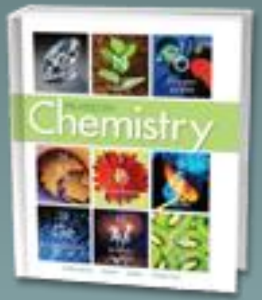
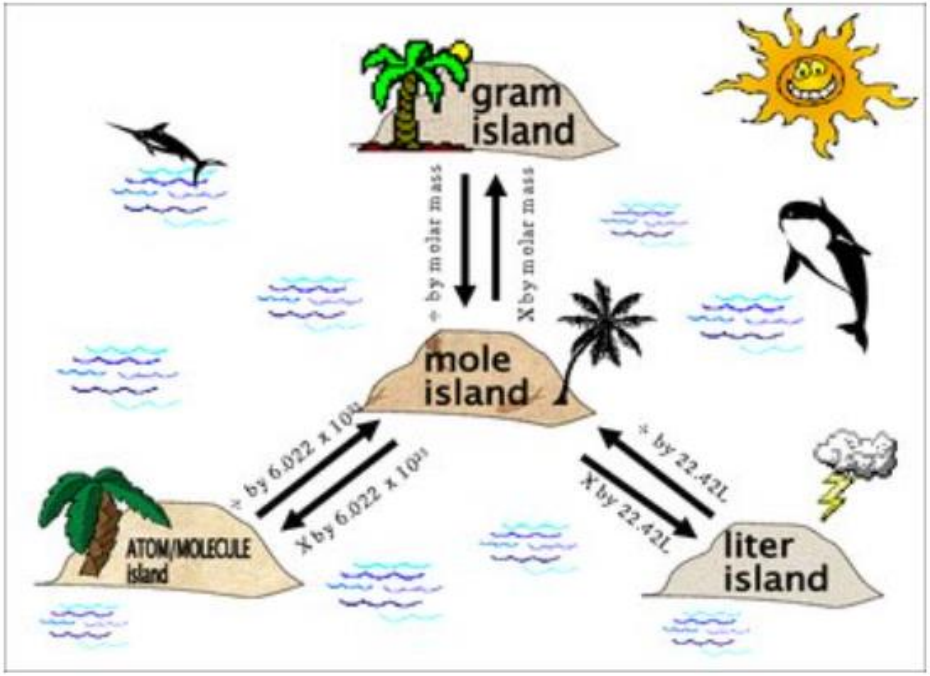


Chapter 12
Stoichiometry

The Arithmetic of Equations

Chemical Calculations

Limiting Reagent and Percent Yield



Topics:

1. Stoichiometry

Objectives:

1. Understand and use stoichiometry in balanced chemical equations (particularly regarding molar quantities of mass, volume, and number).
2. Explain and calculate the interconversion of reactants and products using mole ratios (coefficients).

WARM-UP

What is the Gram Formula Mass of Potassium Chlorate?

How many moles are in 350. g $CaCO_3$?

WARM-UP

What is the Gram Formula Mass of Potassium Chlorate?

$K^{+}Cl^{+5}O_3^{-2}$

K 1 x 39.1 = 39.1

Cl 1 x 35.5 = 35.5

O 3 x 16.0 = 48.0

GFM = 123 g/mol

How many moles are in 350. g $CaCO_3$?

Ca 1 x 40.1 g/mole = 40.1 g/mol

C 1 x 12.0 g/mole = 12.0 g/mol GFM

O 3 x 16.0 g/mole = 48.0 g/mol

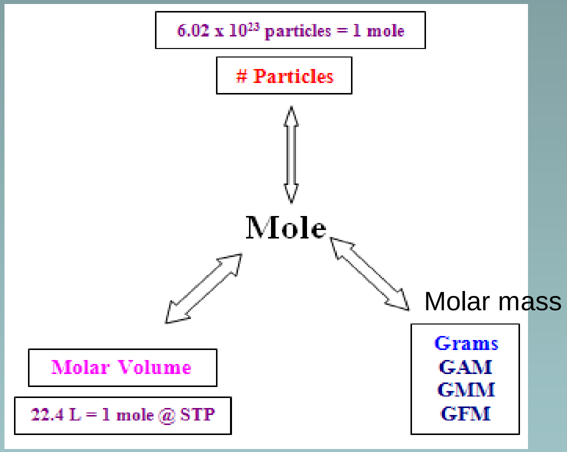
} 100. g/mol

350. g x 1 mol / 100 g = **3.50 moles**

WARM-UP

Molar Quantities

How many grams are there in 4.00×10^{23} particles $AlCl_3$?



How many grams of Hydrogen gas are in 44.8 liters @ STP?

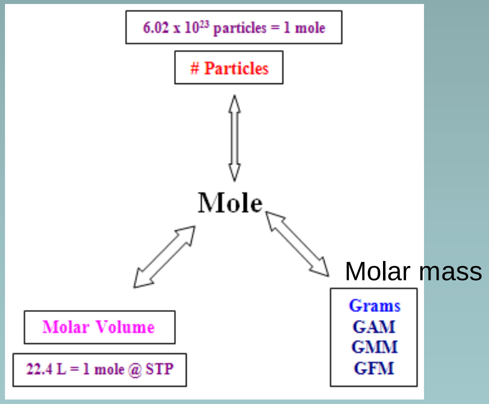
WARM-UP

How many grams are there in 4.00 x 10^{23} particles $AlCl_3$?

Always convert to MOLES as the standard

4.00 x 10^{23} particles x 1 mole/6.02 x 10^{23} particles = 0.664 mol

Molar Mass of $AlCl_3$ = ~133.5 g/mol



$Al^{+3}Cl_3^{-}$

Al	1	x	27.0	=	27.0
Cl	3	x	35.5	=	106.5

0.664 mol x 133.5 g/mole = **88.6 g**

How many grams of Hydrogen gas are in 44.8 liters @ STP?

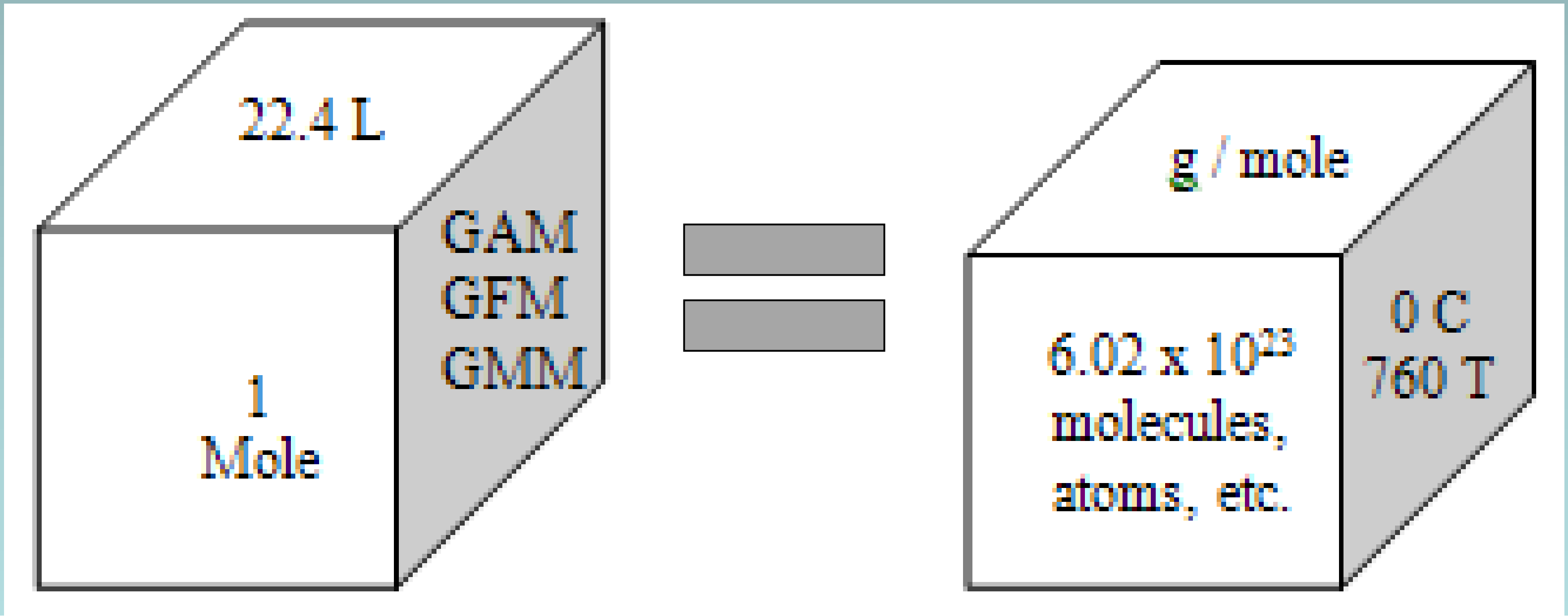
$H_{2\,(g)}$ 44.8 L x 1 mol / 22.4 L = 2.00 mol

Molar Mass of H_2 = ~2.00 g/mol

2.00 mol x 2 g / mol = **4.00 g**

Stoichiometry of Equations

The goal in manipulating molar mass, molar volume, and representative particles (N_A) was to be able to determine exact quantities of a substance in a reaction [analytical or quantitative analysis] AND how they relate to each other.



Stoichiometry of Equations

The calculations of reactants and products in chemical reactions is called **stoichiometry**.

For chemists, stoichiometry is a form of bookkeeping.

Stoichiometry of Equations

A balanced chemical equation tells you the relative amounts of reactants and product in the reaction.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The balanced chemical equation can be interpreted using different quantities including numbers of atoms, molecules, moles, mass, and/or volume.

What are the mole ratios of the molecules?

Stoichiometry of Equations

A balanced chemical equation tells you the relative amounts of reactants and product in the reaction.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The coefficients in the equation represent moles and establish **mole ratios** between any two reactants or products.

For instance:

$N_2:H_2 = 1:3$ $N_2:NH_3 = 1:2$ $H_2:NH_3 = 3:2$

QUICK CHECK

$$2\ C_2H_{2\ (l)} + 5\ O_{2\ (g)} \rightarrow 4\ CO_{2\ (g)} + 2\ H_2O_{(g)}$$

__ mol of $C_2H_{2\ (l)}$ react with __ mol $O_{2\ (g)}$ to yield __ mol of CO_2 and __ mol of water.

6 mol of $C_2H_{2\ (l)}$ would react with __ mol $O_{2\ (g)}$ to yield __ mol of CO_2 and __ mol of water.

If only 1 mol of CO_2 is produced, then __ mol of $C_2H_{2\ (l)}$ react with __ mol $O_{2\ (g)}$ to yield __ mol of water.

All of these represent Theoretical Yield.

$$2\,C_2H_{2\,(l)} + 5\,O_{2\,(g)} \rightarrow 4\,CO_{2\,(g)} + 2\,H_2O_{(g)}$$

2 mol of $C_2H_{2\,(l)}$ react with 5 $O_{2\,(g)}$ to yield 4 mol of CO_2 and 2 mol of water.

6 mol of $C_2H_{2\,(l)}$ would react with 15 $O_{2\,(g)}$ to yield 12 mol of CO_2 and 6 mol of water.

If only 1 mol of CO_2 is produced, then 0.5 mol of $C_2H_{2\,(l)}$ react with 1.25 mol $O_{2\,(g)}$ to yield 0.5 mol of water.

Theoretical Yield is the expected moles.

TRY IT

Atoms or Molecules

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Based on the equation, how many molecules are represented?

How many atoms are represented?

TRY IT

Atoms or Molecules

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

2 atoms/molecule

How many molecules are represented?

$$1 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } N_2 \end{array} \right)$$

6.02×10^{23}
molecules N_2

How many atoms are represented?

$$2 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } N_2 \end{array} \right)$$

12.0×10^{23} atoms N
in 1 mol N_2

TRY IT

Atoms or Molecules

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

2 atoms/molecule   2 atoms/molecule

How many molecules are represented?

$$1 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } N_2 \end{array} \right) + 3 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } H_2 \end{array} \right)$$

6.02×10^{23} molecules N_2 18.1×10^{23} molecules H_2

How many atoms are represented?

$$2 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } N_2 \end{array} \right) + 2 \times \left(\begin{array}{c} 18.1 \times 10^{23} \\ \text{molecules } H_2 \end{array} \right)$$

12.0×10^{23} atoms N in 1 mol N_2 36.2×10^{23} atoms H in 3 mol H_2

TRY IT

Atoms or Molecules

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

2 atoms/molecule 2 atoms/molecule 4 atoms/molecule

How many molecules are represented?

$$1 \times \left(\begin{array}{c}6.02 \times 10^{23} \\ \text{molecules } N_2\end{array}\right) + 3 \times \left(\begin{array}{c}6.02 \times 10^{23} \\ \text{molecules } H_2\end{array}\right) \rightarrow 2 \times \left(\begin{array}{c}6.02 \times 10^{23} \\ \text{molecules } NH_3\end{array}\right)$$

6.02×10^{23} molecules N_2

18.1×10^{23} molecules H_2

12.0×10^{23} molecules NH_3

How many atoms are represented?

$$2 \times \left(\begin{array}{c}6.02 \times 10^{23} \\ \text{molecules } N_2\end{array}\right) + 2 \times \left(\begin{array}{c}18.1 \times 10^{23} \\ \text{molecules } H_2\end{array}\right) \rightarrow 4 \times \left(\begin{array}{c}12.0 \times 10^{23} \\ \text{molecules } NH_3\end{array}\right)$$

12.0×10^{23} atoms N in 1 mol N_2

36.2×10^{23} atoms H in 3 mol H_2

48.2×10^{23} atoms in 2 mol NH_3

TRY IT

Atoms or Molecules

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

2 atoms/molecule

2 atoms/molecule

4 atoms/molecule

How many molecules are represented?

$$1 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } N_2 \end{array} \right) + 3 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } H_2 \end{array} \right) \rightarrow 2 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } NH_3 \end{array} \right)$$

6.02×10^{23} molecules N_2

18.1×10^{23} molecules H_2

12.0×10^{23} molecules NH_3

How many atoms are represented?

$$2 \times \left(\begin{array}{c} 6.02 \times 10^{23} \\ \text{molecules } N_2 \end{array} \right) + 2 \times \left(\begin{array}{c} 18.1 \times 10^{23} \\ \text{molecules } H_2 \end{array} \right) \rightarrow 4 \times \left(\begin{array}{c} 12.0 \times 10^{23} \\ \text{molecules } NH_3 \end{array} \right)$$

12.0×10^{23} atoms N in 1 mol N_2

36.2×10^{23} atoms H in 3 mol H_2

48.2×10^{23} atoms in 2 mol NH_3

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Based on the equation, how many grams of each molecule are represented?

$N_2(g)$

$3H_2(g)$

$2NH_3(g)$

TRY IT

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Based on the equation, how many grams of each molecules are represented?

$N_2(g)$ N 2 x 14.0 g/mol = 28.0 g/mole x 1 mol = 28.0 g

$3H_2(g)$ H 2 x 1.00 g/mol = 2.00 g/mole x 3 mol = 6.00 g

$2NH_3(g)$ N 1 x 14.0 g/mol = 14.0 g/mol
H 3 x 1.00 g/mol = 3.00 g/mol
17.0 g/mol x 2 mol = 34.0 g

*The **coefficients** represent moles and form **mole ratios**.*

TRY IT

Molar Volume

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Based on the equation, how many liters of each molecules are represented? 1 mol of any gas at STP occupies a volume of 22.4 L.

$N_2(g)$

$3H_2(g)$

$2NH_3(g)$

Stoichiometry of Equations

TRY IT

Molar Volume

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Based on the equation, how many liters of each molecules are represented? 1 mol of any gas at STP occupies a volume of 22.4 L.

$N_2(g)$ 1 mol x 22.4 L/mol = 22.4 L

$3H_2(g)$ 3 mol x 22.4 L/mol = 67.2 L

$2NH_3(g)$ 2 mol x 22.4 L/mol = 44.8 L

*The **coefficients** represent moles and form **mole ratios**.*

Molar Mass

Hydrogen sulfide is found in volcanic gases and combusts to form sulfur dioxide and water. What is the molar mass of each substance?

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

$H_2S(g)$

$O_2(g)$

$SO_2(g)$

$H_2O(g)$

Molar Mass

Hydrogen sulfide is found in volcanic gases and combusts to form sulfur dioxide and water. What is the molar mass of each substance?

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

$H_2S(g)$	H	2 x 1.00 g/mol = 2.00 g/mol	
	S	1 x 32.1 g/mol = 32.1 g/mol	34.1 g/mol
$O_2(g)$	O	2 x 16.0 g/mol =	32.0 g/mol
$SO_2(g)$	S	1 x 32.1 g/mol = 32.1 g/mol	
	O	2 x 16.0 g/mol = 32.0 g/mol	64.1 g/mol
$H_2O(g)$	H	2 x 1.00 g/mol = 2.00 g/mol	
	O	1 x 16.0 g/mol = 16.0 g/mol	18.0 g/mol

Mole Ratios

Hydrogen sulfide is found in volcanic gases and combusts to form sulfur dioxide and water (use previous problem). What is the theoretical mass of each substance based on the equation? **Prove the law of conservation of mass.**

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

Use the coefficients to find mass of reactants & products.

Learning Mole Ratios

Hydrogen sulfide is found in volcanic gases and combusts to form sulfur dioxide and water (use previous problem). What is the theoretical mass of each substance based on the equation? Prove the law of conservation of mass.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

Use the coefficients to find mass of reactants & products.

$$2 \text{ mol } H_2S + 3 \text{ mol } O_2 \longrightarrow 2 \text{ mol } SO_2 + 2 \text{ mol } H_2O$$

$$\left(2 \cancel{\text{mol}} \times 34.1 \frac{\text{g}}{\cancel{\text{mol}}}\right) + \left(3 \cancel{\text{mol}} \times 32.0 \frac{\text{g}}{\cancel{\text{mol}}}\right) \rightarrow \left(2 \cancel{\text{mol}} \times 64.1 \frac{\text{g}}{\cancel{\text{mol}}}\right) + \left(2 \cancel{\text{mol}} \times 18.0 \frac{\text{g}}{\cancel{\text{mol}}}\right)$$

$$68.2 \text{ g } H_2S + 96.0 \; O_2 \rightarrow 128.2 \text{ g } SO_2 + 36.0 \text{ g } H_2O$$

$$164 \text{ g} = 164 \text{ g}$$

This shows the law of Conservation of Mass

Stoichiometry of Equations

STRATEGY

General Problem Solving Rules

1. **Write a balanced equation**
    - *Based on the information given and using the knowledge gained in stoichiometry of formulas*
2. **Determine MOLES of reactants and products**
    - *The "MOLE" concept is the basis, the standard, for Quantitative Analysis*
3. **Use the MOLE RATIOs to interconvert between reactants and products**
    - *Coefficients in an equation represent the number of moles of any molecule or compound in that equation*
    - Since "MOLES" is a standard among all substances, we can use a MOLE RATIO to interconvert different quantitative measurements
4. **Convert moles to the desired unit** or quantity

How many moles of NH_3 are produced when 0.60 mol of nitrogen reacts with hydrogen?

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Determine moles:

Determine mole ratio:

Use mole ratio to interconvert:

STRATEGY

How many moles of NH_3 are produced when 0.60 mol of nitrogen reacts with hydrogen?

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Determine moles:

1 mol N_2 combines with 3 mol H_2 to produce 2 mol NH_3

Determine mole ratio: N_2:NH_3 =

Use mole ratio to interconvert to find mol $NH_{3(g)}$:

STRATEGY

Using Mole Ratios

How many moles of NH_3 are produced when 0.60 mol of nitrogen reacts with hydrogen?

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Determine moles:

1 mol N_2 combines with 3 mol H_2 to produce 2 mol NH_3

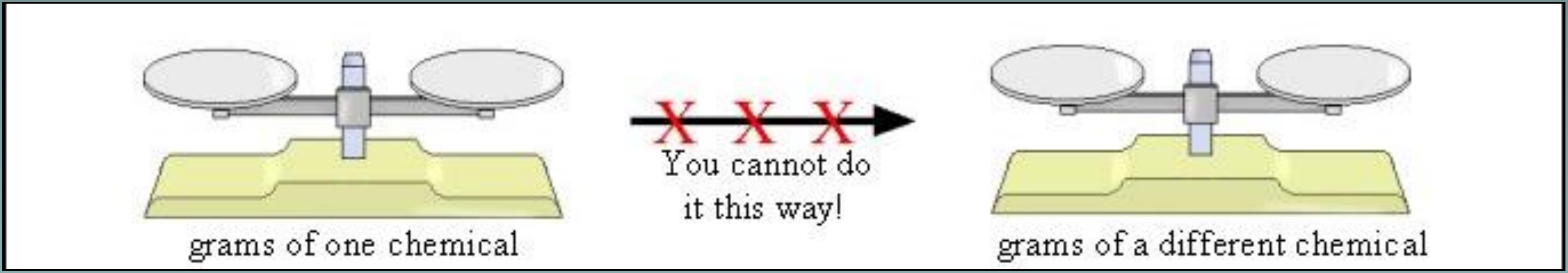
Determine mole ratio: $N_2:NH_3 = 1:2$

Use mole ratio to interconvert: 0.60/1 mol = X/2

$$X = 0.60 \cancel{\text{mol N}_2} \times \frac{2 \text{ mol NH}_3}{1 \cancel{\text{mol N}_2}} = 1.2 \text{ mol NH}_3$$

The math can be done in more than one way.

You MUST always use MOLES as the standard of conversion.



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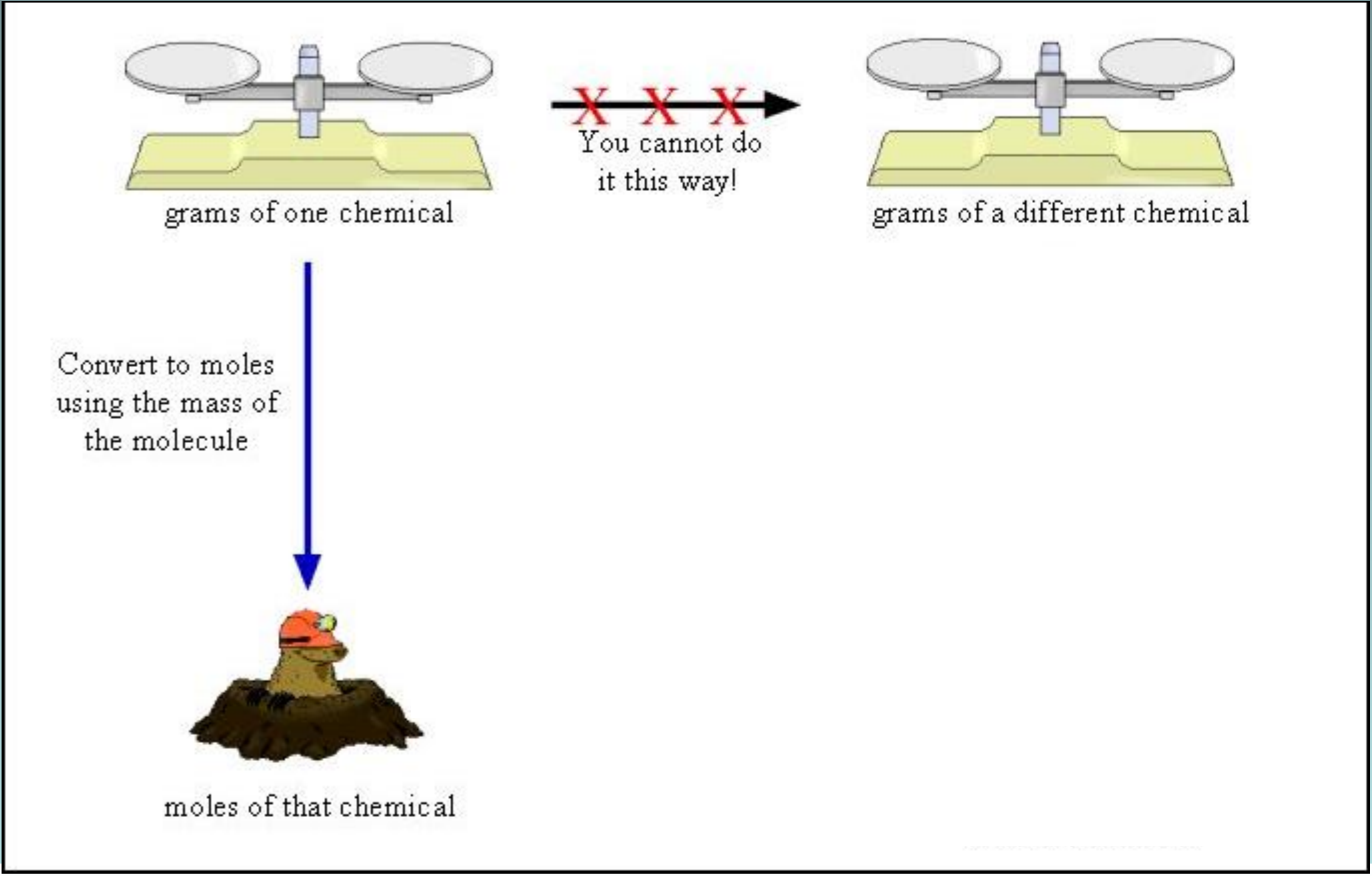

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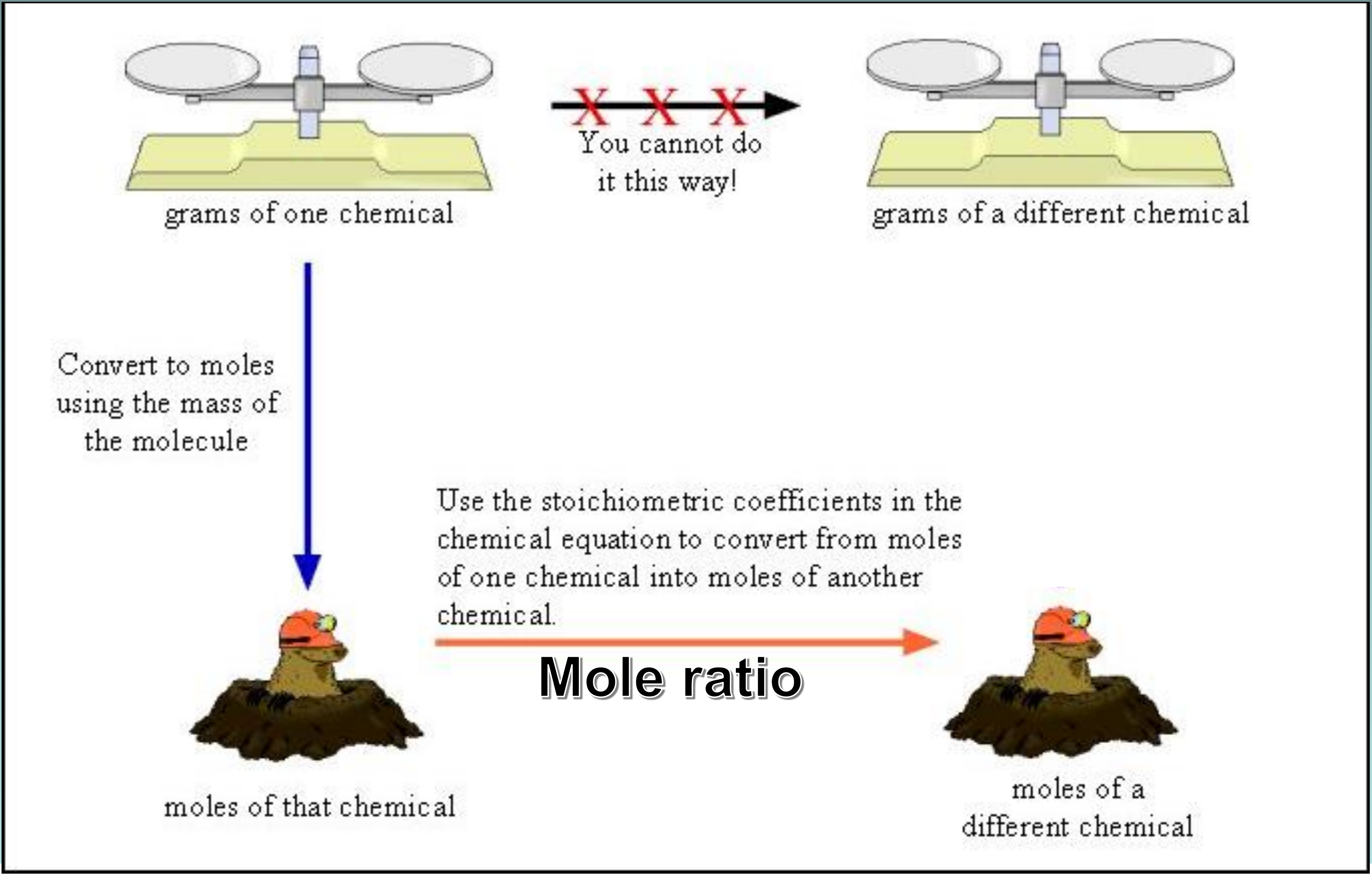

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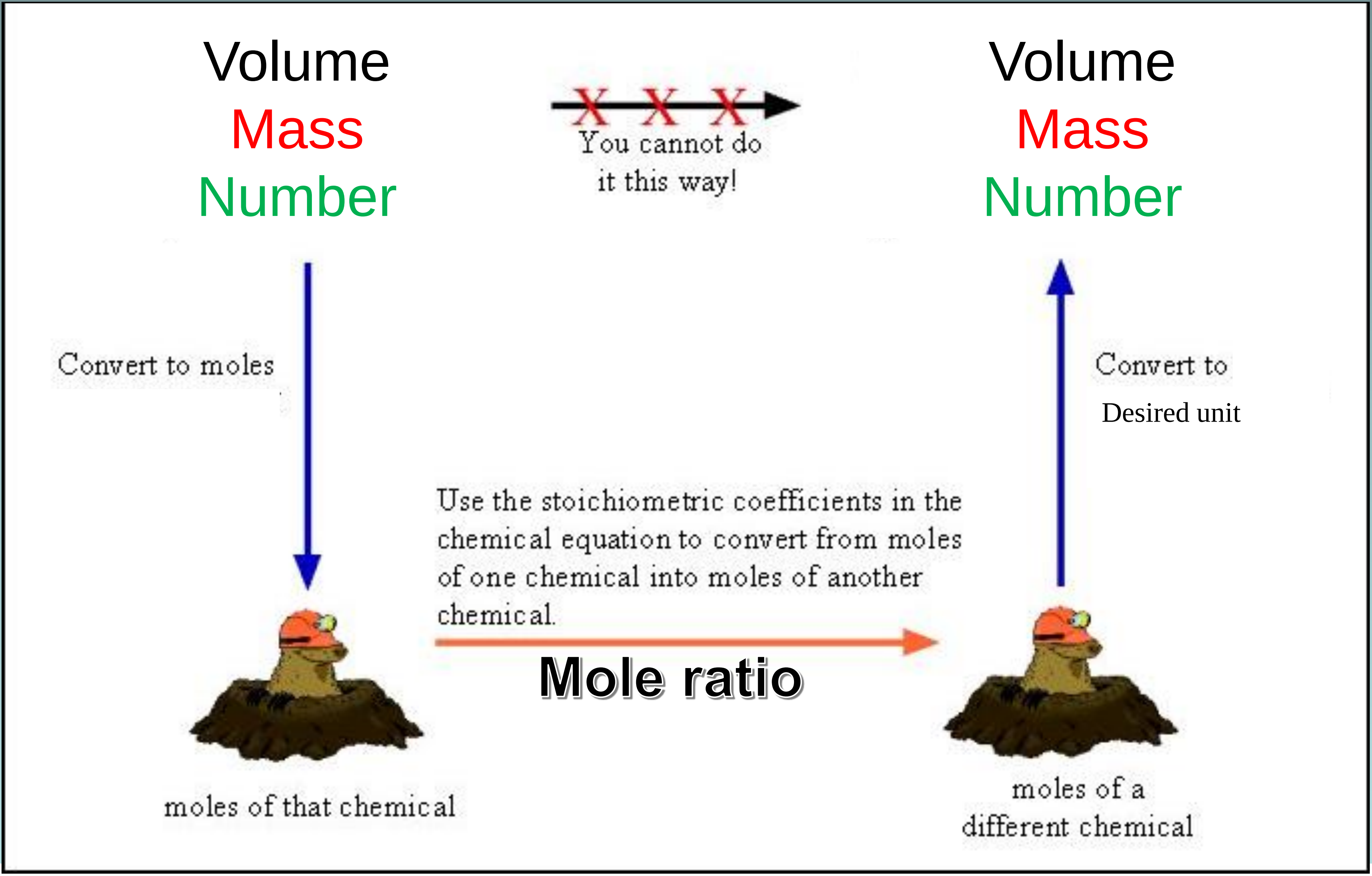

Mass-Mass Calculations

Calculate the number of grams of NH_3 produced by the reaction of 5.40 g of hydrogen with an excess of nitrogen. The balanced equation is:

Find mol H_2:

Mole ratio H_2:NH_3 =

Convert to mol NH_3 →

Convert mol to grams

Mass-Mass Calculations

Calculate the number of grams of NH_3 produced by the reaction of 5.40 g of hydrogen with an excess of nitrogen. The balanced equation is:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Find mol H_2: **GMM = 2.00 g/mol**

5.40 g H_2 x 1 mol/2.00 g = 2.70 mol H_2

Mole ratio H_2:NH_3 = 3:2

Convert to mol NH_3 → 2.70/3 = X/2 → 3X = 5.40

X = 1.80 mol NH_3

Convert mol to grams **GMM NH_3 = 17.0 g/mol**

1.80 mol x 17.0 g/mol = 30.6 g NH_3

Volume – Volume Calculations

Nitrogen monoxide and oxygen gas combine to form nitrogen dioxide, which contributes to photochemical smog. How many liters of nitrogen dioxide are produced when 34.0 L of oxygen react with an excess of nitrogen monoxide? Assume conditions are at STP.

Find mol O_2:

Mole ratio O_2 :NO_2 =

Convert to mol NO_2 →

Convert mol to liters

Volume – Volume Calculations

Nitrogen monoxide and oxygen gas combine to form nitrogen dioxide, which contributes to photochemical smog. How many liters of nitrogen dioxide are produced when 34.0 L of oxygen react with an excess of nitrogen monoxide? Assume conditions are at STP.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Find mol O_2: 34.0 L x 1 mol/22.4 L = 1.52 mol O_2

Mole ratio O_2 :NO_2 = 1:2

Convert to mol NO_2 → 1.52/1 = X/2 → 3.04 mol NO_2

Convert mol to liters

3.04 mol x 22.4 L/mol = 68.1 L NO_2

Volume – Mass Calculations

Methane burns in air by the following reaction:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

What volume of water vapor is produced at STP by burning 501 g of methane?

Find mol CH_4:

Mole ratio CH_4:H_2O =

Convert to mol H_2O →

Convert mol to liters

Volume – Mass Calculations

Methane burns in air by the following reaction:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

What volume of water vapor is produced at STP by burning 501 g of methane?

Find mol CH_4: GMM = 16.0 g/mol

501 g x 1 mol/16 g = 31.3 mol

Mole ratio CH_4:H_2O = 1:2

Convert to mol H_2O → 31.3 mol/1 mol = X/2

X = 62.6 mol

Convert mol to liters

62.6 mol x 22.4 L/mol = 1403 L H_2O = 1.40 x 10^3 L H_2O

Review

QUICK CHECK

For the reaction:

$$2Fe + 3Cl_2 \longrightarrow 2FeCl_3$$

What is the mole ratio of all substances?

If only 1.5 mol of chlorine gas was available, how much product could be produced theoretically?

The following balanced equation shows the decomposition of ammonia (NH_3) into nitrogen (N_2) and hydrogen (H_2):

$$2NH_3 \longrightarrow N_2 + 3H_2$$

A quantity of NH_3 decomposes to produce 0.0351 mol N_2. How many moles of H_2 are produced?

Review

For the reaction:

$$2Fe + 3Cl_2 \longrightarrow 2FeCl_3$$

What is the mole ratio of all substances?

2:3:2

If only 1.5 mol of chlorine gas was available, how much product could be produced theoretically?

$1.5/3 = X/2 \rightarrow 3X = 3$

$X = 1.0$ mol

The following balanced equation shows the decomposition of ammonia (NH_3) into nitrogen (N_2) and hydrogen (H_2):

$$2NH_3 \longrightarrow N_2 + 3H_2$$

A quantity of NH_3 decomposes to produce 0.0351 mol N_2. How many moles of H_2 are produced?

Mole ratio $N_2:H_2 = 1:3$

$0.0351/1$ mol $= X/3$ mol

$X = 0.105$ mol H_2

Review

Phosphorus burns in air to produce a phosphorus oxide. If 403 g of Phosphorus react with oxygen, how many grams of tetra phosphorus decaoxide are produced?

Review

Phosphorus burns in air to produce a phosphorus oxide. If 403 g of Phosphorus react with oxygen, how many grams of tetra phosphorus decaoxide are produced?

$$4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$$

Find mol P: **GAM = 31 g/mol**

403 g P x 1 mol/31.0 g = 13.0 mol P

Mole ratio P:P_4O_{10} = 4:1

Convert to mol P_4O_{10} → 13.0/4 = X/1 → 3.25 mol P_4O_{10}

Convert mol to grams **GMM P_4O_{10} = 284 g/mol**

3.25 mol x 284 g/mol = <u>923 g P_4O_{10}</u>

KEY

Atomic Mass	12.0111
Selected Oxidation States	−4, +2, +4
Symbol	C
Atomic Number	6
Electron Configuration	$1s^2 2s^2 2p^2$

Relative atomic masses are based on ^{12}C = 12.00000

New Designation / Former Designation (prior to 1984 IUPAC decision)

s-block — *d*-block — Transition Elements

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	(11)
1	1.00794 (+1, −1) **H** 1 $1s^1$										
2	6.941 (+1) **Li** 3 $1s^2 2s^1$	9.01218 (+2) **Be** 4 $1s^2 2s^2$									
3	22.98977 (+1) **Na** 11 $[Ne]3s^1$	24.305 (+2) **Mg** 12 $[Ne]3s^2$									
4	39.0983 (+1) **K** 19 $[Ar]4s^1$	40.08 (+2) **Ca** 20 $[Ar]4s^2$	44.9559 (+3) **Sc** 21 $[Ar]3d^1 4s^2$	47.88 (+2, +3, +4) **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 (+2, +3, +4, +5) **V** 23 $[Ar]3d^3 4s^2$	51.996 (+2, +3, +6) **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 (+2, +3, +4, +7) **Mn** 25 $[Ar]3d^5 4s^2$	55.847 (+2, +3) **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 (+2, +3) **Co** 27 $[Ar]3d^7 4s^2$	58.69 (+2, +3) **Ni** 28 $[Ar]3d^8 4s^2$	63.54… 29 [Ar]3d…
5	85.4678 (+1) **Rb** 37 $[Kr]5s^1$	87.62 (+2) **Sr** 38 $[Kr]5s^2$	88.9059 (+3) **Y** 39 $[Kr]4d^1 5s^2$	91.224 (+4) **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 (+3, +5) **Nb** 41 $[Kr]4d^4 5s^1$	95.94 (+3, +6) **Mo** 42 $[Kr]4d^5 5s^1$	(98) (+4, +6, +7) **Tc** 43 $[Kr]4d^6 5s^1$	101.07 (+3) **Ru** 44 $[Kr]4d^7 5s^1$	102.906 (+3) **Rh** 45 $[Kr]4d^8 5s^1$	106.42 (+2, +4) **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86… 47 [Kr]4d…
6	132.905 (+1) **Cs** 55 $[Xe]6s^1$	137.33 (+2) **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 (+4) **Hf** 72 $[Xe]4f^{14} 5d^2 6s^2$	180.948 (+5) **Ta** 73 $[Xe]4f^{14} 5d^3 6s^2$	183.85 (+6) **W** 74 $[Xe]4f^{14} 5d^4 6s^2$	186.207 (+4, +6, +7) **Re** 75 $[Xe]4f^{14} 5d^5 6s^2$	190.2 (+3, +4) **Os** 76 $[Xe]4f^{14} 5d^6 6s^2$	192.22 (+3, +4) **Ir** 77 $[Xe]4f^{14} 5d^7 6s^2$	195.08 (+2, +4) **Pt** 78 $[Xe]4f^{14} 5d^9 6s^1$	196.96… 79 [Xe]4f…
7	(223) (+1) **Fr** 87 $[Rn]7s^1$	226.025 (+2) **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		

* The sys… 103 wil…

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ation States

s-block
18
0

4.00260	0
He	2
$1s^2$	

p-block
GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 0
			10.81 +3 **B** 5 $1s^2 2s^2 2p^1$	12.0111 −4 +2 +4 **C** 6 $1s^2 2s^2 2p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^2 2s^2 2p^3$	15.9994 −2 **O** 8 $1s^2 2s^2 2p^4$	18.998403 −1 **F** 9 $1s^2 2s^2 2p^5$	20.179 0 **Ne** 10 $1s^2 2s^2 2p^6$
			26.98154 +3 **Al** 13 $[Ne]3s^2 3p^1$	28.0855 −4 +2 +4 **Si** 14 $[Ne]3s^2 3p^2$	30.97376 −3 +3 +5 **P** 15 $[Ne]3s^2 3p^3$	32.06 −2 +4 +6 **S** 16 $[Ne]3s^2 3p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 $[Ne]3s^2 3p^5$	39.948 0 **Ar** 18 $[Ne]3s^2 3p^6$
58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 +1 +2 **Cu** 29 $[Ar]3d^{10} 4s^1$	65.39 +2 **Zn** 30 $[Ar]3d^{10} 4s^2$	69.72 +3 **Ga** 31 $[Ar]3d^{10} 4s^2 4p^1$	72.59 −4 +2 +4 **Ge** 32 $[Ar]3d^{10} 4s^2 4p^2$	74.9216 −3 +3 +5 **As** 33 $[Ar]3d^{10} 4s^2 4p^3$	78.96 −2 +4 +6 **Se** 34 $[Ar]3d^{10} 4s^2 4p^4$	79.904 −1 +1 +5 **Br** 35 $[Ar]3d^{10} 4s^2 4p^5$	83.80 0 +2 **Kr** 36 $[Ar]3d^{10} 4s^2 4p^6$
106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.868 +1 **Ag** 47 $[Kr]4d^{10} 5s^1$	112.41 +2 **Cd** 48 $[Kr]4d^{10} 5s^2$	114.82 +3 **In** 49 $[Kr]4d^{10} 5s^2 5p^1$	118.71 +2 +4 **Sn** 50 $[Kr]4d^{10} 5s^2 5p^2$	121.75 −3 +3 +5 **Sb** 51 $[Kr]4d^{10} 5s^2 5p^3$	127.60 −2 +4 +6 **Te** 52 $[Kr]4d^{10} 5s^2 5p^4$	126.905 −1 +1 +5 +7 **I** 53 $[Kr]4d^{10} 5s^2 5p^5$	131.29 0 +2 +4 +6 **Xe** 54 $[Kr]4d^{10} 5s^2 5p^6$
195.08 +2 +4 **Pt** 78 $[Xe]4f^{14} 5d^9 6s^1$	196.967 +1 +3 **Au** 79 $[Xe]4f^{14} 5d^{10} 6s^1$	200.59 +1 +2 **Hg** 80 $[Xe]4f^{14} 5d^{10} 6s^2$	204.383 +1 +3 **Tl** 81 $[Xe]4f^{14} 5d^{10} 6s^2 6p^1$	207.2 +2 +4 **Pb** 82 $[Xe]4f^{14} 5d^{10} 6s^2 6p^2$	208.980 +3 +5 **Bi** 83 $[Xe]4f^{14} 5d^{10} 6s^2 6p^3$	(209) +2 +4 **Po** 84 $[Xe]4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 $[Xe]4f^{14} 5d^{10} 6s^2 6p^5$	(222) 0 **Rn** 86 $[Xe]4f^{14} 5d^{10} 6s^2 6p^6$

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium
$(NH_4)^{+1}$

IONIZATION ENERGIES AND ELECTRONEGATIVITIES

H 313 ← First Ionization Energy (kcal/mol of atoms)
H 2.2 ← Electronegativity*

1	2	13	14	15	16	17	18
H 313 2.2							He 567
Li 125 1.0	Be 215 1.5	B 191 2.0	C 260 2.6	N 336 3.1	O 314 3.5	F 402 4.0	Ne 497
Na 119 0.9	Mg 176 1.2	Al 138 1.5	Si 188 1.9	P 242 2.2	S 239 2.6	Cl 300 3.2	Ar 363
K 100 0.8	Ca 141 1.0	Ga 138 1.6	Ge 182 1.9	As 226 2.0	Se 225 2.5	Br 273 2.9	Kr 323
Rb 96 0.8	Sr 131 1.0	In 133 1.7	Sn 169 1.8	Sb 199 2.1	Te 208 2.3	I 241 2.7	Xe 280
Cs 90 0.7	Ba 120 0.9	Tl 141 1.8	Pb 171 1.8	Bi 168 1.9	Po 194 2.0	At 2.2	Rn 248
Fr 0.7	Ra 122 0.9						

* Arbitrary scale based on fluorine = 4.0