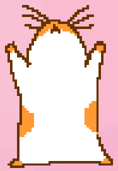
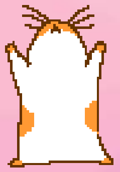
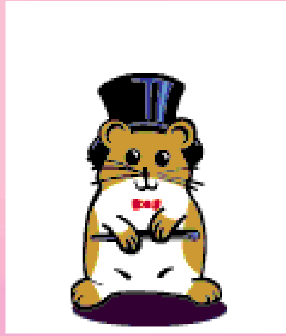
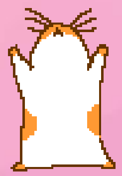
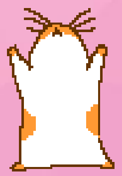
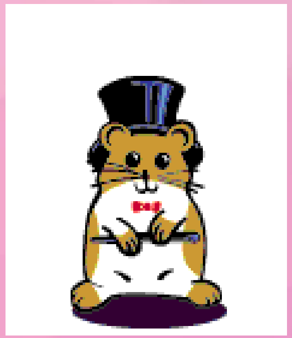
Moles

Chemistry

Karl Steffin, 2001

8/30/2024

By end of this unit I can…

MS6: explain and calculate the relationships between mass, moles and particles.

MS7: calculate percent composition of a compound/molecule/alloy.

MS8: calculate the empirical formula of a compound/molecule/alloy.

MS9: calculate the molecular formula of a compound/molecule/alloy.

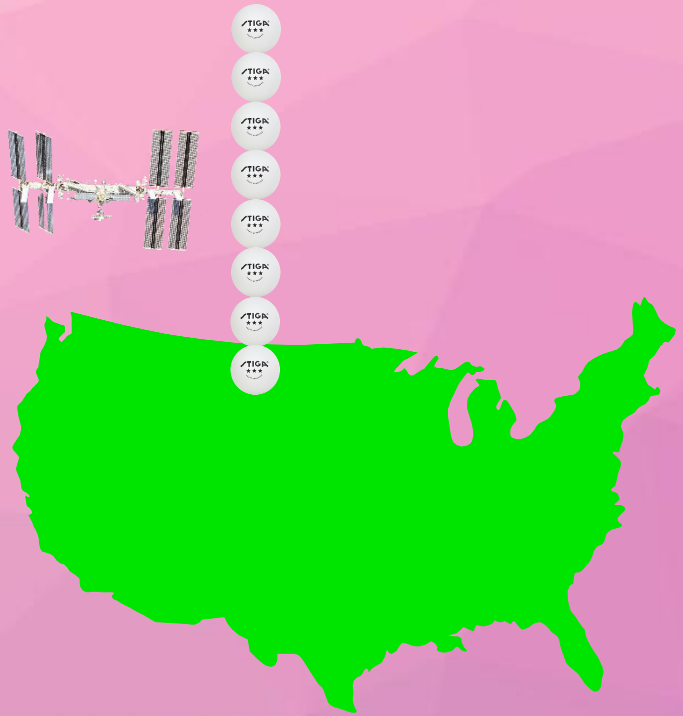
Why Moles?

Chefs often buy things in groups. It would be unreasonable for a baker to just by one egg, or a cheese monger to buy one cup of milk.

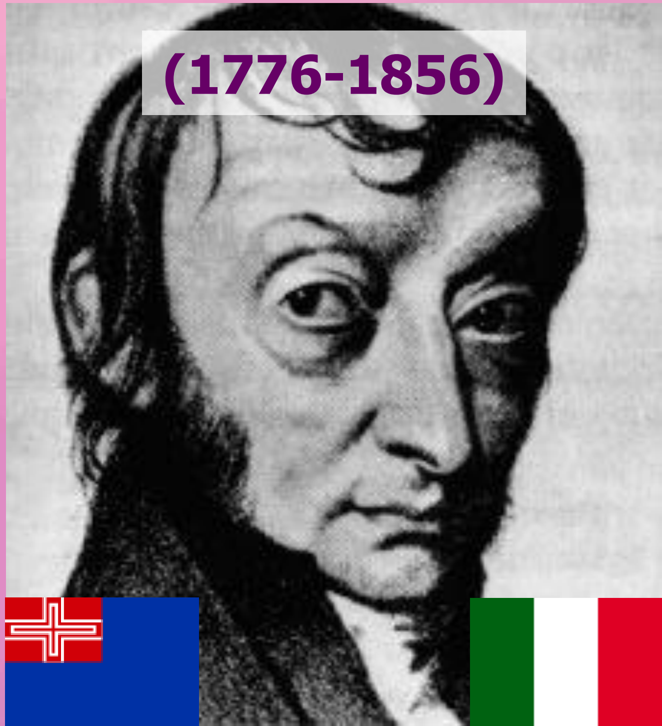
Chemists work on the atomic level, and they too also ‘buy’ things in groups. It is not practical to count every single atom when mixing a chemical. Chemistry therefore needs a way to remain precise while also being efficient.

Amadeo Avogadro Di Quaregna

- Avagadro stated that 1 mole is equal to 602,000,000,000,000,000,000,000. ($6.02 \times 10^{23} = N_{Ava}$) units (atoms, ions, Compounds/Molecules).



1 mole of ping pong balls would cover the United States to a depth of over 621 miles (2x the altitude of the ISS) .



Prove It?

- $D_{PP} = 4x10^{-2}$-m $M_{PP} = 2.7$-g
  $SA_{PP} = 1.6x10^{-3}$-m^2 $SA_{USA} = 9.6x10^{12}$-m^2
  $\Sigma SA_{PP} = SA_{PP}$ x $N_a = 9.6x10^{20}$ -m
  $L = \Sigma SA_{PP}/SA_{USA} = 1.0x10^8$-layers
  $Depth(D) = D_{PP}xL = 4x10^6$-m (2500-mi)

770 balls per square meter.
N_a balls x M_{PP}= $1.6x10^{21}$-kg
That's 44,800,000,000,000 fully loaded semis!

Source: USATT

Another Mind Game:

- You have a 6.02×10^{23} pennies.
- Every day you (being the nice person you are) give $1 million to every person on earth.
- Not counting inflation or interest, how many days would it take you to give your original gains away?

860,000 days (over 2355 years)

What does this mean?

- Moles are a universal 'middleman' to convert to/from other units.
  - Ex: Calculate how many grams are in one mole of Potassium Hydroxide (KOH).
- The number of grams needed is the sum of the periodic weights of K, O, and H.
  - Periodic Weights: Always round to the tenth.

39.1-g + 16.0-g + 1.0-g = 56.1-g

1-mole KOH = 56.1-grams KOH

Trial and Error

- **How many grams are in 1 mole of H_2SO_4?**

Given: 2 H (1.0-g each) = 2.0-g

1 S (32.1-g) = 32.1-g

4 O (16.0-g each) = 64.0-g

2.0-g + 32.1-g + 64.0-g = 98.1-g

1-mole H_2SO_4 = 98.1-g H_2SO_4

Trial and Error Cont.

- How many grams are in 3 moles of H_2O?

Given 2 H (1.0-g each) and 1 O (16.0-g).

2(1.0-g) + 16.0-g = 18.0-g

One mole is 18.0-g, but three are needed…

18.0-g x 3 = 54.0-g

3-moles H_2O = 54.0-g H_2O.

Error and Trial

- How many moles are in 702.0-g of NaCl?

One mole of NaCl is (23.0-g+35.5-g=58.5-g)

Truth for NaCl: 1-mole = 58.5-g

To get rid of the mass divide.

$$702.0\text{-g NaCl} \times \frac{1\text{-mole}}{58.5\text{-g}} = \boxed{12.0\text{-moles NaCl}}$$

702.0-g NaCl = 12.0-mole NaCl.

This is called Dimensional Analysis.

The 'Mole' Matrix

Going to Moles

- Volume → $\frac{\text{1-mol}}{\text{22.4-L}}$ → Mole
- Mass → $\frac{\text{1-mol}}{\text{P. Table}}$ → Mole
- Pieces → $\frac{\text{1-mol}}{N_{Ava}}$ → Mole

Leaving Moles

- Mole → $\frac{\text{22.4-L}}{\text{1-mol}}$ → Volume
- Mole → $\frac{\text{P. Table}}{\text{1-mol}}$ → Mass
- Mole → $\frac{N_{Ava}}{\text{1-mol}}$ → Pieces

Using Liters (Gasses Only)

- If given a molecule’s volume be careful!!!
- The truth 1-mol = 22.4-L only applies to gasses under the following conditions:
  - Temperature must be 273.15-K (0°-C).
  - Pressure must be 1-atm.
  - This is called STP (Standard Temp/Pressure)
- Until the unit on gasses (in spring) always assume any volume given for a gas is at STP.

Solving: Rest of the year

- A general pattern to solve most problems:

1. Write what is known:
   - ##.#-Unit Name (16.5-g NaOH)
   - If the Unit is not moles, convert to moles by…
2. Multiply by a ratio aka 'truth fraction'.
   - Change only one thing at a time
   - The numerator must *equal* the denominator
   - Numerator--- Thing that is wanted.
   - Denominator--- Thing that is removed.
3. Repeat step 2 as needed.

Using the Matrix 1 Step

How many Liters are in 15.0-moles of Nitrogen Dioxide at STP?

$$15.0\text{-}\cancel{mol}\ NO_2 \times \frac{22.4\text{-L}}{1\text{-}\cancel{mol}} = \boxed{336.0\text{-L } NO_2}$$

Using the Matrix 2 Steps

How many molecules are in 250.0-g of Table Sugar ($C_{12}H_{22}O_{11}$)?

$$250.0\text{-}\cancel{g}\ \text{Sugar} \times \frac{1\text{-}\cancel{mol}}{342\text{-}\cancel{g}} \times \frac{N_a\text{-Mol}}{1\text{-}\cancel{mol}}$$

$= 4.4 \times 10^{23}$-Mol Sugar

mol is mole while Mol is Molecule

1 Mol sugar has 45 atoms in it (another truth)

Percent Composition

- Knowing how abundant an element is in a certain molecules is important.
- Review %:
  - % = Part/Whole… Part = Whole x %
  - 0<%<100… 0.0<%<1.0
  - The sum of all Parts = 100%

% Comp. example I

- **Find the % Comp of Hydrogen in Methane.**

  Methane is CH_4.

1. **Find the molar mass of Methane. (whole)**
2. **Divide the mass of all the H (part) by the molar mass (whole).**

   CH_4=12.0-g+4.0-g = 16.0-g

   4.0-g/16.0-g=.25 = 25.0% H
3. **To find C follow the same process.**

   Or… 100.0%-25.0%= 75.0% C

% Comp Example II

- **Find the percentage composition of a compound that contains .10-g of H, 2.30-g Na and 1.60-g O.**

Total Mass .10-g+2.30-g+1.60-g = 4.0-g

H→ .10-g/4.0-g=.025x100 = 2.5% H

O → 1.60-g/4.0-g=.40x100 = 40.0% O

Na → 2.30-g/4.0-g=.575x100 = 57.5% Na

Empirical Formulas

EF: A formula that gives the simple whole number ratio of each element.

1. Find the Molar Mass of each Element.
2. Divide each ans. by the smallest ans.
3. If any answer in step 2 is a fraction: multiply each by the inverse fraction.

Ex) Determine the Empirical Formula for a compound containing 1.203-g Ca and 2.128-g Cl.

Empirical Formulas EX I

1. Find the Molar Mass of each Element.

- Ca: 1.203-g x 1-mol/40.1-g= .030-mol
- Cl: 2.128-g x 1-mol/35.5-g= .060-mol

2. Divide each by the smallest number.

- Ca: .030/.030=1
- Cl: .060/.030=2
- For every 1 Ca there are 2 Cl's. $CaCl_2$
  - Step three was not needed in this problem.

Empirical Formulas EX II

What is the EF of a compound containing 77.72% Iron, 22.28% Carbon?

- If given %, just change the unit to grams.

1. 77.72-g Fe x 1-mol/55.8-g= 1.3928 Fe

   22.28-g C x 1-mol/12.0-g= 1.8566 C
2. Fe: 1.3928/1.3928 = 1

   C: 1.8566/1.3928 = 1.333 (1 ⅓)
3. Multiply by the fractions (⅓) inverse.

   Fe: 1 x 3 = 3 , C: 1.333 x 3 = 4 **Fe_3C_4**

Determining Molecular Formulas

- Empirical models only give ratios
- There is a huge difference between the ion OH^- and the molecule H_2O_2.
  - Both have a 1:1 ratio though
- Determining the MF that considers the actual number of each atom in a compound may be more beneficial.

M Form Example I

Find the MF for a compound that contains 4.90-g N and 11.2-g O. The compounds Molar Mass is 92.0 g/mol.

- **First find the Empirical Formula:**
  - **N: 4.90-g x 1 mol/14.0-g = .35 .35/.35 = 1**
  - **O: 11.2-g x 1 mol/16.0-g = .70 .70/.35 = 2**

- **The MF is any ratio of $N_{(x)}O_{(2x)}$**

M Form Example I cont.

- The smallest mass of $N_{(x)}O_{(2x)}$ is NO_2.
- Find the EF Mass of NO_2? 46.0-g
- x = MF Mass / EF Mass

$$\frac{92.0\text{-g}}{46.0\text{-g}} = 2$$

- Plug back into x. N_2O_4

M Form Example II

β-carotene has an EF of C_5H_7. What is the MF if it has a molar mass of 536-g/mol?

- **We have the Empirical Formula:**
  - **MF = $C_{5x}H_{7x}$**
  - **EF (x=1): C_5H_7 = 67-g**
  - **X=MF Mass/EF Mass**

$$\frac{536\text{-g}}{67\text{-g}} = 8 = C_{40}H_{56}$$