SCH 4CI Determining the Mass of Atoms

Isotope: An atom of an element that has the same number of protons as the element, but different numbers of neutrons.

Example Oxygen



Isotopic	99.759%	0.037%	0.204%
Abundance:			

_____: the relative quantities of isotopes in a natural sample of an element, expressed as percentages.

Determining percent = <u>the number of oxygen 16 atoms</u> X 100% Number of oxygen atoms, 16, 17, and 18

A _____average is used to determine the relative atomic mass of each element on the periodic table.

Avg Atomic Mass =

Calculate the Average Atomic mass for oxygen.

Question: Chlorine has 2 isotopes, CI-35 and CI-37, If CI-35 has an isotopic abundance of 75.78%, determine the average atomic mass for chlorine.

Atomic Mass	The mass of one atom of an element, expressed in a tomic m ass u nits, amu or u
Molecular Mass	The mass of one molecule, expressed in amu, or u
Formula Unit	The mass of one formula unit of an ionic compound, expressed in amu or u

Practice:

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- a) What is the mass of one iron atom?
- b) What is the mass of one Uranium atom?
- c) What is the mass of one carbon dioxide molecule?
- d) What is the mass of one carbon tetrachloride molecule?
- e) What is the mass of one calcium chloride formula unit?
- f) What is the mass of ammonium phosphate?

SCH 4CI The Mole and Molar Mass

Since atoms and molecules are so small, chemists always work with extremely large numbers of chemical entities. It can be compared to chefs who also use large quantities of food items.

Number of omelettes	Recipe
1	2 eggs + 3 mushrooms + 1 pepper \rightarrow 1 omelette
2	eggs + mushrooms + peppers \rightarrow 2 omelettes
12 (dozen)	eggs + mushrooms + peppers \rightarrow 12 omelettes
Term dozen	

For Example... Lets pretend to make an omelette

In 1811, a chemist named Amedeo Avogadro realized that any convenient macroscopic quantity of matter must contain an **enormous number of chemical entities**. Chemists do not use the term dozen they use the term **Mole**.

1 mole = 6.02×10^{23} entities

This number 6.02 X 10^{23} , is referred to as Avogadro's Number, Na

Mole = _____ mol = ____ symbol for mole = ___

If there are 2 mols of sodium chloride, calculate how many molecules of sodium chloride would there be?



Figure 5 One mole of eggs would cover the entire surface of Earth to a depth of over 60 km.

Moles and Chemical Equations:

Individual Entities	$ H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(I)}$
Multiples of 6.02 X 10 ²³	$\underline{\qquad} H_{2(g)} \hspace{0.1 cm} \textbf{+} \underline{\qquad} O_{2(g)} H_2O_{(I)}$
Multiples of a mole	$\underline{\qquad} H_{2(g)} + \underline{\qquad} O_{2(g)} \rightarrow \underline{\qquad} H_2O_{(I)}$

Molar Mass of Molecules and Ionic Compounds

Molar mass, the mass, in grams of one mole of a chemical entity, ${\bf M}$

Calculate the molar mass of water	Calculate the molar mass of iron (III) chloride
What is the mass of 2 mol of water?	What is the mass of 4 mol of iron (III) chloride?
General Equation:	
If there is a 100g of water, how many moles is there?	If there is 100g of iron (III) chloride, how many moles is there?
How many atoms are in 100g of water?	How many atoms are in 100g of iron (III) chloride?
Summary to convert from moles to atoms and ato	ms to moles

Table 5 Quantity Symbols and Units

Symbol	Quantity	Unit
п	amount (in moles)	mol
т	mass	mg, g, kg
М	molar mass	g/mol
N	number of entities	atoms, ions, formula units, molecules
NA	Avogadro's constant, 6.03 $ imes$ 10 23	_

Mole Calculations



Converting from mass to moles

1. Determine how many moles is 500g of sodium chloride?

2. How many moles is 25g of glucose, $C_6H_{12}O_6$?

Converting from number of atoms/molecules to moles

3. A sample contains 5.6 X 10²⁵ carbon atoms, how many moles is this?

4. A sample contains 90 helium atoms, how many moles is this?

Mole Calculations con't...

Mass	Moles	Molecules	
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Practice:

1. How many atoms of gold are in 275.8g nuggat of pure gold?

2. How many water molecules are in a 750g sample of water?

3. Sand is composed of silicon dioxide, $SiO_{2(s)}$, How many atoms of oxygen are in a bag of pure sand , which contains 1.00kg of silicon dioxide?

Is the mass percent of an element in a compound
Is the mass percent of each element in a compound

Since the ratio of elements in a chemical formula are the same, Louis Proust was able to develop the

Law of Definite Proportions: the elements in a chemical compounds are always present in the same proportions by mass.

Practice:

Determine the mass percent of...

a) Carbon in Carbon dioxide

b) Carbon in carbon tetrachloride

Determine the percentage composition for NaOCI, bleach

Determine the percentage composition for C₈H₈O₃

Using the following "raw" data and the formula below, determine if the information is describing the same substance by determining the percent composition of each and comparing the results.

a) Raw Data

b) C₆H₁₂

mass of sample: 35.8g mass of carbon in sample: 30.10g mass of hydrogen in sample: 5.70g

SUMMARY - Determining Percentage Composition from...

Chemical Formula	MASS data (raw data)
1) Calculate the molar mass of the compound, this becomes the sample mass	1) Measure the mass of each elements in the sample
2) use periodic table to determine the mass of each element in 1 mol of compound	2) Measure the mass of the total sample
3) Calculate the mass percent of each of the elements in the compound.	3) Calculate the mass percent of each element by dividing the mass of each element by the total mass of the sample

SCH 4Cl Percent Composition Practice – Answer the questions on a separate piece of paper.

1. Calculate the mass percent of oxygen in iron (II) oxide, FeO.

2. Calculate the mass percent of nitrogen in dintirogen tetraoxide, N₂O₄.

3. A 650 mg sample is analyzed and found to contain 52.0 mg of hydrogen. What is the mass percent of hydrogen in the sample?

4. Which substance has the greater mass percent of chromium? Chromic acid, H_2CrO_4 or dichromic acid, $H_2Cr_2O_7$, complete the calculation to validate your answer.

5. Many metals are refined from sulphide mineral deposits that were laid down by volcanoes billions of years ago. Name the following compounds and list the sulphide compounds in order from greatest to least mass percent of sulphur, PbS, ZnS and Cu₂S.

6. What is the percentage composition of silver oxide, Ag₂O?

7. What is the percentage composition of strontium nitrate, Sr(NO₃)₂?

8. A 19.6 g sample of compound A contains, 16.1 g of nitrogen and 3.5 g of hydrogen. Determine the percentage composition of the compound.

9. A 15 g sample of compound D contains 7.22g of nickel, 2.53g of phosphorous and 5.25g of oxygen, determine the percentage composition.

10. Acetylene, C_2H_2 , is made up of two carbon atoms and two hydrogen atoms. Explain why acetylene does not contain 50% of each element by mass?

Activity 6.1 Mass Percent of oxygen, page 260 – Complete Procedure and answer Questions

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Empirical Formula	A formula that shows the smallest whole-number ratio of the elements in a compound
Molecular Formula	The formula for a compound that shows the number of atoms of each element that make up a molecule of that compound

For example Benzene C_6H_6 ... Molecular formula is

Empirical formula is

How to calculate the empirical Formula

- Step 1: List given values.
- Step 2: Convert the percent of each element into grams, assuming the sample is 100 g
- Step 3: Convert mass (m) into Amount in moles (n)
- Step 4: Calculate Lowest Whole-Number Ratio (Divide by smallest number of moles, from step 3).

The percentage composition of a compound was found to be 69.9% iron and 30.1% oxygen. What is the empirical formula of the compound?

Determining the molecular formula

*In order to determine the molecular formula the molar mass of the complete compound must be given.

*This information can be determined using a mass spectrometer

To determine the Molecular Formula

-follow steps 1-4 and add

Step 5: determine the whole number multiple by dividing the Molar mass of the Molecular formula divided by the Molar mass of the empirical formula **Step 6**: multiply the "whole number multiple" to the subscripts in the empirical formula

- Q Determine the molecular formula for a sugar, whose Molar mass is 150g/mol and the empirical formula is CH_2O
 - 1) Determine the Molar mass of E.F.
 - 2) Determine the whole number multiple
 - 3) Apply multiple to E.F.

Q – A fat that is used to make soap contains 76.5% C, 12.2% H and 11.3% O by mass. Determine the molecular formula of the fat if its molar mass is 706.3 g/mol.

Part 1 Calculating Percent Concentrations, m/v, m/m, v/v

-Measurement of a quantity of a chemical entity
-is the quantity of solute per unit quantity of solution -can be expressed in a variety of ways



Mass/Volume Percent

Percent (m/v) = <u>Mass solute (in grams)</u> X 100% Volume of solution (in mL)

Practice: A solution contains 21.4g of sodium nitrate, dissolved I 250mL of solution. Determine the percent (m/v) concentration of the solution.

Mass Percent

Percent (m/m) = <u>Mass solute (g)</u> X 100% Mass of solution (g)

Practice: Find the mass of pure silver in a sterling silver ring that has a mass of 6.45g and the m/m% is 95.5%.

Percent (V/V) = <u>Volume of solute (mL)</u> X 100% Volume of Solution (mL)

Practice: Rubbing alcohol is sold in pharmacies with a v/v concentration of 70%. What volume of alcohol is present in 500mL bottle of rubbing alcohol.

Practice: Acetic acid is a liquid at room temperature. How much pure water should be add to 15.0 mL of pure acetic acid to make a 5.00% (v/v) solution of acetic acid? Assume that the total volume of the solution equals the sum of the volumes of the water and the acetic acid.

MORE Practice!!!! YES do these questions!

- 1. A student carefully evaporated all the water from an 80.0mL salt solution. She found that the mass of the residue from the sample was 1.40g. Calculate the percent (m/v) concentration of the salt solution.
- 2. What volume of 5.0% (m/v) solution of sodium chloride can be made using 40g of NaCl?
- 3. How would you prepare 400 mL of a 3.5% (m/v) solution of sodium acetate?
- 4. Calculate the percent (m/m) concentration of a solution that contains 11g of pure sodium hydroxide in 75g of solution.
- 5. a) How much chromium, nickel and iron would you need to make a 500 kg (500 000g) batch of 18/8 stainless steel, which is made with 18% (m/m) chromium and 8% (m/m) nickel in iron?
 b) Identify which metals are the solute and which metal is the solvent
 c) When a metal is mixed with another metal this is called an _____.
- 6. If 80 mL of ethanol is diluted with water to a final volume of 500mL, what is the percent (v/v) concentration of ethanol in the solution?
- 7. A particular brand of windshield washer fluid contains 40% (v/v) methanol. How much pure methanol does a 4.0L container of this fluid contain? Note: 4.0L = 4000mL.
- Your teacher has 3.0L of a 15% (v/v) solution of sulfuric acid. What will the volume of the solution be if the solution is diluted to 10% (v/v)? Hint: Determine the volume of the solute first, then solve for the volume of the solution with a 10% (v/v).

-The concentration of a solution expressed as moles of solute that is dissolved in one litre of solution

Formula:

Practice:

-If 0.18 mol of sodium chloride was dissolved in 300mL of water, calculate the molar concentration for the solution.

-If 25g of sodium chloride is dissolved in 1400mL of water, calculate the molar concentration of the solution.

-What mass of calcium chloride is dissolved in 400mL of a .65M of calcium chloride solution?

-Concentration unit that is used for very low concentrations; one part solute per million parts of solution	
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-Concentrations in parts per million (ppm) can be expressed using a variety of units. When solving a problem choose the units that match the information given in the problem. For aqueous solutions,

1 ppm = 1 g/10⁶ mL = 1 g/1000 L = 1 mg/L Note: 1 g = 1000 mg

DID you Know?

-1 ppm = approximately 1 drop in a full bathtub

-1 ppb = approximately 1 drop is a full swimming pool

-1 ppt = approximately 1 drop in 1000 swimming pools

Practice:

-In a chemical analysis, 0.005 g of oxygen was measured in 2500mL, Calculate the ppm.

More Practice Questions:

- 1. Household bleach is an aqueous solution that contains 5.25g sodium hypochlorite, NaOCI per 100mL of solution. Determine the molar concentration of sodium hypochlorite in bleach.
- 2. A stock solution of hydrochloric acid, HCl, is made my dissolving 7.66g of HCl in enough distilled water to produce 1.50L of solution. Calculate the molar concentration.
- 3. What amount of silver nitrate, AgNO₃ is in 50.0mL of a 0.570 mol/L solution?
- 4. What amount of potassium hydroxide, KOH, is in a sample of 30mL with a concentration of 0.0176 mol/L?
- 5. Seawater contains approximately 0.055mol/L of magnesium chloride, MgCl₂. What volume of seawater contains 4.1 mol of magnesium chloride?
- 6. How many litres of a 0.0020 M of sodium dichromate solution, Na₂Cr₂O₇ contains 5.0 mol of sodium dichromate?
- Copper is an element that is required in very small concentrations in the bodies of all animals. What is the concentration of copper in parts per million, if 1.0 L of drinking water contains 3.0 X 10⁻⁵g of copper?

Dilution	

Experiments sometimes require several concentrations of the same solution. If you begin with a solution of known concentration (stock solution), you can prepare a solution of lower concentration by dilution. Diluting a stock solution is faster and a more accurate way to make lower concentrations of a solution than making different concentrations from scratch.



Practice:

If a solution has an initial volume of 65mL and an initial concentration of 0.85M, what is the new concentration if 150mL of water is added.

Step 1 find moles in initial sol'n

Step 2 Find new conc with new final volume

Dilution Equation:

Practice:

You are asked to dilute a 1.75M copper (II) sulphate solution to make 250mL of 0.55M copper (II) sulphate solution. What volume of 2.0M stock solution would be needed?

More Practice:

- 1. A lab technician dilutes 45.5mL of a 1.50M sodium sulphate solution to a final volume of 200.0mL. What is the concentration of the diluted solution?
- 2. Another lab technician dilutes 50mL of a 3.50M nitric acid solution to a 2.50M nitric acid solution. What is the final volume?
- 3. Calculate the final concentration of a glucose solution if 240mL of 15% m/v glucose is diluted with water to 300.0mL
- 4. A laboratory technician needs to make 500.0mL of a 0.100M sulphuric acid solution. What volume of 16.0M sulphuric acid does the technician need to use?
- 5. Calculate the final concentration of a 0.400M barium chloride solution when 125mL of the solution is diluted by adding 500mL of distilled water.

SUMMARY Concentration of a Solution Equations

Туре	Equation	Units
percentage V/V	$c = \frac{v_{\rm solute}}{v_{\rm solution}} \times 100\%$	% V/V
percentage W/V	$c = \frac{m_{\rm solute}}{v_{\rm solution}} \times 100\%$	% W/V
very low (number)	$c = \frac{m_{\rm solute}}{v_{\rm solution}} \times 100\%$	mg/L = ppm µg/L = ppb ng/L = ppt
molar	$c = \frac{n_{\rm solute}}{v_{\rm solution}} \times 100\%$	mol/L

SCH 4Cl The Mole and Chemical Equations: Stoichiometry

Stoichiometry	-Mathematical procedures for calculating the quantities of reactants and products involved in chemical reactions
Mole Ratio	-The ratio of the amount in moles, of reactants and products in a chemical reaction

*The coefficients in a balanced chemical reaction indicate a variety of things;

- 1) how many molecules react
- 2) how many molecules are produced
- 3) also indicate the molar ratios of R and P
- 4) can be used to determine the mass of R and P required or produced
- ... Using the mole ratio is stoichiometry!

Making Cookies ©









Write the equation to make 24 cookies

Use the mole ratio to determine the following;

- a) how many cookies will be made if 4 eggs are used?
- b) How many cookies will be made if 3 cups of chocolate chips are used?
- c) How many cups of flour will produce 72 cookies?
- d) How many eggs are needed to make 36 cookies?
- e) What amount of flour, eggs and chocolate chips are needed to make 100 cookies?

Let's apply stoichiometry to Chemical Equations using chemical Formulas ... 🕲

Write the Balanced Chemical Equation for the formation of water.

Balanced Chemical Equation:

Mole Ratio:

Use the mole ratio to determine the following;

- a) If there are 8 molecules of oxygen gas, how many hydrogen molecules are needed?
- b) If there are 2 moles of hydrogen gas, how many moles of oxygen are required?
- c) If there are 10 moles of hydrogen gas, how many moles of oxygen are required?

Converting Moles to mass of product produced using Stoichiometry

-Nitrogen gas reacts with oxygen gas to produce dinitrogen monoxide, answer the following questions.

- a) Write the balanced chemical equation
- b) If 25 moles of nitrogen reacts, how many moles of oxygen is required?
- c) What is the mass of oxygen required?
- d) What mass of dinitrogen monoxide is produced?

Converting from Mass of Reactants to Mass of Products and vice versa

-Propane gas, C_3H_8 reacts with oxygen in a complete combustion reaction to produce carbon dioxide gas, and water vapour. If 50g of propane reacts what mass of carbon dioxide gas is produced?



Summary of Steps to complete Stoichiometry Questions:

Practice Problems:

1. Use the following balanced equation to answer the questions below;

$2 \text{ NH}_{3(g)} + \text{ CO}_{2(g)} \rightarrow \text{NH}_2\text{CONH}_{2(s)} + \text{ H}_2\text{O}_{(g)}$

- a) What moles of carbon dioxide is required if 50 moles of ammonia reacts? Mole ratio: _____ Answer: _____
- b) What moles of water is produced if 75 mol of carbon dioxide reacts? Mole ratio: _____ Answer: _____
- c) What moles of ammonia must have reacted if 300 mols of water is produced? Mole ratio: _____ Answer: _____

2. Use the following balanced equation to answer the questions below;

 $4 \, Ag_{(s)} \, + \, 2 \, H_2 S_{(g)} \, + \, O_{2(g)} \, \rightarrow \, 2 \, Ag_2 S_{(s)} \, + \, 2 \, H_2 O_{(l)}$

- a) How many moles of hydrosulfuric acid is required to react with 18 mol of silver? Mole ratio:______ Answer: _____
- b) How many moles of oxygen gas is required to reach with 18 mol of silver? Mole ratio:_____ Answer: _____
- c) How many moles of water is produced if 35 mol of hydrosulfuric acid reacts? Mole ratio: _____ Answer: _____
- 3. If 5 mol of iron (III) oxide reacts with carbon monoxide, what mass of iron will be produced?

 $Fe_2O_{3(s)}$ + 3 $CO_{(g)}$ \rightarrow 2 $Fe_{(s)}$ + 3 $CO_{2(g)}$

4. If 60g of carbon dioxide reacts with lithium hydroxide, calculate the mass of lithium hydroxide required. Remember to balance the equation first!

 $\underline{\qquad} \mathsf{CO}_{2(g)} + \underline{\qquad} \mathsf{LiOH}_{(s)} \rightarrow \underline{\qquad} \mathsf{Li}_2 \mathsf{CO}_{3(s)} + \underline{\qquad} \mathsf{H}_2 \mathsf{O}_{(g)}$

-the reactant that is completely consumed in a chemical reaction, and therefore controls how much product is produced
-the reactant that is present in more than the required amount for a complete reaction to occur

Key Point: The LIMITING reactant will determine the quantity of your products.

Ex Shoe Company:

1 Shoe + 1 Lace \rightarrow 1 Laced Shoe



Ex. Sweater Factory

1 Sweater + 5 Buttons \rightarrow Buttoned Sweater



Let's apply the concepts of limiting reactants to chemistry questions $\ensuremath{\textcircled{\sc b}}$

Practice #1

If 20mol of aluminum reacts with 45 mol of oxygen to produce aluminum oxide, determine which reactant is the limiting reactant and which is in excess.

Practice #2

If 60g of aluminum reacts with 100g of oxygen to produce aluminum oxide, determine which substance is the limiting reactant.

Practice #3

A reaction mixture contains 58.5 g of sodium and 125.8 g of chlorine gas, Calculate the mass of sodium chloride that is produced.

More Practice:

- 1. If 35mol of hydrogen gas reacts with 40mol of oxygen gas to produce water, which substance is the limiting reactant?
- 2. a) Identifying the limiting reactant and excess reactant when 10.0g of hydrogen gas and 41.0g of oxygen gas react to form water as the only product.

b) Determine the mass of water that is obtained from the reaction.

- 3. Sulfur dioxide gas and oxygen gas react to produce gaseous sulfur trioxide.
 - a) Identify the limiting reactant and excess reactant when 192.18g of sulfur dioxide reacts with 45.5g of oxygen gas.

b) What mass of sulfur trioxide is produced?

-The quantity of product produced in a chemical reaction
-The quantity of produce that is actually produced in a chemical reaction -produced in the lab, ie experiment
-The quantity of product calculated from a balanced chemical equation -determined using stoichiometry
-Actual vs Theoretical Yield expressed as a percentage of Theoretical yield

percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

Practice:

-Iron is produced from its ore, hematite, $Fe_2O_{3(s)}$, by heating hematite with carbon monoxide in a blast furnace. If 635g of iron is obtained from 1150g of Fe_2O_3 , what is the percentage yield of iron?

 $\underline{\qquad} \mathsf{Fe}_2\mathsf{O}_3 \ \textbf{+} \underline{\qquad} \mathsf{CO} \ \rightarrow \ \underline{\qquad} \mathsf{Fe} \ \textbf{+} \ \underline{\qquad} \mathsf{CO}_2$

Practice 2

-Aluminum metal reacts with bromine to produce solid aluminum bromide as the only product. If 73.7g of aluminum reacts with excess bromine, and 55.5g of aluminum bromide is produced, calculate the percent yield.

More Practice Questions:

- 1. Distinguish between actual yield and theoretical yield.
- 2. If 25g is obtained of a substance and 32g was expected, what is the percent yield for this reaction.
- 3. If the percent yield is 88% and the theoretical yield is 250g, what was the actual yield?
- 4. Zinc reacts with hydrochloric acid, producing zinc chloride and hydrogen gas. Calculate the percentage yield if 25g of zinc chloride is produced when 18g of hydrochloric acid reacts with excess of zinc.

 $\underline{\qquad} Zn \ \ \ + \underline{\qquad} HCl \rightarrow \underline{\qquad} ZnCl_2 \ \ \ + \underline{\qquad} H_2$

5. In an experiment 76.4g of iron sulphide, FeS, is added to excess oxygen, and 68.5g of iron (III) oxide is produced, Calculate the percent yield of iron (III) oxide.

$4 \; FeS + 7 \; O_2 \rightarrow 2 \; Fe_2O_3 \; + 4 \; SO_2$

6. In theory can the actual yield ever be greater than the theoretical yield?