Ultimate Stoichiometry Grade 11 Guide

Significant Figures, The Mole, Avogadro's Number, Molar Mass, Molecular Mass, Gas Laws + Gas Stoich, Formulas, And More!

By Derek Fraser

Significant Figures

- Used to show when digits in a measurement become uncertain, and to keep answer precise
- Every measured digit is precise (Unless otherwise mentioned, from scale, or from thermometer)
- Zeros after or within a number are always significant unless there is no decimal within the number or before it
- Zeros before the number are NOT significant figures, instead placeholders.
- During calculations (Not final answer) never round to number of sig figs, instead round to an extra digit (ex: 1/3 = 0.33 instead of 0.3)
- During calculations when showing where the last significant figure is (as mentioned above you add one digit) you can underline it, which helps bring it through the calculation and avoid confusion.

Addition and Subtraction

- Final answer must have same number of decimal spots as lowest number of decimal spots out of all the original measurements

Multiplication and Division

- Instead of decimal spots, now you use significant figures. Final answer must be same number of sig figs as lowest amount of sig figs in original measurements.

Questions: Solve and List number of significant figures / digits the final answer

1) a) 2.45 g / 24.32 * 10^3 mol= _________ , # of Sig Figs / Digits = _____
   b) 4.249 mm + 924 mm = _________, # of Sig Figs / Digits = _____
2) a) 200,000.0 km * 2.0000000 km = _______, # of Sig Figs / Digits = _____
   b) 1.4 * 10^{28} m^3 / (1 * $10^9)^3$ m^2 = _______, # of Sig Figs / Digits = _____

Solutions:

1) a) 1.01 * 10^{-4} g/mol, 3 Sig Figs   b) 928 mm, 3 Sig Figs
2) a) 400,000.00 km^2 b) 14 m, 2 sig figs

The Mole & It's Uses, + Mole Calculations

The Mole

- An SI unit for amount, which is equal to Avogadro's Number of particles
- Used throughout stoichiometry to calculate the unknown

Avogadro's Number

- = $6.022 * 10^{23}$ particles / molecules per mole
- Used to identify number of particles or molecules in a mol.
- Also used to calculate # of moles from particles
- N_A used to represent avogadro's number

Molar Mass

- Not always g/mol, can be kg / kmol or mg / mmol for example.
- Used to calculate # of moles from mass

Molecular Mass

- The mass of a compounds molecular formula.
- How To: when you have the molecular formula, get the molar mass of each element, and multiply each elements molar mass by the number of atoms that element has in the molecular formula, then add it all up and you get Molecular Mass (the mass of the molecule).

Limiting Reactant

- During some chemical reactions, some of the original reactant (2) is left over because the other reactant (1) was fully used, therefore the reactant (1) is the limiter as reactant (2) has nothing left to react with. When doing a question asking for this, use moles as they are standard across all molecules / compounds (instead of grams which vary by molar mass of the molecule / compound).

Important!

- When finding moles to get limiting reactant, divide each mole number by the corresponding coefficient in the balanced chemical equation. Then you get what I call **True** number of moles, the lowest amount of moles necessary, and can determine Limiting reactant from there

Finding Empirical Formula

- Empirical Formula is found from having the moles of each element in a certain compound.
- Moles can be found using mass of each element in compound, or %composition (assume 100 grams)

Finding Molecular Formula

- Once you have the empirical formula, you can find the molecular formula (true formula instead of simplified version) by using the mass of the molecular formula (given) and divide it by the molar mass of the empirical formula (all elements molar masses added up). Once you get the result, which is called empirical units, you multiply every element by the Empirical units and attain the molecular formula.

Percent Error

- Percent error is found by taking the theoretical result (given or calculated) and subtracting the result you got from lab or the result you got. Then dividing all that by theoretical. And multiplying by 100%
- Ex. 5 = Theoretical, and 10 = result you got. (5-10)/10 = -½ * 100, -50% is your answer

Units

Quantity	Symbol	Unit
Mass	m	grams
Amount	n	mols

Molar Mass	M	g/mol, or g • mol $^{-1}$
# of particles	N	none

Formulas

$$\frac{Grams}{Mol} = Molar\ Mass\ in\ g/mol$$

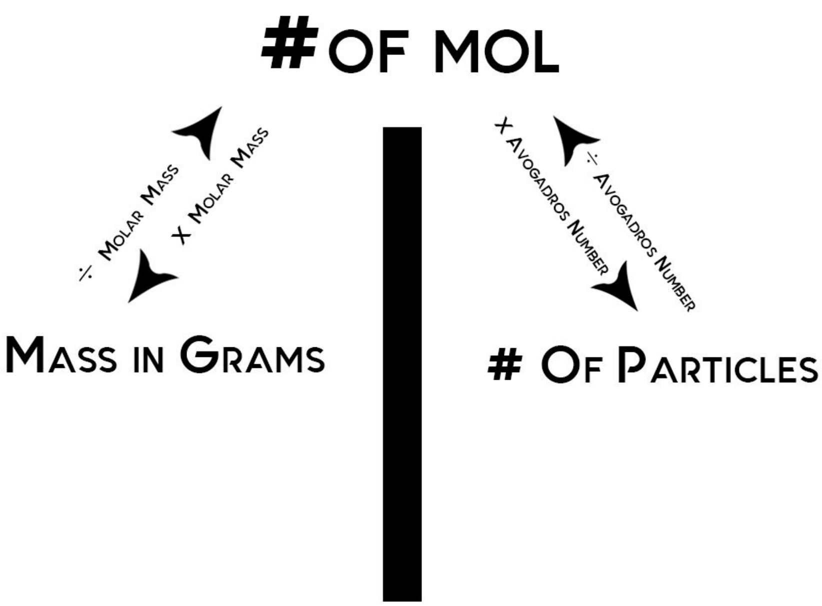
$$\#\ of\ Element = \#\ particles\ of\ compound * number\ of\ element$$

Example Compound: $CaCl_2$ (1.00 * 10^{23} molecules of Calcium Chloride)

Example: # of Cl= 1.00 * 10^{23} * 2

$N_x = (m/M) * 6.022 * 10^{23}$

The Image below shows what to do for whatever you want to find. The line means there is no **DIRECT** way of going from grams to # of particles. The formula above depicts two equations, division by molar mass, then multiplication by avogadro's number.



Questions Easy:

1) State the mass of the following compounds
   a) 1.000 mol of CO_2
   b) 7.93 * 10^{24} molecules of NO_2
   c) (2.00 mol + 6.022 * 10^{24} molecules) of O_2
2) Determine the Molecular Mass of each compound
   a) NaCN
   b) Li_2SO_4
3) Calculate the number of Moles
   a) 6.022 * 10^{24} particles of CO_2
   b) 21 g of Na

Questions Medium:

1) Calculate the number of molecules of each
   a) 4.0 g of $C_2H_3O_2$
   b) 12 kg of H_2O
   c) 400 Tons of O_3
2) An unknown element measured to have 3.5 moles and a mass of 306.67 g. Find what element it is
3) Determine the Molecular Mass of $C_{12}H_{24}O_{12}$, also known as lactose monohydrate
   a) Calculate the amount of moles in 0.50 grams of lactose monohydrate

Questions Challenging:

1) Jimmy is fascinated by volcanoes. He is attempting to recreate one, so he grabs some chemicals from his dads laboratory that he knows will react. He decides to add 5.2 grams of Sodium Bicarbonate to 6.7 grams of Acetic Acid.
   a) Write the balanced chemical equation.
   b) How much carbon dioxide gas is produced, in grams?
   c) State the limiting reactant for this question.
   d) Calculate the mass of CO_2 produced if the moles of Sodium Bicarbonate used in the reaction is doubled.

Solutions Easy:

1) a) m_{CO2} = (1.000 mol) * (12.011 g/mol)
   m_{CO2} = 12.01 g
   b) n_{NO2} = (7.93 * 10^{24} #) / (6.022 * 10^{23} #/mol)
   n_{NO2} = $13.\underline{1}7$ mol
   m_{NO2} = ($13.\underline{1}7$ mol) * (46.01 g/mol)
   m_{NO2} = 606 g
   c) n_{O2} = 2.00 mol + (6.022 * 10^{24} #)
   n_{O2} = 2.00 mol + 10.00 mol (we know 6.022 * 10^{23} is 1 mol, therefore 10^{24} is 10 mol)

n_{O2} = 12.00 mol
m_{O2} = 12.00 mol * 12.011 g/mol
m_{O2} = 144.1 g

2) a) M_{Na} = 22.99 g/mol M_C = 12.011 g/mol M_N = 14.01 g/mol
Molecular Mass = 22.99 g/mol + 12.011 g/mol + 14.01 g/mol
Molecular Mass = 49.01 g/mol
b) M_{Li} = (6.94 g/mol * 2) M_S = 32.06 g/mol M_{O4} = (15.999 g/mol * 4)
Molecular Mass $_{Li2SO4}$ = 13.88 g/mol + 32.06 g/mol + 63.996 g/mol
Molecular Mass $_{Li2SO4}$ = 109.94 g/mol

3) a) n_{CO2} = $(6.022 * 10^{24}$ #/mol) / $(6.022 * 10^{23}$ #/mol)
n_{CO2} = 362.6 mol
b) n_{Na} = (21 g) / (22.99 g/mol)
n_{Na} = 0.91 mol

Solutions Medium:

1) a) n_{C2H3O2} = (4.0 g) / (59.04 g/mol)
n_{C2H3O2} = $0.06\underline{7}8$ mol
N_{C2H3O2} = ($0.06\underline{7}8$ mol) * $(6.022 * 10^{23}$ #/mol)
N_{C2H3O2} = $4.1 * 10^{22}$ molecules
b) n_{H2O} = (12 kg) / (18.02 kg/kmol)
n_{H2O} = $0.6\underline{6}6$ kmol
^ converted to mol for simplicity, could also use avogadro's number with $* 10^{26}$
$\#_{H2O}$ = ($6\underline{6}6$ mol) * $(6.022 * 10^{23}$ #/mol)
$\#_{H2O}$ = $4.0 * 10^{26}$
c) n_{O3} = (400 Mg) / (48 Mg/Mmol)
Mg refers to Megagrams instead of milligrams, Megagram = 1000 kg or 1 ton, Mmol refers to mega moles which is equal to 1000 kmol
n_{O3} = $8.\underline{3}3$ Mmol
$\#_{O3}$ = ($8.\underline{3}3$ Mmol) * $(6.022 * 10^{29}$ #/Mmol)
$\#_{O3}$ = $5.0 * 10^{30}$ #

2) $M_{Unknown}$ = (306.67 g) / (3.500 mol)
$M_{Unknown}$ = 87.62 g/mol
Strontium has a molar mass of 87.62, ∴ Strontium is the mystery element

3) Molecular Mass $_{C12H24O12}$ = (12.011 g/mol * 12) + (1.008 g/mol * 24) + (15.999 g/mol * 12)
Molecular Mass $_{C12H24O12}$ = $144.1\underline{3}2$ g/mol + $24.1\underline{9}2$ g/mol + $191.9\underline{8}8$ g/mol
Molecular Mass $_{C12H24O12}$ = $360.3\underline{1}2$ g/mol

a) $n_{C12H24O12}$ = (0.50 g) / ($360.3\underline{1}2$ g/mol)
$n_{C12H24O12}$ = 1.4 mmol or 0.0014 mol

Solutions Challenging:

1)

Sodium Bicarbonate Molar Mass: 84.01 g/mol   Acetic Acid Molar Mass: 60.05 g/mol

a) Chemical Equation: $NaHCO_{3\,(s)} + CH_3COOH_{\,(aq)} = CO_{2\,(g)} + H_2O_{\,(l)} + NaCH_3COO_{\,(aq)}$

b)

Sodium Bicarbonate Molar Mass: 84.01 g/mol   Acetic Acid Molar Mass: 60.05 g/mol

n_{NaHCO3} = (5.2 g) / (84.01 g/mol) $n_{CH3COOH}$ = (6.7 g) / (60.05 g/mol)

$n_{NaHCO3} = 0.06\underline{1}9$ mol $n_{CH3COOH} = 0.1\underline{1}2$ mol

^ Sodium Bicarbonate is the limiting reactant, therefore we will use its mol value. Note: Sodium Bicarbonate has a 1:1 ratio with Carbon Dioxide.

$m_{CO2} = (0.06\underline{1}9 \text{ mol}) * (44.01 \text{ g/mol})$

m_{CO2} = 2.7 g

∴ 2.7 g of CO_2 is produced when jimmy reacts the two masses of compounds.

c)

Sodium Bicarbonate is the limiting reactant because it has the lowest number of moles after ratios (1:1 in this case).

d)

Double the mol value for Sodium Bicarbonate

$n_{NaHCO3} = 0.06\underline{1}9 \text{ mol} * 2$

$n_{NaHCO3} = 0.1\underline{2}4$ mol $n_{CH3COOH} = 0.1\underline{1}2$ mol

now Acetic Acid becomes the limiting reactant ^

$n_{CO2} = (0.1\underline{1}2 \text{ mol}) * (44.01 \text{ g/mol})$

n_{CO2} = 4.9 g

∴ with the quantity of Sodium Bicarbonate doubled, Acetic Acid became the limiting reactant and 4.9 grams of CO_2 were produced.

Gas Law Stoichiometry

When using gas law stoichiometry, **ALWAYS** make sure to keep the units proportional to each other.

DON'T use **Liters** and **mmol** in the same equation, they are not proportional to each other.

YOU CAN however use **mmol** and **mL** or **mol** and **Liters** as these are considered proportional.

Condition Types

Standard Temperature and Pressure (STP)

STP: 101.325 kPa, 273.15 K (0 Degrees Celsius),

Standard Ambient Temperature and Pressure (SATP)

SATP: 101.3 kPa, 298.15 K (25 Degrees Celsius)

Units

Term	Symbol	Units / Value
Pressure	P	Pa, kPa, MPa
Volume	V	mL, L, ML
Temperature	T	Kelvin (273.15 + Celsius)
Gas Constant	R	8.314 kPa•L/mol•K
Moles	n	mol, kmol, Mmol

Formulas

- Understanding PV/T = Constant, therefore P/T = Constant As Well
- PV = nRT
- $P_1V_1 = P_2V_2$ therefore P_1V_1 = Constant
- $V_{New} = V_{old} * (T_{New} / T_{Old})$
- Celsius to Fahrenheit: $T_{Fahrenheit} = T_{Celsius} * 1.8 + 32$
- Kelvin to Celsius: $T_{Celsius} = T_{Kelvin} - 273.15$ K

Questions Easy (Getting used to gas calculations):

1) Find the Volume of 20.0 L warmed up to 20 Degrees Celsius, From 0.

2) Find the Temperature of a gas that changed in volume from 12.50 L at an unknown temperature to 29.0 L at 0 degrees

Questions Interpretation (Understanding Word Problems):

1) Ms. Pall is making herself some tea as she has a slight sore throat and feels very cold. The interesting thing about Ms. Pall is, she doesn't like drinking tea, instead she prefers to inhale it. She releases 500 mL of warm steam (100% H_2O) into a container, which fills it, and then forgets to add the tea packet. The temperature of the steam is 102 Celsius, and the initial pressure before anything changed, and after the air was added is 200 kPa. Then when Ms. Pall left to photocopy sheets she had lost for her class, the temperature rose by 20 degrees celsius and the pressure changed to 250 kPa. What is the volume that Ms. Pall's "Tea" is now occupying?

Questions Challenging (Combination):

1) Derek Fraser decides he wants to try an example he found of condensation. He takes his water bottle, and fills it full, to 1.00 L, then constantly presses on the water bottle, if the volume becomes 0.5 liters after his full force is being applied, and the original pressure was 100 kPa what is the pressure being exerted.

2) Timmy is curious about the temperature of gaseous formaldehyde. Timmy has access to his dad's (Philip) laboratory, in which he can heat things to extremely high temperatures. He already knows there is 12.5 L of formaldehyde in a bag, and knows the pressure inside the bag is the same as the external pressure, 101.0 kPa in the room. There is $4.02 * 10^{22}$ molecules of formaldehyde inside the bag. Find the temperature in fahrenheit.

Solutions Easy:

1)

$V_{New} = V_{old} * (T_{New} / T_{Old})$

$V_{New} = 20.0 \text{ L} * (293.15 \text{ K} / 273.15 \text{ K})$

$V_{New} = 20.0 \text{ L} * (1.073\underline{2}2)$

$V_{New} = 21.5 \text{ L}$

2)

$V_{New} = V_{old} * (T_{New} / T_{Old})$

$29.0 \text{ L} = 12.50 \text{ L} * (273.15 \text{ K} / T_{Old})$

$29.0 \text{ L} * T_{Old} = 12.50 \text{ L} * 273.15 \text{ K}$
(Rearrange formula to isolate for old temperature)
$T_{Old} = (12.50 \text{ L} * 273.15 \text{ K}) / (29.0 \text{ L})$

$T_{Old} = (341\underline{4}.4 \text{ L}\bullet\text{K}) / (29.0 \text{ L})$

$T_{Old} = 118 \text{ K}$

Solutions Interpretation:

1)

$(P_1V_1)/T_1 = (P_2V_2)/T_2$

$(P_1V_1T_2) / (P_2T_1) = V_2$

((200 kPa) * (0.500 L) * (395.15 K)) / ((375.15 K) * (250 kPa)) = V_2

V_2 = (10$\underline{0}$.0 kPa•L * 395.15 K) / (375.15 K * 250 kPa)
(Both brackets calculated, then divided)
V_2 = 0.421 L

∴ After Ms. Pall finishes photocopying her tea is occupying a volume of 0.421 L. Ms Pall now sits in her class enjoying her “tea” and teaching the class happily ever after.

Solutions Hard:

1)

$P_1V_1 = P_2V_2$

(100 kPa) * (1.00 L) = (P_2) * (0.5 L)

(100 kPa * 1.00 L) / (0.5 L) = P_2

P_2 = 100 kPa•L / 0.5 L

P_2 = 200 kPa

∴ Derek is creating a pressure of 200 kPa inside the water bottle.

2)

n_{CH2O} = 4.020 * 10^{22} # / 6.022 * 10^{23} # / mol

n_{CH2O} = 0.0667$\underline{5}$5 mol

PV = nRT
(Rearranging to isolate for temperature)
T = PV/nR

T_{CH2O} = ((101.0 kPa) * (12.50 L)) / ((0.0667$\underline{5}$5 mol) * (8.314 kPa•L /mol•K))

T_{CH2O} = (126$\underline{2}$.5 kPa•L) / (0.555$\underline{0}$0 kPa•L / K)

T_{CH2O} = 2275 K

Temperature in Celsius_{CH2O} = 2275 K - 273.15 K

Temperature in Celsius_{CH2O} = 2002 ° Celsius

∴ Temp in Celsius of the Formaldehyde is 2002° Celsius

Temperature in Fahrenheit_{CH2O} = 2002 Celsius * 1.8 Fahrenheit / Celsius + 32 Fahrenheit

Temperature in Fahrenheit_{CH2O} = 3635 Fahrenheit

∴ Temp in Fahrenheit of the Formaldehyde is 3635° Fahrenheit

Solution Stoichiometry

Solutions are often given in M, (mols / liter).

Just like gas laws, you **NEED** to keep the units proportional.

Remember: mols in a calculation do not change, they remain the same.

1 kg of water is equal to 1 L. This is what the system was based off.

Units

Term	Symbol	Units
Concentration	C	M, or mol/L
Moles	n	mmol, mol, kmol
Volume	V	mL, L, or kL

Formulas

- $C = n/V$, formula for concentration
- $C_1V_1 = C_2V_2$, moles remain the same throughout equation

Questions Easy:

1) There are 40 mol of NO_3 in 20 L of H_2O, what is the concentration?
2) There is 20 M of NaCl with a volume of 20 L, how many moles of Sodium Chloride is there?

Questions Interpretation:

1) Philip pop decides he wants to run a public pool. He needs to create a total concentration of 0.0002000 M of chlorine. His pool occupies a total of 500.0 L. Find how much mass of chlorine he needs to reach the required chlorine concentration. The formula for chlorine is Cl_2.

Questions Challenging:

1) Derek Fraser has 1.000 kg of Francium orthotellurate which he dissolved in 400. mL of water. Derek further dissolves it in water, and the final mass of the solution is 9.620 kg. What is the final concentration of the solution?

Solutions Easy:

1)

C_{NO3} = 40 mol / 20 L

C_{NO3} = 2 M

2)

n_{NaCl}’= 20 M * 20 L

n_{NaCl} = 400 mol

Solutions Medium:

n_{Cl2} = (0.0002000 M) / (500.0 L)

n_{Cl2} = 0.00000040000 mol

m_{Cl2} = (0.00000040000 mol) * (70.91 g/mol)

m_{Cl2} = 0.00002836 g

∴ Philip needs 0.00002836 g, or .02836 mg of chlorine to get the required concentration

Solutions Challenging:

1)

We will use $C_1V_1 = C_2V_2$

First we find C_1 because we have V_1

$n_{Fr6TeO6}$ = 1000. g / 1562 g/mol

$n_{Fr6TeO6}$ = 0.640$\underline{2}$0 mol

$C_{Fr6TeO6}$ = 0.640$\underline{2}$0 mol / 0.400 L

$C_{Fr6TeO6}$ = 1.6$\underline{0}$1 M

Now we must find V_2

m_2 = 9.620 Kg - 1.000 Kg (because there is 1.000 Kg of the solute to begin with, and must follow law of conservation of mass.)

m_2 = 8.620 Kg

V_2 = 8.620 L (remember 1kg of water is 1L)

(now we can plug all our values into the rearranged formula, isolated for the second concentration)

C_2 = (1.6$\underline{0}$1 M * 0.400 L) / 8.620 L

C_2 = 0.0743 M

∴ The final concentration of Francium orthotellurate is 0.0743 M

Thank You For Reading!

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