Chapter 10

The Mole

Mole

- Means an amount….
- If we talk about eggs…
- If we talk about shoes…
- If we talk about cards…
- Avogadro’s number = 6.02×10^{23}

Terms

- Atomic Mass – the mass of an atom based on the mass of Carbon-12 (expressed in amu)
- Mole = 6.02 x 10^{23} particles.
  - Atoms/molecules and moles – when you talk about a mole of particles, the particles are usually atoms or molecules.

Molecules and Formula units

- Molecules are held together by covalent bonds.
  - Molecular mass – mass in amu of one molecule
- Formula units are held together by ionic bonds.
  - Formula Mass – the mass of one formula unit.

More terms…

- Molar Mass – Mass of 1 mole of a substance in grams.

- ALL MASSES are determined using the periodic table
- For Molecular and Formula masses add all elements in the compound and use the unit AMU
- For Molar mass add all elements in the compound and use the unit g

Converting from g to moles to particles (and back the other way too)

- Unit converters
  - 1 mole = 6.02 x 10^{23} particles
  - 1 mole = # of grams (from PT)

- Set up unit converter as a fraction so that units cancel and you are left with new unit on the top

Conversion Examples

- What is the mass of 0.89 mol of $CaCl_2$?

$$0.89 \text{ mol } CaCl_2 \times \frac{111.1 \text{ g } CaCl_2}{1 \text{ mol}} = 99 \text{ g } CaCl_2$$

- A bottle of $PbSO_4$ contains 158.1 g. How many moles of $PbSO_4$ are there?

$$158.1 \text{ g } PbSO_4 \times \frac{1 \text{ mol}}{303.3 \text{ g } PbSO_4} = 0.52 \text{ mol } PbSO_4$$

More examples…

- Determine the number of atoms that are in 0.58 mol of Se.

$$0.58 \text{ mol} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 3.49 \times 10^{23} \text{ atoms}$$

- How many moles of barium nitrate ($Ba(NO_3)_2$ contain 6.80×10^{24} formula units?

$$6.80 \times 10^{24} \text{ formula units} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \quad Ba(NO_3)_2} = 11.3 \text{ mol}$$

More Conversions…

- If you have 27.4 g of gold how many atoms do you have?

$$27.4 \text{ g Au} \times \frac{1 \text{ mol}}{197.0 \text{ g Au}} \times \frac{6.02 \times 10^{23}}{1 \text{ mol}} = 8.4 \times 10^{24} \text{ atoms}$$

More Converting…Moles to L
(and back)

- Unit converter (a new one)
  - 1 mole = 22.4 L at STP (standard conditions)
- Ex. How many L would 1.6 moles of N_2 gas occupy at STP?

$$1.6 \text{ mol } N_2 \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 35.8 \text{ L } N_2$$

- How many *grams* would 13.5 L of CO_2 gas be equal to?

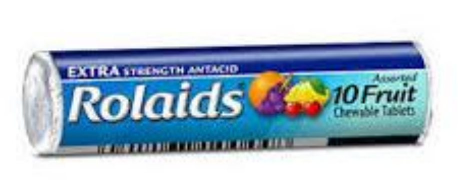
$$13.5 \text{ L } CO_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{44.0 \text{ g } CO_2}{1 \text{ mol } CO_2} = 26.5 \text{ g } CO_2$$

Percent Composition

- Also called MASS percent
  - Compares grams of each individual element in a compound to the total mass of the compound
  - Can be used to distinguish between two compounds that have the same elements in them…ex. CO and CO_2

    - % = (g element/total grams of compound) * 100

Examples from Rolaids WS



1 a. Calcium carbonate is $CaCO_3$

Magnesium hydroxide is $Mg(OH)_2$

1 b. $CaCO_3$ = 100.1 g

$Mg(OH)_2$ = 58.3 g

1 c. % C in $CaCO_3$ C = 12.0 g

so % C = (12.0 g / 100.1 g)x 100 = 12.0 % C

1 d. Try that yourself…

Did you get 54.9%?

Empirical Formula

- Chemical formula that gives the simplest whole-number ratio of atoms in moles
- Ex. WS 10-3 #12
  - Convert all g or % to moles
    - $1.723 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = 0.144 \text{ mol C}$
    - $0.289 \text{ g H} \times \frac{1 \text{ mol H}}{1.0 \text{ g H}} = 0.29 \text{ mol H}$
    - $0.459 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 0.0287 \text{ mol O}$

Ex. continued…

- Divide each mol amount by the lowest of them
  - $\frac{0.144 \text{ mol C}}{0.0287} = 5.02 \text{ mol C}$
  - $\frac{0.29 \text{ mol H}}{0.0287} = 10.0 \text{ mol H}$
  - $\frac{0.0287 \text{ mol O}}{0.0287} = 1 \text{ mol O}$
- Round these values to whole numbers (but not by more than 0.1) or multiply by 2 to get them to be whole numbers

Ex. Continued…

- Use the whole numbers as subscripts for the final formula
  - $C_5H_{10}O$
- Try # 18 on the same worksheet
  - $2.16 \text{ g Al} \times \frac{1 \text{mol}}{27.0 \text{ g}} = \frac{0.0800 \text{ mol Al}}{0.0800} = 1 \times 2 = 2$
  - $3.85 \text{ g S} \times \frac{1 \text{ mol}}{32.1 \text{ g}} = \frac{0.120 \text{ mol S}}{0.0800} = 1.5 \times 2 = 3$
  - $7.68 \text{ g O} \times \frac{1 \text{ mol}}{16.0 \text{ g}} = \frac{0.480 \text{ mol O}}{0.0800} = 6 \times 2 = 12$

$Al_2S_3O_{12}$

or

$Al_2(SO_4)_3$

Molecular Formula

- Molecular Formula – chemical formula that gives the actual number of atoms in moles of each element in a molecule of a compound
- Always a whole number multiple of the simplest ratio (Empirical formula)
- Whole number multiple will be the whole number relationship between the mass of the empirical formula and

Ex. WS 10-3 # 20

- Calculate the empirical formula first
  - $42.56 \text{ g Pd} \times \frac{1 \text{mol Pd}}{106.4 \text{ g Pd}} = 0.4000 \text{ mol Pd}$
  - $0.80 \text{ g H} \times \frac{1 \text{mol H}}{1.0 \text{ g H}} = 0.80 \text{ mol H}$
  - $\frac{0.4000 \text{ mol Pd}}{0.80} = 1 \text{ mol Pd}$ $\frac{0.80 \text{ mol H}}{0.80} = 2 \text{ mol H}$
  - PdH_2

Ex. Continued…

- Calculate the molar mass of the empirical formula
  - PdH_2 = 106.4 + (2 * 1.0) = 108.4 g
- Divide molar mass of molecular formula (given in the problem) by molar mass of empirical formula
  - 216.8 g/108.4g = 2
- Multiply subscripts in the empirical formula ALL by this whole number
  - Pd_2H_4