

2<sup>nd</sup>

Semester

Academic year 2025

# Stoichiometry

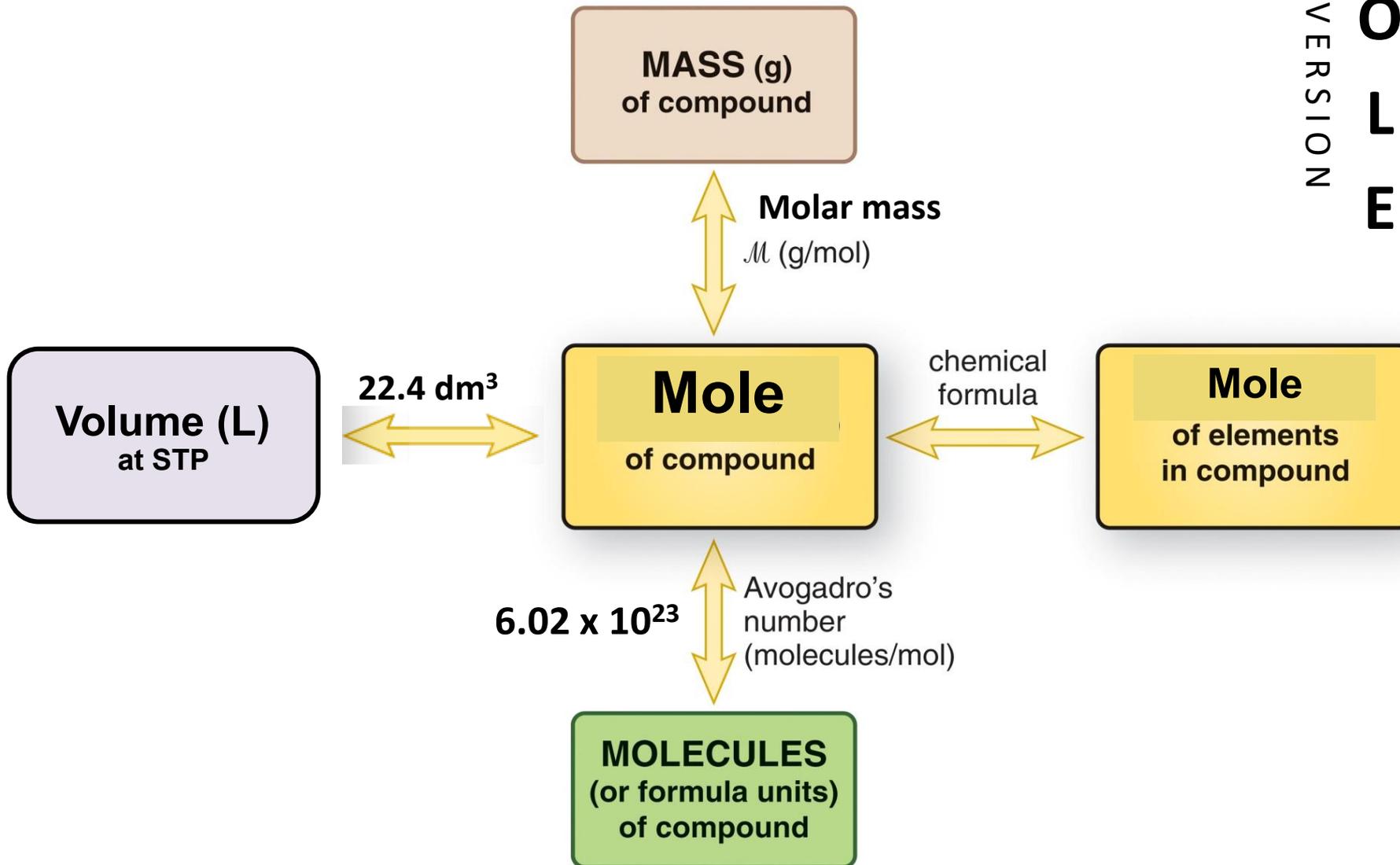
Mass Relationships in Chemical Reactions



CHEMISTRY

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# M O L E C O N V E R S I O N



# OUTLINE

- 1) Atomic mass, average atomic mass
- 2) Molecular weight / Formula weight
- 3) Mole
  - 3.1 Relationship between mole and avogadro's number
  - 3.2 Converting mole to gram
  - 3.3 Converting mole to number of particles
- 4) Avogadro's law (STP)
- 5) Preparation of solution, Term of Concentration Units
- 6) % composition
- 7) Determining formula
- 8) How to balance chemical equation
- 9) Mole relationship
- 10) Limiting agent
- 11) %yield

# The modern periodic table.

MAIN-GROUP ELEMENTS		TRANSITION ELEMENTS										MAIN-GROUP ELEMENTS					
1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8) (9) (10)			1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1 <b>H</b> 1.008												<b>B</b> 10.81	<b>C</b> 12.01	<b>N</b> 14.01	<b>O</b> 16.00	<b>F</b> 19.00	<b>He</b> 4.003
2 <b>Li</b> 6.941	<b>Be</b> 9.012											<b>Al</b> 26.98	<b>Si</b> 28.09	<b>P</b> 30.97	<b>S</b> 32.07	<b>Cl</b> 35.45	<b>Ar</b> 39.95
3 <b>Na</b> 22.99	<b>Mg</b> 24.31											<b>Ga</b> 69.72	<b>Ge</b> 72.61	<b>As</b> 74.92	<b>Se</b> 78.96	<b>Br</b> 79.90	<b>Kr</b> 83.80
4 <b>K</b> 39.10	<b>Ca</b> 40.08	<b>Sc</b> 44.96	<b>Ti</b> 47.88	<b>V</b> 50.94	<b>Cr</b> 52.00	<b>Mn</b> 54.94	<b>Fe</b> 55.85	<b>Co</b> 58.93	<b>Ni</b> 58.69	<b>Cu</b> 63.55	<b>Zn</b> 65.41	<b>In</b> 114.8	<b>Sn</b> 118.7	<b>Sb</b> 121.8	<b>Te</b> 127.6	<b>I</b> 126.9	<b>Xe</b> 131.3
5 <b>Rb</b> 85.47	<b>Sr</b> 87.62	<b>Y</b> 88.91	<b>Zr</b> 91.22	<b>Nb</b> 92.91	<b>Mo</b> 95.94	<b>Tc</b> (98)	<b>Ru</b> 101.1	<b>Rh</b> 102.9	<b>Pd</b> 106.4	<b>Ag</b> 107.9	<b>Cd</b> 112.4	<b>Bi</b> 209.0	<b>Po</b> (209)	<b>At</b> (210)	<b>Rn</b> (222)		
6 <b>Cs</b> 132.9	<b>Ba</b> 137.3	<b>La</b> 138.9	<b>Hf</b> 178.5	<b>Ta</b> 180.9	<b>W</b> 183.9	<b>Re</b> 186.2	<b>Os</b> 190.2	<b>Ir</b> 192.2	<b>Pt</b> 195.1	<b>Au</b> 197.0	<b>Hg</b> 200.6	<b>Tl</b> 204.4	<b>Pb</b> 207.2	<b>Bi</b> 209.0	<b>Po</b> (209)	<b>At</b> (210)	<b>Rn</b> (222)
7 <b>Fr</b> (223)	<b>Ra</b> (226)	<b>Ac</b> (227)	<b>Rf</b> (263)	<b>Db</b> (262)	<b>Sg</b> (266)	<b>Bh</b> (267)	<b>Hs</b> (277)	<b>Mt</b> (268)	<b>Ds</b> (281)	<b>Rg</b> (272)	<b>Cn</b> (285)	<b>Uu</b> (286)	<b>Uub</b> (289)	<b>Uuq</b> (292)	<b>Uuo</b> (294)		

4 — Atomic number  
**Be** — Atomic symbol  
 9.012 — Atomic mass (amu)

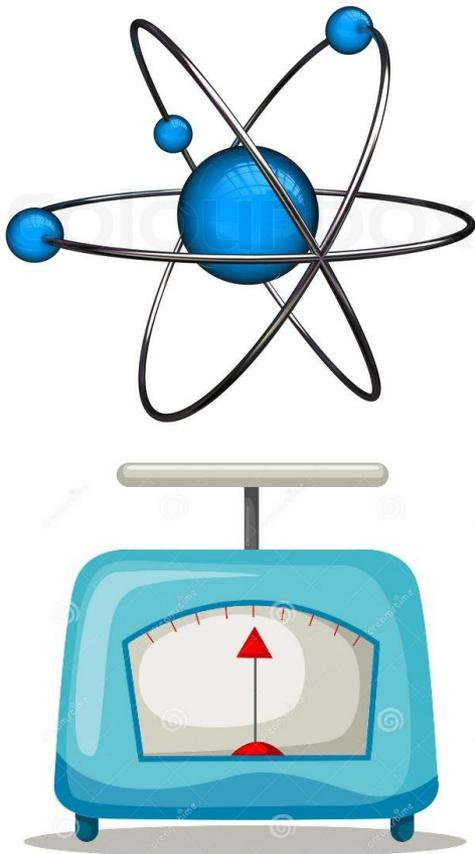
- Metals (main-group)
- Metals (transition)
- Metals (inner transition)
- Metalloids
- Nonmetals

## INNER TRANSITION ELEMENTS

6	Lanthanides	58 <b>Ce</b> 140.1	59 <b>Pr</b> 140.9	60 <b>Nd</b> 144.2	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.4	63 <b>Eu</b> 152.0	64 <b>Gd</b> 157.3	65 <b>Tb</b> 158.9	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.9	68 <b>Er</b> 167.3	69 <b>Tm</b> 168.9	70 <b>Yb</b> 173.0	71 <b>Lu</b> 175.0
7	Actinides	90 <b>Th</b> 232.0	91 <b>Pa</b> (231)	92 <b>U</b> 238.0	93 <b>Np</b> (237)	94 <b>Pu</b> (242)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (260)

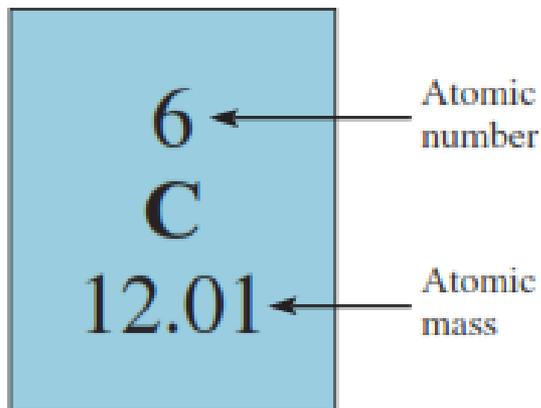
# *Atomic Mass*

How Much Do Atoms Weigh?



# Atomic mass

**Atomic mass** (sometimes called *atomic weight*) is the mass of an atom in atomic mass units (*amu*)



By definition:  
1 atom  $^{12}\text{C}$  “weighs” 12 amu

On this scale

$$^1\text{H} = 1.008 \text{ amu}$$

$$^{16}\text{O} = 16.00 \text{ amu}$$

# Atomic mass unit

An **atomic mass unit** (amu) is defined as the mass of 1/12 the mass of 1 carbon-12 atom. The relative masses of atoms are internationally agreed upon and universally accepted.

$$\text{amu} = \frac{1}{12} \text{ mass of C-12 one atom}$$

$$1 \text{ amu} = 1.67 \times 10^{-24} \text{ g}$$

Atoms have very tiny masses so scientists made a unit to avoid using very small numbers

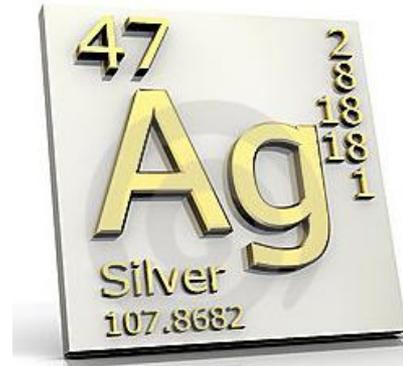
# Periodic Table of the Elements

<i>IA</i>										<i>VIIIA</i>																																							
1 2.1 <b>H</b> Hydrogen 1.008											2 4.003 <b>He</b> Helium																																						
										<i>IIIA</i>					<i>IVA</i>					<i>VA</i>					<i>VIA</i>					<i>VIIA</i>																			
3 1.0 <b>Li</b> Lithium 6.941	4 1.5 <b>Be</b> Beryllium 9.012											5 2.0 <b>B</b> Boron 10.81	6 2.5 <b>C</b> Carbon 12.01	7 3.0 <b>N</b> Nitrogen 14.01	8 3.5 <b>O</b> Oxygen 16.00	9 4.0 <b>F</b> Fluorine 19.00	10 20.18 <b>Ne</b> Neon																																
11 0.9 <b>Na</b> Sodium 22.99	12 1.2 <b>Mg</b> Magnesium 24.31											13 1.5 <b>Al</b> Aluminum 26.98	14 1.8 <b>Si</b> Silicon 28.09	15 2.1 <b>P</b> Phosphorus 30.97	16 2.5 <b>S</b> Sulfur 32.07	17 3.0 <b>Cl</b> Chlorine 35.45	18 39.95 <b>Ar</b> Argon																																
										<i>IIIB</i>					<i>IVB</i>					<i>VB</i>					<i>VIB</i>					<i>VII B</i>					<i>VIII B</i>					<i>IB</i>					<i>IIB</i>				
19 0.8 <b>K</b> Potassium 39.10	20 1.0 <b>Ca</b> Calcium 40.08	21 1.3 <b>Sc</b> Scandium 44.96	22 1.5 <b>Ti</b> Titanium 47.88	23 1.6 <b>V</b> Vanadium 50.94	24 1.6 <b>Cr</b> Chromium 52.00	25 1.5 <b>Mn</b> Manganese 54.94	26 1.8 <b>Fe</b> Iron 55.85	27 1.8 <b>Co</b> Cobalt 58.93	28 1.9 <b>Ni</b> Nickel 58.69	29 1.9 <b>Cu</b> Copper 63.55	30 1.6 <b>Zn</b> Zinc 65.39	31 1.6 <b>Ga</b> Gallium 69.72	32 1.8 <b>Ge</b> Germanium 72.61	33 2.0 <b>As</b> Arsenic 74.92	34 2.4 <b>Se</b> Selenium 78.96	35 2.8 <b>Br</b> Bromine 79.90	36 83.80 <b>Kr</b> Krypton																																
37 0.8 <b>Rb</b> Rubidium 85.47	38 1.0 <b>Sr</b> Strontium 87.62	39 1.2 <b>Y</b> Yttrium 88.91	40 1.4 <b>Zr</b> Zirconium 91.22	41 1.6 <b>Nb</b> Niobium 92.91	42 1.8 <b>Mo</b> Molybdenum 95.94	43 1.9 <b>Tc</b> Technetium 98	44 2.2 <b>Ru</b> Ruthenium 101.1	45 2.2 <b>Rh</b> Rhodium 102.9	46 2.2 <b>Pd</b> Palladium 106.4	47 1.9 <b>Ag</b> Silver 107.9	48 1.7 <b>Cd</b> Cadmium 112.4	49 1.7 <b>In</b> Indium 114.8	50 1.8 <b>Sn</b> Tin 118.7	51 1.9 <b>Sb</b> Antimony 121.8	52 2.1 <b>Te</b> Tellurium 127.6	53 2.5 <b>I</b> Iodine 126.9	54 131.3 <b>Xe</b> Xenon																																
55 0.7 <b>Cs</b> Cesium 132.9	56 0.9 <b>Ba</b> Barium 137.3	57 1.1 <b>La</b> Lanthanum 138.9	72 1.3 <b>Hf</b> Hafnium 178.5	73 1.5 <b>Ta</b> Tantalum 180.9	74 1.7 <b>W</b> Tungsten 183.9	75 1.9 <b>Re</b> Rhenium 186.2	76 2.2 <b>Os</b> Osmium 190.2	77 2.2 <b>Ir</b> Iridium 192.2	78 2.2 <b>Pt</b> Platinum 195.1	79 2.4 <b>Au</b> Gold 197.0	80 1.9 <b>Hg</b> Mercury 200.6	81 1.8 <b>Tl</b> Thallium 204.4	82 1.8 <b>Pb</b> Lead 207.2	83 1.9 <b>Bi</b> Bismuth 209.0	84 2.0 <b>Po</b> Polonium 209	85 2.2 <b>At</b> Astatine 210	86 222 <b>Rn</b> Radon																																
87 0.7 <b>Fr</b> Francium 223	88 0.9 <b>Ra</b> Radium 226.0	89 1.3 <b>Ac</b> Actinium 227.0	104 <b>Rf</b> Rutherfordium 267	105 <b>Db</b> Dubnium 268	106 <b>Sg</b> Seaborgium 271	107 <b>Bh</b> Bohrium 272	108 <b>Hs</b> Hassium 270	109 <b>Mt</b> Meitnerium 276	110 <b>Ds</b> Darmstadtium 281	111 <b>Rg</b> Roentgenium 280	112 <b>Uub</b> Ununbium 285	113 <b>Uut</b> Ununtrium 284	114 <b>Uuq</b> Ununquadium 289	115 <b>Uup</b> Ununpentium 288	116 <b>Uuh</b> Ununhexium 293	117 <b>Uus</b> Ununseptium (-)	118 294 <b>Uno</b> Ununoctium																																

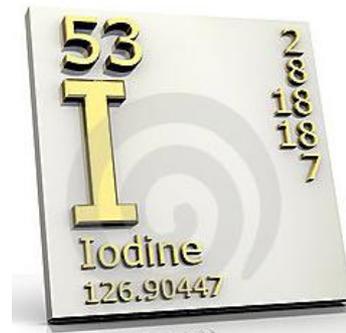
atomic number → 14 1.8 ← electronegativity  
 ← symbol: **Si**  
 atomic weight → Silicon 28.09  
 ← symbol: **Si**  
 black = solid  
 white = synthetic  
 red = gaseous  
 blue = liquid  
 (25° C, 1 atm.)

# Question | Atomic mass

1) What is the mass (in grams) of one Ag atom?



2) What is the mass (in grams) of one iodine (I) atom? (atomic mass = 127)



## คำถามแนวคิดเรื่อง โมล (ก่อนเรียน)

- ❑ ระหว่างลูกหวายรางวัลที่ 1 จำนวน 10 ใบ **Vs** มีเงิน 1 โมล อะไรมากกว่ากัน
- ❑ หากต้องการ Cu (copper) 1 โมล ต้องทำอะไร
- ❑ หากอาจารย์ให้ไปตักน้ำ 1 โมล ต้องทำอะไร

# M O L E

Avogadro's Number and  
Molar mass of Elements



# Mole (A unit to count numbers of particles)



Dozen = 12

**New definition of Mole** (Jan 2018)

The ***mole***, symbol *mol*, is the SI unit of amount of substance. One mole contains exactly  $6.022\,140\,76 \times 10^{23}$  elementary entities.

This number is the fixed numerical value of the Avogadro constant,  $N_A$ , and is called the **Avogadro number**.

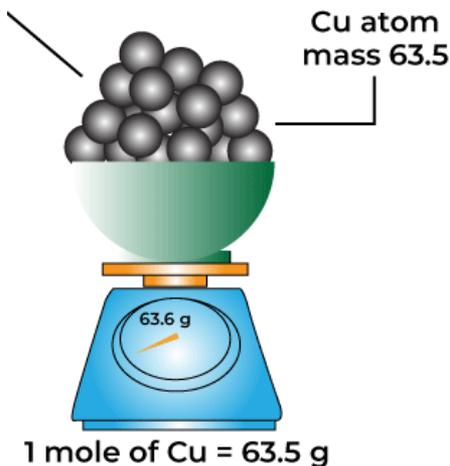
$$1 \text{ mol} = N_A = 6.02 \times 10^{23} \text{ entities}$$

  
Avogadro number

# Relationship between mole and number of atom/molecule



Cu 1 atom = 63.5 amu



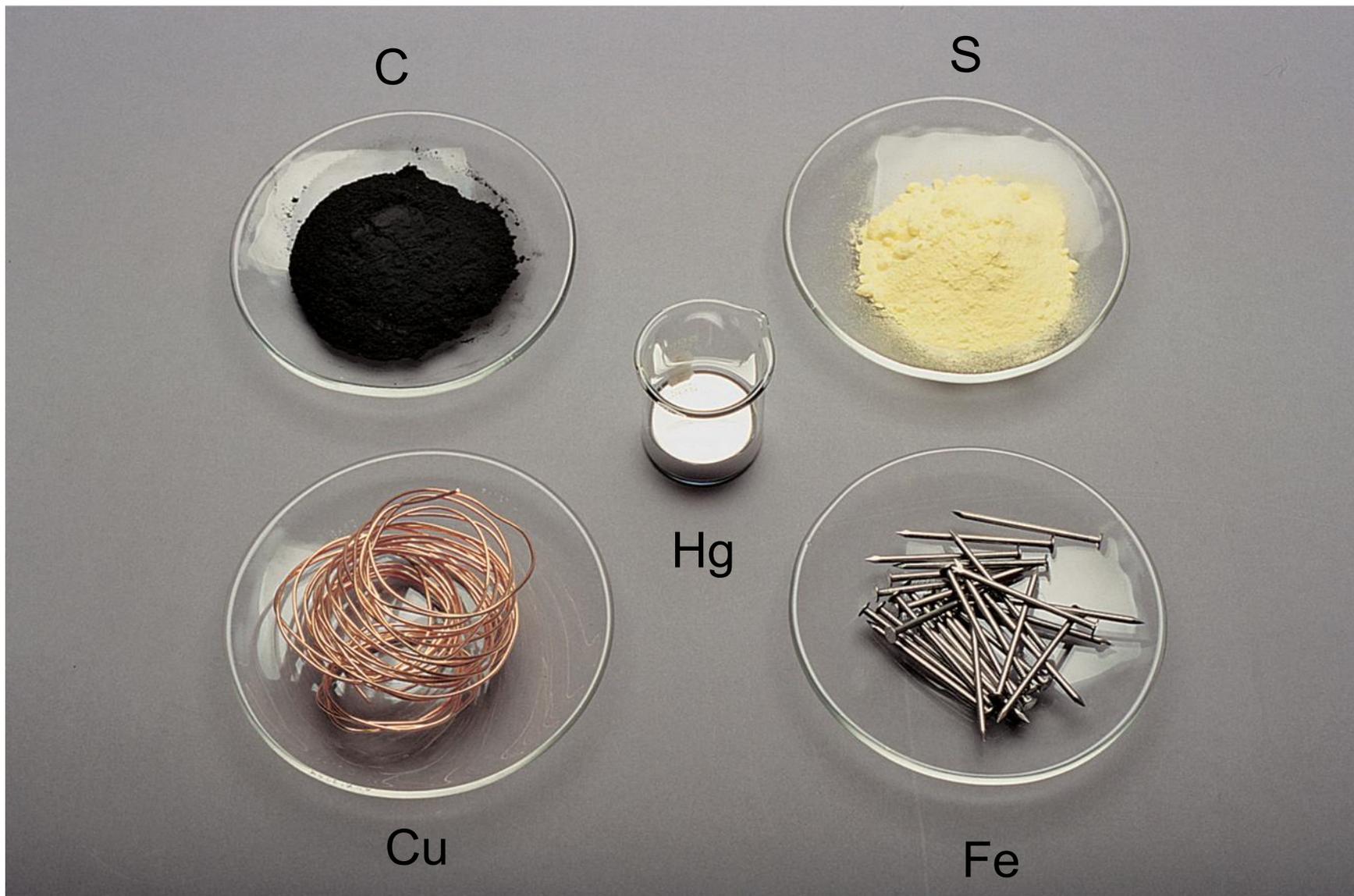
Copper 1 atom has mass  $63.5 \times 1.67 \times 10^{-24}$  g

Copper  $6.02 \times 10^{23}$  atoms has mass  $63.5 \times (1.66 \times 10^{-24}) \times 6.02 \times 10^{23}$

**Therefore,** 1 mole of copper atom =  $6.02 \times 10^{23}$  atoms = 63.5 grams

# One Mole of:

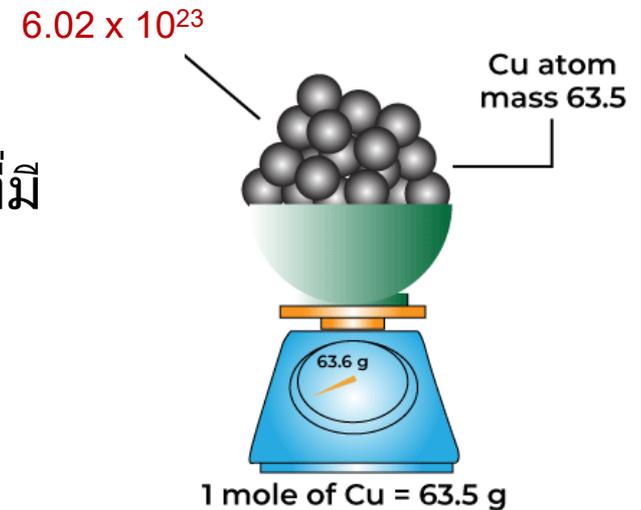
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# Molar mass (มวลต่อโมล)

Molar mass คือ น้ำหนักของสารในหน่วยกรัม ที่มีจำนวน 1 โมล (หน่วย g/mol)



## □ ความสัมพันธ์ของมวลต่อโมลและมวลอะตอม (Atomic mass vs. Molar mass)

มวลอะตอม ของ Cu อะตอม เท่ากับ 63.5 amu

มวลของ Cu อะตอม จำนวน 1 mol เท่ากับ  $63.5 \times 1.66 \times 10^{-24} \times 6.02 \times 10^{23} = 63.5 \text{ g}$

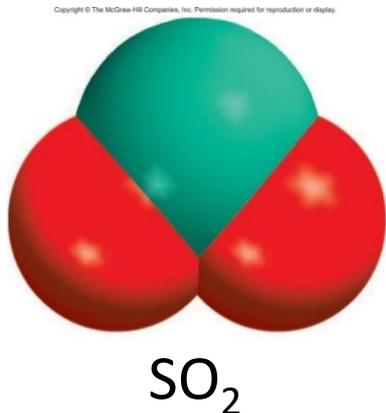
ดังนั้น มวลต่อโมล (molar mass) = 63.5 g/mol

$$\text{atomic mass (amu)} = \text{molar mass (grams/mol)}$$

มวลต่อโมล และ มวลอะตอม มีตัวเลขเดียวกัน แต่คนละหน่วย

# การหา molar mass ของสารประกอบ

- ❑ Molar mass ของสารประกอบ หาได้จาก ผลรวมของ molar mass ของแต่ละอะตอม
- ❑ สามารถหา molar mass ของแต่ละอะตอมได้จากมวลอะตอมในตารางธาตุ

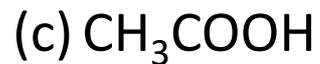
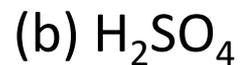


1S	32.00 g/mol
2O	2 x (16.00 g/mol)
SO <sub>2</sub>	<hr/> 64.00 g/mol

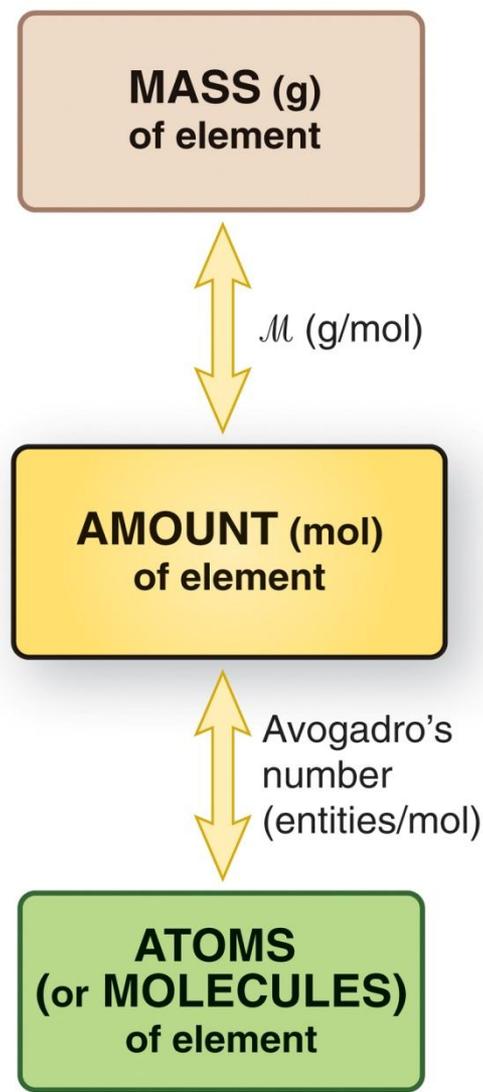
Molar mass of SO<sub>2</sub> is **64 g/mol**

## Question | MW

Calculate the molar mass (in g/mol ) of the following compounds:



# Mass-mole-number relationships for elements



# Interconverting Moles, Mass, and Number of Chemical Entities

**Mole**

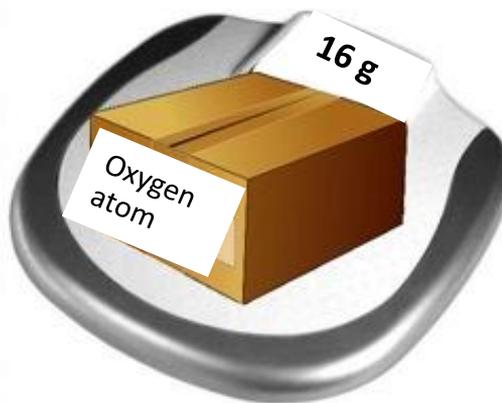


**Mass (g)**

$$\text{Mole} = \frac{\text{mass (g)}}{\text{Molar mass}}$$

Mass of O-atom 16 grams = 1 mole

$$\text{Mass of O-atom } g \text{ grams} = \frac{g}{16} \quad \rightarrow \quad \text{Mole} = \frac{g}{\text{molar mass}}$$



There are  $6.02 \times 10^{23}$  carbon atoms in this box

# Interconverting Moles, Mass, and Number of Chemical Entities

**Mole**



**Mass (g)**

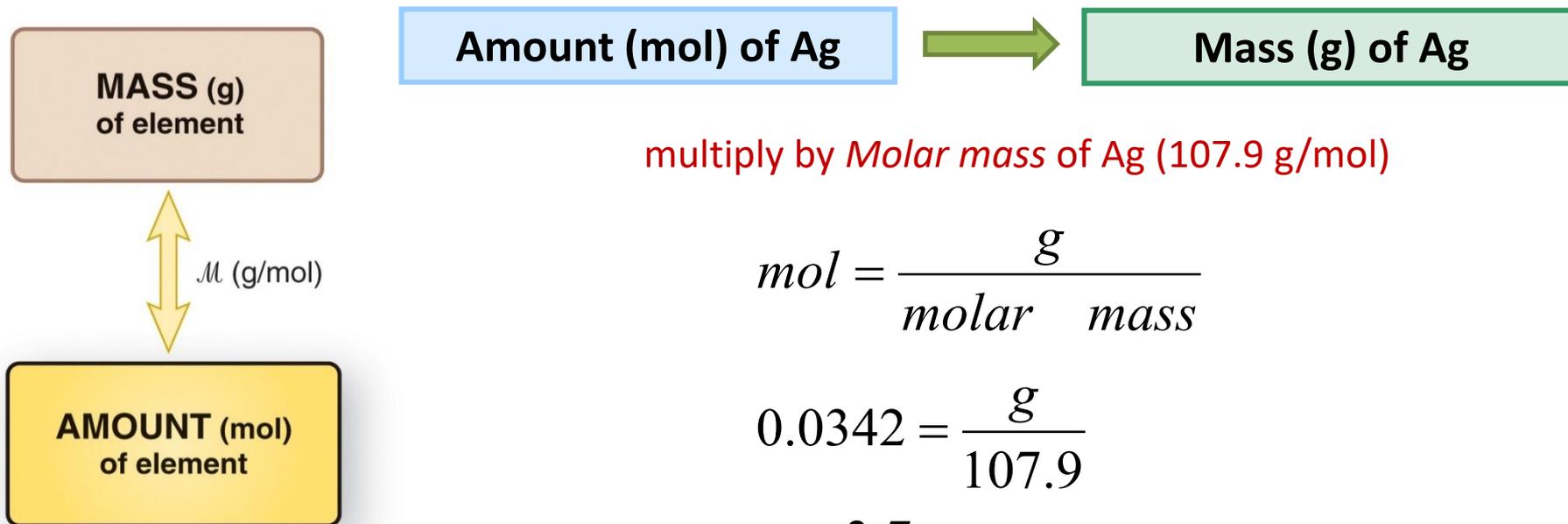
$$\text{Mole} = \frac{\text{mass (g)}}{\text{Molar mass}}$$

$$\text{Mole} = \frac{\cancel{g}}{\cancel{g} / \text{mol}}$$

# Amount-Mass-Number Conversions Involving Elements

**PROBLEM:** Silver (Ag) is used in jewelry and tableware but no longer in U.S. coins. How many grams of Ag are in 0.0342 mol of Ag?

**PLAN:** To convert mol of Ag to mass of Ag in g we need the molar mass of Ag.



## Sample Problem 1.1

**PROBLEM:** How many moles of carbon are in 0.315 g of graphite?  
จงคำนวณหาจำนวนโมลของ C ที่หนัก 0.315 กรัม

## Sample Problem 1.1

**PROBLEM:** How many mass in grams of  $\text{PCl}_3$  are in 0.186 mol?

**Step 1:** Calculate the molar mass of  $\text{PCl}_3$

$$\begin{aligned}\text{molar mass of } \text{PCl}_3 &= \text{P} + 3 \times (\text{Cl}) \\ &= 31 + (3 \times 35.5) \\ &= 137.5 \text{ g/mol}\end{aligned}$$

**Step 2:** Convert NO. of mol of  $\text{PCl}_3$  to mass in grams

$$\begin{aligned}\text{mol} &= \frac{\text{g}}{\text{molar mass}} \\ 0.186 \text{ mol} &= \frac{\text{g}}{137.5 \text{ g/mol}} \\ \text{g} &= 25.58 \text{ grams}\end{aligned}$$

Therefore, There are 25.58 gram of  $\text{PCl}_3$  in 0.186 mol of  $\text{PCl}_3$

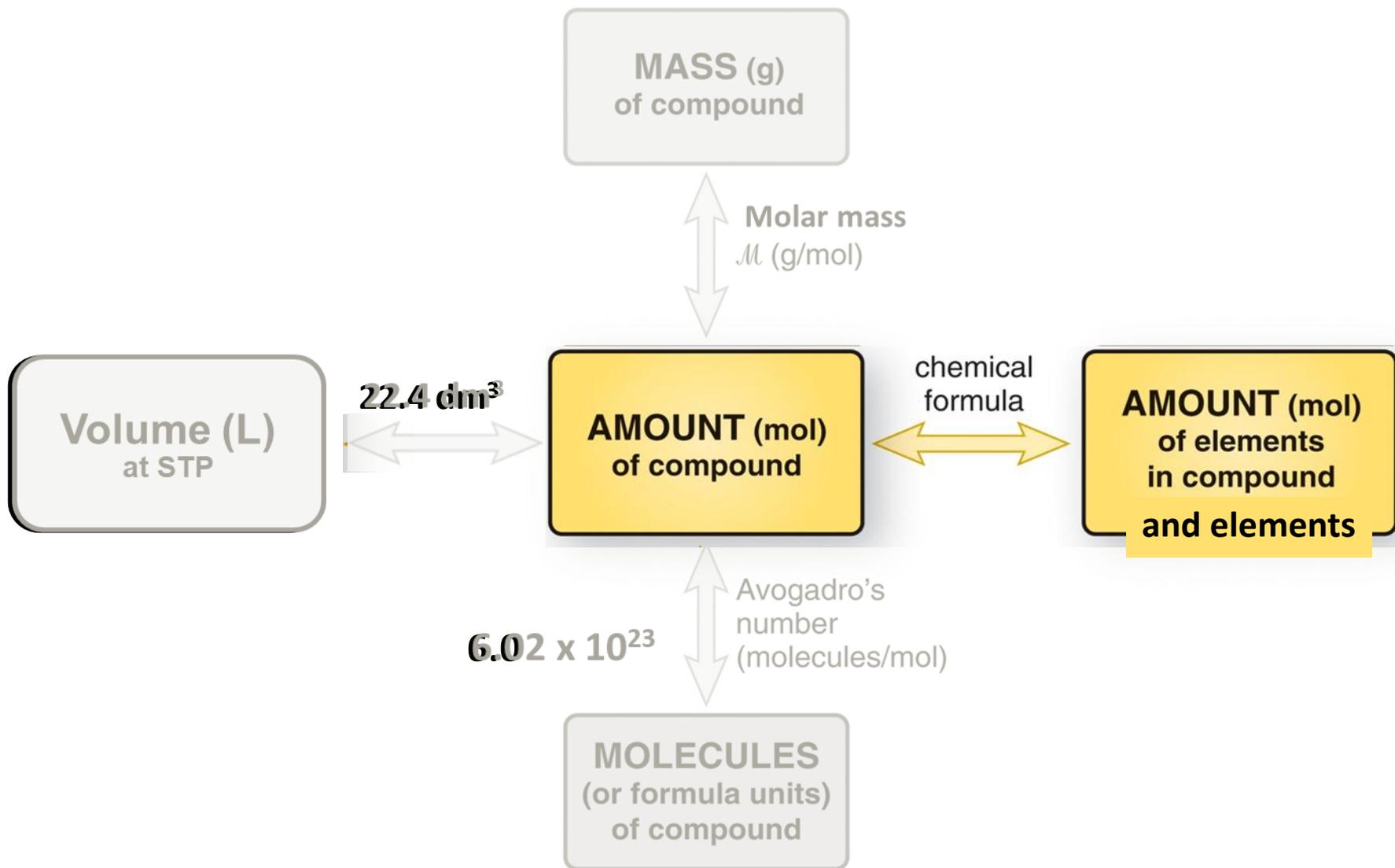
## Sample Problem 1.2

**PROBLEM:** จงหามวลของ  $\text{ZnCl}_2$  (ในหน่วย กรัม) ที่มีจำนวนโมล เท่ากับ 0.065 โมล

## Sample Problem 1.3

**PROBLEM:** How many moles of  $\text{Al}_2\text{O}_3$  are in 47.5 grams of  $\text{Al}_2\text{O}_3$ ?

# Amount-mass-number relationships for compounds.



# Interconverting Moles, Mass, and Number of Chemical Entities

**Mole**



**MOLECULES**  
(or formula units)  
of compound

$$\text{Mole} = \frac{\text{number of molecule}}{6.02 \times 10^{23}}$$

$$\text{O}_2 \quad 6.02 \times 10^{23} \text{ molecules} = 1 \text{ mole}$$

$$\text{O}_2 \quad N \text{ molecules} = \frac{N}{6.02 \times 10^{23}} \text{ mole}$$



$6.02 \times 10^{23}$  molecules

# Interconverting Moles, Mass, and Number of Chemical Entities

**Mole**



**Mass (g)**

$$\text{Mole} = \frac{\text{mass (g)}}{\text{Molar mass}} = \frac{\text{g}}{\text{molar mass}}$$

**Mole**



**MOLECULES  
(or formula units)  
of compound**

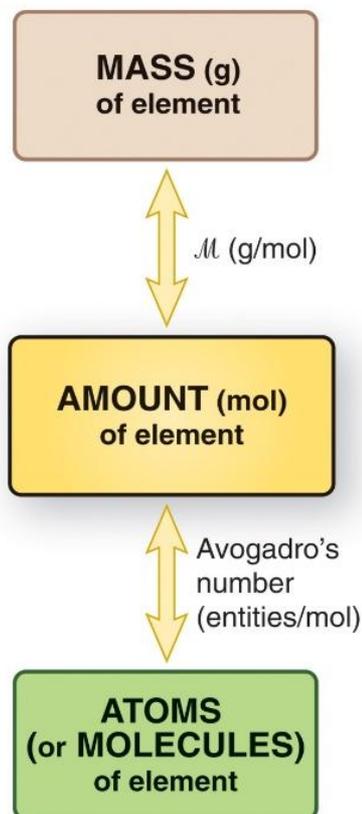
$$\text{Mole} = \frac{\text{number of molecule}}{6.02 \times 10^{23}}$$

$$\text{mol} = \frac{\text{g}}{\text{molar mass}} = \frac{N}{6.02 \times 10^{23}} = \frac{V(\text{L})}{22.4} = \frac{N_A}{\text{mol}_A \times (6.02 \times 10^{23})}$$

## Sample Problem 1.2

## Converting Between Number of Entities and Amount of an Element

**PROBLEM:** How many molecules are in  $2.85 \times 10^{-3}$  mol of  $\text{CO}_2$ ?



$$\text{mol} = \frac{N}{6.02 \times 10^{23}}$$

$$2.85 \times 10^{-3} = \frac{N}{6.02 \times 10^{23}}$$

$$N = 1.72 \times 10^{21} \text{ CO}_2 \text{ molecules}$$

## Sample Problem 1.2A

### Converting Between Number of Entities and Amount of an Element

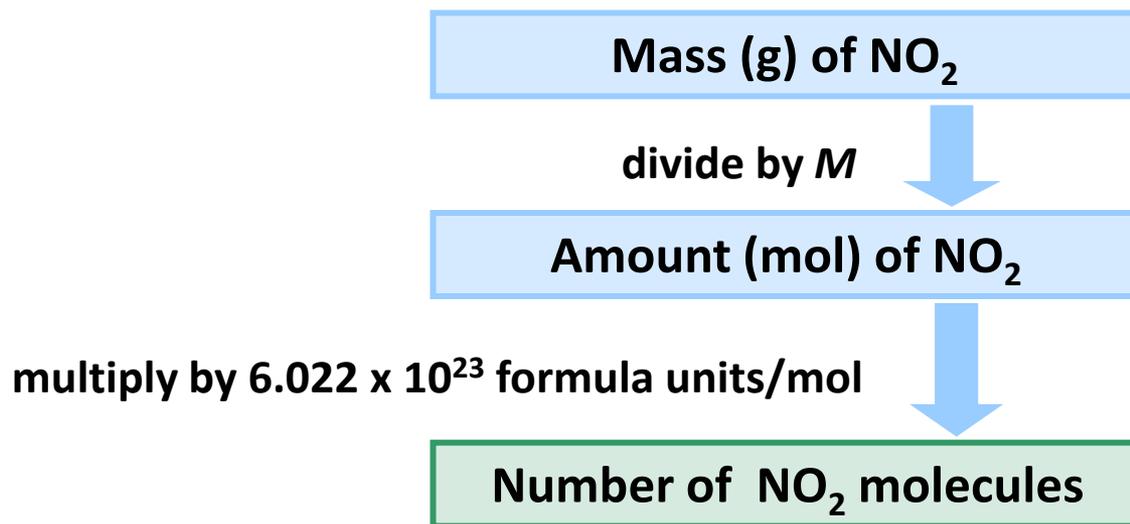
**PROBLEM:** How many  $\text{PCl}_3$  molecules are in  $1.24 \times 10^{-3}$  mol of  $\text{PCl}_3$  ?

### Sample Problem 3.4

## Converting Between Number of Entities and Mass of Compound I

**PROBLEM:** Nitrogen dioxide is a component of urban smog that forms from the gases in car exhausts. **How many molecules are in 8.92 g of nitrogen dioxide?**

**PLAN:** Write the formula for the compound and calculate its molar mass. Use the given mass to calculate first the number of moles and then the number of molecules.



### Sample Problem 3.4

## Converting Between Number of Entities and Mass of Compound I

**PROBLEM:** Nitrogen dioxide is a component of urban smog that forms from the gases in car exhausts. **How many molecules are in 8.92 g of nitrogen dioxide (NO<sub>2</sub>)?**

$$\begin{aligned}\text{Molar mass} &= (\text{N}) + 2(\text{O}) \\ &= 14 + 2(16) = 46 \text{ g/mol}\end{aligned}$$

$$\text{mol} = \frac{\text{g}}{\text{molar mass}} = \frac{N}{6.02 \times 10^{23}} = \frac{V(\text{L})}{22.4} = \frac{N_A}{\text{mol}_A \times (6.02 \times 10^{23})}$$

$$\frac{8.92 \text{ g}}{46 \text{ g/mol}} = \frac{N_{\text{NO}_2}}{6.02 \times 10^{23}}$$

$$N_{\text{NO}_2} = 1.17 \times 10^{23} \text{ NO}_2 \text{ molecules}$$

**Therefore, there are  $1.17 \times 10^{23}$  molecules in 8.92 g of NO<sub>2</sub>**

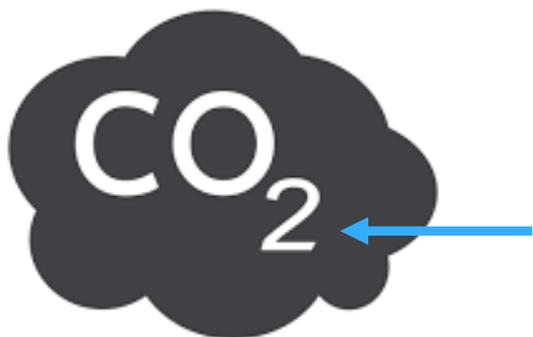
**Sample Problem 3.4A**

**Converting Between Number of Entities and Mass of Compound I**

**PROBLEM:** How many HCl molecules are there in a 3.46 g sample of hydrogen chloride, HCl?

# Relationship

between  
moles and Chemical Formulas



What does the subscript in a chemical formula tell you?



# Relationship between moles and Chemical Formulas

✓ H<sub>2</sub>O จำนวน 1 โมเลกุล มี H กี่อะตอม

H<sub>2</sub>O      1      molecule      ประกอบด้วย H จำนวน      2      atoms

✓ H<sub>2</sub>O จำนวน 1 mol มีกี่โมเลกุล

H<sub>2</sub>O      1      molecule      ประกอบด้วย H จำนวน      2  
atoms

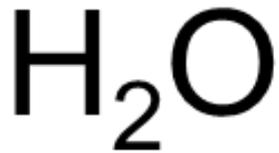
H<sub>2</sub>O       $1 \times 6.02 \times 10^{23}$       molecule      ประกอบด้วย H จำนวน       $2 \times 6.02 \times 10^{23}$   
atoms      เท่ากับกี่โมล      เท่ากับกี่โมล

**ดังนั้น**

H<sub>2</sub>O \_\_\_\_\_mole      ประกอบด้วย H จำนวน \_\_\_\_\_mole

# Relationship between moles and Chemical Formulas

- เลขห้อยในสูตรโมเลกุลของสารจำนวน 1 โมล จะมีตัวเลขเท่ากับจำนวนโมลของอะตอมนั้น



เลขห้อย 2 ตรงไฮโดรเจน บ่งบอกว่า มี H อะตอม จำนวน 2 โมล  
เลขห้อย 1 ตรงออกซิเจน บ่งบอกว่า มี O อะตอม จำนวน 1 โมล

**Example 1** | How many mole of O-atom in 1.5 mol of  $C_3H_6O$

**Example 2** | How many mole of C-atom in 1.5 mol of  $C_3H_6O$

# Interconverting Moles, Mass, and Number of Chemical Entities

Mole



Mass (g)

$$\text{Mole} = \frac{\text{mass (g)}}{\text{Molar mass}}$$

Mole



MOLECULES  
(or formula units)  
of compound

$$\text{Mole} = \frac{\text{number of molecule/atom/ion}}{6.02 \times 10^{23}}$$

$$\text{mol} = \frac{N_A}{\text{mol}_A}$$

Mole



Atom

$$\text{mol} = \frac{g}{MW} = \frac{N}{6.02 \times 10^{23}} = \frac{N_A}{\text{mol}_A \times (6.02 \times 10^{23})}$$

## Follow-Up problems

1) จงหาจำนวน C อะตอม ที่อยู่ใน 1.65 mol ของ  $\text{CO}_2$

2) Calculate number of P-atom in 1.65 mol of  $\text{P}_4\text{O}_{10}$

## Sample Problem 1.8

### Converting Between Number of Entities and Mass of an Element

**PROBLEM:** How many O-atoms are in 4.4 g of CO<sub>2</sub>?

**PLAN:** The number of atoms cannot be calculated directly from the mass. We must first determine the number of moles of O-atoms in the sample and then use Avogadro's number.

$$\frac{\text{g}}{\text{molar mass}} = \frac{N_{\text{Atoms}}}{\text{mol}_A \times 6.02 \times 10^{23}}$$
$$\frac{4.4}{44 \text{ g/mol}} = \frac{N_{\text{O}}}{2 \times 6.02 \times 10^{23}}$$

$$N_{\text{O}} = 1.204 \times 10^{23} \text{ atoms}$$

There are  $1.204 \times 10^{23}$  O-atoms are in 4.4 g of CO<sub>2</sub>

## Follow-Up problems

3) Calculate number of O-atom in 18 grams of  $C_6H_{12}O_6$   
(molar mass of  $C_6H_{12}O_6$  is 180 g/mol)

4) Calculate number of H-atom in 18 grams of  $C_6H_{12}O_6$   
(molar mass of  $C_6H_{12}O_6$  is 180 g/mol)

## Follow-Up problems

3) How many Fe atoms are in 95.8 grams of Fe?

4) How many S atoms are in 3.2 grams of S?

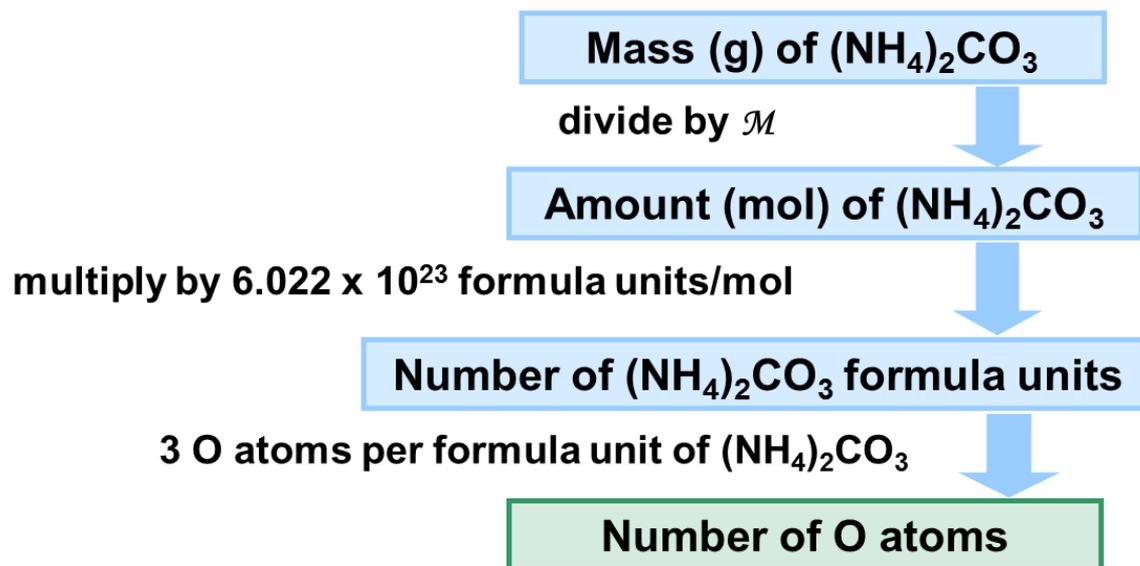
### Sample Problem 3.5

## Converting Between Number of Entities and Mass of Compound II

**PROBLEM:** Ammonium carbonate, a white solid that decomposes on warming, is an component of baking powder.

- How many molecules are in 41.6 g of ammonium carbonate  $[(\text{NH}_4)_2\text{CO}_3]$ ?
- How many O atoms are in 41.6 g of  $(\text{NH}_4)_2\text{CO}_3$ ?

**PLAN:**



### Sample Problem 3.5

#### SOLUTION:

a) How many formula units are in 41.6 g of ammonium carbonate?

Molar mass of  $(\text{NH}_4)_2\text{CO}_3 = 96.09 \text{ g/mol}$

$$\text{mol} = \frac{g}{MW} = \frac{N}{6.02 \times 10^{23}} \quad \longrightarrow \quad \frac{41.6 \text{ g}}{96.09 \text{ g/mol}} = \frac{N}{6.02 \times 10^{23}}$$

$$\mathbf{N = 2.61 \times 10^{23} \text{ molecules } (\text{NH}_4)_2\text{CO}_3}$$

**Therefore**, there are  $2.61 \times 10^{23}$  molecules of  $(\text{NH}_4)_2\text{CO}_3$  in 41.6 g of  $(\text{NH}_4)_2\text{CO}_3$

### Sample Problem 3.5

**SOLUTION:**

b) How many O atoms are in this sample?

$$\frac{g}{MW} = \frac{N_A}{\text{mol}_A \times (6.02 \times 10^{23})}$$

$$\frac{41.6g}{96.09g / \text{mol}} = \frac{N_A}{\text{mol}_A \times (6.02 \times 10^{23})}$$

$$N_A = 7.82 \times 10^{23} \text{ O atoms}$$

**Therefore,** there are  $7.82 \times 10^{23}$  O atom in 41.6 g of  $(\text{NH}_4)_2\text{CO}_3$

**Comment :** A common mistake is to forget the subscript 2 outside the parentheses in  $(\text{NH}_4)_2\text{CO}_3$ , which would give a much lower molar mass

## Sample Problem 3.5A

**PROBLEM:** Tetraphosphorus decoxide ( $\text{P}_4\text{O}_{10}$ ) reacts with water to form phosphoric acid, a major industrial acid. In the laboratory, the oxide is a drying agent.

- (a) What is the mass (g) of  $4.65 \times 10^{22}$  molecules of  $\text{P}_4\text{O}_{10}$ ?  
(b) How many P atoms are present in this sample?

# References

- 1) Chang, R.; Overby, J. S. *General Chemistry: The Essential Concepts*; McGraw-Hill, 2011.
- 2) Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change*; McGraw-Hill Education, 2011.