Unit 5

On completion of the unit you should be able to:

1. write the number of particles in a mole.
2. calculate the formula (or molecular) mass of compounds.
3. solve problems involving conversions between the mass, the number of moles, the number of formula units and the volume (for gaseous substances at standard temperature and pressure).
4. given the formula of a compound calculate the percent composition.
5. given the composition of a compound calculate the empirical formula.
6. given the composition and molecular mass of a molecular compound calculate the molecular formula.
7. express solution concentration in moles/liter.
8. do calculations involving solutions which have concentrations expressed in moles/liter.
9. solve dilution calculation.

Today's focus.

THE MOLE CONCEPT
5.1 **Mole concept**
Reading: Hebden – page 78
5.2 **Formula mass**
5.3 **Information in chemical formulae**
5.4 **From amu to gram**
5.5 **Molar mass**
Reading: Hebden – page 79
5.6 **Calculations involving Avogadro's number**
Reading: Hebden – page 81-88

5.7 **Molar volume of a gas**
Reading: Hebden – page 82
5.8 **Percent composition of compounds**
Reading: Hebden – page 90
5.9 **Empirical formula**
Reading: Hebden – page 91-95
5.10 **Molarity and solution preparation**
Reading: Hebden – page 96-98
5.11 **Solution dilution**
Reading: Hebden – page 99

Mole Concept

Avogadro's Number is 6.02×10^{23}

The **mole unit** is used to express:

1. A mass quantity
2. A counting quantity

1 water molecule

1 mole of water molecules

$\frac{\text{amu}}{\text{molecule}}$

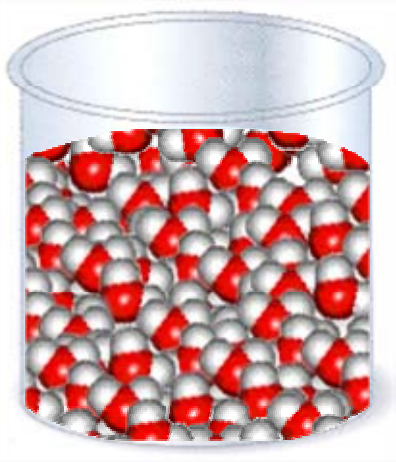
Conversion Factors:

6.02×10^{23} amu = 1 gram

(Scale up so that we can weigh in the lab)

6.02×10^{23} water molecules = 1 mole of water molecules

(12 = 1 dozen)



$\frac{\text{g}}{\text{mole}}$

Formula Mass

also called:
Molar mass or Molecular mass

Q: What is the formula mass of water?

1.008	15.999
H	O
1	8

H_2O

(1.008x2)+(15.999x1) =

$$18.015 \frac{g}{\text{mole of } H_2O}$$

$$18.015 \frac{\text{amu}}{\text{molecule of } H_2O}$$

Formula Mass

also called:
Molar mass or Molecular mass

Q: What is the formula mass of ammonium sulfate?

1.008	14.007	15.999	32.06
H	N	O	S
1	7	8	6

$(NH_4)_2SO_4$

(1.008x8)+(14.007x2)+(15.999x4)+(32.06x1) = $132.13 \frac{g}{mole}$

$132.13 \frac{amu}{formula\ unit}$

Make sure you count the number of atoms in the chemical formula accurately.

Formula Mass

also called:
Molar mass or Molecular mass

Q: What is the *molar mass* of cupric sulfate pentahydrate?

1.008	63.546	15.999	32.06
H	Cu	O	S
1	29	8	16

$CuSO_4 \cdot \underbrace{5H_2O}_{18.015 \times 5}$

$(63.546 \times 1) + (15.999 \times 4) + (32.06 \times 1) + (18.015 \times 5) = 249.68 \frac{g}{mole}$

"Molar" mass implies per mole

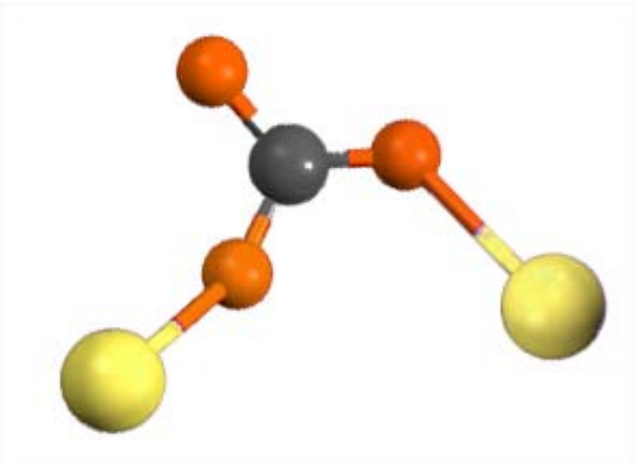
Information in Chemical Formulae

Sodium carbonate

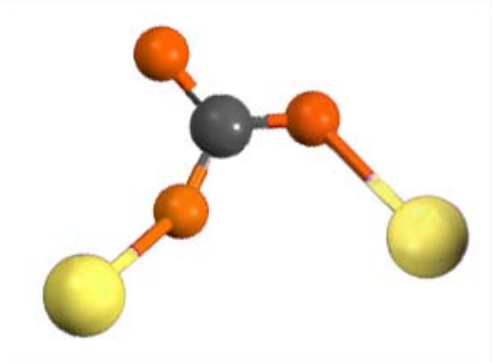
Na_2CO_3

What are the *parts* needed to make ONE formula unit of sodium carbonate?

22.990	12.011	15.999
Na	C	O
11	6	8

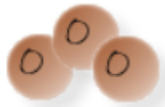
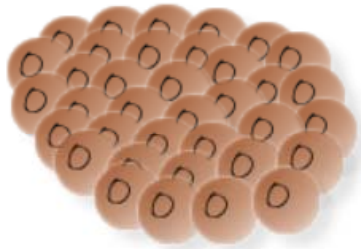
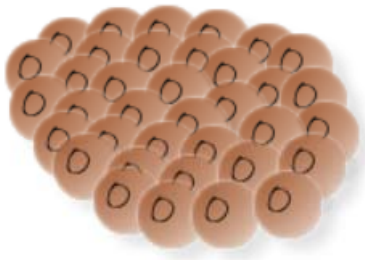


Information in Chemical Formulae



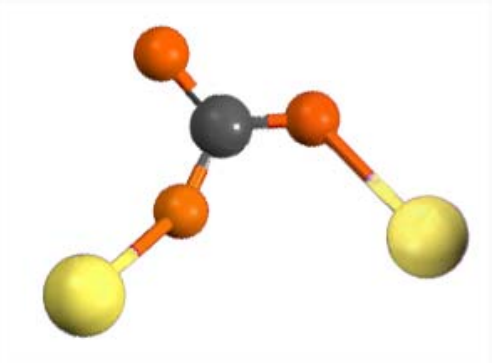
Na_2CO_3

Number of ratio of atoms: (parts)

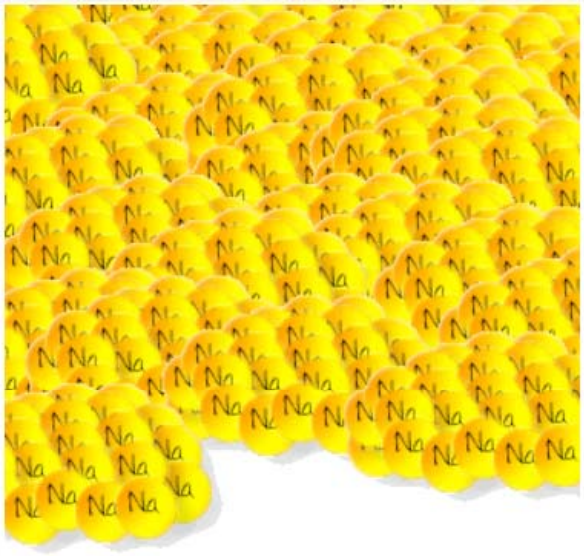
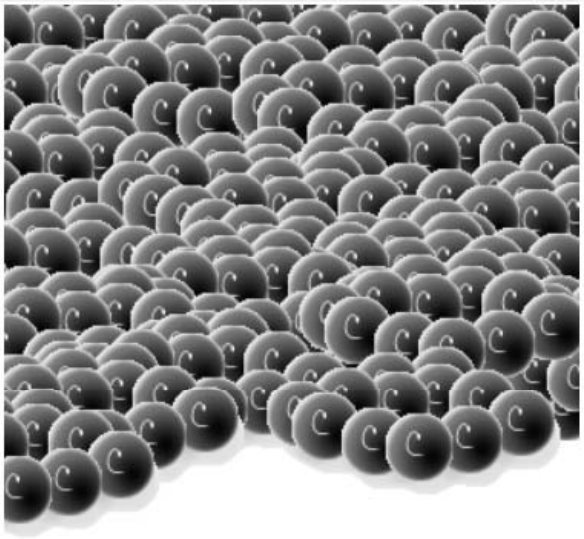
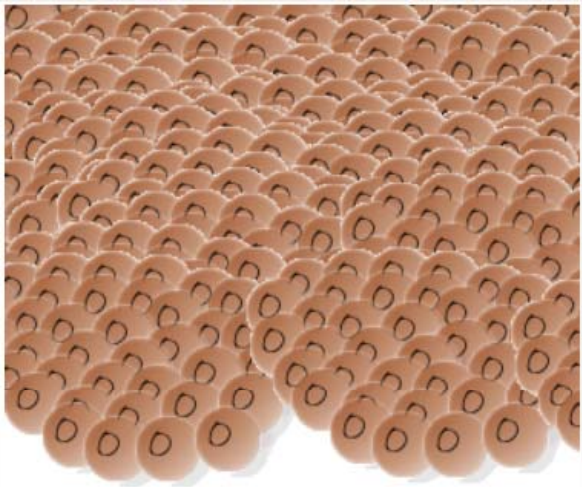
	Na	:	C	:	O
one formula unit	 **two** Na atoms		 **one** C atom		 **three** O atoms
12 formula units	 **2**(12) = 24 Na atoms		 **1**(12) = 12 C atoms		 **3**(12) = 36 O atoms
one dozen formula units	**two** dozens (= 24)  2(12) Na atoms		**one** dozen (= 12)  1(12) C atoms		**three** dozens (= 36)  3(12) O atoms

Information in Chemical Formulae

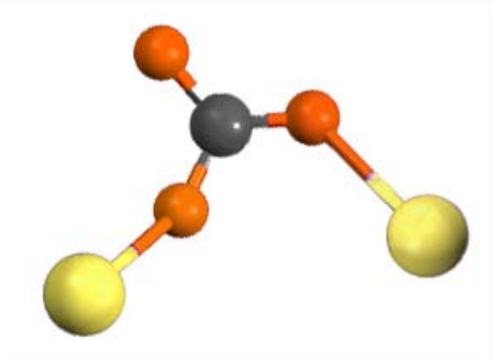
Na_2CO_3



Number of ratio of atoms: (parts)

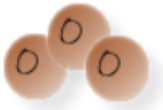
	Na	: C	: O
6.022 x 10^{23} formula units			
	2(6.022 x 10^{23}) = 12.044 x 10^{23} Na atoms	**1**(6.022 x 10^{23}) = 6.022 x 10^{23} C atoms	**3**(6.022 x 10^{23}) = 18.066 x 10^{23} O atoms
one mole formula units	**2** moles (= 12.044 x 10^{23}) Na atoms	**1** mole (= 6.022 x 10^{23}) C atoms	**3** moles (= 18.066 x 10^{23}) O atoms

Information in Chemical Formulae



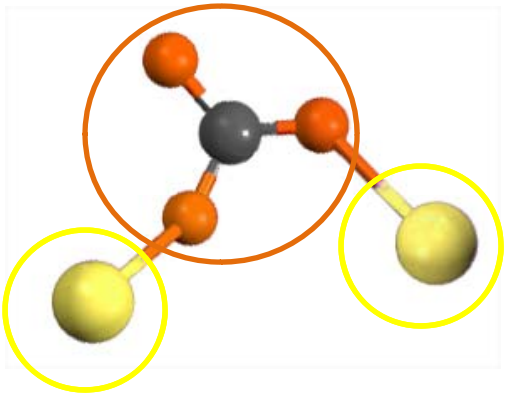
Na_2CO_3

Summary:

one formula unit	 **two** Na atoms	 **one** C atom	 **three** O atoms
one mole formula units	**2** moles (= 12.044×10^{23}) Na atoms	**1** mole (= 6.022×10^{23}) C atoms	**3** moles (= 18.066×10^{23}) O atoms

Number ratio of Na:C:O is always **2:1:3**

Information in Chemical Formulae



Na_2CO_3

Number of ratio of ions: (parts)

Na^+ CO_3^{2-}

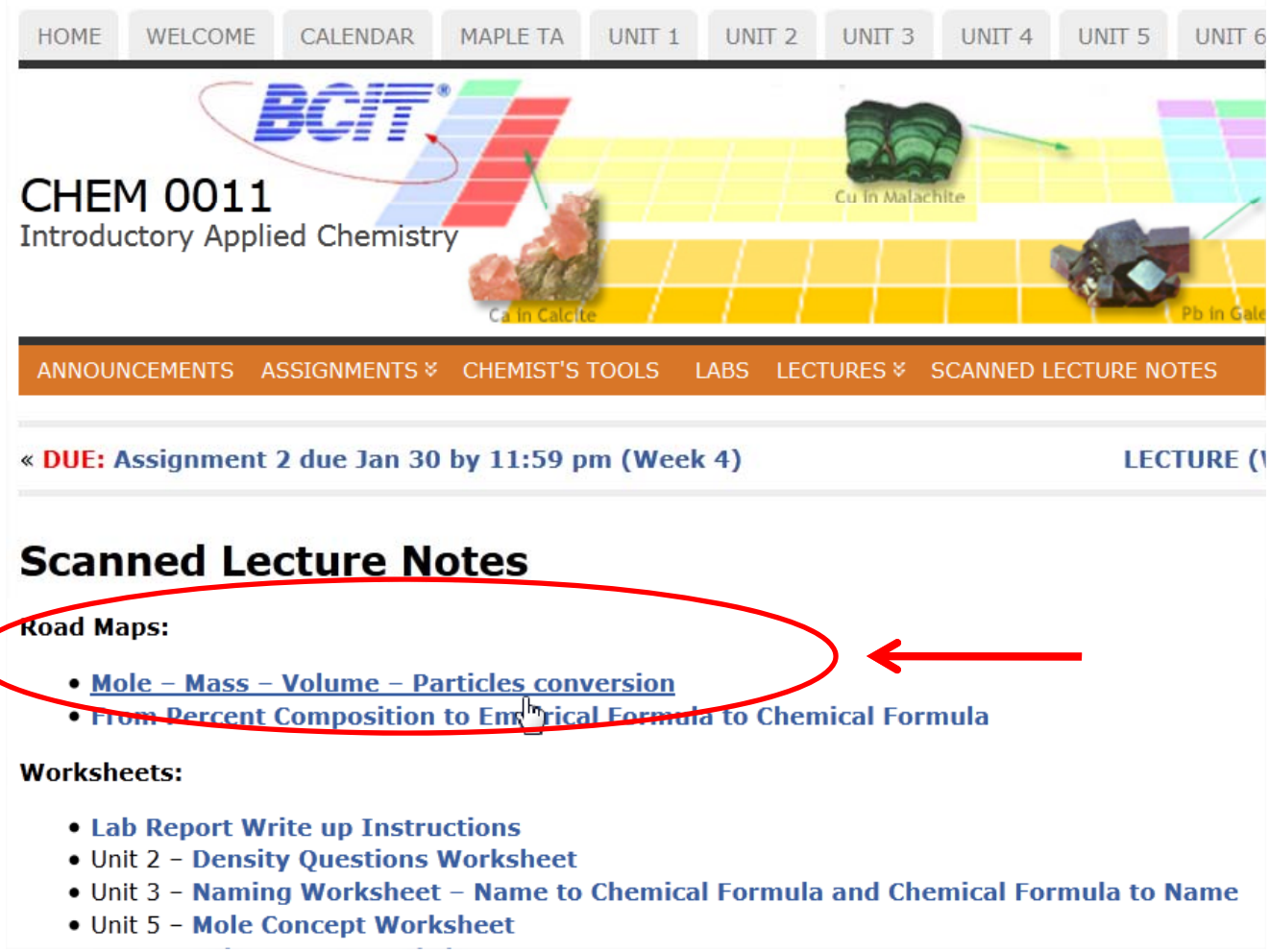
The chemical formula of Na_2CO_3	consists of:	
	number of Na^+ ions	**number of CO_3^{2-} ions**
one formula unit	**two** Na^+ ions	**one** CO_3^{2-} ion
one dozen formula units	**two** dozens Na^+ ions	**one** dozen CO_3^{2-} ion
one mole formula units	**two** moles Na^+ ions	**one** mole CO_3^{2-} ion

Number ratio of Na^+:CO_3^{2-} is always **2:1**

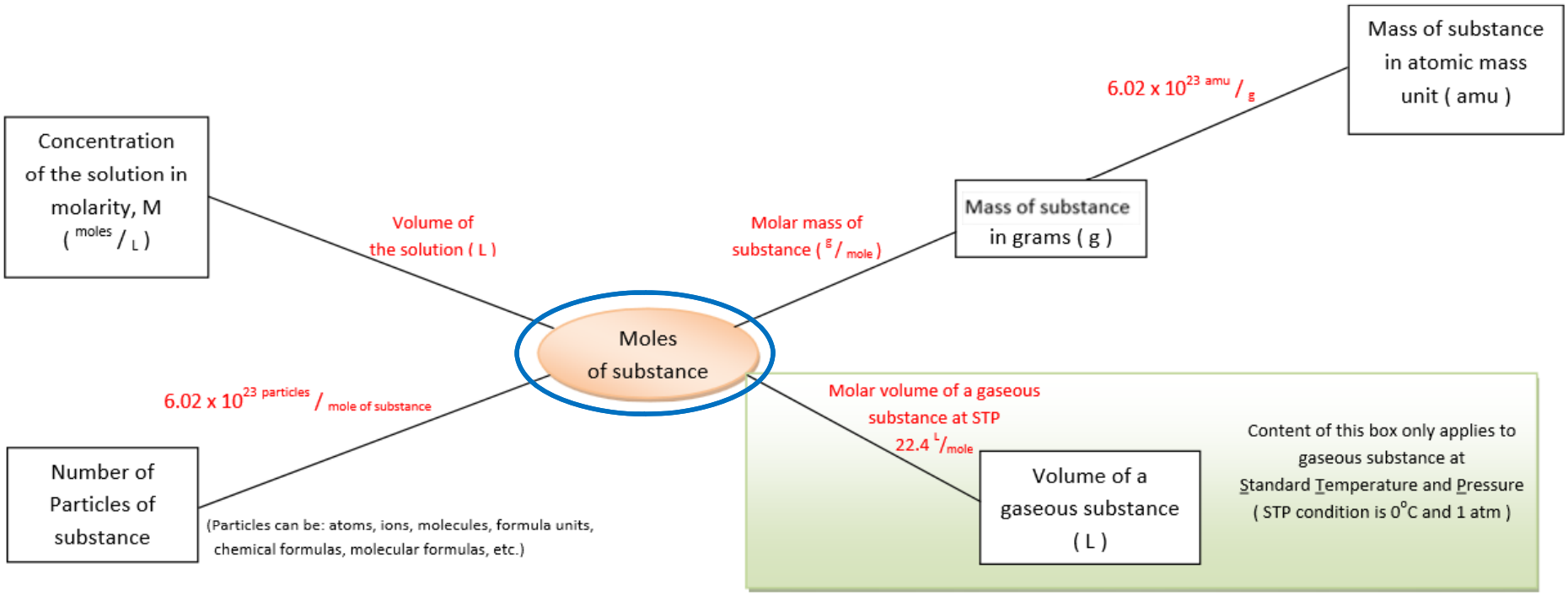
Calculations involving:

- Moles, Mass, and Number of particles

Use Dimensional Analysis & Road map



Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

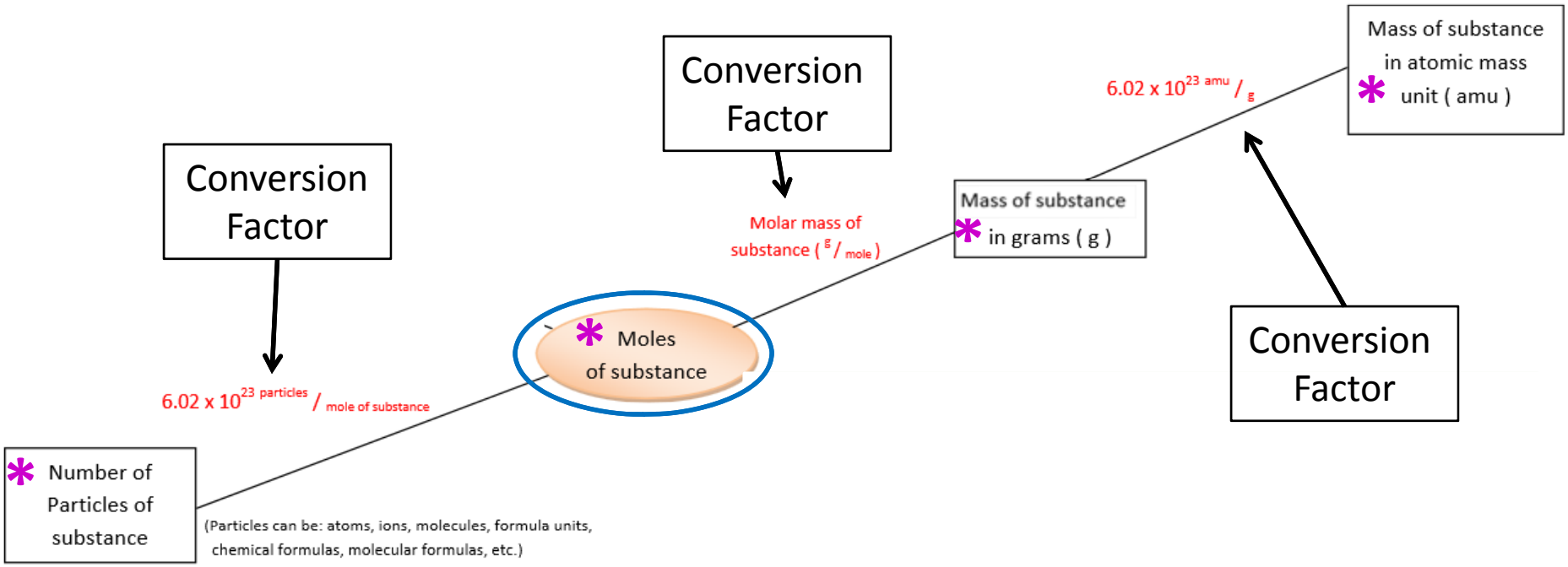


Particles can be:

- # of atoms,
- # of ions,
- # of molecules,
- # of formula units

} Parts of a formula unit

Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

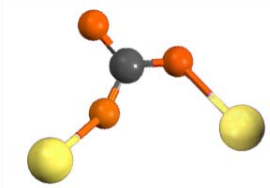


Particles can be:

# of atoms,
# of ions,
# of molecules,
# of formula units

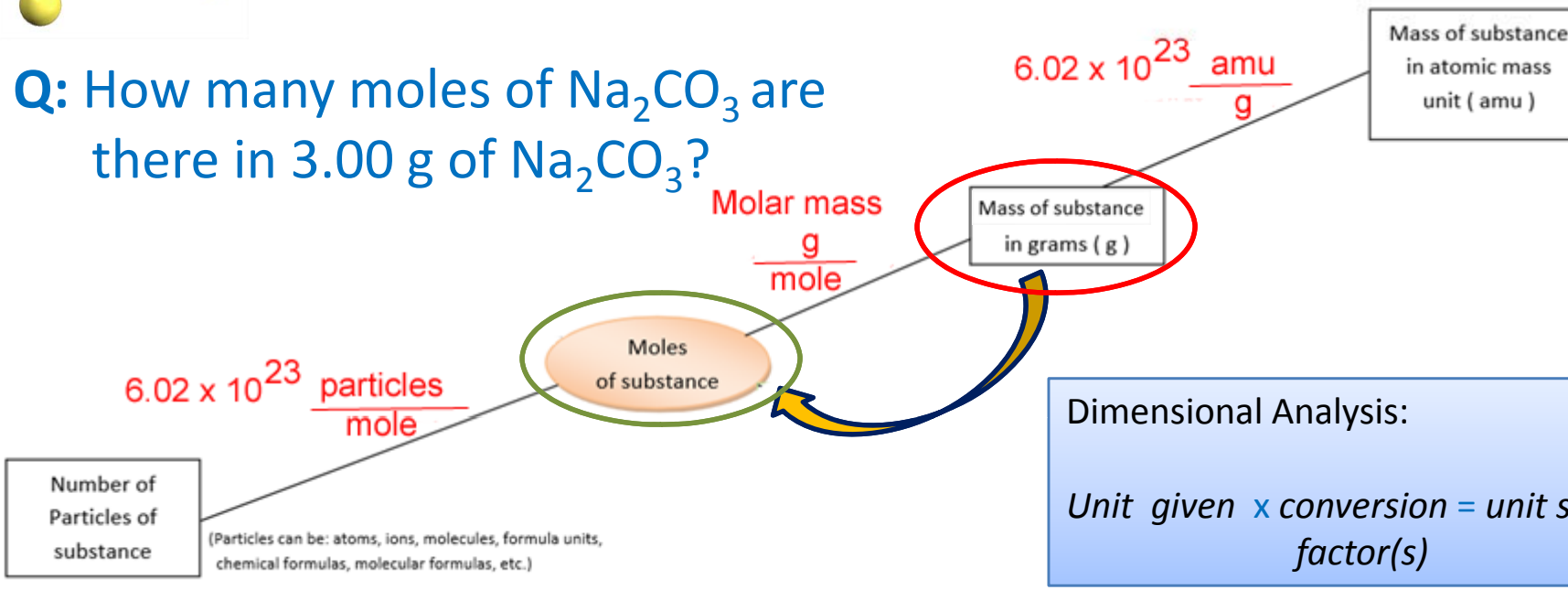
} Parts of a formula unit

* **In a problem, look for *unit given* and *unit sought*.**



Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

Q: How many moles of Na_2CO_3 are there in 3.00 g of Na_2CO_3?



Dimensional Analysis:

Unit given x conversion = unit sought
factor(s)

Particles can be:
- # of atoms,
- # of ions,
- # of molecules,
- # of formula units

Do you expect the answer to be a big number or a small number?

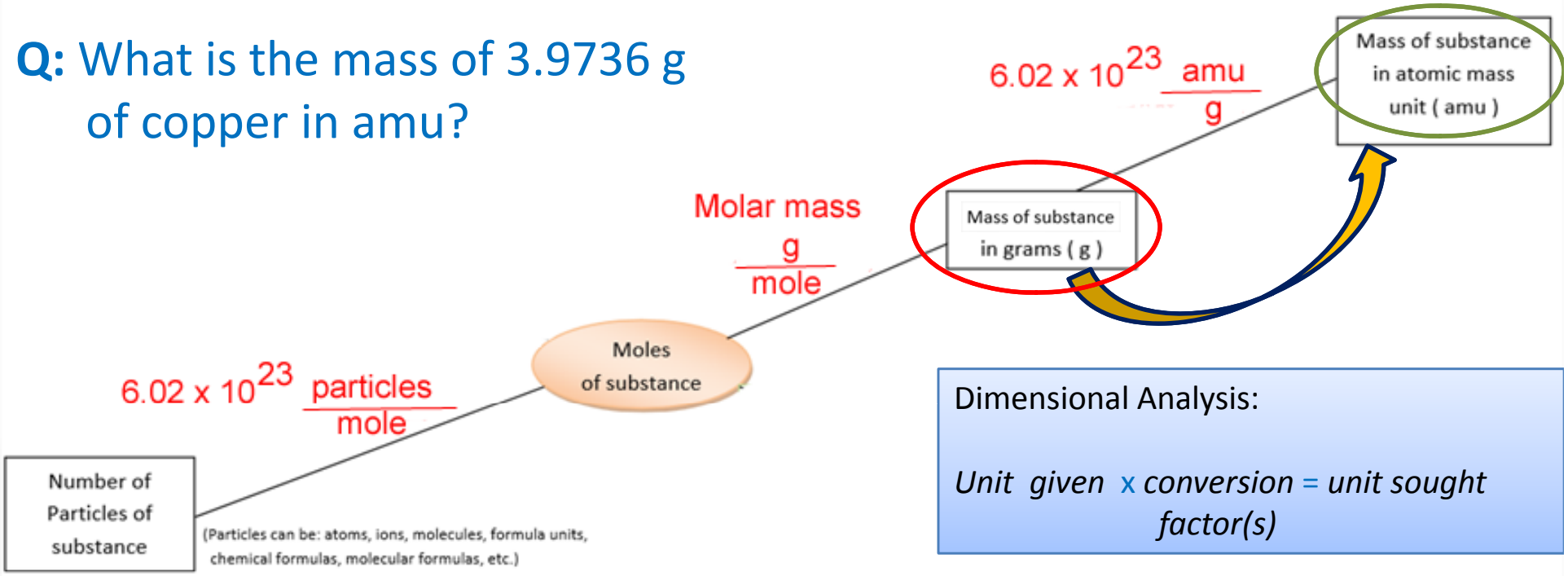
Conversion Factor: Molar Mass = 105.988 $^{g}/_{mole}$

$$3.00 \text{ g } Na_2CO_3 \times \frac{1}{105 \quad .988} \frac{\text{mole}}{\text{g } Na_2CO_3} = ? \text{ moles } Na_2CO_3$$

A: 0.0283 moles Na_2CO_3

Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

Q: What is the mass of 3.9736 g of copper in amu?



Dimensional Analysis:

Unit given x *conversion* = *unit sought*
factor(s)

Particles can be:
- # of atoms,
- # of ions,
- # of molecules,
- # of formula units

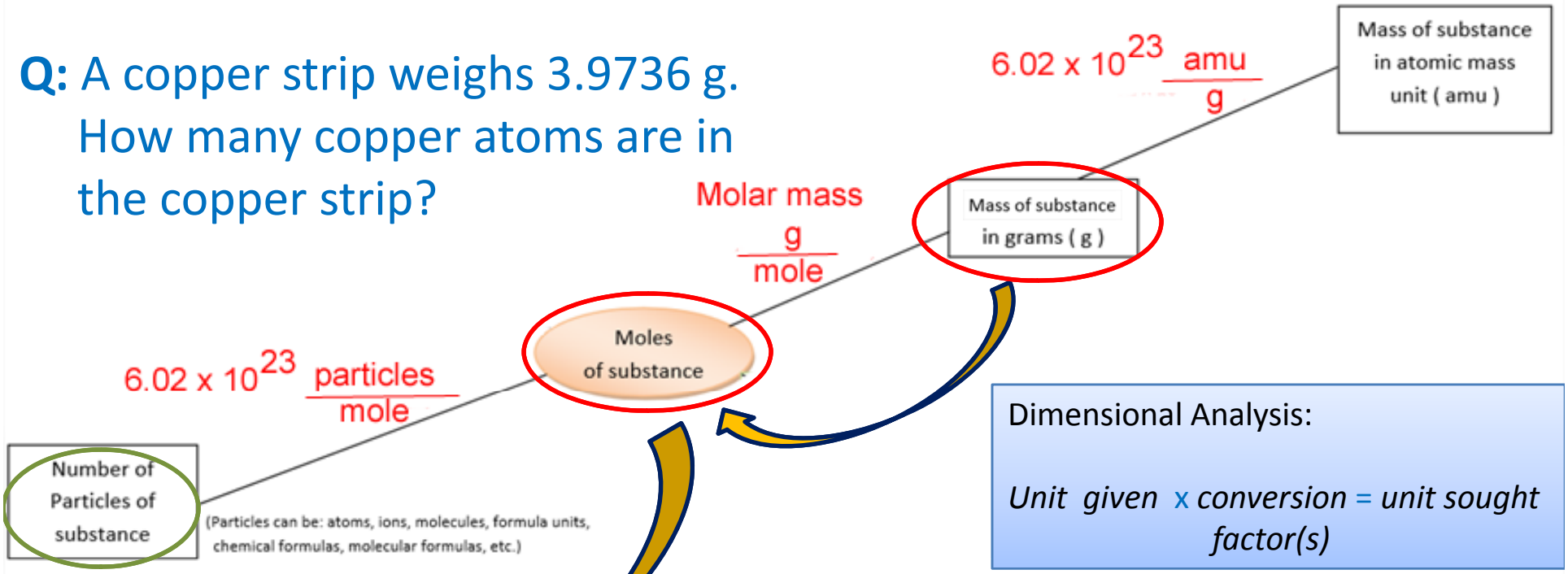
Do you expect the answer to be a big number or a small number?

$$3.9736 \text{ g Cu} \times 6.02 \times 10^{23} \frac{\text{amu}}{\text{g}} = ? \text{ amu}$$

A: 2.39×10^{24} amu

Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

Q: A copper strip weighs 3.9736 g. How many copper atoms are in the copper strip?



Particles can be:
- # of atoms,
- # of ions,
- # of molecules,
- # of formula units

Dimensional Analysis:

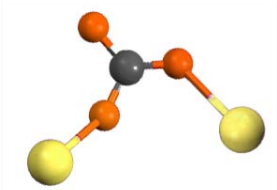
Unit given x *conversion factor(s)* = *unit sought*

Do you expect the answer to be a big number or a small number?

Conversion Factor: Atomic Mass = 63.546 $^{g}/_{mole}$

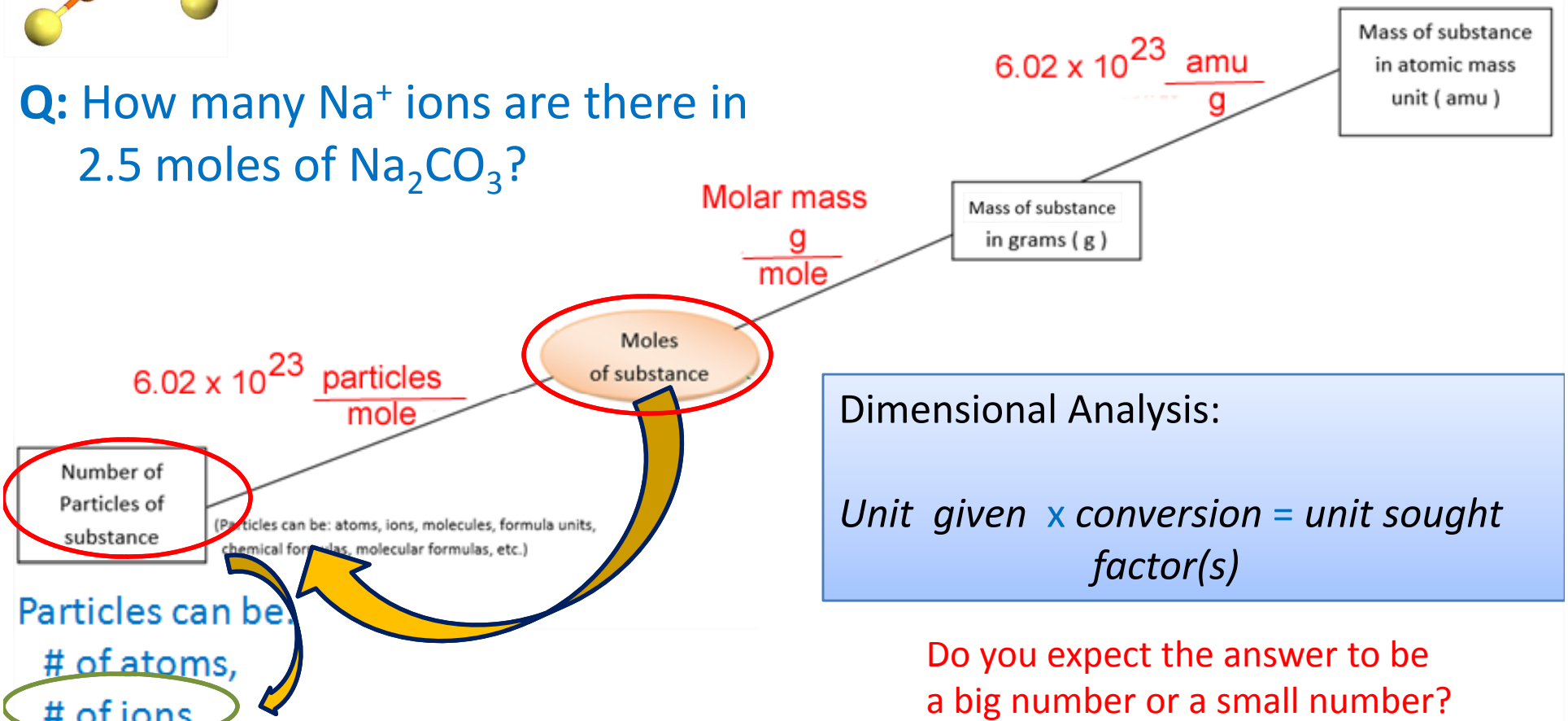
$$3.9736\ \cancel{g\ Cu} \times \frac{1}{63.546}\ \frac{\cancel{mole}}{\cancel{g\ Cu}} \times 6.02 \times 10^{23}\ \frac{Cu\ atoms}{\cancel{mole}} = ?\ Cu\ atoms$$

A: 3.76×10^{22} Cu atoms



Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

Q: How many Na^+ ions are there in 2.5 moles of Na_2CO_3?



Particles can be:
- # of atoms,
- # of ions,
- # of molecules,
- # of formula units

Dimensional Analysis:

Unit given x conversion = unit sought
factor(s)

Do you expect the answer to be a big number or a small number?

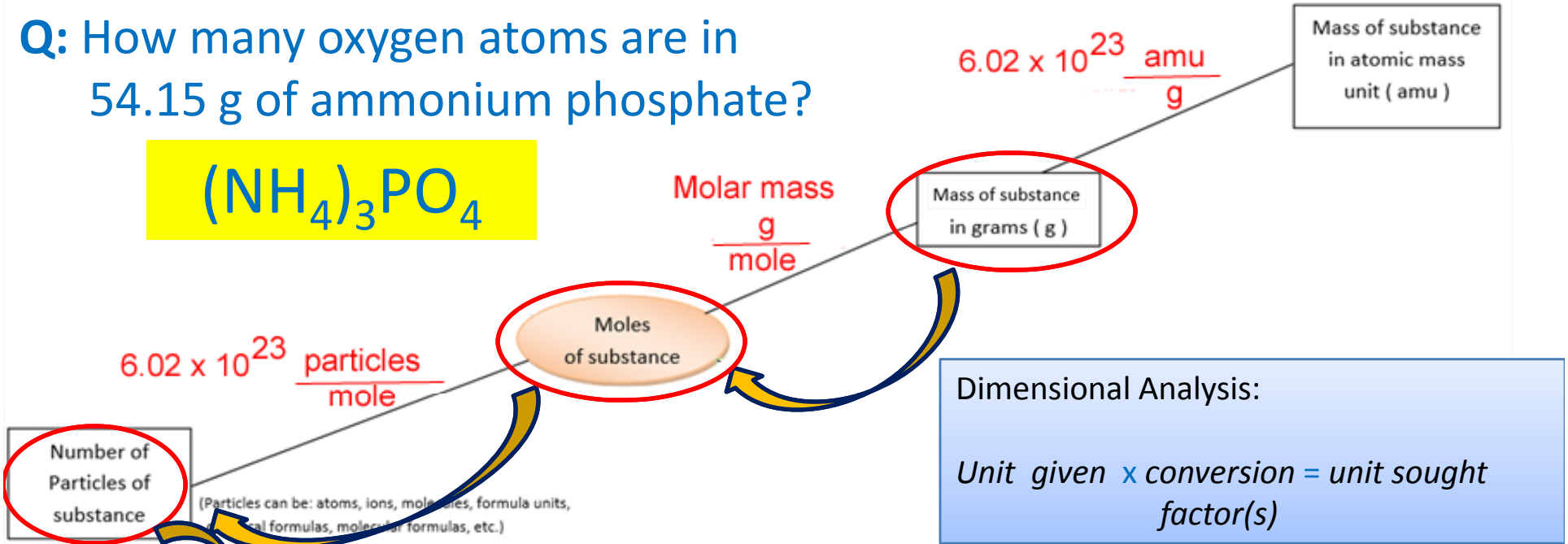
$$2.5 \text{ moles } Na_2CO_3 \times 6.02 \times 10^{23} \frac{Na_2CO_3 \text{ formula units}}{\text{mole of } Na_2CO_3} \times 2 \frac{Na^+ \text{ ions}}{Na_2CO_3 \text{ formula unit}} = ? \; Na^+ \text{ ions}$$

A: 3.0×10^{24} Na^+ ions

Expanded Road Map for "Mole - Mass - Volume - Particles" Calculations

Q: How many oxygen atoms are in 54.15 g of ammonium phosphate?

$(NH_4)_3PO_4$



Dimensional Analysis:

Unit given x conversion = unit sought
factor(s)

Particles can be:
# of atoms,
# of ions,
# of molecules,
# of formula units

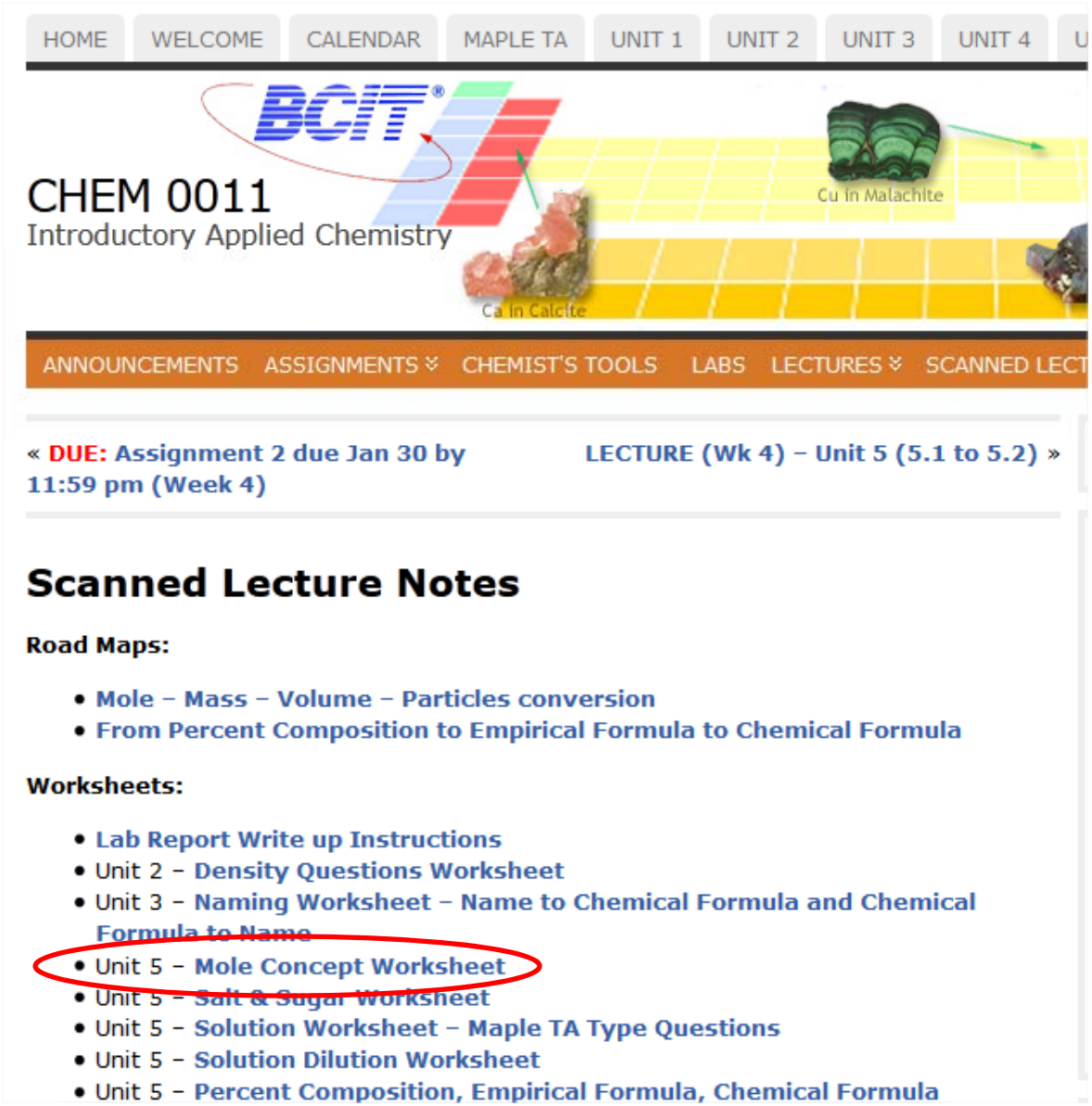
Do you expect the answer to be a big number or a small number?

Conversion Factor: Molar Mass = 149.05 $^{g}/_{mole}$

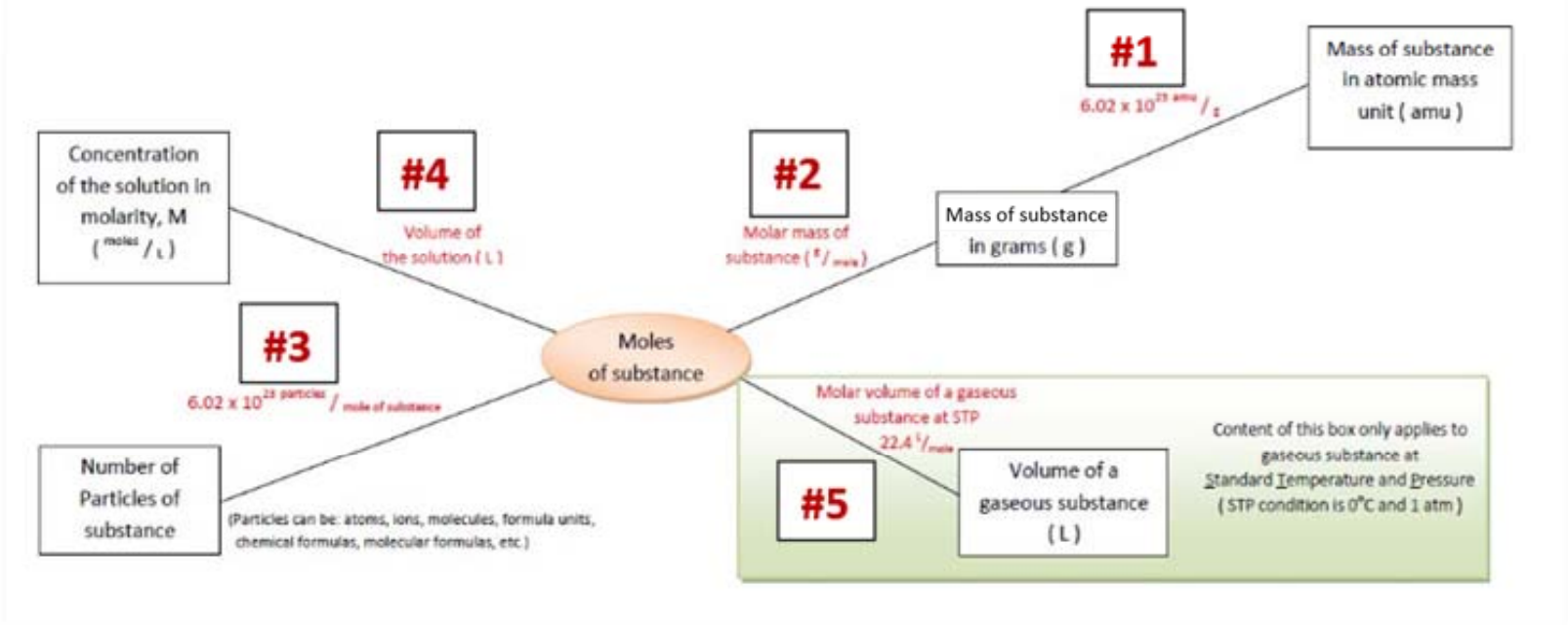
$$54.15\ \text{g}\ (NH_4)_3PO_4 \times \frac{1}{149.05} \frac{\text{mole}}{\text{g}\ (NH_4)_3PO_4} \times 6.02 \times 10^{23} \frac{(NH_4)_3PO_4}{\text{mole}} \times 4 \frac{\text{O atoms}}{(NH_4)_3PO_4} = ?\ \text{O atoms}$$

A: 8.75×10^{23} O atoms

Mole Concept Worksheet



Mole Concept Worksheet



1. One mole of aluminum, Al, is equivalent to

(a) 26.9815 amu.
(b) 6.02E23 grams.
(c) 6.02E23 atoms.
(d) 26.9815 atoms.

1 mole Al = ? amu
or
1 mole Al = ? g
or
1 mole Al = ? atoms

Your plan of action:

Plan of action to test (a): (#2, #1)

Cannot be (b) or (d) because

1 mole $\neq$ 6.02x10^{23} g. → 6.02 x 10^{23} $\frac{amu}{g}$

1 mole $\neq$ 26.9815 atoms. → 6.02x10^{23} $\frac{atoms}{mole}$

Plan of action for (c):

1 mole = 6.02x10^{23} atoms. → Correct!

(a) 1 ~~mole Al~~ x 26.982 $\frac{\cancel{g}}{\cancel{mole}}$ x 6.02 x 10^{23} $\frac{amu}{\cancel{g}}$ = 1.62x10^{25} amu Not (a)

Ans: (c)

Do the Mole Concept Worksheet.
Answers will be posted later in the week.

Try some mole concept
practice problems in Maple TA.

Use Dimensional Analysis in your
calculations!!