Moles & Molar Mass

A mole: A quantity of 6.02×10^{23} of a given substance.
Molar mass (g/mol): The mass per 1 mole of a given substance.

1) Which of the following describes the average **mass** of a carbon atom?
   (a) 12.01 g *(b)* 12.01 g/mol *(c)* 12.01 amu *(d)* 6.02×10^{23}
2) Which of the following is the **molar mass** of carbon?
   (a) 12.01 g *(b)* 12.01 g/mol *(c)* 12.01 amu *(d)* 6.02×10^{23}
3) Which of the following is the **mass** of 1 mole of carbon?
   (a) 12.01 g *(b)* 12.01 g/mol *(c)* 12.01 amu *(d)* 6.02×10^{23}
4) Which of the following describes the **number** of atoms that make up 1 mole of carbon?
   (a) 12.01 g *(b)* 12.01 g/mol *(c)* 12.01 amu *(d)* 6.02×10^{23}
5) Give the molar mass of each of the following; show any calculations.

   (i) Argon gas, $Ar_{(g)}$:

   (ii) Oxygen gas, $O_{2(g)}$:

   (iii) Methane, $CH_{4(g)}$:

   (iv) Methanol, $CH_3OH_{(l)}$:

   (v) Mercury, $Hg_{(l)}$:

   (vi) Hydrogen gas, $H_{2(g)}$:

   (vii) Lithium hydride, $LiH_{(s)}$:

   (viii) Baking soda, $NaHCO_{3(s)}$:

6) Determine the chemical formula and molar mass of each of the following compounds.

   (i) Silicon dioxide:

   (ii) Barium iodide:

   (iii) Calcium hydroxide:

   (iv) Aluminium sulphide:

   (v) Copper (II) chloride:

   (vi) Lead (II) phosphate:

7) The average mass of a kumquat is approximately 14.3 g. Use this value to determine the molar mass of kumquats. *(Answer in scientific notation, rounded to 3 digits)*

Molar Mass (Converting: Moles↔Grams)

Molar mass is used as a proportion to convert 'moles' into 'grams', and vice-versa.

Examples done for you: *(Answers rounded to 3 digits)*

1) Calculate the mass of 7.50 moles of carbon. *(answer rounded to 3 digits)*

   First, we need the molar mass (mm) of carbon: $mm = 12.01\ g/mol$

   We set up the following proportion: $\frac{12.01\ g}{1\ mol} = \frac{m}{7.50\ mol}$

   Solving for mass (m) we get: $m = 90.1\ g$ *of carbon*

2) A 6.85 g sample of calcium contains how many moles of calcium?

   First, we need the molar mass (mm) of calcium: $mm = 40.08\ g/mol$

   We set up the following proportion: $\frac{40.08\ g}{1\ mol} = \frac{6.85\ g}{n}$

   Solving for number of moles (n) we get: $n = 0.171\ mol$ *of calcium*

Examples for you to do: *(Round answers to 3 digits)*

3) Given 3.84 mol of beryllium; mass = ?

4) How many moles in 40.0 g of aluminium?

5) How many moles in 2.74 g of sodium?

6) Determine the mass of 123 mol of helium.

7) Given 0.0752 mol of sulphur; mass = ?

8) How many moles in 1.00 kg of gold?

Molar Mass (Converting: Moles↔Grams)

Determine first the molecular formula, then the molar mass, then complete the conversion.

1) Determine the mass of 3.57 mol of calcium chloride.

Ca^{2+} Cl^{-}

(i) Calcium chloride: $CaCl_2$

(ii) $mm = \left(40.08 + 2(35.45)\right)\ \text{g/mol}$

$mm = 110.98\ \text{g/mol}$

(iii) $\frac{110.98\ \text{g}}{1\ \text{mol}} = \frac{m}{3.57\ \text{mol}}$

$\boxed{m = 396\ \text{g}\ CaCl_2}$

2) Determine the mass of 3.80 mol of water.

3) How many moles of magnesium fluoride are in a 50.0 g sample of this salt?

4) How many moles of sodium carbonate are in a 2.46 g sample of this salt?

5) A lab experiment requires that you obtain 0.287 mol of copper (II) sulphate to make a solution. What mass of copper (II) sulphate needs to be measured on the balance?

Molar Mass (Converting: Moles↔Grams)

Complete the following table; show work on a separate sheet of paper.

Molar Mass, Mass and Number of Moles of various Substances

Name	Formula	Molar Mass	Mass	# Moles
Carbon				9.00 mol
Copper			100 g	
Helium gas	He			0.150 mol
Oxygen gas	O_2		72.0 g	
Sodium chloride				0.250 mol
Carbon dioxide				1.50 mol
Water			355 g	
Strontium fluoride				0.0750 mol
Lithium oxide			24.0 g	
Potassium sulphate				5.55 mol

$$molar\ mass\ (g/mol) = \frac{mass\ (g)}{\#\ moles\ (mol)}$$

$$mm = \frac{m}{n}$$

Avogadro's Number (How Many)

$$1\,mol = 6.02 \times 10^{23}$$

1) 1.5 mol carbon atoms contains how many carbon atoms? _____

2) 0.01 mol sodium atoms contains how many sodium atoms? _____

3) 1.505×10^{23} aluminium atoms is how many moles of aluminium? _____

4) 9.03×10^{25} water molecules atoms is how many moles of water? _____

5) 1 mol CO_2 contains how many carbon atoms? _____

6) 1 mol CO_2 contains how many oxygen atoms? _____

7) 5 mol $C_6H_{12}O_6$ contains how many carbon atoms? _____

8) 2.5 mol CH_3COOH contains how many hydrogen atoms? _____

9) 12 g of helium contains how many helium atoms? _____

10) 9.01 g of water contains how many water molecules? _____

11) 9.01 g of water contains how many hydrogen atoms? _____

12) 38 g Cr_2O_3 contains how many oxygen atoms? _____

13) 3.01×10^{22} molecules of $C_6H_{12}O_6$ has what mass? _____

Lab: Counting Atoms

Observations:

Element	Symbol	Mass of empty vial (g)	Mass of vial + contents (g)
Lead			
Copper			
Magnesium			

Analysis:

1) Calculate the mass of each element *(show the calculation; include units)*.

   (i) Lead:

   (ii) Copper:

   (iii) Magnesium:

2) Look up and record the molar mass of each element.

   (i) Lead: *(ii)* Copper: *(iii)* Magnesium:

3) Using the information from the previous questions, calculate the number of moles of each element in the vials.

4) Calculate the number of atoms of each element in the vials *(1 mole* $= 6.02 \times 10^{23}$ *atoms)*.

   (i) Lead:

   (ii) Copper:

   (iii) Magnesium:

Lab: Counting More Atoms

Observations:

Element		Vial number	Mass of empty vial (g)	Mass of vial + contents (g)
Name	Symbol			
zinc				
bismuth				
calcium				
silver				
aluminum				
sulfur				
carbon				
antimony				
iron				

Analysis: Show work neatly on a separate page.

Element symbol	Mass (g)	Molar mass (g/mol)	Number of moles (mol)	Number of atoms

Lab: Counting Molecules

Observations:

Molecule		Vial number	Mass of Empty Vial (g)	Mass of Vial + Contents (g)
Name	**Formula**			
Potassium chromate				
Potassium dichromate				
Molybdenum oxide				
Potassium permanganate				
Copper (II) chloride				

Analysis: Show work neatly on a separate page.

Molecular formula	Mass (g)	Molar mass (g/mol)	Number of moles (mol)

Lab: A Mole of Smartie Atoms

Objective: The purpose of this lab is to perform scientific measurements and calculations as an excuse to eat a box of smarties.

PART A: Molar Mass of Smartie Atoms.

1) Record the mass written on the Smarties box: _____

2) Measure the mass of the box of Smarties on a balance: _____

3) Empty the Smartie atoms onto a paper towel; mass the empty box: _____

4) Calculate the total mass of Smartie atoms that were in the box:

5) Count the total number of Smartie atoms: _____

6) It takes 6.02×10^{23} Smartie atoms to make up 1 mole. Knowing the total number of Smartie atoms *(step 5)*, how many moles of Smartie atoms were in the box?

7) Knowing the mass *(step 4)* and the number of moles *(step 6)*, determine the molar mass of Smartie atoms.

PART B: Relative Mass of Smartie Isotopes.

8) Using the empty box as a weighing boat, measure and record the total mass of each of the different coloured Smartie isotopes; complete the table below by calculating the relative mass *(divide by the total from step 4)* of each of the Smartie isotopes.

Isotope Colour	Total Isotope Mass (g)	% Relative Mass

9) Carefully dispose of all Smartie atoms; the box goes in recycling.

Moles

1) Complete the following table of chemical compounds and their molar mass.
Show all calculations; don't need to include units since the unit is given in the table heading.

Name	Formula	Molar Mass (g/mol)
Carbon monoxide		
Lithium chloride		
Magnesium fluoride		
Sodium nitride		
Sodium nitrate		
Potassium hydroxide		

2) 0.25 mol of an unknown gas has a mass of 11 g.
Rounding the molar mass to the nearest whole number, which of the following could be the unknown gas?

- ☐ Nitrogen dioxide
- ☐ Propane, C_3H_8
- ☐ Carbon dioxide
- ☐ Ozone, O_3

3) Calculate the mass of 2.50 mol of ammonia gas, $NH_{3(g)}$.

4) Ammonium sulphate is a type of salt commonly used as a soil fertilizer; it consists of an ionic bond between ammonium, NH_4^+, and sulphate, SO_4^{2-} ions. How many moles of ammonium sulphate would be contained in a 725 g sample of this compound?

5) A piece of steel consists of 98% iron and 2% carbon. Determine the molar mass of this steel.

Molar Concentration (Molarity)

Molarity: The concentration of a solution with the amount of solute given in moles.
Molar concentration is normally measured in mol/L.
The unit 'mol/L' is often just written as 'M'.
For example: 3 mol/L may be written simply as 3 M
(3 moles per litre solution or 3 molar solution)

1) 500 mL of solution containing 2 moles of solute has a molar concentration of _____

2) A 12.5 mL sample of a 2.5 mol/L solution will contain _____mol of solute.

3) A 4.0 L bottle of 2.5 M hydrochloric acid will contain _____mol of HCl.

4) What volume of 0.50 mol/L copper (II) chloride$_{(aq)}$ will contain 0.025 mol of $CuCl_2$?

5) *(i)* A 600 mL bottle of 2.4 M sodium bromide solution will contain _____mol of NaBr.

(ii) A 600 mL bottle of 2.4 M sodium bromide solution will contain _____g of NaBr.

6) 30.0 g of sodium hydroxide, NaOH, is dissolved in some water and transferred into a 250 mL volumetric flask. Distilled water is added until the solution reaches the 250 mL mark. Determine the molar concentration of this solution.

Molar Concentration (Molarity)

7) What mass of potassium hydroxide is needed to make 750 mL of a 2 M KOH solution?

8) In the lab is a 2 litre bottle of fruit drink that has a sugar concentration of 0.25 mol/L. You are asked to transfer an amount of this drink that will contain 25.0 g of sugar, $C_{12}H_{22}O_{11}$, into a beaker. What volume of this drink should be measured to accomplish this task?

9) A 235 mL cup of coffee contains 95 mg of caffeine, $C_8H_{10}N_4O_2$. Calculate the molar concentration of caffeine in this coffee.

10) A solution of aluminium nitrate has a concentration of 320 g/L. Determine the molar concentration of this solution.

11) A lab technician transfers 75 mL of 5 M HCl *(hydrochloric acid)* solution into a flask, then adds 550 mL of distilled water to dilute the solution. Calculate the final concentration of HCl in the flask.

12) You are asked to prepare 500 mL of ammonium hydroxide solution that will have a concentration of 0.5 mol/L. To do this you will take some of a stock solution of ammonium hydroxide that has a concentration of 140 g/L and dilute it to obtain the desired solution. What volume of the stock solution is needed for this dilution?

Stoichiometry *(mole ratios)*

The calculation of amounts of reactants and products in a chemical reaction;
based on conservation of mass and relative proportions from a balanced chemical equation.

1) Consider the formation of lithium sulphide, described by the following balanced equation.

$$2\ Li_{(s)} + S_{(s)} \rightarrow Li_2S_{(s)}$$

2 lithium atoms combine with 1 sulphur atom to produce 1 lithium sulphide molecule.

(i) 6 lithium atoms will react with ____ sulphur atoms *(and produce 3 Li_2S molecules).*

(ii) 6 dozen lithium atoms will react with ____dozen sulphur atoms.

(iii) 6 moles of lithium atoms will react with _____ of sulphur atoms.

(iv) 14 mol of lithium will react with sulphur to produce _____ of lithium sulphide.

(v) To produce 1.6 mol Li_2S requires the reaction of _____mol Li with _____mol S.

2) Consider the formation of calcium phosphide, Ca_3P_2.

(i) Balance the following chemical equation: $\_\_\ Ca_{(s)} + \_\_\ P_{(s)} \rightarrow \_\_\ Ca_3P_{2(s)}$

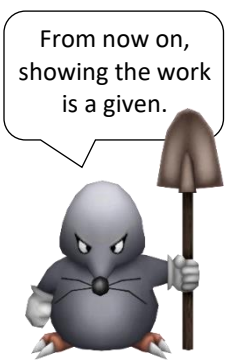
(ii) 12 mol of calcium will react with what quantity of phosphorus? *(Show the work)*

(iii) 0.42 mol of phosphorus will react with what quantity of calcium? *(Show the work)*

3) Consider the formation of aluminium fluoride *(you figure out the chemical formula)*.

(i) Write a balanced chemical equation to describe the reaction between aluminium, Al, and fluorine gas, F_2, in the formation of aluminium fluoride.

(ii) The reaction of 4.32 mol of Al will use up what quantity of fluorine gas?



Stoichiometry *(mole ratios)*

4) Consider the formation of chromium (III) oxide.
   (i) Write a balanced chemical equation to describe the reaction between chromium, Cr, and oxygen, O_2, in the formation of chromium (III) oxide.

   (ii) The reaction of 6.8 mol of chromium will use up what quantity of oxygen gas?

   (iii) How much chromium would be used to produce 0.765 moles of chromium (III) oxide?

5) Consider the combustion *(burning)* of butane, given by the following (not yet balanced) chemical equation.

$$2\ C_4H_{10(g)} + \_\_\_\ O_{2(g)} \rightarrow \_\_\_\ CO_{2(g)} + \_\_\_\ H_2O_{(g)}$$

   (i) The reaction of 0.32 mol of butane will use up what quantity of oxygen gas?

   (ii) What amount of butane underwent combustion if 76.8 mol of CO_2 were produced?

6) What quantity of aluminium hydroxide, $Al(OH)_3$, would be needed to neutralize 0.54 moles of sulphuric acid, H_2SO_4? *(Hint: The salt produced is aluminium sulphate … you figure out the rest)*

Stoichiometry *(with mass)*

1) Consider the formation of ammonia gas: $N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$

   What mass of ammonia will be produced by the reaction of 2.40 moles of hydrogen gas?

2) Consider the combustion of propane: $C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$

   What mass of oxygen was used up in the reaction if 0.45 moles of CO_2 were produced?

3) Consider the chemical reaction between manganese (IV) oxide and hydrochloric acid:

   $$\_\_\_\ MnO_2 + \_\_\_\ HCl \rightarrow \_\_\_\ MnCl_2 + \_\_\_\ Cl_2 + \_\_\_\ H_2O$$

   17.4 g of MnO_2 would react with how many moles of HCl?

Stoichiometry *(with mass)*

4) During cellular respiration *(a slow combustion reaction)* glucose, $C_6H_{12}O_6$, reacts with oxygen gas, producing carbon dioxide and water, as well as energy for the body.

   (i) Write a balanced chemical equation for cellular respiration.

   (ii) Calculate the mass of carbon dioxide produced by the combustion of 150 g of glucose.

5) During fermentation, glucose is converted into ethanol and carbon dioxide:

$$C_6H_{12}O_6 \rightarrow \_\_\_ C_2H_5OH + \_\_\_ CO_2$$

   500 g of glucose would be converted into what mass of each product?

500 g of glucose → _____ of ethanol + _____ of carbon dioxide.

Stoichiometry

For the following questions, show all work clearly on a separate sheet of paper.

1) Solid copper can be prepared from copper oxide by reaction with ammonia, according to the following unbalanced *(not for long)* chemical equation.

$$\_\_\_\ CuO_{(s)} + \_\_\_\ NH_{3(g)} \rightarrow \_\_\_\ Cu_{(s)} + \_\_\_\ N_{2(g)} + \_\_\_\ H_2O_{(l)}$$

How many moles of ammonia, NH_3, are needed to obtain 9.0 moles of copper, Cu?

2) When methane gas ($CH_{4(g)}$) burns, it reacts with oxygen gas ($O_{2(g)}$) in a chemical reaction that produces carbon dioxide gas ($CO_{2(g)}$) and water vapour ($H_2O_{(g)}$).

(i) Write a balanced chemical equation for the combustion *(burning)* of methane gas.

(ii) What mass of CH_4, when burned, will yield 40.0 moles of water vapour?

3) Sodium bicarbonate, $NaHCO_3$, can be used as an antacid because it can neutralize excess hydrochloric acid, HCl, secreted by the stomach, with the following reaction:

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

1.00 g of sodium bicarbonate can neutralize how many moles of hydrochloric acid?

4) Magnesium hydroxide, $Mg(OH)_2$, can also be used as an antacid because neutralizes acid in the stomach, with the following reaction:

$$Mg(OH)_2 + 2\ HCl \rightarrow MgCl_2 + 2\ H_2O$$

1.00 g of magnesium hydroxide can neutralize how many moles of hydrochloric acid?

5) Referring back to the answers to questions #3 & #4, which antacid (for equal mass) is more effective: sodium bicarbonate or magnesium hydroxide? *(Justify your answer)*

_____

_____

_____

6) Consider the following chemical reaction:

$$4\,Au + 8\,KCN + O_2 + 2\,H_2O \rightarrow 4\,KAu(CN)_2 + 4\,KOH$$

What mass of $KAu(CN)_2$ will be produced by the reaction of 34.8 g of KCN?

7) Octane, C_8H_{18}, is a component of gasoline that, when it burns *(reacts with oxygen gas)*, produces *(the usual)* carbon dioxide and water vapour.

(i) Write a balanced chemical equation to show this reaction:

(ii) What mass of carbon dioxide will be produced by the combustion of 250 g of octane?

8) Salicylic acid, $C_7H_6O_3$, is made to react with acetic anhydride, $C_4H_6O_3$, to make the chemical compound aspirin, $C_9H_8O_4$.The chemical reaction is as follows:

$$2\,C_7H_6O_3 + C_4H_6O_3 \rightarrow 2\,C_9H_8O_4 + H_2O$$

What mass of acetic anhydride is needed to completely react with 1.00 kg of salicylic acid to produce aspirin?

9) The decomposition of nitroglycerin is described by the following chemical reaction:

$$4\,C_3H_5N_3O_9 \rightarrow 6\,N_2 + 12\,CO_2 + 10\,H_2O + O_2$$

636 g of nitroglycerin will produce what amounts of each of the products?

Product / Amount	N_2	CO_2	H_2O	O_2
# Moles (mol)				
Mass (g)				

10) *(i)* Calculate the total mass of the products in the previous question (#9).

(ii) Compare the total mass of the products to the mass of decomposed nitroglycerin; what law is *(or, should be)* supported by these numbers?

_____

(iii) Any discrepancy between the numbers is caused by _____

Stoichiometry *(with molarity)*

1) A 20 mL sample of sodium hydroxide that has a concentration of 0.60 mol/L is to be neutralized by adding phosphoric acid. The unbalanced equation follows below:

$$\_\_\_\ NaOH_{(aq)} + \_\_\_\ H_3PO_{4(aq)} \rightarrow \_\_\_\ Na_3PO_{4(aq)} + \_\_\_\ H_2O_{(l)}$$

(i) How many moles of phosphoric acid will be needed to neutralize the sodium hydroxide?

(ii) If the concentration of the phosphoric acid is 0.25 mol/L, what volume *(in mL)* will be needed for the neutralization?

2) A 75.0 mL sample of hydrochloric acid that has a concentration of 1.20 mol/L is to be neutralized by adding calcium hydroxide. The unbalanced equation follows below:

$$\_\_\_\ HCl_{(aq)} + \_\_\_\ Ca(OH)_{2(s)} \rightarrow \_\_\_\ CaCl_{2(aq)} + \_\_\_\ H_2O_{(l)}$$

What mass of calcium hydroxide will be needed to neutralize the hydrochloric acid?

Stoichiometry *(with molarity)*

3) A 2.70 g piece of magnesium, $Mg_{(s)}$, is to be reacted with 2.00 M nitric acid, $HNO_{3(aq)}$.
The reaction produces magnesium nitrate, $Mg(NO_3)_{2(aq)}$, and releases hydrogen gas, $H_{2(g)}$.

(i) Write a balanced chemical equation for this reaction.

(ii) Calculate the volume of nitric acid needed for this reaction.

4) 250 mL of 0.800 M aluminium sulphate solution is reacted with excess barium nitrate solution.
The reaction produces aluminium nitrate and a precipitate, barium sulphate.

$$\_\_\_\ Al(SO_4)_{3(aq)} + \_\_\_\ Ba(NO_3)_{2(aq)} \rightarrow \_\_\_\ Al(NO_3)_{3(aq)} + \_\_\_\ BaSO_{4(s)}$$

What mass of barium sulphate is produced in this precipitation reaction?

Challenge:

5) A 1.2 g piece of magnesium is placed in a beaker containing 400 mL of 0.2 M HCl.
Is there enough HCl in this beaker to react all 1.2 g of magnesium? Justify your answer.