# U5 - Moles

## Topic 1 - Molar Mass

↳ units switch to grams (g)

↳ $F_2$ → subscript (tells us how many of a certain element we have)

### Molar Mass of Element

Na: 23 g ← A# if normal element

Diatomics - $N_2 O_2 F_2 Cl_2 Br_2 I_2$ ✱ $H_2$

$H_2 = (1)(2) = 2$ g

$O_2 = (16)(2) = 32$ g

### Molar Mass of Compound / Molecule

Must add different elements up.

$NaCl = 23 + 35.5 = 58.5$ g
Na + Cl

$MgBr_2 = 24.3 + 80(2) = 184.3$ g
Mg + $Br_2$

$(NH_4)_2 CO_3$

sol→ $N_2H_8CO_3 = (14)(2) + (1)(8) + 12 + (16)(3)$
$N_2$ $H_8$ C $O_3$
$= 96$ g

Determining the Molar Mass for a molecule:

"Molar Mass" is also known as molecular mass or molecular weight

1. Multiply the number of atoms of the first element by the subscript (the subscript tells you the # of atoms)
2. Multiply the number of atoms of each other element by its subscript.
3. Add those numbers together.

Ex: $K_2CO_3$ = K: 2 atoms x 39.10 g = 78.20 g
C: 1 atom x 12.00 g = 12.00 g
O: 3 atoms x 16.00 g = 48.00 g
} = ~~138.20 g~~

****How do you know how many decimal places to use when getting the mass from the Periodic Table?????? ANSWER: Look at how many sig figs you have in the known. Use that many sig figs in the molar mass.**

How to determine the mass for a DIATOMIC ELEMENT:

A Diatomic Element is an element on the Periodic Table that cannot exist by itself because it is too unstable. There are 7 of these elements and you MUST know them. They are:

| Element Name | Element Symbol (When it is by itself!) |
|---|---|
| Nitrogen | $N_2$ |
| Oxygen | $O_2$ |
| Fluorine | $F_2$ |
| Chlorine | $Cl_2$ |
| Bromine | $Br_2$ |
| Iodine | $I_2$ |
| Hydrogen | $H_2$ |

Remember...
You ONLY use the subscript "2" when any of the elements to the side are BY THEMSELVES!

*SO....Lets do some examples!*

1. Determine the molar mass of Aluminum Chloride

2. Determine the molar mass of Dinitrogen Pentoxide

3. Determine the mass of Gold (II) Sulfate

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KEY

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| Element Name | Element Symbol (When it is by itself!) |
|---|---|
| Nitrogen | $N_2$ = (14)(2) = 28 g |
| Oxygen | $O_2$ = (16)(2) = 32 g |
| Fluorine | $F_2$ = (19)(2) = 38 g |
| Chlorine | $Cl_2$ = (35.5)(2) = 71 g |
| Bromine | $Br_2$ = (80)(2) = 160 g |
| Iodine | $I_2$ = (127)(2) = 254 g |
| Hydrogen | $H_2$ = (1)(2) = 2 g |

Remember...
You ONLY use the subscript "2" when any of the elements to the side are BY THEMSELVES!

*SO....Lets do some examples!*

1. Determine the molar mass of Aluminum Chloride ($AlCl_3$)

$27 + (35.5)(3) = 133.5$ g

2. Determine the molar mass of Dinitrogen Pentoxide ($N_2O_5$)

$(14)(2) + (16)(5) = 108$ g

3. Determine the mass of Gold (II) Sulfate ($AuSO_4$)

$197 + 32 + (16)(4) = 293$ g

# Unit 5

## Mole Concept / Molarity / Empirical & Molecular Formulas

### Mole Concept

- three basic quantities – molar mass, molar volume, number of particles

- mass units on the periodic table are actually dimensionless
  - listed as amu (atomic mass units)
  - most commonly, if the "mole" being used is actually a "gram-mole", then the mass on the periodic table is in units of grams. The quantity for that mass is $6.02 \times 10^{23}$ atoms (known as Avogadro's #).

- molar volume has a defined temperature and pressure, known as STP – stands for standard temperature and pressure – defined as 0°C or 273 K) and 1.0 atmosphere. The molar volume at STP = 22.4 liters.

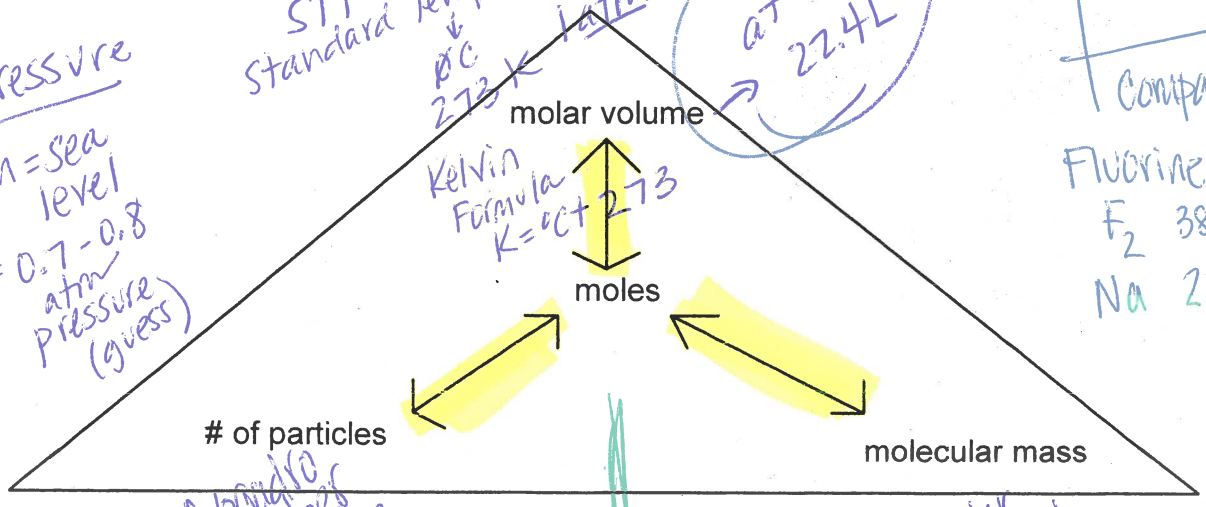
- the number of particles is based on Avogadro's number – may be any type of particle – atoms, ions, people, eyeballs, etc.

- For most mole concept problems, you need to go through three steps:

  #1. Convert the given quantity (whatever it is) into moles

  #2. Use the mole ratio between the substance given and the desired substance

  #3. Get out of moles and into the desired unit.



★ Report SigFigs to least in the problem!

*Example problems:*

1. What is the mass of a 256.0-ml sample of carbon dioxide gas at STP conditions?

$$0.2560 \text{ liters} \times \frac{1 \text{ mole}}{22.4 \text{ liters}} \times \frac{44.0 \text{ grams}}{1 \text{ mole}} = \mathbf{0.503 \text{ grams}}$$

0.5029 grams $CO_{2(g)}$

2. How many carbon atoms are in the sample described in #1?

$$0.2560 \text{ liters} \times \frac{1 \text{ mole}}{22.4 \text{ liters}} \times \frac{1 \text{ mole C}}{1 \text{ mole } CO_2} \times \frac{6.02 \times 10^{23} \text{ atoms of C}}{1 \text{ mole C}} = \mathbf{6.88 \times 10^{21} \text{ atoms}}$$

↳ mole ratio 1 carbon 2 oxygen

3. How many atoms total are there in the gas sample of #1?

$$0.2560 \text{ liters} \times \frac{1 \text{ mole}}{22.4 \text{ liters}} \times \frac{3 \text{ moles atoms}}{1 \text{ mole } CO_2} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mole of atoms}} = \mathbf{2.06 \times 10^{22} \text{ atoms}}$$

atoms total → add up the # of atoms in the sample

ex: $H_2O$ = 3 atoms
$C_6H_{12}O_6$ = 24 atoms
CO = 2 atoms

4. What is the mass, in grams, of a single molecule of carbon dioxide gas?

$$1 \text{ molecule of } CO_2 \times \frac{1 \text{ mole } CO_2}{6.02 \times 10^{23} \text{ molecules}} \times \frac{44.0 \text{ grams}}{1 \text{ mole } CO_2} = \mathbf{7.30 \times 10^{-23} \text{ grams}}$$

↳ for single molecule SigFig to 3 digits.

5. If a sample of cupric sulfate pentahydrate has $8.85 \times 10^{25}$ atoms of oxygen in it, what is the mass (in kg) of this sample? $CuSO_4 \cdot 5\,H_2O$ Molecular Wt. = 249.6 g/mole

$$8.85 \times 10^{25} \text{ atoms of O} \times \frac{1 \text{ mole of O}}{6.02 \times 10^{23} \text{ atoms of O}} \times \frac{1 \text{ mole of cpd.}}{9 \text{ moles of O}} \times \frac{249.6 \text{ grams}}{1 \text{ mole of cpd.}} = \mathbf{4.08 \text{ kilograms}}$$

6. What is the percentage of metal in a 5.00-gram sample of potassium dichromate? $K_2Cr_2O_7$

- note: the 5.00-gram sample does not matter; the percentage of metal in any size sample is the same.

also do basic % comp.

$$\% \text{ metal} = \frac{2(39.1 \text{ g/mole}) + 2(52.0 \text{ g/mole})}{2(39.1 \text{ g/mole}) + 2(52.0 \text{ g/mole}) + 7(16.0 \text{ g/mole})} \times 100 = \mathbf{61.93\ \%}$$

Practice ~~prac~~ problem (like #1 from examples)

- What is the mass of 3.26 L $Cl_{2(g)}$ at STP?

$$\frac{3.26\ L\ Cl_{2(g)}}{} \left| \frac{1\ mol\ Cl_{2(g)}}{22.4\ L\ Cl_{2(g)}} \right| \frac{71\ g\ Cl_{2(g)}}{1\ mol\ Cl_{2(g)}} = 10.3\ g\ Cl_{2(g)}$$

* STP always tells you state of matter is GAS

- Practice Problem (like ex #2)

  How many Oxygen atoms are there in 3.26 L $CO_{2(g)}$ at STP?

$$\frac{3.26\ L\ CO_{2(g)}}{} \left| \frac{1\ mol\ CO_{2(g)}}{22.4\ L\ CO_{2(g)}} \right| \frac{2\ mol\ O}{1\ mol\ CO_2} \left| \frac{6.02 \times 10^{23}\ atoms\ O}{1\ mol\ O} \right| = \boxed{1.75 \times 10^{23}\ atoms\ O}$$

mole ratio in $CO_2$
1 Carbon
2 Oxygen

## Practice Problem (like ex #3)

How many total atoms are there in 3.26 L $CO_{2(g)}$ at STP?

$$\frac{3.26\ \text{L}\ CO_{2(g)}}{} \left| \frac{1\ \text{mol}\ CO_{2(g)}}{22.4\ \text{L}\ CO_{2(g)}} \right| \frac{3\ \text{mol atoms}}{1\ \text{mol}\ CO_{2(g)}} \left| \frac{6.02\times10^{23}\ \text{atoms}}{1\ \text{mol atoms}} \right. =$$

$$= \boxed{2.63\times10^{23}\ \text{atoms}\ CO_{2(g)}}$$

## Practice Problem (like ex #4)

What is the mass, in grams, of a single molecule of nitrogen dioxide gas, $NO_{2(g)}$?

$$\frac{1\ \text{molecule}\ NO_{2(g)}}{} \left| \frac{1\ \text{mol}\ NO_{2(g)}}{6.02\times10^{23}\ \text{molecules}\ NO_{2(g)}} \right| \frac{46\ \text{g}\ NO_{2(g)}}{1\ \text{mol}\ NO_{2(g)}}$$

$$= \boxed{7.64\times10^{-23}\ \text{g}}$$

# Practice problem (like ex. #4)

What is the volume of a single atom of sulfur trioxide ($SO_{3(g)}$) gas at STP?

$$\frac{1\ \text{atom}\ SO_{3(g)}}{1} \left| \frac{1\ \text{mol}\ SO_{3(g)}}{6.02\times10^{23}\ \text{atoms}\ SO_{3(g)}} \right| \frac{22.4\ \text{L}\ SO_{3(g)}}{1\ \text{mol}\ SO_{3(g)}} = 3.72\times10^{-23}\ \text{L}\ SO_{3(g)}$$

# U5: Mole Concept Problem Set #1

Name: _____

1. How many molecules of dinitrogen pentoxide ($N_2O_5$) are there in a 5.00-gram sample of this gas?

2. What is the mass of a single atom of elemental manganese - a solid metal?

3. 67.8 grams of propane gas ($C_3H_8$) occupies what volume at STP conditions?

4. What is the percentage of water in a sample of magnesium sulfate heptahydrate ($MgSO_4 * 7H_2O$) which is Epsom's salt?

5. What is the percentage of metal in a sample of potassium permanganate ($KMnO_4$)?

6. How many grams of oxygen are there in a 10.0-liter sample of sulfur trioxide ($SO_3$)?

7. A) What is the number of molecules in a 5.000-milligram sample of ethanol ($C_2H_5OH$)?

B) What is the number of atoms (total) in this same sample?

8. A) If there are $5.88 \times 10^{25}$ ferrous ions in a sample of ferrous sulfate ($FeSO_3$), how many sulfate ions are also present?

B) What is the mass of this ferrous sulfate sample?

OMIT 8B.

## U5: Mole Concept Problem Set #1

Name: KEY

1. How many molecules of dinitrogen pentoxide ($N_2O_5$) are there in a 5.00-gram sample of this gas?

$$5.00\text{ g } N_2O_5 \left|\frac{1\text{ mol } N_2O_5}{108\text{ g } N_2O_5}\right|\frac{6.02\times10^{23}\text{ molecules}}{1\text{ mol } N_2O_5} = \boxed{2.79\times10^{22}\text{ molecules } N_2O_5}$$

2. What is the mass of a single atom of elemental manganese - a solid metal? – no # given = goto 3 SF

$$1\text{ atom Mn}\left|\frac{1\text{ mol Mn}}{6.02\times10^{23}\text{ atoms Mn}}\right|\frac{55\text{ g Mn}}{1\text{ mol Mn}} = \boxed{9.14\times10^{-23}\text{ g Mn}}$$

3. 67.8 grams of propane gas ($C_3H_8$) occupies what volume at STP conditions?

$$67.8\text{ g } C_3H_8\left|\frac{1\text{ mol } C_3H_8}{44\text{ g } C_3H_8}\right|\frac{22.4\text{ L } C_3H_8}{1\text{ mol } C_3H_8} = \boxed{34.4\text{ L } C_3H_8}$$

4. What is the percentage of water in a sample of magnesium sulfate heptahydrate ($MgSO_4 * 7H_2O$) which is Epsom's salt?

5. What is the percentage of metal in a sample of potassium permanganate ($KMnO_4$)?

6. How many grams of oxygen are there in a 10.0-liter sample of sulfur trioxide ($SO_3$)? – assume STP

$$10.0\text{ L } SO_3\left|\frac{1\text{ mol } SO_3}{22.4\text{ L } SO_3}\right|\frac{3\text{ mol O}}{1\text{ mol } SO_3}\left|\frac{16\text{ g O}}{1\text{ mol O}}\right. = \boxed{21.4\text{ g O}}$$

7. A) What is the number of molecules in a 5.000-milligram sample of ethanol ($C_2H_5OH$)?

$$5.000\ mg\ C_2H_5OH \left| \frac{1\ g\ C_2H_5OH}{1000\ mg\ C_2H_5OH} \right| \frac{1\ mol\ C_2H_5OH}{46\ g\ C_2H_5OH} \left| \frac{6.02\times10^{23}\ molecules\ C_2H_5OH}{1\ mol\ C_2H_5OH} \right.$$

$$= 6.543 \times 10^{19}\ molecules\ C_2H_5OH$$

B) What is the number of atoms (total) in this same sample? $C_2H_5OH = 9$

$$5.000\ mg\ C_2H_5OH \left| \frac{1\ g\ C_2H_5OH}{1000\ mg\ C_2H_5OH} \right| \frac{1\ mol\ C_2H_5OH}{46\ g\ C_2H_5OH} \left| \frac{9\ mol\ atoms}{1\ mol\ C_2H_5OH} \right| \frac{6.02\times10^{23}\ atoms}{1\ mol\ atoms} =$$

$$= 5.889 \times 10^{20}\ atoms\ total\ of\ C_2H_5OH$$

8. A) If there are $5.88 \times 10^{25}$ ferrous ions in a sample of ferrous sulfate ($FeSO_3$), how many sulfate ions are also present?

$$5.88\times10^{25}\ Fe^{2+}\ ions \left| \frac{1\ mol\ Fe^{2+}}{6.02\times10^{23}\ Fe^{2+}\ ions} \right| \frac{1\ mol\ SO_4^{2-}}{1\ mol\ Fe^{2+}} \left| \frac{6.02\times10^{23}\ SO_4^{2-}}{1\ mol\ SO_4^{2-}} \right.$$

$$= 5.88\times10^{25}\ SO_4^{2-}\ ions$$

| Fe | $SO_4$ |
|---|---|
| 1 | 1 |

1 to 1 ratio

B) What is the mass of this ferrous sulfate sample?

OMIT 8B.

whoops! ($FeSO_4$)