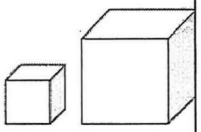
**Chemistry**
**The Mole** → # of atoms in exactly 12.000g of $^{12}C$

Name: Key

## The Mole

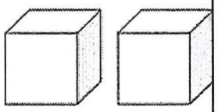
### Comparing Sizes

- Blocks A and B both have a mass of 50 g, but block A has a volume of 50 $cm^3$ while block B has a volume of 400 $cm^3$. Which has more particles?



Unknown size = no particle comparison

- Blocks C and D are both 150 $cm^3$, but block C has a mass of 10 g while block D has a mass of 50 g. Which has more particles?



Unknown mass = no particle comparison

### What is a Mole?

1 pair of socks = 2 socks
1 dozen eggs = 12 eggs
1 gross of goblins = 144 goblins
1 great gross of peanuts = 1728 peanuts

1 score of years = 20 years
1 great score of pennies = 400 pennies
1 mole of an item = _____ items
$6.022 \times 10^{23}$

## Practice

A mole of pennies: $6.022 \times 10^{23}$

A mole of grains of sand: _____

A mole of hockey pucks: _____

## Molar Mass

- Molar Mass - the mass of one mole of a pure substance
  - Units - $\frac{g}{mol}$
  - Is found on the periodic table rounded to two (2) decimal places
  - C: 12.01
  - $C_6H_{12}O_6$:
    - C = $6 \times 12.01$
    - H = $12 \times 1.01$ = 180.18 g/mol
    - O = $6 \times 16.00$
  - Calcium Hydroxide: $Ca(OH)_2$

$40.08 + (2 \times 16.00) + (2 \cdot 1.01) = 74.10\ g/mol$

## Practice:

1. Mg - 24.31 g/mol
2. $MgCl_2$ -

$24.31 + (2 \cdot 35.45) = 95.21\ g/mol$

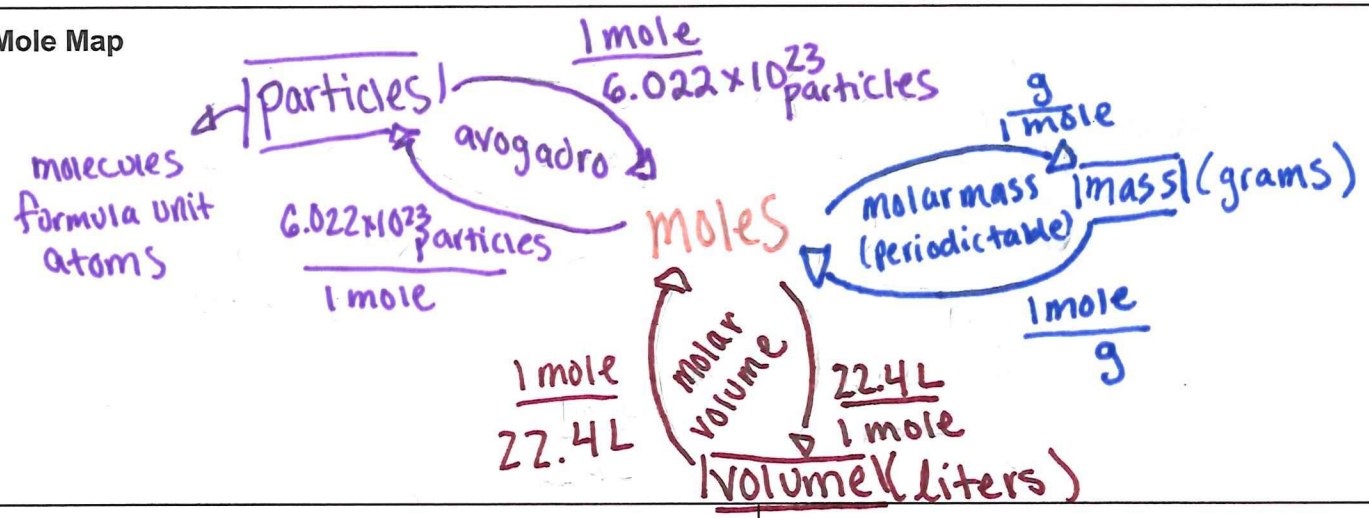
3. $PbSO_4$ -

$207.20 + 32.06 + (4 \times 16.00) = 303.26\ g/mol$

4. A 3.45 g sample of an element contains 0.150 mol of atoms. What is this element?

$\frac{3.45\ g}{0.150\ mol} = 23\ g/mol$ → match to periodic table mass = Na → Sodium

**Creating the Mole Map**




**Relating Mass to Moles to # of Atoms using Dimensional Analysis**

How do we convert among particles, moles and grams?

- Always start with what is given and cancel out units to get to what you are looking for.

- There are 6.23 moles of Al. (given)
  - How many grams of Al are there? (end)

$$6.23 \text{ moles} \times \frac{26.98 \text{ g}}{1 \text{ mole}} = 168.09 \text{ g Al} \rightarrow 168 \text{ g Al}$$

(3) (4) molar mass; 3 sig figs

  - How many molecules? (4)

$$6.23 \text{ moles} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mole}} = 3.75 \times 10^{24} \text{ molecules Al}$$

(3) avogadro

- There are 111.7 g of Fe. (given)
  - How many atoms? (end)

$$111.7 \text{ g Fe} \times \frac{1 \text{ mol}}{55.85 \text{ g Fe}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.204 \times 10^{24} \text{ atoms}$$

(4) (4) molar mass; avogadro; (4)

**Practice**

1. What is the mass of 0.650 moles of copper atoms in grams?

$$0.650 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 41.3075 \rightarrow 41.3 \text{ g Cu}$$

molar mass

2. How many atoms are in a 30.5 g sample of aluminum?

$$30.5 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g Al}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 6.8076 \times 10^{23} \rightarrow 6.81 \times 10^{23} \text{ atoms Al}$$

molar mass; avogadro

3. If you have a $2.34 \times 10^{24}$ molecules of NaCl, how many grams do you have in total? (22.99 + 35.45 = ?)

$$2.34 \times 10^{24} \text{ molecules NaCl} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ m.c.}} \times \frac{58.44 \text{ g}}{1 \text{ mol}} =$$

avo.; molar mass

$$227.0833 \rightarrow 227 \text{ g NaCl}$$

## Molar Volume

**1 mole = 6.022 x $10^{23}$ molecules = 22.4 L (@ STP)**

STP= Standard temp + pressure 0°C + 1 atm

Conversion Factor: $\frac{1\text{ mole}}{22.4\text{ L}}$ or $\frac{22.4\text{ L}}{1\text{ mole}}$

1. What volume will 7.29 moles of $CO_2$ gas occupy at STP?

$7.29\text{ moles} \times \frac{22.4\text{ L}}{1\text{ mol}} = 163.296$

$\Rightarrow 163\text{ L } CO_2 \text{ @ STP}$

2. What mass of $CO_2$ gas occupies a volume of 100. Liters at STP? $12.01 + (2 \cdot 16.00)$

$100.\text{ L} \times \frac{1\text{ mol}}{22.4\text{ L}} \times \frac{44.01\text{ g}}{1\text{ mol}} = 196.47$

(molar vol; molar mass)

$\Rightarrow 196\text{ g } CO_2 \text{ @ STP}$

## Practice

1. What volume will 2.22 moles of $CO_2$ gas occupy at STP?

$2.22\text{ moles } CO_2 \times \frac{22.4\text{ L}}{1\text{ mol}} = 49.728$

$49.7\text{ L } CO_2 \text{ @ STP}$

2. What mass of $SO_2$ gas occupies a volume of 47.9 Liters at STP?

$47.9\text{ L} \times \frac{1\text{ mol}}{22.4\text{ L}} \times \frac{64.07\text{ g}}{1\text{ mol}} = 137.006$

$137\text{ g } SO_2$

(molar mass: $32.07 + (2 \cdot 16)$)

## Mass Percent Composition

1. Find the molar mass of the compound
2. Calculate the mass due to the component in the compound you are solving for.
3. Divide the mass due to the component by the total molar mass of the compound.
4. Multiply by 100.

$$\%X = \frac{\text{mass of } X}{\text{molar mass}} \times 100\%$$

Find the % composition of Nitrogen in $NH_4NO_3$.

① $14.01 \times 2\text{ N} = 28.02$

② $(14.02 \times 2) + (4 \cdot 1.01) + (3 \cdot 16.00) = 80.08$

③ $\frac{28.02}{80.08}$ ④ $\times 100 = 35.00\%$

**Practice:** Determine the percent composition of each element in Calcium Phosphate. $Ca_3(PO_4)_2$

Total: $(3 \cdot 40.08)_{120.24} + (2 \cdot 30.97)_{61.94} + (8 \cdot 16.00)_{128.00} = 310.18\text{ g/mol}$ (Ca, P, O)

Ca: $\frac{120.24}{310.18} \times 100 = 38.76\%$

P: $\frac{61.94}{310.14} \times 100 = 19.97\%$

O: $\frac{128.00}{310.18} \times 100 = 41.27\%$

$\Rightarrow 100\%$ ☺

## Empirical Formula and Molecular Formula

**Empirical Formula:** Simplest form in which a compound is written

-represents the simplest form where there is the lowest whole number ratio of atoms in the compound

**Molecular Formula:** the actual formula of a compound

*Sometimes they are the same*

## Practice

| | Molecular Formula | Empirical Formula | | Molecular Formula | Empirical Formula |
|---|---|---|---|---|---|
| * | $C_5H_5$ | $C_5H_5$ | * | $C_5H_9$ | $C_5H_9$ |
| | $C_6H_6$ | CH | | $C_2H_{10}$ | $CH_5$ |
| | $C_2H_4$ | $CH_2$ | * | $C_{20}H_{49}O_6$ | $C_{10}H_{49}O_6$ |
| | $H_2O_2$ | HO | | $C_2H_8N_4O_2$ | $CH_4N_2O$ |
| | | | ÷17 | $C_{102}H_{51}N_{17}O_{17}F_{34}$ | $C_6H_3NOF_2$ |

## Using Percent Composition to Determine the Empirical Formula

1. Assume 100-gram sample (if percent)
2. Convert from grams to moles using molar mass
3. Divide by the smallest number of moles
4. Write the formula

**Practice**

Determine the empirical formula of a compound containing 32.38% sodium, 22.65% sulfur, and 44.99% oxygen.

① ②

Na → $32.38\,g \times \frac{1\,mol}{22.99\,g} = 1.408\,mol$ / 0.7063 = 1.99 → 2 ③

S → $22.65\,g \times \frac{1\,mol}{32.07\,g} = 0.7063\,mol$ / 0.7063 = 1

↳ smallest

O → $44.99\,g \times \frac{1\,mol}{16.00\,g} = 2.812\,mol$ / 0.7063 = 3.98 → 4

④ $Na_2SO_4$

**Using Percent Composition to Determine the Empirical Formula**

*If the ratios are not whole numbers, multiply all the numbers by a small whole number to get whole numbers.

| Fractional Number | Multiply by this |
|---|---|
| .20/.40/.80 | 5 |
| .25/.75 | 4 |
| .33/.66 | 3 |
| .50 | 2 |

Determine the empirical formula of a 10.150 g sample of a compound containing phosphorus and oxygen with a phosphorus content of 4.433 g.

① ②

P → $4.433\,g \times \frac{1\,mol}{30.97\,g} = 0.1431\,mol$ ③ $/0.1431 = 1 \times 2 = 2$ (3.5)

O → $10.150 - 4.433 = 5.717\,g \times \frac{1\,mol}{16.00\,g} = 0.3573\,mol$ $/0.1431 = 2.5 \times 2 = 5$

④ $P_2O_5$

**Determining the Molecular Formula**

1) Determine Empirical Formula
2) Determine the molar mass of the empirical formula
3) Divide molecular mass by empirical formulas mass to determine how many times greater the molecular mass is than the empirical formula.
4) Multiply the empirical formula subscripts by the answer

The empirical formula from the previous problem was $P_2O_5$. ①
Experimentation shows that the molar mass of this compound is 283.89 g/mol. What is the molecular formula of the compound?

② $(2 \times 30.97) + (5 \times 16.00) = 141.94$

③ $\frac{283.89}{141.94} = 2$ ④ $(P_2O_5)$

$P_4O_{10}$

**Hydrates**

Set number of water molecules loosely bonded to an ionic compound

Dehydrating heating removes the water

anhydrous salt - the dehydrated compound left after heating

**Naming**: Ionic Compound· prefix hydrate

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| mono | di | tri | tetra | penta |
| 6 | 7 | 8 | 9 | 10 |
| hexa | hepta | octa | nona | deca |

*Either an empirical formula or percent composition problem*

**Practice**

1. Write the formula for the following
   a. Copper (II) Sulfate * Pentahydrate $CuSO_4 \cdot 5H_2O$
   b. $Na_2CO_3 \cdot 10\ H_2O$ Sodium carbonate · decahydrate

2. Find the mass percentage of water in $CuSO_4 * 5H_2O$

$\frac{\text{Water mass}}{\text{total mass}} \times 100$

$63.55 + 32.07 + (4 \cdot 16.00) + (5 \cdot 18.01) = 217.6091 \text{ mol}$

$\frac{90.0591 \text{ mol}}{217.6091 \text{ mol}} \times 100$

41.38%

3. Write the formula for a 5.0 g sample of a hydrate of $BaCl_2$ that was heated and only 4.26 g of the anhydrous salt remained.

Hydrate = 5.0g

$BaCl_2$ = 4.26g

Water = 0.74g

$BaCl_2$ $4.26\text{g} \times \frac{1\text{mol}}{208.23\text{g}} = 0.02046$ (smallest) $/ 0.02046 = 1$

$H_2O$ $0.74\text{g} \times \frac{1\text{mol}}{18.01\text{g}} = 0.04109 / 0.02046 = 2$ ← how many waters

$BaCl_2 \cdot 2H_2O$