains 3 carbon atoms and 8 hydrogen atoms. So, the **relative molecular mass** of propane has to be calculated from the relative atomic masses of carbon and hydrogen we can find in the periodic table:

relative **atomic** mass of carbon x number of carbons in propane =12.01 x 3 = 36.03

relative **atomic** mass of hydrogen x number of hydrogens in propane = 1.01 x 8 = 8.08

relative **molecular** mass of propane = 36.03 + 8.08 = 44.11

Now, let's imagine we are performing a reaction that will consume 3 moles of propane. Our balance in the lab, however, tells us the mass of something in grams. So, we need to know what the mass will be for 3 moles of propane so we can weigh out the correct amount.

We know from our last example that the numerical value for 1 mole of a substance in grams will be the same as the value for relative molecular mass of the substance. So, if the relative molecular mass of propane is 44.11, then:

3 moles of propane in grams = 3 x 44.11 grams = 132.33 grams

So, know we know what mass of propane to add to our reaction.

The following exercises will need you to look back at the examples in the handout. They will also force you to use some of what we have learnt in our previous lab sessions. Remember when you're doing the exercise to **think about significant figures** and **show all your working.**

Exercise:

1. Copy out the table below then fill out the empty boxes with the correct information:

Element/Compound Formula	Name	Relative Atomic/Molecular Mass	Number of Moles	Mass in grams
Al	Aluminium	26.98	1.00	
Au			2.00	393.94
NaCl	Sodium Chloride (Table Salt)	58.44		29.22
	Methane	16.04		192.48
C_2H_5OH	Ethanol	46.07	2.70	
Mg_2SiO_4	Olivine		0.20	
HF		20.01		20.01
$Al_2Si_2O_5(OH)_4$	Kaolinite (China Clay)		0.85	219.44
C_6H_6	Benzene	78.11		187.46
$CaCO_3$			9.30	930.84
$Al(OH)_3$	Gibbsite		1.12	

2. For each of the following, calculate how many atoms make up the item:

a) 1 mole of silver (Ag)

b) 37 grams of SiO_2

c) 0.8 kilograms of NH_3

3. The Golden Gate Bridge contains about 75,000,000 kg of iron. Iron is produced by processing iron ore. One type of iron ore is hematite, which has the formula Fe_2O_3. The density of hematite is 5240 kg/m3. Use this information and the periodic table at the back of the handout to help answer the questions below. Show all your working:

a) How many **moles** of iron make up the Golden Gate Bridge?

b) How many **atoms** of iron make up the Golden Gate Bridge?

c) What **mass** of hematite had to be extracted from the Earth to build the Golden Gate Bridge?

d) What **volume** of hematite had to be extracted from the Earth to build the Golden Gate Bridge?

(*Hint: Remember that density = mass / volume)

4. An element has the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^2$. Assume the element has the same number of protons as it does neutrons, then answer the following questions:

a) How many atoms are in 1 mole of the element?

b) What is the mass of 1 atom of the element? (*hint: 1.661×10^{-24} grams is the weight of a single proton or neutron – see page 1 of the handout.)

c) What is the relative atomic mass of the element?

d) What do you think the element is?

Periodic Table of the Elements

1A												3A	4A	5A	6A	7A	8A
1 **H** 1.00794	2A																2 **He** 4.002602
3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984032	10 **Ne** 20.1797
11 **Na** 22.989769	12 **Mg** 24.3050	3B	4B	5B	6B	7B	8B			1B	2B	13 **Al** 26.9815386	14 **Si** 28.0855	15 **P** 30.973762	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.955912	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.938045	26 **Fe** 55.845	27 **Co** 58.933195	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.64	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.96	43 **Tc** [98]	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.293
55 **Cs** 132.9054519	56 **Ba** 137.327	57-71 Lanthanides	72 **Hf** 178.49	73 **Ta** 180.94788	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.084	79 **Au** 196.966569	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98040	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** [226]	89-103 Actinides	104 **Rf** [267]	105 **Db** [268]	106 **Sg** [271]	107 **Bh** [272]	108 **Hs** [270]	109 **Mt** [276]	110 **Ds** [281]	111 **Rg** [280]	112 **Cn** [285]	113 **Uut** [284]	114 **Fl** [289]	115 **Uup** [288]	116 **Lv** [293]	117 **Uus** [294]	118 **Uuo** [294]

Lanthanides	57 **La** 138.90547	58 **Ce** 140.116	59 **Pr** 140.90765	60 **Nd** 144.242	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.92535	66 **Dy** 162.500	67 **Ho** 164.93032	68 **Er** 167.259	69 **Tm** 168.93421	70 **Yb** 173.054	71 **Lu** 174.9668
Actinides	89 **Ac** [227]	90 **Th** 232.03806	91 **Pa** 231.03588	92 **U** 238.02891	93 **Np** [237]	94 **Pu** [244]	95 **Am** [243]	96 **Cm** [247]	97 **Bk** [247]	98 **Cf** [251]	99 **Es** [252]	100 **Fm** [257]	101 **Md** [258]	102 **No** [259]	103 **Lr** [262]