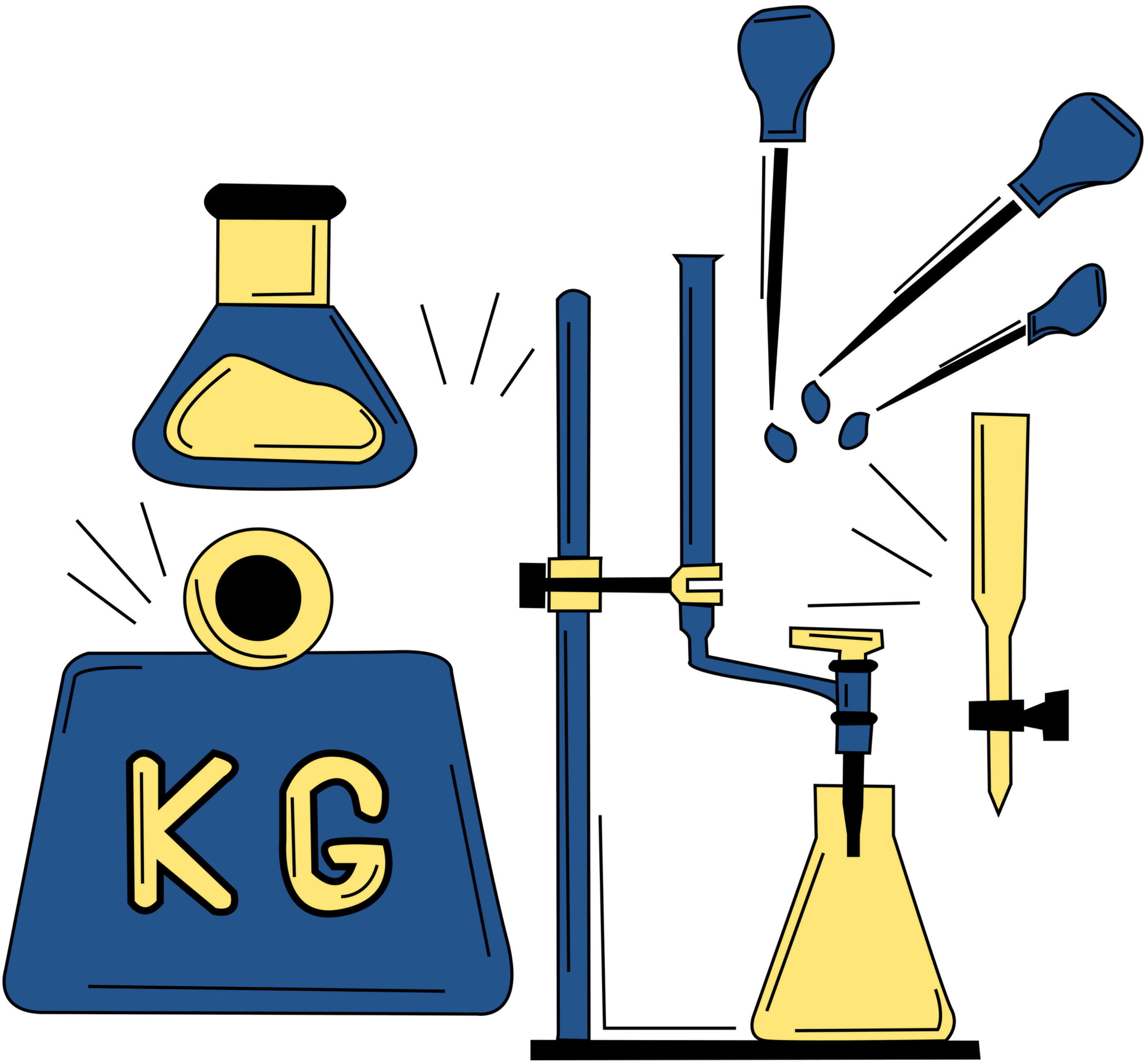
STOICHIOMETRY



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INTRODUCTION

- This guide aims to simplify the stoichiometry chapter in the XI chemistry book by breaking it down into digestible sections. It's important to note that while the book provides an excellent introduction to the subject, stoichiometric calculations can be challenging, and students may need more practice. By following this guide, you can have a clear grasp of the material and avoid common errors.

1. HOW TO APPROACH THE TEXTBOOK?

1.Identify Learning Objectives:

- Clarify your learning objectives for the session. What specific information or skills do you aim to gain from this chapter?

2.Read Strategically:

- Read the introduction and conclusion to understand the overall theme. Focus on the first and last sentences of paragraphs, as they often contain key points. Read any bolded or italicized text, as these are typically emphasized concepts.

3.Take Notes:

- As you read, take notes on key concepts, definitions, and important examples. Use abbreviations and symbols to make your note-taking more efficient.

4.Use Visual Aids:

- Pay attention to charts, graphs, and illustrations. These visual aids can typically simplify complex concepts. Take the time to understand them fully.

2. CHAPTER CONTENT

1.1	Moles
1.2	Avogadro's numbers
1.3	Percentage composition
1.4	Limiting and Non-limiting Reactant
1.5	Theoretical yield, Actual yield, and Percentage yield

1.1 Moles:

- Moles can be defined as the atomic mass, formula mass, or molecular mass of a substance expressed in grams.
- It is a unit of measurement used in chemistry to express the amount of a substance present in a sample

1.1.1 Formula to calculate Moles:

- N=M/M.M
- N=N/Na
- N=Volume given/22.414

1.2 Avogadro's Number:

1.Avogadro's Number:

- Avogadro's number, which is approximately 6.022 × 10^23, signifies the number of atoms, molecules, or ions present in one mole of a substance.
- Therefore, if we consider any gas, one mole of it will contain 6.022 103 particles.
- Calculation of the number of atoms/ions/molecules:
  No. of atoms= Moles x Na

2. Mole Calculation:

- Moles can be calculated by dividing the given mass of a substance by its molar mass.
- To determine the molar mass, you need to find the mass of one mole of the substance in grams per mole (g/mol).
- Once you have the molar mass, you can use the formula Moles = Mass (g) / Molar Mass (g/mol) to calculate the number of moles of the substance.

3.Moles Ratio in Stoichiometric Calculations:

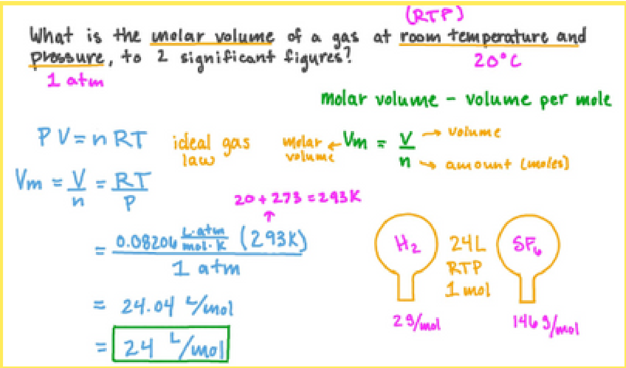
- Stoichiometry is a process that utilizes balanced chemical equations to establish quantitative connections between reactants and products.
- The coefficients featured in the balanced equation symbolize the mole ratios between the various substances that partake in the reaction.
- These precise mole ratios aid in computing the exact quantities of reactants utilized or products produced.

4.Molar Volume:

- It is important to understand that molar volume refers to the volume occupied by one mole of a gas at a specific temperature and pressure.

3a. TIPS AND TRICKS:

- At standard temperature and pressure (STP), which is 0 degrees Celsius, and 1-atmosphere pressure, the molar volume of any ideal gas is 22.4 liters/mol. However, at RTP which is 25 degrees Celsius, the molar volume is 24 liters/mole.
- This concept is important to keep in mind when dealing with gas stoichiometry calculations.



- Understanding the concept of moles, Avogadro's number, and stoichiometry is essential for performing calculations involving chemical reactions and the amounts of substances involved.

1.3: Percentage Composition:

Percentage composition is a small and easy-to-understand subtopic in stoichiometry. However, it is important to grasp this concept as it is often tested in exams and can earn bonus marks.

1.Percentage Composition:

- Percentage composition refers to the relative amount of each element in a compound.
- It is expressed as the percentage of the mass contributed by each element to the total mass of the compound.
- To calculate the percentage composition, the mass of each element is divided by the molar mass of the compound and multiplied by 100.

2.Empirical Formula:

- The empirical formula is a crucial concept in chemistry that represents the simplest whole-number ratio of atoms present in a compound.
- To determine the empirical formula, one needs to convert the percentage composition of the compound to moles and then identify the smallest whole-number ratio.
- For example, the empirical formula for benzene is CH, while for glucose, it is CH_2O.

3.Molecular formula:

- The molecular formula of a compound represents the actual number of atoms of different elements present in a molecule.
- For instance, benzene (C_6H_6), ethane (C_2H_6), and glucose ($C_6H_{12}O_6$) all have molecular formulas.
- In all these compounds, the molecular formulas are simple multiples of empirical formulas.
- Therefore, the molecular formula can be expressed as n x empirical formula, where 'n' is a simple integer.

3b. TIPS AND TRICKS:

- There are numerous compounds whose empirical and molecular formulas are the same, such as NaCl, H2O, CO2, NH3, SO2, CH4, and C12H22O11.
- In these cases, the simple multiple 'n' is unity, and 'n' is the ratio of a substance's molar mass and empirical formula mass.

1.4: Limiting and Non-limiting Reactants:

Understanding the concepts of limiting and excess reagents, and stoichiometric calculations is crucial for accurate calculations and determining the quantities of reactants and products involved in a chemical reaction.

1.Stoichiometric Calculations:

- The balanced chemical equation is used in stoichiometry to determine the quantitative relationships between reactants and products.
- The coefficients in the balanced equation represent the mole ratios between the different substances involved in the reaction.

2.Limiting Reagent:

- The reactant that is completely consumed in a chemical reaction, thereby limiting the amount of product that can be formed, is known as the limiting reagent.
- The limiting reagent determines the theoretical yield of the reaction.

3.Excess Reagent:

- The reactant that is not completely consumed in a chemical reaction and is present in excess quantity after the limiting reagent is consumed is known as the excess reagent.

4.Calculation of Limiting and Excess Reagents:

- To determine the limiting and excess reagents, you need to compare the mole ratios of the reactants to the stoichiometry of the balanced chemical equation.
- The reactant that produces the smaller amount of product is the limiting reagent, while the reactant that produces more product is the excess reagent.

3b. TIPS AND TRICKS:

- To identify a limiting reactant, the following three steps are performed.
  1. Calculate the number of moles from the given amount of reactant.
  2. Find out the number of moles of a product with the help of a balanced chemical equation.
  3. Identify the reactant which produces the least amount of product as a limiting reactant.

Examples:

- Experiment 1:
  In the first experiment, 4 g of H_2 reacts with 32 g of O2 to form 36 g of H2O. This reaction can be represented as 2H2 + O2 → 2H2O. It's important to note that in this experiment, all quantities of H_2 and O2 were consumed because they have a stoichiometric ratio in them.
- Experiment 2:
  In the second experiment, 6 g of H_2 was reacted with 32 g of O2 and 36 g of H2O was produced according to the balanced chemical equation: 2H2 + O2 → 2H2O. Based on the given amounts, it can be concluded that the formation of H2O is limited by the O2 reactant. Additionally, 2 g of H_2 remains unreacted, indicating that it was in excess.

1.5: Actual Yield, Theoretical Yield and Percentage Yield:

- Understanding the concepts of theoretical yield, actual yield, and percentage yield is essential.

1.5.1 Percentage Yield, Theoretical Yield, and Actual Yield:

1. Theoretical Yield:

- The maximum amount of product that can be obtained from a chemical reaction is referred to as its theoretical yield.
- This value is calculated by factoring in the balanced chemical equation and the quantity of the limiting reagent used.
- The assumption is that the reaction will transpire without any byproducts or waste.

2.Actual Yield:

- The actual yield of a chemical reaction is the amount of product that is obtained through experimentation in a laboratory setting.
- It is important to note that the actual yield can be less than the theoretical yield due to a variety of factors, such as incomplete reactions, side reactions, loss of product during purification, or experimental errors.

3.Percentage Yield:

- The percentage yield is the ratio of the actual yield to the theoretical yield, expressed as a percentage.
- It indicates the efficiency of a reaction and is calculated using the formula: Percentage Yield = (Actual Yield / Theoretical Yield) x 100.

Example:

- When limestone ($CaCO_3$) is roasted, quicklime (CaO) is produced according to the following equation. The actual yield of CaO is 2.5 kg when 4.5 kg of limestone is roasted. What is the percentage yield of this reaction? $CaCO_3$ (g) ————→ CaO (g) + CO_2 (g) A). 100 % B). 85.5 % C). 99.2 % D). 40.3 %

Solution:

- Mass of limestone roasted = 4.5 kg = 4500g
- Mass of quicklime produced (actual yield) = 2.5 kg = 2500 g
- Molar mass of $CaCO_3$ = 100 g/mole
- Molar mass of CaO = 56 g/mole
- According to the balanced chemical equation:
  100 g of $CaCO_3$ should give CaO = 56 g
  1 g of $CaCO_3$ should give CaO = 56 100
- 4500 g of $CaCO_3$ should give CaO = 56 100 × 4500 = 2520 g
- Theoretical yield of CaO = 2520 g
- Actual yield of CaO = 2500 g
- % yield = Actual yield/Theoretical yieldx100 = 2500 g 2520 × 100 = 99.2%.

4.Importance of Percentage Yield:

- Percentage yield provides insight into the efficiency of a chemical reaction and the quality of the experimental procedure.
- A high percentage yield indicates a more efficient reaction, while a low percentage yield suggests the presence of inefficiencies or experimental errors.

5.Factors Affecting Percentage Yield:

- Several factors can affect the percentage yield, including the purity of reactants, the presence of side reactions, incomplete reactions, losses during product isolation or purification, and experimental errors.
- Understanding and controlling these factors is crucial for optimizing reaction conditions and maximizing yield.

6.Calculating Theoretical Yield and Percentage Yield:

- To calculate the theoretical yield, you need to determine the stoichiometry of the balanced chemical equation and the amount of limiting reagent used.
- The actual yield is obtained through experimental measurements.
- The percentage yield is then calculated by dividing the actual yield by the theoretical yield and multiplying by 100.

4. IMPORTANT FORMULAE:

1. Determination of Empirical Formula:

- Percentage composition of compound:
  % of element = (Mass of element in a compound/Mass of compound) x 100
- Number of gram atoms:
  No. of gram atoms = (Mass/Atomic Mass) x NA
- Atomic ratio:
  Divide each number of moles by the smallest number of moles to get the mole ratio of elements.
- Whole number ratio:
  If the ratio is a simple whole number, then it gives an empirical formula, otherwise, multiply with a suitable digit to get the whole number ratio.

2.Determination of Molecular Formula:

- It can be determined by the following expression:
- Molecular Formula = n x Empirical Formula
  Here, n = Molar mass empirical formula

5. IMPORTANT NUMERICALS:

Example 1.1:

- Methanol burns according to the following equation.
  2CH3OH + 3O2(g) → 2CO2(g) + 4H2O(9) If 3.50 moles of methanol are burnt in oxygen, calculate
  (a) How many moles of oxygen are used?
  (b) How many moles of water are produced?

Example 1.4:

- 20g of H_2SO_4 on dissolving in water ionizes completely. Calculate
  a) No of H_2SO, molecules
  b) No of H and SO
  c) Mass of individual ion

Example 1.6:

- 200 g of K_2Cr_2O, were reacted with 200g conc. H_2SO_4 Calculate
  (A) Mass of atomic oxygen produced
  (B) Mass of reactant left unreacted
  KCr_2O, +$4H_2SO_4K_2SO_4$ + Cr2(SO4)3 + 4H2O+3(0)

Example 1.10:

- In a reaction, 2.00 moles of CH, were reacted with an excess of Cl, As a result, 177.0 g of CCl, is obtained. What is the
  (a) theoretical yield
  (b) actual yield
  (c) % yield of this reaction?

Self Assessment 1.5:

- 1. The overall balanced equation for the production of ethanol (C_2H_2OH) from glucose it as follows:
  CH2O2C_2H_2OH + 2C020
  (a) What is the theoretical yield of ethanol available from 10.0 g of glucose?
  (b) If in a particular experiment, 10.0 g of glucose produces 0.664 g of ethanol what is the percentage yield?
  (Ans: (a) Theoretical yield of ethanol = 5.152g (b) Percentage yield = 12.89%)
- 2. Solid carbon dioxide (dry ice) may be used for refrigeration. Some of this carbon dioxide is obtained as a by-product when hydrogen is produced from methane in the following reaction.
  CH+2H_2O CO2(g) +4H29)
  (a) What mass of CO2 should be obtained from 1250 g of methane?
  (b) If the actual yield obtained is 3000 g then what is the percentage yield?
  (Ans: a = 3437.5 g b = 87.3%)

6. SAMPLE MCQS:

Q. Given the reaction:
C3H6 + 5O2 → 3CO2 + 4H2O
At STP , how many litres of O2 are needed to completely burn 5.0 litres of C3H6?
(NTS 2010)

- 5
- 10
- 10.5
- 15
- 25 ✓

Explanation:

- Consider that no. of moles of reactants = volume of the reactants.
- As the molar ratio between C3H6 and O2 is 1:5, the volume ratio is also the same. For 1L of C3H6 we need 5L of O2. Since the volume of C3H6 is 5L now, to burn this, we require 25L of O2.
- All other options are incorrect because they do not follow the exact mole-volume relationship required in this case.

Q. If we take 2.2g of CO2, 6.02 x 1021 atoms of nitrogen and 0.03g atoms of sulfur, then the molar ratio of CO2, N and S atoms will be:
(NTS 2013)

- 1:2:5
- 5:1:2
- 2:5:3
- 5:1:3 ✓

Explanation:

- Mass of CO2 = 2.2g
- Molar mass of CO2 = 44g/mol
- Number of moles of CO2= Mass/Molar Mass
- = 2.2/44 = 0.05mol
- Number of atoms of nitrogen = 6.02×10^{21}
- Number of moles of nitrogen= No. Of atoms of N2/ Avogadro's No.
- = $6.02\times10^{21}/6.02\times10^{23}$ = 0.01 mol
- 0.03 gram atom of sulfur means 0.03 moles of sulfur. Thus the mole ratio of CO2:N:S = 0.05:0.01:0.03 = 5:1:3

7. SOME HELPFUL RESOURCES:

1.YouTube Videos:

- Competition wallah
- Chemistry Unleashed
- Professor Dave
- The Organic Chemistry Tutor

2.Guidebooks and Notes:

- KIPS prep book for chemistry
- Wak academy notes
- Anees Hussain's chemistry notes

8. TOPICAL QUESTIONS ON PREMED.PK:

- It's important to note that simply studying a chapter is not enough. To retain the information for a long time, at least until the MDCAT, it's crucial to practice as many questions as possible. During our preparation, the PreMed question bank proved to be an invaluable resource. We solved the topical sets, learned from the explanations provided, and saved the questions we found challenging. Familiarizing yourself with the types of questions asked is essential because the ultimate goal is to be able to solve the MCQs on the MDCAT. We cannot stress this enough!

9. STUDY HACKS:

1.Error log/mistake notebook:

- If you want to up your question-solving game by 1000 percent, please maintain a record of all the questions you get wrong. It could be a separate notebook or something as simple as a Google Doc. (For the legends out there, make Anki cards out of them!) At the very least, save it to your Saved Questions deck on the PreMed.PK website.

2.Practice:

- To excel in this chapter, it's important to practice consistently. The more you practice solving questions, the better you will recognize the types of questions that can appear in this chapter. For practice, I recommend using KIPS and solving KIPS FLPS and Star FLPS as well.

10. REVISION TIPS FOR LAST MINUTE:

Not having enough time for revision is a common problem (we faced it too!). Here’s what we recommend:

1.Read your shortlisted notes:

- The importance of reviewing your notes can not be emphasized enough. Make sure that you go through them before the exam.

2.Positive attitude:

- Have a positive mindset and do not take unnecessary stress as it will hurt your performance.

3.Use multiple resources:

- Using different sources to gain information can have a positive impact on your performance, so feel free to use YouTube, and educational websites to strengthen your preparation.

11. CONCLUSION:

- It can be inferred from the above chapter that practising stoichiometry is essential to having a solid grasp of the subject. Remembering the formulas and basic concepts is important, but regular practice is what will ultimately lead to success. Although stoichiometry is considered an easy chapter, students who do not practise enough may struggle to secure good marks in this chapter.

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A little about the author

I am a strong advocate of self studying and can not emphasize its importance enough. That being said it can be really difficult to find effective and reliable sources for guidance. So, its safe to say preMed.PK is an extremely efficient site that gives you access to past papers, numerous practice questions and beneficial notes. I would definitely suggest this website and also acknowledge its help during my MDCAT journey. These guides will certainly assist your preparation and hopefully lead you towards your own goal.