2nd

Semester

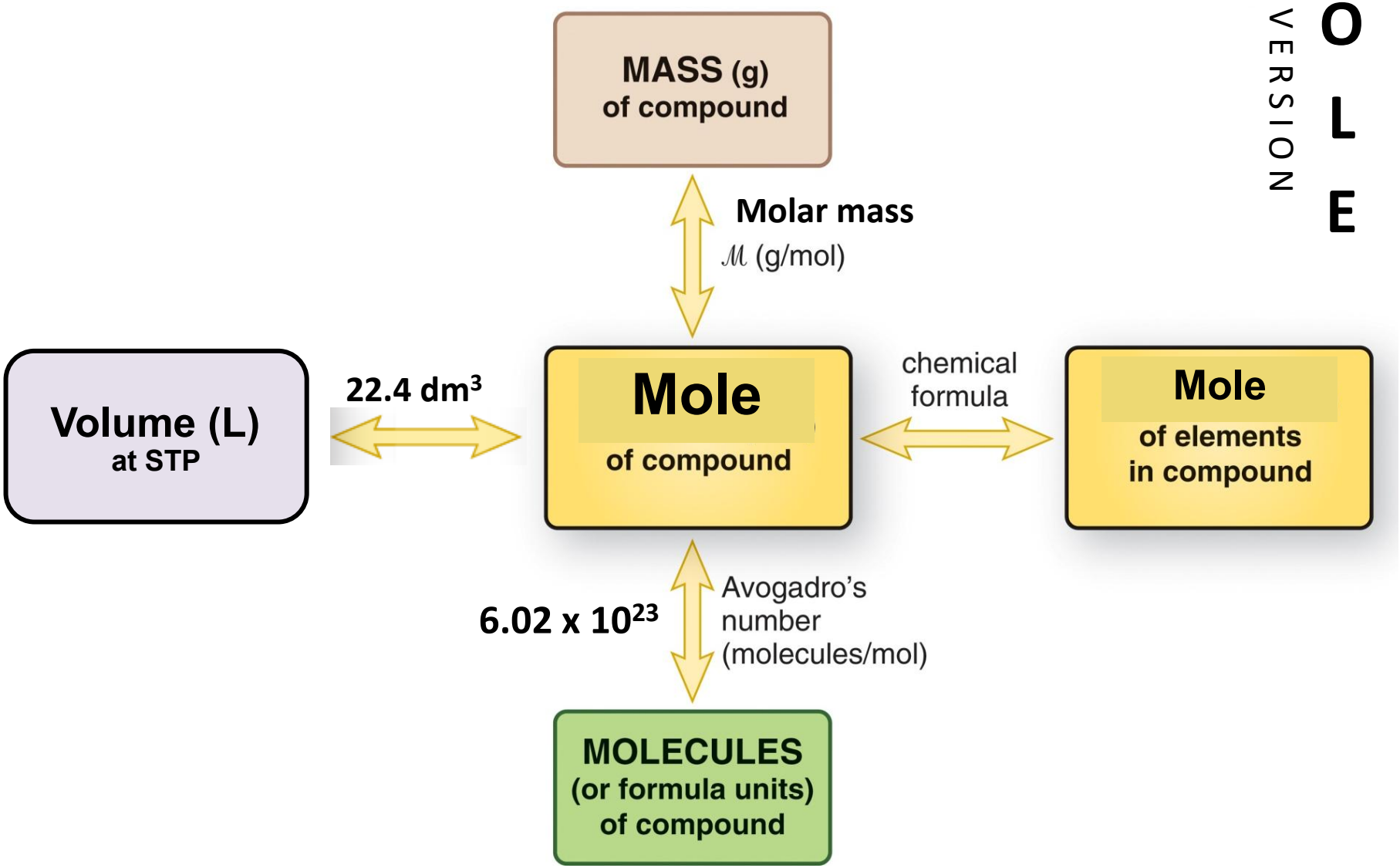
Academic year 2025

Stoichiometry

Mass Relationships in Chemical Reactions

CHEMISTRY

MOLE CONVERSION

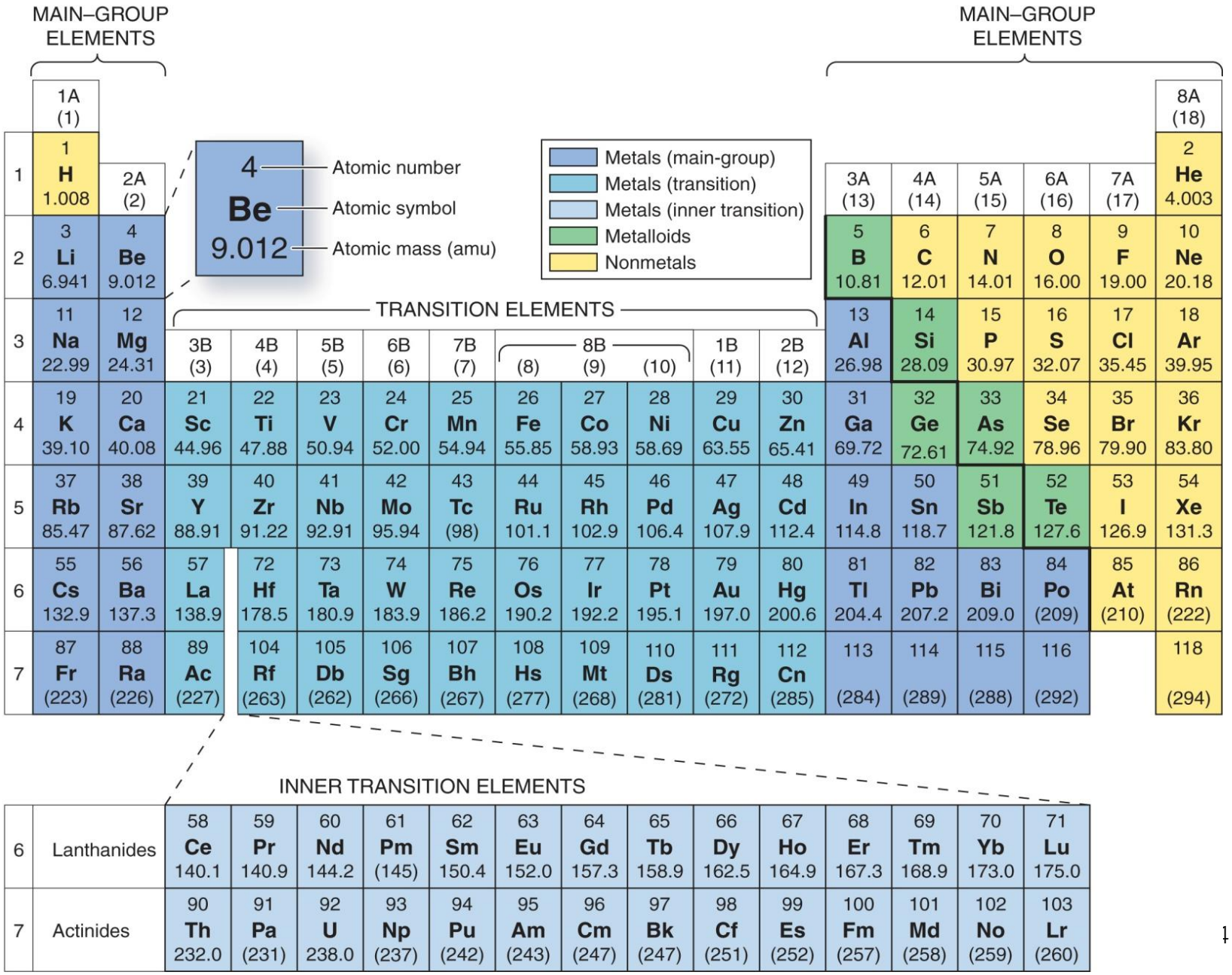


Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

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

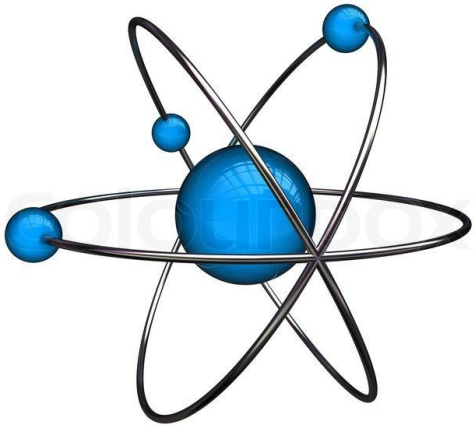
The modern periodic table.

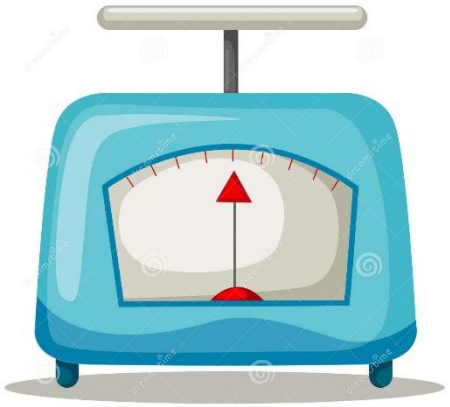


Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change:* McGraw-Hill Science.

Atomic Mass

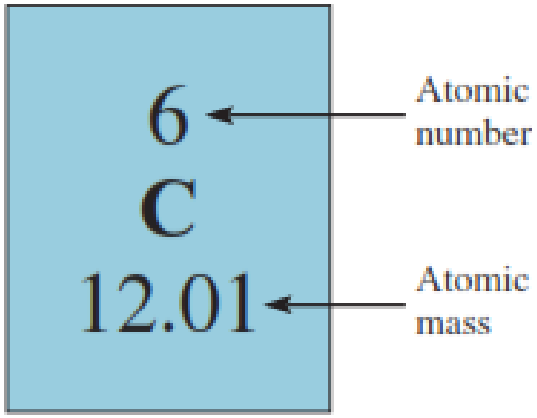
How Much Do Atoms Weigh?





Atomic mass

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



By definition:
1 atom ^{12}C "weighs" 12 amu

On this scale

^{1}H = 1.008 amu

^{16}O = 16.00 amu

Chang, R. *Chemistry*; McGraw-Hill, 2010.

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.

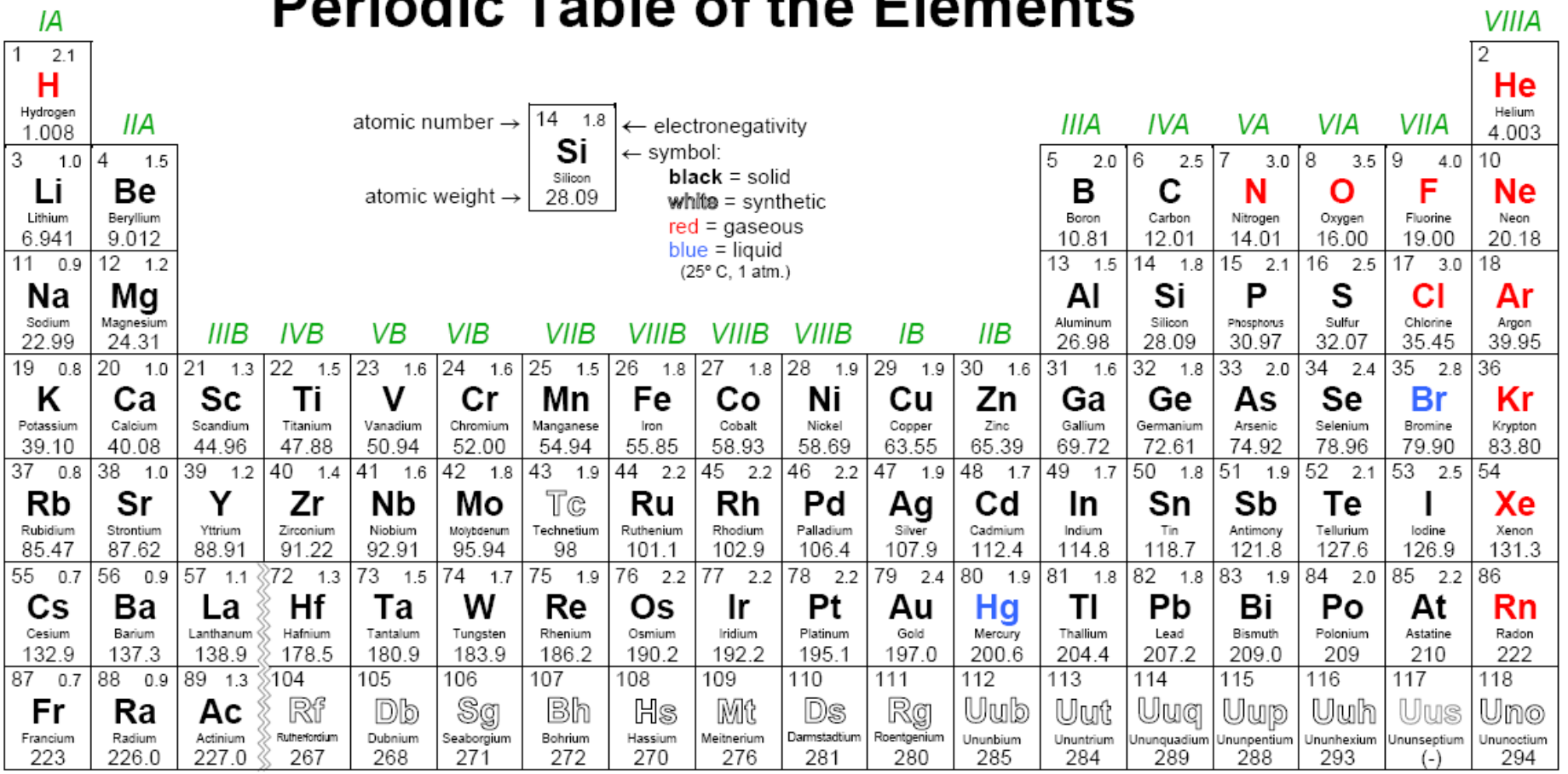
$$\text{amu} = \frac{1}{12} \text{ mass of C-12 one atom}$$

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

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

Chang, R. *Chemistry*; McGraw-Hill, 2010.

Periodic Table of the Elements



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)

- ระหว่างถูกหวยรางวัลที่ 1 จำนวน 10 ใบ ***Vs*** มีเงิน 1 โมล อะไรมากกว่ากัน
- หากต้องการ Cu (copper) 1 โมล ต้องทำอย่างไร
- หากอาจารย์ให้ไปตักน้ำ 1 โมล ต้องทำอย่างไร

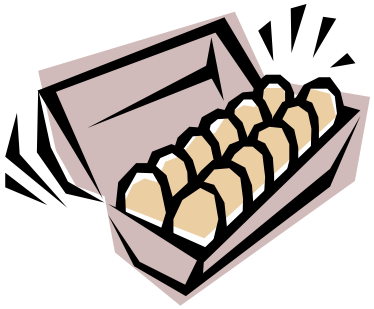
M O L E

A v o g a d r o's N u m b e r

and

M o l a r m a s s of E l e m e n t s

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 × 10^{23} elementary entities.

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

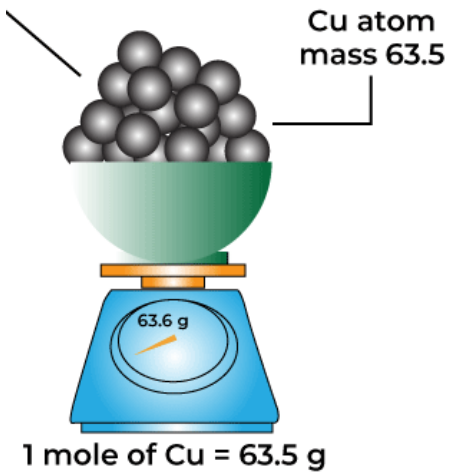
1 mol = N_A = 6.02 x 10^{23} entities

Avogadro number

https://iupac.org/new-definition-mole-arrived/ (Oct 2019)

Relationship between mole and number of atom/molecule

Cu 1 atom = 63.5 amu



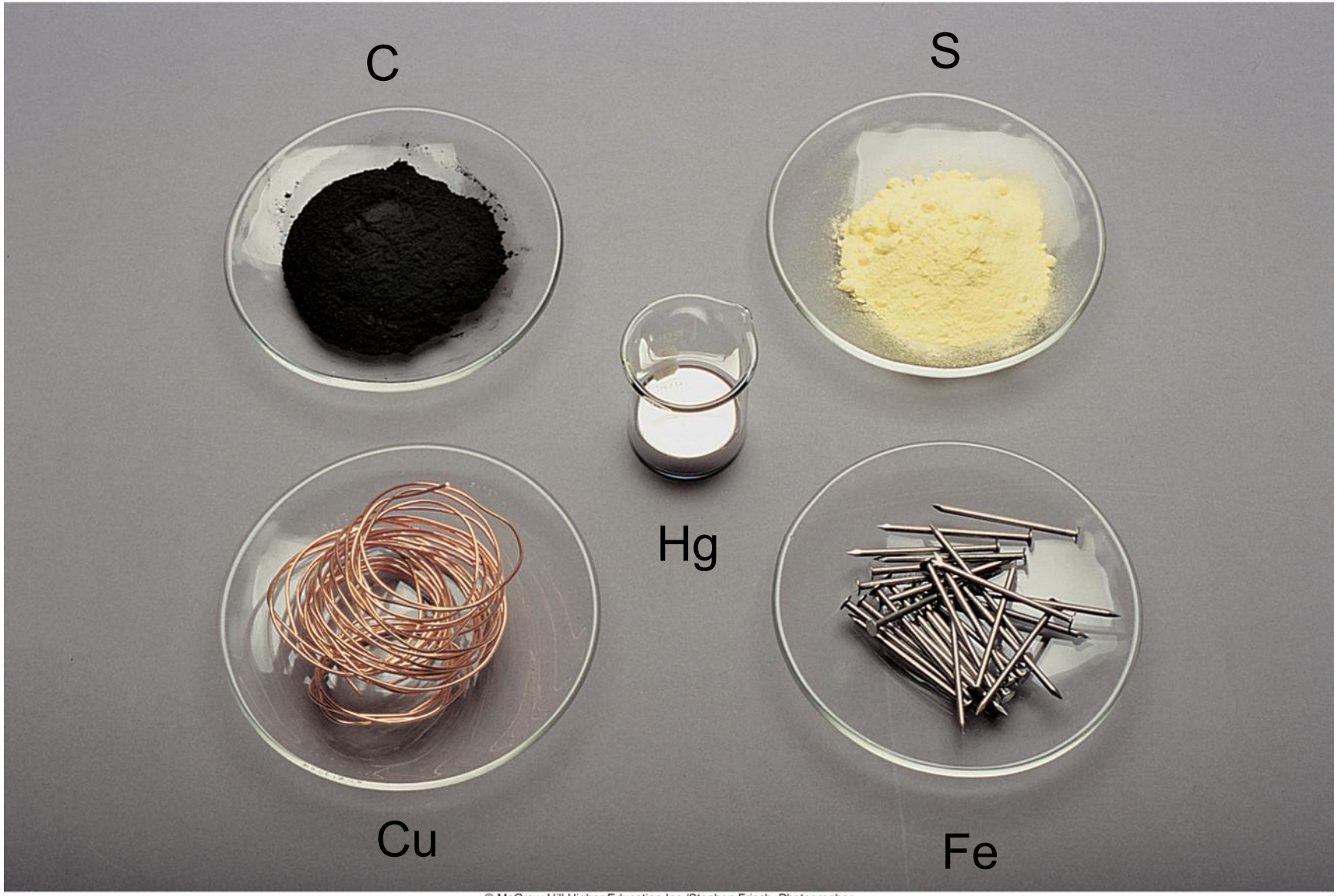
Copper 1 atom has mass $63.5 \times 1.67 \times 10^{-24}$ g

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

Therefore, 1 mole of copper atom = 6.02×10^{23} atoms = 63.5 grams

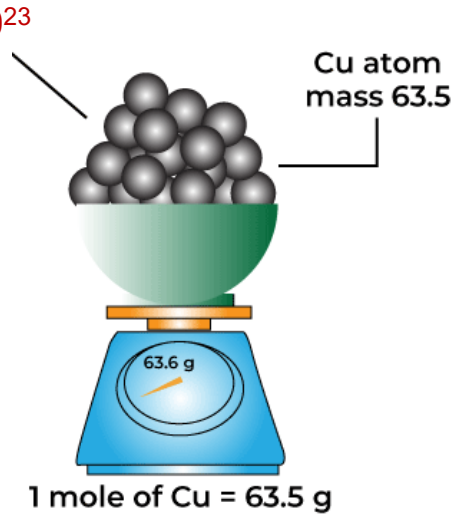
Chang, R. *Chemistry*; McGraw-Hill, 2010.

One Mole of:



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 $63.5 \times 1.66 \times 10^{-24} \times 6.02 \times 10^{23} = 63.5$ g

  ดังนั้น มวลต่อโมล (molar mass) = 63.5 g/mol

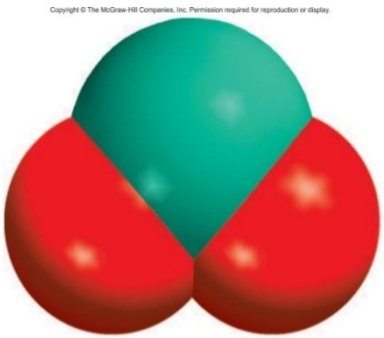
atomic mass (amu) = molar mass (grams/mol)

มวลต่อโมล และ มวลอะตอม มีตัวเลขเดียวกัน แต่คนละหน่วย

Chang, R. *Chemistry*; McGraw-Hill, 2010.

การหา molar mass ของสารประกอบ

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



SO_2

1S	32.00 g/mol
2O	2 x (16.00 g/mol)
SO_2	64.00 g/mol

Molar mass of SO_2 is **64 g/mol**

Chang, R. *Chemistry*; McGraw-Hill, 2010.

Question | MW

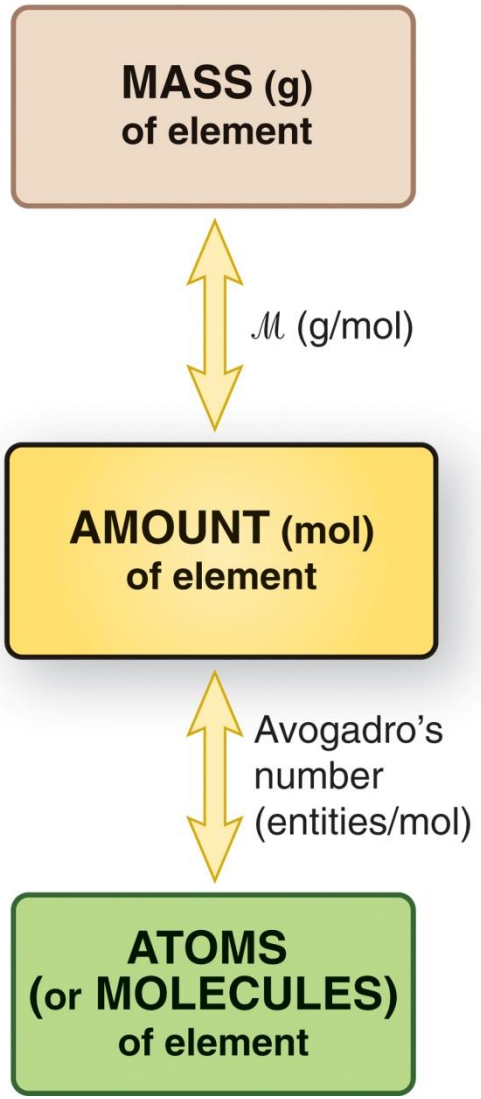
Calculate the molar mass (in g/mol) of the following compounds:

(a) CO_2

(b) H_2SO_4

(c) CH_3COOH

Mass-mole-number relationships for elements



Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

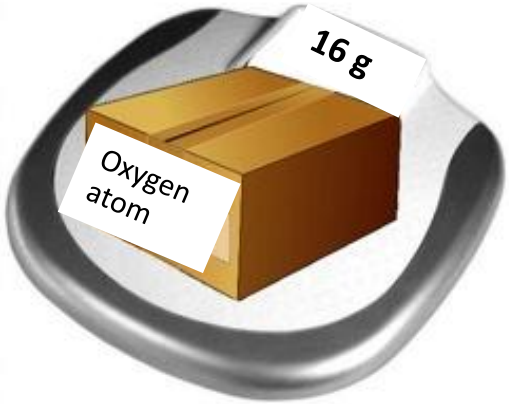
Interconverting Moles, Mass, and Number of Chemical Entities

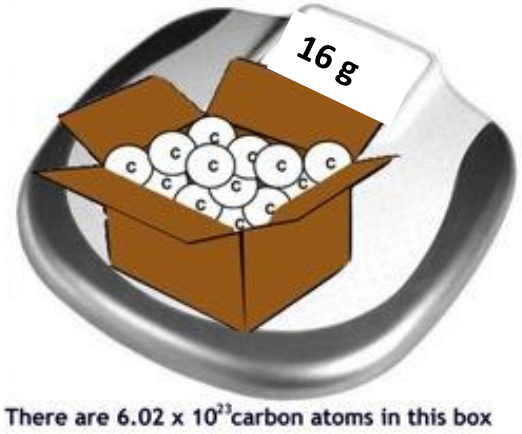
Mole ⟺ **Mass (g)**

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

Mass of O-atom 16 grams = 1 mole

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





Interconverting Moles, Mass, and Number of Chemical Entities

Mole ⟺ **Mass (g)**

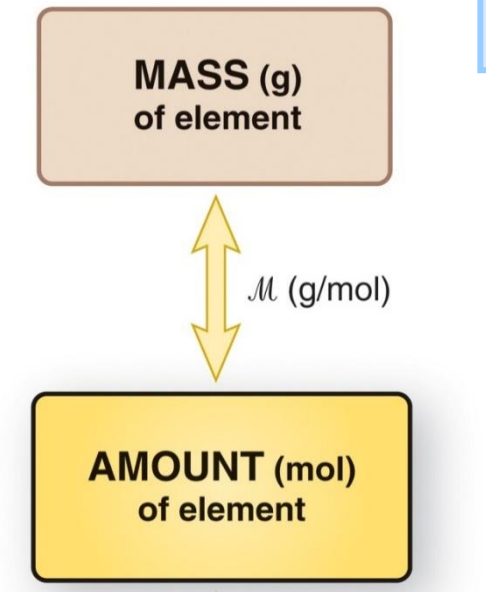
$$\text{Mole} = \frac{\text{mass (g)}}{\text{Molar mass}}$$

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

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.



Amount (mol) of Ag → **Mass (g) of Ag**

multiply by *Molar mass* of Ag (107.9 g/mol)

$$mol = \frac{g}{molar \quad mass}$$

$$0.0342 = \frac{g}{107.9}$$

$$g = 3.7 \quad grams$$

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 PCl_3 are in 0.186 mol?

Step 1: Calculate the molar mass of PCl_3

molar mass of PCl_3 = P + 3x(Cl)
= 31 + (3x35.5)
= 137.5 g/mol

Step 2: Convert NO. of mol of PCl_3 to mass in grams

$$\text{mol} = \frac{\text{g}}{\text{molar mass}}$$

$$0.186 \text{ mol} = \frac{\text{g}}{137.5 \text{ g/mol}}$$

$$\text{g} = 25.58 \text{ grams}$$

Therefore, There are 25.58 gram of PCl_3 in 0.186 mol of PCl3

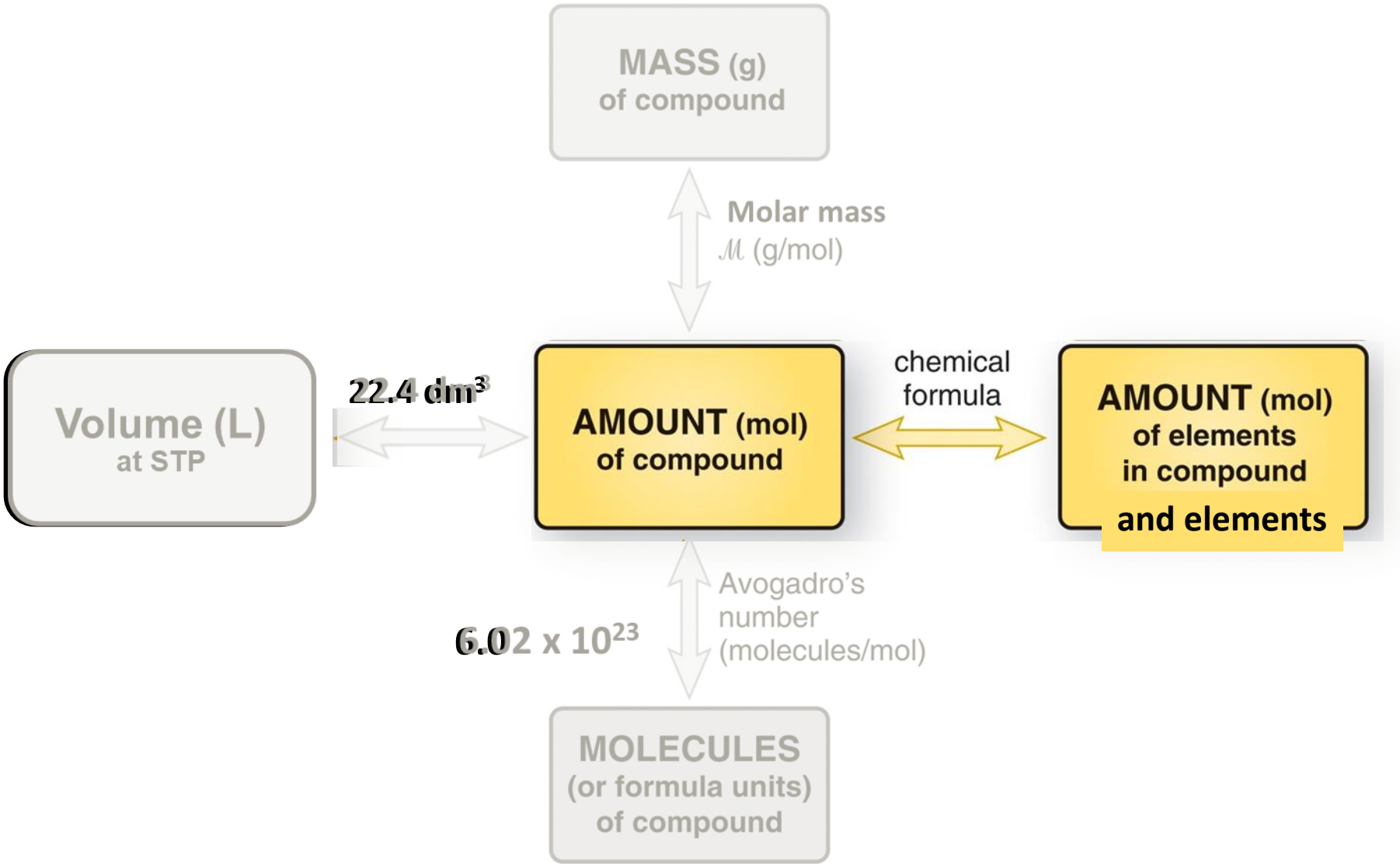
Sample Problem 1.2

PROBLEM: จงหามวลของ $ZnCl_2$ (ในหน่วย กรัม) ที่มีจำนวนโมล เท่ากับ 0.065 โมล

Sample Problem 1.3

PROBLEM: How many moles of Al_2O_3 are in 47.5 grams of Al_2O_3?

Amount-mass-number relationships for compounds.



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Interconverting Moles, Mass, and Number of Chemical Entities

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

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

O_2 $6.02x = 10^{23}$ molecules = 1 mole

O_2 ***N*** molecules = $\frac{N}{6.02 \times 10^{23}}$ mole

$6.02x10^{23}$ 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**

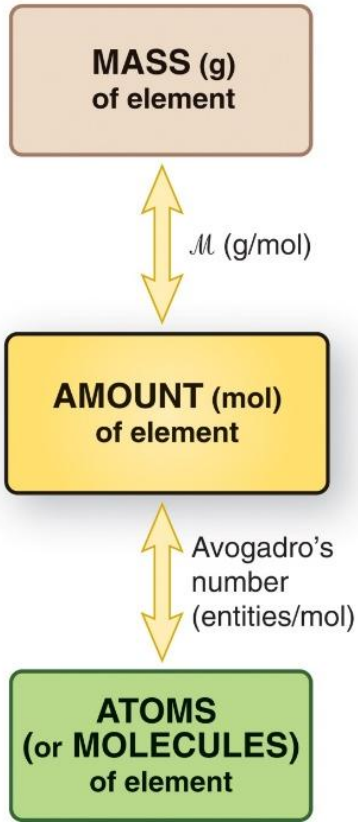
$$\text{Mole} = \frac{\text{number of molecule}}{6.02 \times 10^{23}}$$

$$\text{mol} = \frac{\text{g}}{\text{molar mass}} = \frac{\text{N}}{6.02\times10^{23}} = \frac{\text{V(L)}}{22.4} = \frac{\text{N}_A}{\text{mol}_A \times (6.02\times10^{23})}$$

Sample Problem 1.2

Converting Between Number of Entities and Amount of an Element

PROBLEM: How many molecules are in 2.85×10^{-3} mol of CO_2?



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

$$2.85x10^{-3} = \frac{N}{6.02 \times 10^{23}}$$

N = 1.72×10^{21} CO_2 molecules

Sample Problem 1.2A

Converting Between Number of Entities and Amount of an Element

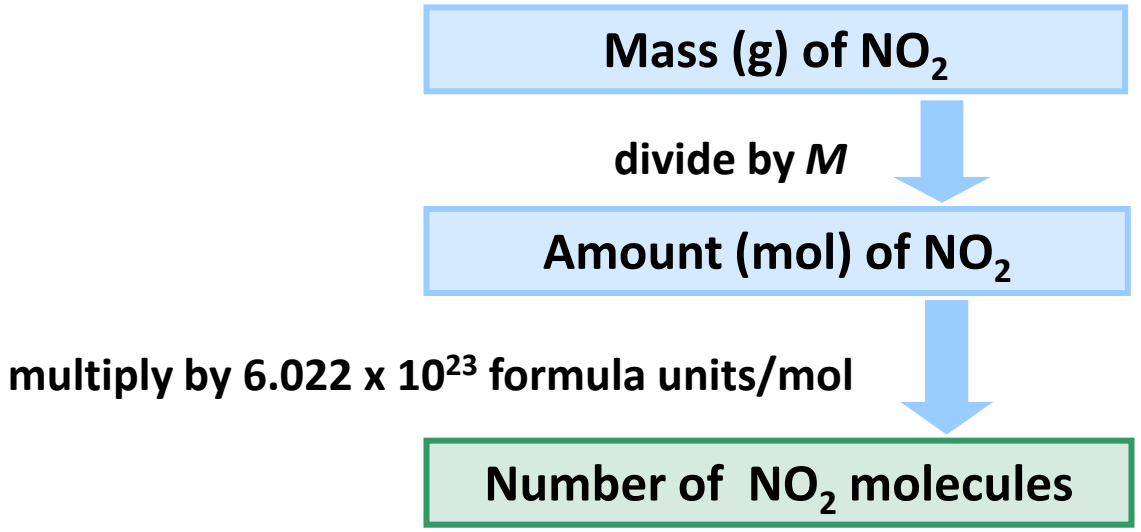
PROBLEM: How many PCl_3 molecules are in 1.24×10^{-3} mol of PCl_3 ?

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.



Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

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_2)?**

Molar mass = (N) + 2(O)
= 14 + 2(16) = 46 g/mol

$$\text{mol} = \frac{\text{g}}{\text{molar mass}} = \frac{\text{N}}{6.02\times10^{23}} = \frac{\text{V(L)}}{22.4} = \frac{\text{N}_A}{\text{mol}_A \times (6.02\times10^{23})}$$

$$\frac{8.92\,g}{46\,g/mol} = \frac{N_{NO_2}}{6.02\times10^{23}}$$

$$N_{NO_2} = 1.17\times10^{23} \quad NO_2 \quad molecules$$

Therefore, there are 1.17×10^{23} molecules in 8.92 g of NO_2

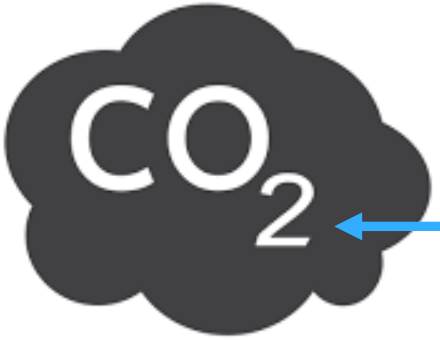
Sample Problem 3.4A

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_2O จำนวน 1 โมเลกุล มี H กี่อะตอม

H_2O	1	molecule	ประกอบด้วย H จำนวน	2	atoms

✓ H_2O จำนวน 1 mol มีกี่โมเลกุล

H_2O	1	molecule	ประกอบด้วย H จำนวน	2	atoms
H_2O	$1 \times 6.02 \times 10^{23}$	molecule	ประกอบด้วย H จำนวน	$2 \times 6.02 \times 10^{23}$	atoms
	เท่ากับกี่โมล			เท่ากับกี่โมล	

ดังนั้น

H_2O	_____	mole	ประกอบด้วย H จำนวน	_____	mole

Relationship between moles and Chemical Formulas

- เลขห้อยในสูตรโมเลกุลของสารจำนวน 1 โมล จะมีตัวเลขเท่ากับจำนวนโมลของอะตอมนั้น

H_2O

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**

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

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

Mole ⟺ **Atom**

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

Follow-Up problems

1) จงหาจำนวน C อะตอม ที่อยู่ใน 1.65 mol ของ CO_2

2) Calculate number of P-atom in 1.65 mol of P_4O_{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_2?**

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.

$$\frac{\text{g}}{\text{molar mass}} = \frac{N_{Atoms}}{\text{mol}_A \times 6.02\times10^{23}}$$

$$\frac{4.4}{44\ \text{g/mol}} = \frac{N_O}{2 \times 6.02\times10^{23}}$$

$$N_o = 1.204 \times 10^{23}\ atoms$$

There are 1.204×10^{23} O-atoms are in 4.4 g of CO_2

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

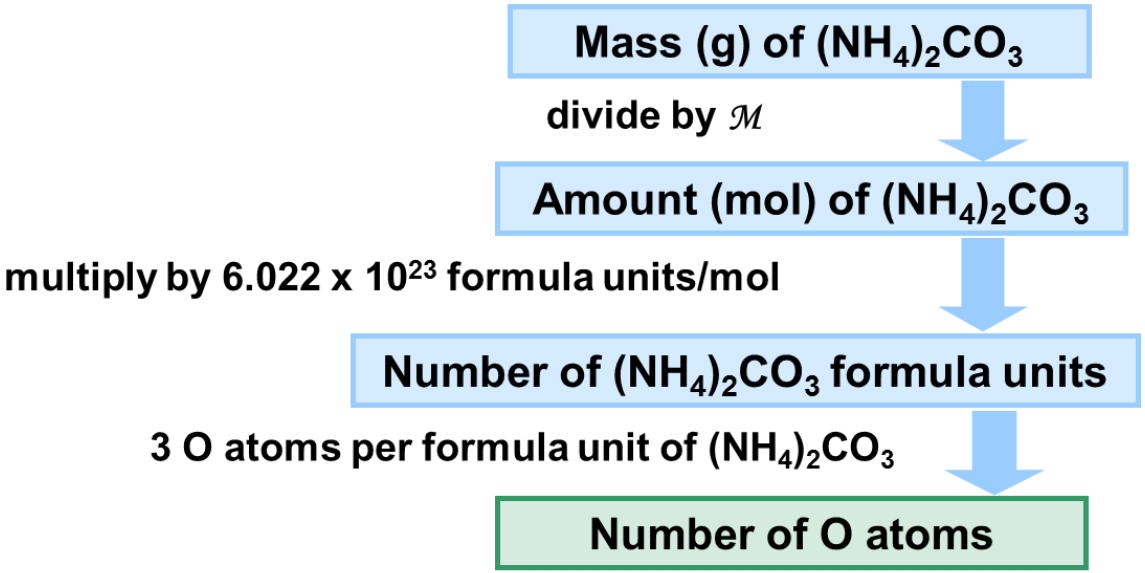
Converting Between Number of Entities and Mass of Compound II

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

a) How many molecules are in 41.6 g of ammonium carbonate [$(NH_4)_2CO_3$]?

b) How many O atoms are in 41.6 g of $(NH_4)_2CO_3$?

PLAN:



Sample Problem 3.5

SOLUTION:

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

Molar mass of $(NH_4)_2CO_3$ = 96.09 g/mol

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

N = 2.61 x 10^{23} molecules $(NH_4)_2CO_3$

Therefore, there are 2.61 x 10^{23} molecules of $(NH_4)_2CO_3$ in 41.6 g of $(NH_4)_2CO_3$

Sample Problem 3.5

SOLUTION: b) How many O atoms are in this sample?

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

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

N_A = 7.82 x 10^{23} O atoms

Therefore, there are 7.82 x 10^{23} O atom in 41.6 g of $(NH_4)_2CO_3$

Comment : A common mistake is to forget the subscript 2 outside the parentheses in $(NH_4)_2CO_3$, which would give a much lower molar mass

Sample Problem 3.5A

PROBLEM: Tetraphosphorus decoxide (P_4O_{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 4.65×10^{22} molecules of P_4O_{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.*