Chapter 1 Introduction to Fundamental Concepts of Chemistry

Multiple Choice Questions (M.C.Qs)

Choose the correct answer for each from the given options:

01 The branch of Science which deals with the properties, composition and the structure of matter is called:
(a) Physics (b) Chemistry (c) Biology (d) Geology

02 The number of moles in 58.5 gm of NaCl is:
(a) 8.5 (b) 1 (c) 35.5 (d) 23

03 The empirical formula of a compound is CH_2O and molecular mass is 60. Its molecular formula is:
(a) CH_2O (b) $C_2H_4O_2$ (c) $C_3H_6O_3$ (d) $C_4H_8O_4$

04 Which number has five significant figures?
(a) 302.10 (b) 3.00002 (c) 30000 (d) 30200

05 A beaker containing 180 gm of water, contains:
(a) 6.02×10^{23} molecules (b) 6.02×10^{24} molecules
(c) 10.02×10^{25} molecules (d) 12.01×10^{22} molecules

06 One cm^3 is equal to:
(a) $10^3 dm^3$ (b) $100\ dm^3$ (c) $1000\ dm^3$ (d) $10 dm^3$

07 The integer part of logarithm is called:
(a) characteristics (b) mantissa (c) base (d) exponent

08 The decimal fraction part of logarithm is called:
(a) base (b) characteristics (c) exponent (d) mantissa

09 The significiant figure of 6.02×10^{23} is:
(a) 1 (b) 2 (c) 3 (d) 4

10 357.00 written in exponential notation is:
(a) 3.57×10^7 (b) 35.7×10^2 (c) 3.57×10^2 (d) 35.7×10^{-1}

11 If decimal is shifted in the given number towards left, the exponent is:
(a) negative (b) positive
(c) neither negative nor positive (d) none of the above

12 When decimal is shifted in the given number towards right the exponent is:
(a) positive (b) negative
(c) neither positive nor negative (d) none of the above

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13. ***When co-efficient numbers are multiplied, the exponent are:***
   (a) divided (b) subtracted (c) added (d) none of them

14. ***When co-efficient numbers are divided, the exponents are:***
   (a) added (b) subtracted (c) divided (d) none of them

15. ***One mole of SO_3 contains:***
   (a) 6.02×10^{23} atoms of oxygen (b) 18.1×10^{23} molecules of SO_2
   (c) 6.02×10^{23} atoms of S (d) none of them

16. ***Molecular formula of vitamin C is $C_6H_8O_6$, its empirical formula is :***
   (a) CHO_2 (b) CH_2O (c) $C_3H_4O_3$ (d) $C_3H_3O_3$

17. ***In every physical measurement, the error that can't be eliminated is :***
   (a) physical error (b) random error
   (c) true error (d) systematic error

18. ***44 grams of CO_2 contains carbon:***
   (a) 1 gram (b) 6 grams (c) 12 grams (d) 24 grams

19. ***The percentage of oxygen in H_2O is :***
   (a) 11.11 (b) 88.88 (c) 80 (d) 10

20. ***The empirical formula of $C_6H_{12}O_6$ is :***
   (a) $C_3H_6O_3$ (b) CH_2O (c) $C_2H_2O_2$ (d) $C_2H_4O_2$

21. ***The molecular mass of Na_2CO_3 is :***
   (a) 106 amu (b) 206 amu (c) 601 amu (d) 212 amu

22. ***The empirical formula of sulphuric acid is :***
   (a) HSO_4 (b) HSO (c) H_2SO_4 (d) HSO_2

23. ***A compound has empirical formula C_3H_3O and molecular mass 110 gram. The molecular formula of compound is :***
   (a) C_3H_3O (b) $C_6H_{12}O$ (c) $C_6H_6O_2$ (d) $C_3H_3O_2$

24. ***Which has maximum number of atoms?***
   (a) 56 gm of Fe (b) 27 gm of Al (c) 24 gm of C (d) 108 gm of Ag

25. ***The percentage of nitrogen in NH_3 is :***
   (a) $\frac{14}{17} \times 100$ (b) $\frac{14}{34} \times 100$ (c) $\frac{3}{17} \times 100$ (d) $\frac{3}{34} \times 100$

26. ***The mass of one molecule of oxygen gas is :***
   (a) $\frac{6.02 \times 10^{23}}{32}$ (b) $\frac{32}{6.02 \times 10^{23}}$ (c) 0.32gm (d) 32 gm

27. ***How many significant figures represented in 0.08000?***
   (a) 3 (b) 4 (c) 5 (d) 6

28. ***To determine the empirical formula, we divide the % of an element by:***
   (a) molecular mass (b) atomic mass (c) formula mass (d) ionic mass

29. ***The limiting reactant is the reactant that:***
   (a) gives least amount of product (b) is in excess amount.
   (c) gives maximum amount of product (d) retains after the reaction.

30. ***One mole of Na contains:***
   (a) 6.02×10^{23} ions (b) 6.02×10^{23} molecules
   (c) 6.02×10^{23} atoms (d) 60.2×10^{23} atoms

31 *5 dm^3 of CO_2 contains molecules:*
(a) 1.344×10^{23} (b) 6.02×10^{23} (c) 1.344×10^{23} (d) 6.02×10^{24}

32 *0.00015 can be written in exponential form as:*
(a) 0.15×10^{-3} (b) 1.5×10^{-4} (c) 1.5×10^{4} (d) 15×10^{-5}

33 *10^{-5} can be written in decimal form as:*
(a) 0.001 (b) 0.0001 (c) 0.00001 (d) 0.0005

34 *The number of significant figure in 0.0009 is :*
(a) 4 (b) 3 (c) 2 (d) 1

35 *A form of number consisting of a coefficient multiplied by a power of 10 is called:*
(a) logarithm (b) exponential notation
(c) significant figure (d) coefficient

36 *The number 0.00057 can be written in decimal as :*
(a) 5.7×10^{3} (b) 5.7×10^{-4} (c) 5.7×10^{4} (d) 5.7×10^{5}

37 *10^{-6} can be written in decimal as :*
(a) 0.00001 (b) 0.00006 (c) 0.000001 (d) 0.0001

38 *The significant figures in 3.40×10^{18} are:*
(a) 2 (b) 3 (c) 4 (d) 5

39 *A formula which gives the relative number of each kind of atom present in a molecule is called:*
(a) structural formula (b) empirical formula
(c) molecular formula (d) atomic formula

40 *A formula which shows actual number of each kind of atoms present in the molecule of a compound is called:*
(a) chemical formula (b) empirical formula
(c) molecular formula (d) structural formula

41 *One litre is also called:*
(a) one kilogram (b) one decimeter (c) one dm^3 (d) one millilitre

42 *The ratio of hydrogen and oxygen in water by mass is :*
(a) 1:2 (b) 2:1 (c) 1:3 (d) 1:8

43 *Stoichiometry is the study of :*
(a) Avogadro's number of a reaction (b) relationship between reactants & products
(c) types of reactants & products (d) balancing of a chemical reaction

44 *In rounding off data, which figure is dropped?*
(a) First (b) Middle (c) Last (d) None

45 *The figure 45.136 will be rounded off to :*
(a) 45.13 (b) 45.16 (c) 45.14 (d) 45.19

46 *The figure 4.674 will be rounded off to :*
(a) 4.68 (b) 4.67 (c) 4.71 (d) 4.66

47 *The figure 8.765 will be rounded off to :*
(a) 8.77 (b) 8.76 (c) 8.75 (d) 8.81

48 *The figure 678.35 will be rounded off to :*
(a) 678.8 (b) 678.4 (c) 678.5 (d) 679.0

49 ***Formula mass is used for which substance?***

(a) Neutral (b) Polar (c) Ionic (d) Non-polar

50 ***The three significant figures of 18295 is :***

(a) 182 (b) 183 (c) 18300 (d) 1.82×10^5

51 ***3.01×10^{23} molecules of oxygen gas at S.T.P. occupy a volume of :***

(a) 22.4 dm^3 (b) 224 dm^3 (c) 11.2 dm^3 (d) 2.24 dm^3

52 ***This has five significant figures:***

(a) 0.00215 (b) 21500 (c) 21.5210 (d) 21.521

53 ***While considering the rule of significant figures the simplified result of 3.1+14.367 is:***

(a) 17.467 (b) 17.47 (c) 17.50 (d) 17.5

Answer Key

1. (b)	9. (c)	17. (b)	25. (a)	33. (c)	41. (c)	49. (c)
2. (b)	10. (c)	18. (c)	26. (d)	34. (d)	42. (d)	50. (d)
3. (b)	11. (b)	19. (b)	27. (b)	35. (b)	43. (b)	51. (c)
4. (a)	12. (b)	20. (b)	28. (b)	36. (b)	44. (c)	52. (d)
5. (b)	13. (c)	21. (a)	29. (a)	37. (c)	45. (c)	53. (d)
6. (a)	14. (b)	22. (c)	30. (c)	38. (b)	46. (b)	
7. (a)	15. (c)	23. (c)	31. (c)	39. (b)	47. (b)	
8. (d)	16. (c)	24. (c)	32. (b)	40. (c)	48. (b)	

Short / Detailed Answer Questions

Q.01 ***Define Chemistry.***

Ans. It is a branch of science that deals with the identification of the substances of which matter is composed; investigation of their properties and the ways in which they interact, combine and change; and the use of these processes to form new substances.

Q.02 ***What is the task of chemistry?***

Ans. The task of chemistry is to investigate all the changes in matter which are taking place on the earth and the rest of the universe. For example, iron rusts, petrol evaporates, digestion of food in animals etc. As a result of these changes, new substances are formed and energy is released or absorbed by the substances. Chemistry also studies in laboratory and on large scale in the industries where thousands of different types of chemicals are manufactured.

Q.03 ***Define significant figures.*** *Karachi Board: 2004, 2006, 2008, 2011, 2013*

Ans. Significant figures are those numbers in which all the digits are reliable except the last digit, the value of which is uncertain.

For example: One finds the weight of something as 7.6 gm. Other finds weight of the same thing as 7.62gm. Therefore 7.62 is more precise result.

Q.04 ***(a) Define and explain significant figures?***
(b) Write down the rules for determining significant figures?
(c) Using significant figures rules, simplify: ***Karachi Board: 2012***

$$\frac{56 \times 725 \times 273}{760 \times 298}$$

Ans. ***(a)*** *They are defined as reliable digits in a number known with certainty, except the last digit, the value of which is uncertain or doubtful.*

Explanation of significant figures:

If a piece of wood is measured with an ordinary scale, one may read its length as 4.2 cm. If we take a scale which is divided in millimeters also. One person may read the length 4.24 cm.

4.2 cm has two significant figures.
4.24 cm has three significant figures.

Therefore 4.24 cm is more precise result.

(b) ***Rules for determining significant figures:***

(i) All non-zero digits are significant.
363 has 3 significant figures.
0.68 has 2 significant figures.

(ii) Zero between the non-zero digits are significant.
5004 has 4 significant figures.
20.4 has 3 significant figures.

(iii) Zeros locating the decimal point in number less than one are not significant.
0.062 has 2 significant figures.
0.001 has only 1 significant figures.

(iv) Final zeros to the right of the decimal point are significant.
2.000 has 4 significant figures.
506.40 has 5 significant figures.

(v) Numbers without decimal - their final zeros are non-significant.
40 has 1 significant figures
2360 has 3 significant figures

(c) ***See Example 1.3 on page 16.***

Q.05 ***What is rounding off data?***

Ans. The process of reducing the number of significant figures in a measured quantity to the desired number is called rounding off data.

e.g ***(i)*** 45.136 ⟶ 45.14
(ii) 6.75 ⟶ 6.8

Q.06 ***Explain the rules for rounding off data with examples.***

Ans. To round off means to reduce the numbers of significant figures. Dropping of last digit to the desired number is called rounding off data.

Rules for rounding of data:

(i) If the digit to be dropped is greater than 5, then the preceding digit is increased by 1.

Example:

5.768 rounded off to ⟶ 5.77
35.137 rounded off to ⟶ 35.14

(ii) If the digit to be dropped is less than 5, then simply drop it.

Example:

5.734 rounded off to ⟶ 5.73

15.74 rounded off to ⟶ 15.7

(iii) If the digit to be dropped is exactly 5 then two possible situations (a & b) arise due to even and odd nature of the last digit.

(a) If the digit to be retained is even number or zero, Then just drop the 5 and no change is made.

Example:

7.865 is rounded off to ⟶ 7.86

38.45 is rounded off to ⟶ 38.4

(b) If the digit to be retained is odd, then add 1 to it.

Example: 6.75 is rounded off to ⟶ 6.8

5.2755 is rounded off to ⟶ 5.28

Q.07 ***Describe the use of significant digits in addition & subtraction.***

Ans. *(i)* The process of reducing the number of significant figures in a measured quantity to the desired number is called rounding off data.

e.g. *(i)* 45.136 ⟶ 45.14

(ii) 6.75 ⟶ 6.8

(ii) If numbers having positive or negative exponents, adjust exponents so that they are all the same before adding or subtracting.

Example: $5.00 \times 10^{-3} + 0.775 \times 10^{-3} + 0.0001 \times 10^{-3} = 5.7751 \times 10^{-3}$

Round up $= 6 \times 10^{-3}$

(iii) For the addition of significant figures, all measurements should be in the same unit,

Example: 15.5m + 651.8cm + 4291 mm

15.5 m	=	15.5 m
651.8 cm	=	6.518 m
4291 mm	=	4.291 m
Total	=	26.309 m
Round up	=	26.3 m

Q.08 ***Explain the use of significant digits in multiplication and division.***

Ans. It is necessary to count the significant figures and to be sure that numbers to significant figures in the result is same as the least number of significant figures in any of the multiplied or divided term.

Example:

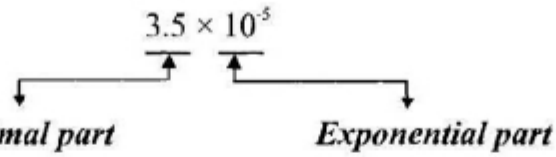
(i)	$(1.32) \times (4.421)$	=	5.835	=	5.84
(ii)	$15.88 \div 7.95$	=	1.997	=	2.0
(iii)	$\frac{31.23 \times 4.5}{9.41395}$	=	14.928	=	15

Q.09 ***Define exponential notation with examples.*** ***Karachi Board: 2011-2013-2019***

Ans. A system in which numbers are written as a product of two factors,

(i) decimal part

(ii) 10 raised to a suitable power is known as exponential notation.



Q.10 ***What is logarithm? Give few examples of exponential notation.***

Ans. ***Logarithm:*** In the expression, $a^x = y$

'x' is called the logarithm of 'y' to the base 'a'.

A logarithm is an exponent so the same rules that apply to the exponents can be applied to the logarithm. In logarithm the base is usually 10.

Suppose, $N = 10^x$, now if $N = 1{,}000$ then $x = 3$ i.e $1000 = 10^3$.

The power (or exponent) x is called logarithm of the number N.

This may he written in algebraic form as

$$\log N = x$$

Examples of exponential notation:

100 ⟶ 10^2

10000 ⟶ 10^4

0.01 ⟶ 10^{-2}

0.0001 ⟶ 10^{-4}

63526 ⟶ 6.3526×10^4

Q.11 ***Describe the components of logarithm.***

Ans. Logarithm consists of two components:

1. Characteristic ***2. Mantissa***

1. Characteristic: It is the integer part and may be positive or negative. It is actually the power of 10.

Number	Exponential form	Characteristics
10	10^1	1
100	10^2	2
1000	10^3	3
0.1	10^{-1}	–1
0.01	10^{-2}	–2
0.001	10^{-3}	–3

Now consider a digit 273, characteristic is calculated by subtracting from total number of digits. 273 contain 3 digits so 3-1 = 2 is its characteristic.

2. Mantissa: The decimal fractional part of the logarithm is called mantissa. It is always positive.

Mantissa is determined by using the logarithm tables.

Example: 0.0035, 0.35, 3.5 and 35000 have same mantissa but different characteristics i.e. -3, -1, 0 and 4 respectively.

Q.12 ***Describe rules in logarithm calculation.***

Ans. The following rules are used to calculate the problems by logarithm, in the form of formula:

1. $\log a \times b = \log a + \log b$
2. $\log a/b = \log a - \log b$
3. $\log (a)^n = n \log a$
4. $\log \sqrt[n]{a} = \log a^{\frac{1}{n}} = \frac{1}{n} \log a$

Q.13 ***What is error and deviation?*** ***Karachi Board: 2004, 2005***

Ans. An error is the difference between measured and actual value. It is due to defects in the instrument, or lack of handling the apparatus or improper functioning of the instrument etc.
The errors are classified into two types:

(i) Systematic errors ***(ii) Random error***

(i) Systematic error: It is caused by the improper functioning of instrument.

(ii) Random error: The error that the remaining variations indicate are called random error. It is unavoidable and it may be positive or negative. ***Karachi Board: 2016-2019***

Q.14 ***What is atomic mass?*** ***Karachi Board: 2005, 2007***

Ans. It is the mass of one atom of an element compared with the mass of one atom of C^{12}. As atomic mass is ratio therefore, has no unit. Generally atomic masses are shown in a.m.u.
In other words, the sum of the protons and neutrons present in an atom is called its atomic mass or mass number, e.g. Na_{11}^{23} (atomic mass 23 = 11 protons + 12 neutrons)

Q.15 ***Define molecular mass.*** ***Karachi Board: 2005, 2007***

Ans. The sum of the atomic masses of the atoms of all the elements present in a molecule is shown by its molecular formula.
The molecular mass of water (H_2O) is (1 + 1 + 16) = 18 a.m.u

Q.16 ***Define formula mass.*** ***Karachi Board: 2005, 2007***

Ans. It is used for ionic substances in which molecules are not discrete but are bonded to one another in a network structure. Such compounds are represented by their simplest (empirical) formula.

Example: Formula mass of NaCl will be

Na	=	23 × 1	=	23
Cl	=	35.5 × 1	=	35.5
				58.5 a.m.u.

Q.17 ***Define empirical formula.*** ***Karachi Board: 2005, 2006***

Ans. It is that formula which showing minimum relative numbers of each type of atoms in a molecule of a compound.

	Molecular formula	***Empirical formula***	
Example:	Benzene C_6H_6	CH	(1:1)
	Glucose $C_6H_{12}O_6$	CH_2O	(1:2:1)

There are some compound (mostly ionic compounds) which have same empirical and molecular formula.

e.g.,	*(i)*	Calcium carbonate.	$CaCO_3$	$CaCO_3$
	(ii)	Water	H_2O	H_2O

Q.18 ***What are the steps involved in determining the empirical formula?***

Ans. ***Empirical Formula:*** The formula showing minimum relative numbers of each type of atoms in a molecule of a compound is called empirical formula.

The determination of empirical formula involves the following steps:

1. Detect the element present in the compound (detection of elements done by experiments).
2. Mass of each element is calculated from the mass of compound.
3. Calculate the percentage of each element present in the compound.

$$\text{percentage of the element} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100$$

4. Calculate the atomic ratio of the element

$$\text{atomic ratio of the element} = \frac{\text{percentage of element}}{\text{atomic weight}}$$

5. Atomic ratios are divided by the least number and if resulting digit is not a whole number, make it a whole number.
6. The whole number represents ratio of atom of the elements in the molecule. This is Empirical formula.

Q.19 ***Define molecular formula.*** ***Karachi Board: 2006, 2007, 2012***

Ans. Molecular formula of a compound is the formula which shows actual numbers of the various kinds of atoms present in one molecular of a compound.

e.g. Molecular formula of sugar is $C_{12}H_{22}O_{11}$

Molecular formula of nitric acid is HNO_3

Q.20 ***How can we determine molecular formula?***

Ans. ***Determination of molecular formula:***

The following steps are involved in determining the molecular formula.

1. First find out the empirical formula.
2. Calculating the empirical formula weight by adding weight of its atom.
3. Calculate numbers of empirical units (n) with the help of formula. If not a whole number, make it a whole number.

$$n = \frac{\text{molecular weight}}{\text{empirical formula weight}}$$

Molecular formula = n × empirical formula.

Q.21 ***Define mole.*** *Karachi Board: 2005, 2017*

Ans. It is define as gram atomic mass or gram formula mass or gram molecular mass of any substance (atoms, molecules, ions) which contains 6.02×10^{23} particles.

e.g	Carbon	12 grams	1 mole of carbon
	Water	18 grams	1 mole of water

Q.22 ***Define molar mass.*** *Karachi Board: 2007*

Ans. It is defined as the mass of a given substance (element or compound) divided by its atomic or molecular mass. Its unit is g/mol.

e.g., Molar mass of water (H_2O) = 18 g. mol^{-1}

Q.23 ***Define molar volume.*** *Karachi Board: 2004, 2006, 2014, 2018*

Ans. Molar volume is the volume occupied by one mole of any substance at any given temperature & pressure . It is calculated by dividing the molar mass of an object by its density.

$$V_m = \frac{\text{Mass}}{\text{Density}} = \frac{M}{D}$$

Q.24 ***Define Avogadro's number.*** *Karachi Board: 2013*

Ans. Amadeo Avogadro, an Italian scientist , calculated the number of atoms, molecules or ions present is one mole. The number is 6.02×10^{23} particles. It is represented by N_A.

Example:	32gm of O_2	= 1 mole	= 6.02×10^{23} molecules
	24 gm. of Mg	= 1 mole	= 6.02×10^{23} atoms
	58.5 gm. Of NaCl	= 1 mole	= 6.02×10^{23} Na^+ ions
			= 6.02×10^{23} Cl^- ions

Q.25 ***Define stoichiometry .*** *Karachi Board: 2013, 2014 , 2018*

Ans. The word stoichion means element. The study of the relationships between the amount of the reactants and the products in a chemical reaction as given by the balanced chemical equation is called stoichiometry.

Q.26 ***What are the important assumptions for stoichiometry?*** *Karachi Board: 2013, 2014, 2015*

Ans. There are three important assumptions while considering stoichiometric calculations.

(1) Chemical equation must be balanced.
(2) Reactants are completely converted into products.
(3) There should not be any side reaction.

Q.27 ***What are the different types of stoichiometric calculations? Give in detail its different relationships.***

Ans. There are three relationships involved for the stoichiometric calculations from the balanced chemical equations which are:

(i) Mass - Mass relationships
(ii) Mass - Volume relationships
(iii) Volume - Volume relationships

(i) ***Mass-Mass relationships:***

In such relationships, we can determine the unknown mass of a reactant or product from a given mass of the substance in a chemical reaction with the help of balanced chemical equation.

There are two different methods to obtain mass of reactant or product.

(a) Unit factor method (b) Mole method

These two methods are explained on page # 19 - 20 numerical examples of text book. (See examples 1.7 & 1.8)

(ii) ***Mass-Volume relationships:***

The molar quantities of gases can be expressed in terms of volumes as well as mass because one mole of any gas measured at S.T.P. occupies a volume of 22.4 dm^3. Thus the volume of a gas and its mass are interchangeable. This relationship is based on Avogadro's law.

- 1 gm. mole of any gas at S.T.P has a volume of 22.4 dm^3 or litres.
- 1 oz. mole of any gas at S.T.P has a volume of 22.4 cubic feet.

(See example 1.8 page #20)

(iii) ***Volume - Volume relationship:***

In this type of relationship the volume of a substance is calculated from the given volume of another substance.

The relationship between volume of gases in a chemical change is based on "Gay-Lussac's Law" of combining volumes which states that "Gases react or formed in the ratio of small whole number by volume under similar conditions of temperature and pressure".

(For example see page #21 Example 1.9)

Q.28 ***What is limiting reactant? How it helps to control the quantities of products?***

Karachi Board: 2007, 2008, 2013, 2014, 2017

Ans. The limiting reactant is a reagent. This produces the least amount of product after its complete consumption. After the complete consumption of the limiting reactants no more products are formed during a chemical reaction. Thus a limiting reactant controls the quantities of products in a chemical reaction.

Q.29 ***Define actual and theoretical field.***

Ans. The amount of the product that is obtained in a chemical reaction is called actual field. The amount of product calculated from a balanced chemical equation is called theoretical field.

$$\% \text{ yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Solved Problems of Textbook

Example 1.1: *Consider the addition of following numbers 5.00×10^{-3}, 0.775×10^{-3} and 0.0001×10^{-3}.*

Solution:

5.00×10^{-3}
0.775×10^{-3}
0.0001×10^{-3}
Total 5.7751×10^{-3}
(Round up) $\mathbf{6 \times 10^{-3}}$ **Ans.**

Example 1.2: *Add 15.5 m, 651.8 cm and 4291 mm.*

Solution:

For the addition of significant figures, all measurement should be in the same unit, so values are to be changed in metres and then are added.

15.5 m	=	15.5 m
651.8 cm	=	6.518 m
4291 m.m	=	4.291 m
Total	=	26.309 m
(Round up)	=	**26.3 m** **Ans.**

The General Application of Significant Figures

Example 1.3: *Using significant figure rules, simplify:* $\frac{56 \times 725 \times 273}{760 \times 298}$

Solution:

(i)	56×725	= 40600	= 41000	(2 significant figures retained)
(ii)	41000×273	= 11193000	= 11000000	(2 significant figures retained)
(iii)	760×298	= 226480	= 230000	(2 significant figures retained)

Finally:

(iv) $\frac{11000000}{230000}$ = **47.8** = **48** **Ans.** (2 significant figures retained)

Empirical Formula

Example 1.4: *1.367g of an organic compound containing C, H, and O, was combusted in a stream of air to yield 3.002 g CO_2 and 1.640 g H_2O. What is its empirical formula?*

Solution:

The masses of CO_2 and H_2O are used to find out the masses of carbon and hydrogen:

$$\text{Mass of C} = \frac{1 \text{ mole of C}}{1 \text{ mole of } CO_2} \times 3.002 \text{ g } CO_2 = \frac{12\text{g C}}{44\text{g } CO_2} \times 3.002 \text{ g } CO_2 = 0.819 \text{ g C}$$

$$\text{Mass of H} = \frac{2 \text{ moles of H}}{1 \text{ mole of } H_2O} \times 1.640 \text{ g } H_2O = \frac{2 \text{ g H}}{18 \text{ g } H_2O} \times 1.640\text{g } H_2O = 0.18 \text{ g H}$$

(ii) Now, the percentage of C and H is calculated:

1.367 g compound contains 0.819 g C

100 g compound contains $\frac{0.819 \text{ g} \times 100 \text{ g}}{1.367 \text{ g}} = 59.9 \text{ g C}$

C = 59.9 %

1.367 g compound contains 0.18 g H

100 g compound contains $\frac{0.18 \text{ g} \times 100 \text{ g}}{1.367 \text{ g}} = 13.16 \text{ g H}$

H = 13.16 %

Percentage of oxygen is calculated by subtracting the % of C and H from 100:

O % = 100 - 59.9 - 13.16 = 26.94 %

O = 26.94%

(iii) To obtain mole ratio of C, H, and O, their percentages are divided by their atomic masses:

$$C = \frac{59.9}{12} = 5$$

$$H = \frac{13.6}{1} = 13.6$$

$$O = \frac{29.94}{16} = 1.68$$

(iv) The quotients are divided by the smallest quotient (1.68) to obtain the simplest ratio of atoms:

$$C = \frac{5}{1.68} = 3$$

$$H = \frac{13.16}{1.68} = 8$$

$$O = \frac{1.68}{1.68} = 1$$

Thus the empirical formula of the compound = C_3H_8O **Ans.**

Example 1.5: ***1.0g of the sample of butane, a hydrocarbon fuel was burned in an excess of oxygen to yield 3.03g CO_2 and 1.55g H_2O. If molecular mass of the compound is 58, find out its molecular formula.***

Solution:

To determine empirical formula

(i) To calculate masses of carbon and hydrogen from the masses of CO_2 and H_2O.

$$\text{Mass of C} = \frac{1 \text{ mole C}}{1 \text{ mole } CO_2} \times 3.03\text{g } CO_2 = \frac{12\text{ g}}{44\text{ g}} \times 3.03\text{ g} = 0.83\text{ g C}$$

$$\text{Mass of H} = \frac{2 \text{ moles H}}{1 \text{ mole } H_2O} \times 1.55\text{g } H_2O = \frac{2\text{ g}}{18\text{ g}} \times 1.55\text{ g} = 0.17\text{g H}$$

(ii) To calculate percentage of carbon and hydrogen:

1.0g of the compound contains 0.83g C

100g of the compound contains $0.83\text{ g} \times \frac{100\text{ g}}{1.0\text{ g}} = 83\text{g C} = 83\%$

Since butane contains only carbon and hydrogen, hence:

Percentage of Hydrogen = 100 - 83 = 17 % H

(iii) To calculate mole ratio of the elements by dividing the percentages by their atomic masses:

$$C = \frac{83}{12} = 6.91 \quad ; \quad H = \frac{17}{1} = 17$$

(iv) To obtain the simplest ratio, the quotients are divided by the least ratio:

$$C = \frac{6.91}{6.91} = 1 \quad ; \quad H = \frac{17}{6.91} = 2.5$$

In order to obtain nearest whole number ratios, both the members are multiplied by 2:

$$C = 1 \times 2 = 2 \quad ; \quad H = 2.5 \times 2 = 5$$

Thus the empirical formula of the compound = C_2H_5

The empirical formula mass of C_2H_5 = (12) (2) + (1) (5)

= 24 + 5 = 29

(v) The value of the integer 'n' is calculated as follows:

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{58}{29} = 2$$

Molecular formula = $(\text{Empirical formula})_n$

= $(C_2H_5)_2$

= C_4H_{10}

Hence molecular formula of Butane = **C_4H_{10}** **Ans.**

Stoichiometric Calculation — Mass – Mass Relationship

Example 1.6: ***Calculate the weight (mass) of carbon dioxide (CO_2) that can be obtained by heating 25 g of limestone ($CaCO_3$). And also calculate the weight (mass) of calcium oxide (CaO).***

Solution:

Equation of the reaction is as follows:

$$\underset{\substack{1\text{ mole}\\100\text{g}}}{CaCO_{3(s)}} \xrightarrow{\text{heat}} \underset{\substack{1\text{ mole}\\56\text{g}}}{CaO_{(s)}} + \underset{\substack{1\text{ mole}\\44\text{g}}}{CO_{2(g)}}$$

Method I:

No. of moles in 25g of $CaCO_3$ $= \frac{25}{100} = 0.25$ mole

1mole of $CaCO_3$ yields 1 mole of CO_2

0.25 mole of $CaCO_3$ yields 1×0.25 mole of CO_2

$= 0.25$ mole of CO_2

Mass of CO_2 in 0.25 mole $= 0.25 \times 44$

$= 11$ g

1 mole of $CaCO_3$ yields 1 mole of CaO

0.25 mole of $CaCO_3$ yields 0.25 mole of CaO

$= 0.25$ mole of CaO

Mass of CaO in 0.25 mole $= 0.25 \times 56$

$= 14$ g

Method II:

100g of $CaCO_3$ yields 44 g of CO_2

1g of $CaCO_3$ yields $\frac{44}{100}$ g of CO_2

25g of $CaCO_3$ yields $= \frac{44\text{g}}{100\text{g}} \times 25$ g

$= 11$ g of CO_2

100g of $CaCO_3$ yields 56 g of CaO

1g of $CaCO_3$ yields $\frac{56\text{ g of CaO}}{100}$

25g of $CaCO_3$ yields $= \frac{56\text{g} \times 25\text{g}}{100\text{g}} =$ **14 g of CaO** **Ans.**

Example 1.7: ***Chlorine is produced on large scale by the electrolysis of NaCl aqueous solution. Calculate the weight (mass) of NaCl required to produce 142 g of chlorine.***

Solution:

$$\underset{2(58.5) = 117\text{g}}{2NaCl_{(s)} + 2H_2O_{(l)}} \xrightarrow{\text{Electrolysis}} \underset{71\text{g}}{Cl_{2(g)} + H_{2(g)} + 2NaOH_{(s)}}$$

Method I

71g of Cl_2 are produced by 117g of NaCl

1g of Cl_2 is produced by $\frac{117}{71}$ g of NaCl

142g of Cl_2 is produced by $\frac{117g}{71g} \times 142g$

$= 234$ g of NaCl

Method II

No. of g moles of Cl_2 in 142 g $= \frac{142 \text{ g of } Cl_2}{71 \text{ g } Cl_2}$

$= 2$ g moles of Cl_2

According to above equation:

One mole of Cl_2 requires 2 moles of NaCl

2 g moles of Cl_2 require $2 \times 2 = 4$ moles of NaCl

Weight (mass) of NaCl in 4 moles $= 4 \times 58.5$

$=$ **234g of NaCl** **Ans.**

Stoichiometric Calculation – Mass – Volume Relationship

Example 1.8: ***Calculate the volume of CO_2 gas produced at standard temperature and pressure by the combustion of 20 g of CH_4.***

Solution:

The equation for the reaction is:

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Method I:

No. of moles of CH_4 in 20 grams $= \frac{\text{Given mass of } CH_4}{\text{Molar mass of } CH_4}$

$= \frac{20g}{16g} = \frac{5}{4} =$ *1.25 moles*

One mole of CH_4 gives one mole of CO_2

1.25 mole of CH_4 gives 1.25 mole of CO_2

No. of moles of CO_2 gas at S.T.P. $= 1.25$

One mole of CO_2 gas at S.T.P. occupies a volume of 22.4 dm^3

1.25 mole of CO_2 gas at S.T.P. occupies a volume $22.4 \times 1.25 = 28$ dm^3

Method II:

Molecular weight (mass) of $CH_4 = 16$

Molecular weight (mass) of $CO_2 = 44$

16 gram of CH_4 give 44 gram of CO_2

1 gram of CH_4 gives $\frac{44}{16}$ g of CO_2

20 grams of CH_4 give $\frac{44g}{16g} \times 20\ g = 55$ grams of CO_2

44 grams of CO_2 at S.T.P. occupy a volume 22.4 dm^3

1 gram of CO_2 at S.T.P. occupies a volume $\frac{22.4}{44}$ dm^3

55 grams of CO_2 at S.T.P. occupy a volume $\frac{22.4}{44g}$ $dm^3 \times 55\ g$

$= 28\ dm^3$ **Ans.**

Example 1.9: ***Calculate the volume of O_2 at S.T.P. for the complete combustion of two moles of carbon disulphide (CS_2). Calculate the volume of CO_2 and SO_2 produced also.***

Solution:

$$CS_{2(l)} + 3O_{2(g)} \longrightarrow CO_{2(g)} + 2SO_{2(g)}$$

This equation shows that 1 mole of CS_2 reacts with 3 moles of O_2 to give 1 mole of CO_2 and 2 moles of SO_2.

Thus

1 mole of CS_2 reacts with 3 moles of O_2
2 moles of CS_2 react with 3×2 = 6 moles of O_2
Volume of 6 moles of O_2 at S.T.P. = 6×22.4
= 134.4 dm^3

1 mole of CS_2 gives 1 mole of CO_2
2 moles of CS_2 give 2 moles of CO_2
Volume of 2 moles of CO_2 = 2×22.4 dm^3
= 44.8 dm^3

1 mole of CS_2 gives 2 moles of SO_2
2 moles of CS_2 gives 2×2 = 4 moles of SO_2
Volume of 4 moles of SO_2 = 4×22.4 dm^3
= 89.6 dm^3

Stoichiometric Calculation – Volume – Volume Relationship

Example 1.10: ***What volume of O_2 at S.T.P. is required to burn 500 dm^3 of Ethene (C_2H_4) gas? What volume of CO_2 will be formed?***

Solution:

$$C_2H_{4(g)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 2H_2O_{(g)}$$

According to the equation one dm^3 of C_2H_4 will require three dm^3 of oxygen gas. So,

1 dm^3 of Ethene (C_2H_4) requires 3 dm^3 of O_2
500 dm^3 of Ethene require 3×500 = 1500 dm^3 of O_2

1 dm^3 of Ethene (C_2H_4) produces 2 dm^3 of CO_2
500 dm^3 of Ethene produce 2×500 = **1000 dm^3 of CO_2** **Ans.**

Example 1.11: ***Hydrogen Sulphide burns in oxygen according to the equation.***

$$2H_2S_{(g)} + 3O_{2(g)} \longrightarrow 2H_2O_{(l)} + 2SO_{2(g)}$$

Calculate the volume of O_2 at S.T.P. required to burn 900 dm^3 of H_2S and also find the volume of SO_2 gas produced.

Solution:

According to equation:

2 dm^3 of H_2S gas requires 3 dm^3 of O_2 for combustion

1 dm^3 of H_2S gas requires $\frac{3}{2}$ dm^3 of O_2 for combustion

$\therefore$ 900 dm^3 of H_2S gas requires $\frac{3}{2} \times 900$ = **1350 dm^3 of O_2**

2 dm^3 of H_2S gas gives 2 dm^3 of SO_2

$\therefore$ 900 dm^3 of H_2S gas gives 900 dm^3 of SO_2 = **900 dm^3 of SO_2** **Ans.**

Limiting Reactant

Example 1.12: ***Sodium thiosulphate ($Na_2S_2O_3$) can be prepared by the reaction given below:***

$$2Na_2S_{(aq)} + NaCO_{3(aq)} + 4SO_{2(g)} \longrightarrow 3Na_2S_2O_{3(aq)} + CO_{2(g)}$$

How many grams of sodium thiosulphate will be produced when 200g each of the three reagents Na_2S, Na_2CO_3 and SO_2 are reacted together?

Solution:

According to balanced chemical equation, the exact mole ratios of the reactants (Na_2S, $NaCO_3$ and SO_2) are 2:1:4.

Amount of each of the reactants is 200g.

Number of moles of Na_2S in 200g is $\frac{200}{78}$ = 2.56 moles

Number of moles of Na_2CO_3 in 200g is $\frac{200}{106}$ = 1.886 moles

Number of moles of SO_2 in 200g is $\frac{200}{64}$ = 3.12 moles

Because the quantity of Na_2CO_3 is the smallest amount of all the reagents used in the reaction, this can be the limiting factor so the amount of the other reagents used will be as:

(i) 1 mole of Na_2CO_3 reacts with 2 moles of Na_2S

1.886 moles of Na_2CO_3 react with 2×1.886 = 3.772 moles

(ii) 1 mole of Na_2CO_3 reacts with 4 moles of SO_2

1.886 moles of Na_2CO_3 react with 4×1.886 = 7.544 moles.

From the calculations, we got that neither Na_2S nor SO_2 are available in the quantities to consume 1.886 moles of Na_2CO_3, so Na_2CO_3 is present in excess.

Let us see Na_2S:

2 moles of Na_2S react with 4 moles of SO_2

2.56 moles of Na_2S react with $\frac{4 \times 2.56}{2}$ = 5.12 moles

But the actual amount of SO_2 available is only 3.12 moles which means the Na_2S is in excess and SO_2 is the limiting reactant. So the amount of SO_2 is used to calculate the amount of $Na_2S_2O_3$.

According to balanced chemical equation:

4 moles of SO_2 produce 3 moles of $Na_2S_2O_3$

1 mole of SO_2 produces $\frac{3}{4}$ moles of $Na_2S_2O_3$

3.12 moles of SO_2 produce $\frac{3 \times 3.12}{4}$ = 2.34 moles.

Amount in grams = 2.34×158 = **369.72g** **Ans.**
(Molecular mass of $Na_2S_2O_3$ = 158g)

Solved Problems From Past Papers

Problem 1.1: ***Calculate the number of moles in 3800gm of:*** ***Karachi Board: 2003***

(i) $Ca(OH)_2$ (ii) SO_2 (iii) H_2 molecules

Solution:

(i) $Ca(OH)_2$

Molecular mass of $Ca(OH)_2$
= 40.078 + 15.999 + 15.999 + 1.008 + 1.008
= 74.092
= 74

$$\text{No. of moles} = \frac{\text{Mass in gm}}{\text{Molecular mass}} = \frac{3800\text{g}}{74\text{g}}$$

No. of moles = **5.35 mol** **Ans.**

(ii) SO_2

Molecular mass of SO_2 = 32 + 16 + 16 = 64

$$\text{No. of moles} = \frac{\text{Mass in gm}}{\text{Molecular mass}}$$

$$\text{Molecular mass of } SO_2 = \frac{3800}{64}$$

= 59.375
= **59.38 mol** **Ans.**

(iii) ***H_2 molecule***

$$\text{No. of moles} = \frac{\text{Mass in gm}}{\text{Molecular mass}}$$

$$\text{No. of moles} = \frac{3800\text{g}}{2\text{g}} = \textbf{1900 mol} \qquad \textbf{Ans.}$$

Problem 1.2: ***Calculate the mass in gm of 3.01×10^{21} molecules of water.***

Solution:

1mole of H_2O = 18gm = 6.02×10^{23} molecules
6.02×10^{23} molecules of H_2O = 18gm

$$1 \text{ molecule of } H_2O = \frac{18}{6.02 \times 10^{23}}$$

$$3.01 \times 10^{23} \text{ molecules of } H_2O = \frac{18 \times 3.01 \times 10^{23}}{6.02 \times 10^{23}} \text{ gm} = \textbf{9gm of } \mathbf{H_2O} \qquad \textbf{Ans.}$$

Problem 1.3: ***Acetic Acid contains C, H and Oxygen. 2.14gm of a sample of acetic acid on complete combustion gave 3.105gm of CO_2 and 1.27gm of water. The molecular mass of acetic acid is 60. Find the empirical and molecular formula.***

Solution:

$$\text{Mass of Carbon} = \frac{12}{44} \times 3.105 = 0.85 \text{ gm}$$

$$\text{Mass of Hydrogen} = \frac{2}{18} \times 1.27 = 0.14 \text{ gm}$$

$$\%\text{ of C} = \frac{0.85}{2.14} \times 100 = 40\,\%$$

$$\%\text{ of H} = \frac{0.14}{2.14} \times 100 = 6.5\,\%$$

Total % of C and H = 6.5 + 40 = 46.5 % of O = 100 - 46.5 = 53.5%

$$\text{Mole ratio of carbon} = \frac{40}{12} = 3.3$$

$$\text{Mole ratio of Hydrogen} = \frac{6.5}{1} = 6.5$$

$$\text{Mole ratio of Oxygen} = \frac{53.5}{16} = 3.3$$

Divide each mole ratio by the smallest:

$$C = \frac{3.3}{3.3} = 1, \quad H = \frac{6.5}{3.3} = 2, \quad O = \frac{3.3}{3.3} = 1$$

Empirical formula = CH_2O
Empirical formula mass = 12 + 2 + 16 = 30

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

$$n = \frac{60}{30} = 2$$

Molecular Formula = (Empirical formula)$_n$

= $(CH_2O)_2$

Molecular Formula = **$C_2H_4O_2$** **Ans.**

Problem 1.4: ***Calculate the mass of 2.408×10^{23} atoms of Na.*** *Karachi Board: 2004*

Solution:

6.02×10^{23} atoms of Na = 23 gm

1 atoms of Na $= \frac{23}{6.02 \times 10^{23}}$

2.408×10^{23} atoms of Na $= \frac{23 \times 2.408 \times 10^{23}}{6.02 \times 10^{23}}$ gm

Mass of Na = **9.2 gm** **Ans.**

Problem 1.5: ***Calculate the number of moles of Na in 4.6gm.***

Solution:

$$\text{No. of moles} = \frac{\text{Mass in gm}}{\text{Atomic mass}}$$

No. of moles $= \frac{4.6}{23} = 0.2$ moles

0.2 moles of Na **Ans.**

Problem 1.6: ***30 gm of limestone ($CaCO_3$) was heated. Calculate the mass and volume of CO_2 produced.***

Solution:

Equation of the reaction:

$$CaCO_3 \xrightarrow{\Delta \text{ heat}} CaO + CO_2$$

To calculate the mass of CO_2 produced:

Molecular mass of CO_2 = 12 + 16 + 16 = 44

Molecular mass of $CaCO_3$ = 40 + 12 + 16 + 16 + 16 = 100

100 gm of $CaCO_3$ produces 44 gm of CO_2

1 gm of $CaCO_3$ produce $= \frac{44}{100}$

30 gm of $CaCO_3$ produce $= \frac{44 \times 30}{100} = 13.2$ gm

30gm of $CaCO_3$ produces 13.2 gm of CO_2 **Ans.**

To calculate the volume of CO_2 at S.T.P.:

44 gm of CO_2 occupies the volume of 22.4 dm^3

1gm of CO_2 occupies the volume of $\frac{22.4}{44}$

13.2 gm of CO_2 occupies the volume $= \frac{22.4 \times 13.2}{44}$

Volume of CO_2 = 6.72 dm^3 **Ans.**

Problem 1.7: ***The molecular mass of a compound is 180 and its empirical formula is CH_2O. Find the molecular formula.*** ***Karachi Board: 2005***

Solution:

Molecular mass = 180 = 12 + 12 + 16 Empirical formula = CH_2O

Molecular formula = ? Empirical formula mass = 12 + 2 + 16 = 30

Molecular formula = $(\text{empirical formula})_n$

$$n = \frac{\text{Molecular formula mass}}{\text{Empirical formula mass}}$$

$$n = \frac{180}{30} = n = 6$$

Molecular formula = $(CH_2O)_6$

Molecular formula = $C_6H_{12}O_6$ **Ans.**

Problem 1.8: ***54 gm of N_2O_5 is decomposed on heating as under:***

$$2N_2O_5 \xrightarrow{\text{heat}} 4NO_2 + O_2$$

Find out the volume of NO_2 and O_2 at S.T.P.

Solution:

Mass of N_2O_5 = 54gm

Molecular. Mass of N_2O_5 = 14 + 14 + 16 + 16 + 16 + 16 + 16 = 108 gm

Volume of NO_2 = ?

Volume of O_2 = ?

Molar Volume = 22.4 dm^3

$$2Na_2O_5 \xrightarrow{\text{heat}} 4NO_2 + O_2$$

Moles of $N_2O_5 = \frac{54}{108} = 0.5$ moles

2 moles of N_2O_5 produces = 4 moles of NO_2

1 moles of N_2O_5 produces $- \frac{4}{2}$ moles of NO_2

0.5 moles of N_2O_5 produces $= \frac{4 \times 0.5}{2} = 1$ mole of NO_2

Volume of NO_2 = molar volume × no. of moles
= 22.4 × 1
= **22.4 dm³** **Ans.**

2 moles of N_2O_5 produce ⟶ 1 mole of O_2

1 mole of N_2O_5 produces ⟶ $\frac{1}{2}$ mole of O_2

0.5 moles of N_2O_5 produces ⟶ $\frac{1}{2} \times 0.5$ moles of O_2

= 0.25 moles of O_2

Volume of O_2 = molar volume × no. of moles
= 22.4 × 0.25
Volume of O_2 = **5.6 dm³** **Ans.**

Problem 1.9: ***Give the significant values of the following:*** ***Karachi Board: 2006***

1.	*685*	⟶	*significant value*	*(Ans. 3)*
2.	*9000*	⟶	*significant value*	*(Ans. 1)*
3.	*0.58*	⟶	*significant value*	*(Ans. 2)*
4.	*0.004*	⟶	*significant value*	*(Ans. 1)*

Problem 1.10: ***An organic compound contains 67.7% of C and 7.41% of H, and 25.90% of N. The molecular mass of the compound is 108. Determine the empirical and molecular formulae of the compound.***

Solution:

(i) Atomic ratio of element = $\frac{\%\text{ of element}}{\text{atomic mass}}$

Atomic ratio of C = $\frac{67.7}{12}$ = 5.641

Atomic ratio of H = $\frac{7.41}{1}$ = 7.41

Atomic ratio of N = $\frac{25.90}{14}$ = 1.85

(ii) ***Simple ratio:***

C	H	N
$\frac{5.641}{1.85}$	$\frac{7.41}{1.85}$	$\frac{1.85}{1.85}$
C = 3.04	H = 4.00	N = 1

or C = 3, H = 4, N = 1

Empirical formula = C_3H_4N

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

$$n = \frac{108}{54} = 2$$

Molecular formula = (empirical formula)$_n$
Molecular formula = $(C_3H_4N)_2$
Molecular formula = $\mathbf{C_6H_8N_2}$ **Ans.**

Problem 1.11: ***Calculate the weight in gms of 3.01×10^{20} molecules of glucose.***
No. of Molecules of glucose = 3.01×10^{20}
Mol. Mass of glucose = 180 gm
Mass of glucose = ?

Solution:

6.02×10^{23} molecules are in 180gm of glucose

1 molecule is in $\frac{180}{6.02 \times 10^{23}}$ of glucose

3.01×10^{20} molecules of glucose are in $\frac{180 \times 3.01 \times 10^{20}}{6.02 \times 10^{23}}$ gm = **0.09 gm** **Ans.**

Problem 1.12: ***Diethyl zinc is a chemical used in the library to protect the books from the worms. Its composition is 53% zinc, 39.9% C, and 8.1% hydrogen. Find the empirical formula of the compound.*** ***Karachi Board: 2007***

Solution:

Atomic ratio of Zn = $\frac{53}{65.4} = 0.81$

Atomic ratio of C = $\frac{38.9}{12} = 3.24$

Atomic ratio of H = $\frac{8.1}{1} = 8.1$

Simplest ratio is:

Zn = 0.81, C = 3.24, H = 8.1

Dividing each by the least value:

Zn = $\frac{0.81}{0.81} = 1$, C = $\frac{3.24}{0.81} = 4$, H = $\frac{8.1}{0.81} = 10$

Empirical formula = ZnC_4H_{10} **Ans**

Problem 1.13: ***Find the mass of $KClO_3$ required to prepare 3.2 gm of O_2.*** ***Karachi Board: 2007***

$$2KClO_3 \xrightarrow{\text{heat}} 2KCl + 3O_2$$

Solution:

$$2KClO_3 \xrightarrow{\text{heat}} 2KCl + 3O_2$$
245gm 96 gm

96gm O_2 is produced by 245gm of $KClO_3$

1 gm O_2 is produced by $\frac{245}{96}$ gm of $KClO_3$

3.2 gm O_2 is produced by $\frac{245 \times 3.2}{96} = 8.16$ gm of $KClO_3$

Mass of $KClO_3$ = **8.16 gm** **Ans.**

Problem 1.14: ***Multiply 4.46 × 1.2 according to multiplication rules.*** ***Karachi Board: 2007***

Solution:

$4.46 \times 1.2 = 4.5 \times 1.2$

$= 5.40$ **Ans.**

Problem 1.15: ***How many significant figures are there in 0.0821?*** ***Karachi Board: 2007***

Solution:

There are 3 significant figures in 0.082.

Problem 1.16: ***What in the mass of 3.01×10^{22} molecules of N_2?*** ***Karachi Board: 2007***

Solution:

6.02×10^{23} molecules are in 1 mole of N_2
6.02×10^{23} molecules are in 28 gm of N_2

1 molecule is in $\frac{28}{6.02 \times 10^{23}}$ gm of N_2

3.01×10^{22} molecules are in $\frac{28 \times 3.01 \times 10^{22}}{6.02 \times 10^{23}}$ gm of N_2

Mass of N_2 = **1.4gm** **Ans.**

Problem 1.17: ***An organic compound producing air pollution contains 8.73% C, 77.45% Cl, and 13.82% F. Find the molecular formula of the compound if its molecular mass is 137.5 a.m.u.*** ***Karachi Board: 2008***

Solution:

Atomic ratio of C $= \frac{8.73}{12} = 0.727$

Atomic ratio of Cl $= \frac{77.45}{35.5} = 2.18$

Atomic ratio of F $= \frac{13.82}{19} = 0.727$

Calculation of simple ratio:

$C = \frac{0.727}{0.727} = 1$

$$Cl = \frac{2.18}{0.727} = 2.99$$

$$F = \frac{0.727}{0.727} = 1$$

The empirical formula of the compound = $CFCl_3$
Empirical formula mass = 12 + 19 + 3 (35.5) = 137.5

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

$$n = \frac{137.5}{137.5} = 1$$

Molecular formula = $(\text{empirical formula})_n = (CFCl_3)_1$
Molecular formula = **$CFCl_3$** **Ans.**

Problem 1.18: ***Simplify:*** $\frac{2.417 \times 8.123}{4.956}$ ***, according to the rules of significant figures.***

Karachi Board: 2008

Solution:

$$\frac{2.417 \times 8.123}{4.956} = \frac{19.633291}{4.956} = 3.96151$$

$$= \mathbf{3.961} \quad \textbf{Ans.}$$

Problem 1.19: ***Zn reacts with H_2SO_4 (dilute) as given:***

$$Zn + H_2SO_4 \text{ (dil)} \longrightarrow ZnSO_4 + H_2$$

Calculate the mass of $ZnSO_4$, the volume of H_2 and the number of molecules of H_2 which will be produced by reacting 163.5gm of Zn with H_2SO_4 at S.T.P.
(Atomic masses of Zn = 65.4, S = 32, O = 16, H = 1)

Karachi Board: 2008-2019

Solution:

(i) Mass of $ZnSO_4$

64.5 gm of Zn produces ⟶ 161.4 gm of $ZnSO_4$

1 gm of Zn produces ⟶ $\frac{161.4}{64.5}$ of $ZnSO_4$

163.5 gm of Zn produces ⟶ $\frac{161.4 \times 163.5}{64.5}$ of $ZnSO_4$

Mass of $ZnSO_4$ = 403.5 gm **Ans.**

(ii) Volume of H_2 at S.T.P.

1 molecule of Zn produces 1 mole of H_2 (according to the equation)
2.5 mole of Zn produces $1 \times 2.5 = 2.5$ moles of H_2
Volume of H_2 = number of moles × molar volume = 2.5×22.4
Volume of H_2 = 56 dm^3 **Ans.**

(iii) No. of molecules of H_2

No. of molecules = mole × N_A
= $2.5 \times 6.02 \times 10^{23}$
No. of Molecules = 1.505×10^{24} molecules **Ans.**

Problem 1.20: *For the reaction, $3Mg + N_2 \longrightarrow Mg_3N_2$. 1.5 gm of Mg and 1.5 gm nitrogen react together, what is the actual amount of Mg_3N_2 formed and which element is the limiting reactant?*

Karachi Board: 2009

Solution:

$$3Mg + N_2 \longrightarrow Mg_3N_2$$

Mass of Mg – 1.5gm, Mass of N_2 = 1.5gm, Mass of Mg_3N_2 formed = ?

No. of moles of Mg $= \frac{1.5}{24} = 0.0625$ moles

From equation:

3 moles of Mg give 1 mole of Mg_3N_2

1 mole of Mg gives $\frac{1}{3}$ moles of Mg_3N_2

0.0625 moles of Mg gives $\frac{1}{3} \times 0.0625$ moles of Mg_3N_2

Moles of Mg_3N_2 = 0.0208 moles of Mg_3N_2

No. of moles of N_2 $= \frac{1.5}{28} = 0.053$ moles

From equation:

1 mole of N_2 gives 1 mole of Mg_3N_2

0.053 moles of N_2 give 0.053 moles of Mg_3N_2

moles of N_2 = moles of Mg_3N_2 = 0.053 moles

Since, Mg gives least number of moles of product therefore it is limiting reactant.

1 mole of Mg_3N_2 = 100 gm

0.0208 moles of Mg_3N_2 = 100×0.0208 gm = 2.08 gm

Mass of Mg_3N_2 = ***2.08 gm*** **Ans.**

Problem 1.21: *Complete combustion of CH_4 gives the reaction:* *Karachi Board: 2010*

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Calculate the mass and the volume of CO_2 gas produced at S.T.P. by the combustion of 9.6 gm of CH_4.

Solution:

To calculate the mass of CO_2 produced:

From equation:

1 mole of CH_4 produces 1 mole of CO_2

16 gm of CH_4 produces ⟶ 44 gm of CO_2

9.6 gm of CH_4 produces ⟶ $\frac{44}{16} \times 9.6 = 26.4$ gm of CO_2

Volume of CO_2 produced:

1 mole of CO_2 at S.T.P. = 22.4 dm^3

44 gm of CO_2 at S.T.P. = 22.4 dm^3

26.4 gm of CO_2 at S.T.P. $= \frac{22.4}{44} \times 26.4 = 13.44$ dm^3

Volume of CO_2 = **13.44 dm^3** **Ans.**

Problem 1.22: *What is the molecular formula of a compound that contains 80% carbon and 20% hydrogen? Its molecular mass is 30.* *Karachi Board: 2010*

Solution:

$$\text{Atomic ratio of Carbon} = \frac{80}{12} = 6.66$$

$$\text{Atomic ratio of Hydrogen} = \frac{20}{1} = 20$$

Calculation of simple ratio:

$$C = \frac{6.66}{6.66} = 1, \qquad H = \frac{20}{6.66} = 3$$

The empirical formula = CH_3

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

$$n = \frac{30}{15} = 2$$

$$\text{Molecular formula} = (\text{Empirical formula})_n$$
$$\text{Molecular formula} = (CH_3)_2 \longrightarrow C_2H_6$$
$$\text{Molecular formula} = C_xH_y$$

Ans.

Problem 1.23: *54g of solid dinitrogen pentaoxide, N_2O_5 is decomposed on heating as:*

$$2N_2O_{5(g)} \longrightarrow 4NO_{2(g)} + O_{2(g)}$$

Find the volumes of NO_2 and O_2 at S.T.P. *Karachi Board: 2011*

Solution:

See Problem 1.8 on page 26.

Problem 1.24: *Simplify the following by using exponential notation.* *Karachi Board: 2012*
43100 + 3900 + 2100

Solution:

$4.31 \times 10^4 + 3.9 \times 10^3 + 2.1 \times 10^3$
$= 4.9 \times 10^4$

Ans.

Problem 1.25: *An organic compound containing carbon, hydrogen and oxygen has 26.7% C, 2.2% H by weight. Find the molecular formula of the compound, if molecular mass of the compound is 90 a.m.u.* *Karachi Board: 2012*

Solution:

In the given organic compound:

Percentage of carbon = 26.7%
Percentage of hydrogen = 2.2%
∴ Percentage of oxygen = 100 – (26.7 + 2.2)
= 71.1%

Calculations of atomic ratios:

$$\text{Ratio of carbon} = \frac{26.7}{12} = 2.225$$

$$\text{Ratio of hydrogen} = \frac{2.2}{1} = 2.2$$

Ratio of oxygen $= \frac{71.1}{16} = 4.44$

Dividing atomic ratio by least atomic ratio:

Simple ratio for C $= \frac{2.2}{2.2} = 1$

Simple ratio for H $= \frac{2.2}{2.2} = 1$

Simple ratio for O $= \frac{4.44}{2.2} = 2$

$\therefore$ Empirical formula $= C_1H_1O_2$ or CHO_2

Calculation of empirical formula mass:

Empirical formula mass $= 12 \times 1 + 1 \times 1 + 16 \times 2$
$= 12 + 1 + 32$
$= 45$

Molecular mass of the compound = 90 a.m.u.

$\therefore n = \frac{90}{45} = 2$

We know that, Molecular formula $= (\text{Empirical formula})_n$
Molecular formula $= (CHO_2)_2$
Molecular formula $= C_2H_2O_4$ **Ans.**

Problem 1.26: ***Find the mass and number of molecules in 18000 cm^3 of H_2S at S.T.P.***

Karachi Board: 2012

Solution:

$\therefore$ Volume of $H_2S = 1800\ cm^3$

$= \frac{1800}{1000} = 1.8\ cm^3$

Molar mass of H_2S at S.T.P. = ?
No. of moles at S.T.P. = ?

Calculations:

We know that at S.T.P.

22.4 dm^3 of H_2S = 1 mole

1 dm^3 of $H_2S = \frac{1}{22.4}$ mole

1.8 dm^3 of $H_2S = \frac{1.8}{22.4}$ mole $= 0.8$ mole

Molecular mass of $H_2S = 1 \times 2 + 32$
$= 2 + 32$
$= 34$

$\therefore$ 1 mole of H_2S gas = 34 gm

Mass = Mole × Molecular Weight

= 0.8 × 34

= 27.32 gm **Ans.**

No. of molecules = $0.8 \times 6.02 \times 10^{23}$

= 4.81×10^{23} **Ans.**

Problem 1.27: ***What is the minimum mass of $Al(OH)_3$ that can be obtained by the reaction of 13.4gm of $AlCl_3$ with 10gm of NaOH according to the following equation:***

Solution: *Karachi Board: 2012*

Mass of $AlCl_3$ = 13.4 gm
Molecular mass of $AlCl_3$ = 133.5 gm
Molecular mass of $Al(OH)_3$ = 78 gm
Mass of NaOH = 10 gm
Molecular mass of NaOH = 40 gm
Mass of $Al(OH)_3$ = ?

Equation:

$$AlCl_3 + 3NaOH \longrightarrow Al(OH)_3 + 3NaCl$$

According to the above balanced equation:

133.5gm $AlCl_3$ gives 78gm of $Al(OH)_3$

1 gm $AlCl_3$ gives $\frac{78}{133.5}$ gm of $Al(OH)_3$

13.4 gm $AlCl_3$ gives $\frac{78 \times 13.4}{133.5}$ = 7.83 gm of $Al(OH)_3$

According to the equation, mass of 3 moles of NaOH = 3 × 40 = 120

120 gm of NaOH produces 78 gm of $Al(OH)_3$

1 gm of NaOH produces $\frac{78}{120}$ gm of $Al(OH)_3$

10 gm of NaOH produces $\frac{78 \times 10}{120}$ = 6.5 gm of $Al(OH)_3$

The minimum mass of $Al(OH)_3$ is 6.5 gm. **Ans.**

Problem 1.28: ***Find the weight of Barium Sulphate precipitated on adding a solution containing 82 gm of Potassium Sulphate to a solution containing 82 gm Barium Chloride.***

$$K_2SO_{4(aq)} + BaCl_{2(aq)} \longrightarrow BaSO_{4(s)} + 2KCl$$ *Karachi Board: 2013*

Solution:

Data:

Weight of K_2SO_4 = 82 gm
Weight of $BaCl_2$ = 82 gm
Weight of $BaSO_4$ = ?

Equation: $K_2SO_4 + BaCl_2 \longrightarrow BaSO_4 + 2KCl$

Molecular mass of K_2SO_4 = 174 gm

Mole of given K_2SO_4 = $\frac{82}{174}$ = 0.471 moles

Molecular mass of $BaCl_2$ = 208 gm

Mole of given $BaCl_2$ = $\frac{82}{208}$ = 0.394 moles

Molecular mass of $BaSO_4$ = 137 + 32 + 64 = 233 gm

Since $BaCl_2$ gives least value (0.394). Hence it is limiting reactant.

As per equation,

208 gm $BaCl_2$ gives 233 gm of $BaSO_4$

1 gm $BaCl_2$ gives $\frac{233}{208}$ gm of $BaSO_4$

82 gm $BaCl_2$ gives $\frac{233 \times 82}{208}$ = 91.85 gm of $BaSO_4$

Weight of $BaSO_4$ = 91.85 gm **Ans.**

Problem 1.29: ***Calculate the number of moles in 2400 g of:***
(i) CO_2 (ii) Oxygen molecule (iii) $CaCO_3$ (iv) $MgBr_2$

Solution:

No. of moles = $\frac{\text{mass in gm.}}{\text{molecular mass}}$

(i) Molecular mass of CO_2 = 12 + 16 + 16 = 44 gm No. of moles = $\frac{2400}{44}$ = 54.54 moles

(ii) Molecular mass of O_2 = 16 + 16 = 32 gm No. of moles = $\frac{2400}{32}$ = 75 moles

(iii) Molecular mass of $CaCO_3$ = 40+12+16+16+16 = 100 gm No. of moles = $\frac{2400}{100}$ = 24 moles

(iv) Molecular mass of $MgBr_2$ = 24.3+79.9+79.9 = 184.1 gm No. of moles = $\frac{2400}{184.1}$ = 13.036 moles

Problem 1.30: ***In a collection of 24×10^{25} molecules of C_2H_5OH, what is the number of moles? (Atomic mass: C = 12, O = 16, H = 1)***

Solution:

Data:

No. of molecules of C_2H_5OH = 24×10^{25}

According to Avagadro's number:

6.02×10^{23} molecules of C_2H_5OH = 1 mole

$\therefore$ 1 molecule of $C_2H_5OH = \frac{1}{6.02 \times 10^{23}}$

$\therefore$ 24×10^{25} molecules of $C_2H_5OH = \frac{24 \times 10^{25}}{6.02 \times 10^{23}} = \frac{24}{6.02} \times 10^{25-23}$

Number of moles = 3.987×10^2 moles **Ans.**

Problem 1.31: ***$ZnCl_2$ is prepared by the reaction $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$, 6.54 gram of Zn reacts with 73 grams of HCl. Find the limiting reactant and the mass of $ZnCl_2$ produced.*** ***Karachi Board: 2014***

Solution:

Data:

Amount of Zn = 6.54 g

Amount of Zn in mole = $\frac{6.54}{65.4}$ = 0.1 mole

Amount of HCl = 73 g

Amount of HCl in mole = $\frac{73}{36.5}$ = 2 moles

Amount of $ZnCl_2$ produced = ?

Equation:

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

1 mole of Zn produces 1 mole of $ZnCl_2$

0.1 mole of Zn produces 0.1 mole of $ZnCl_2$

Amount of $ZnCl_2$ produced by given amount of Zn is 0.1 mole or $(0.1 \times 136.4) = 13.64$g

2 moles of HCl produces 1 mole of $ZnCl_2$

Amount of $ZnCl_2$ produced by given amount of HCl is 1 mole or 136.4 g

Zn produces least amount, it is limiting reactant and $ZnCl_2$ will produce 13.64g **Ans.**

Problem 1.32: ***The mass of a substance is 18.8865 gram and its volume is 7.9 cm^3. What will be its density considering significant figures and rounding off the above obtained?*** ***Karachi Board: 2014***

Solution:

Data:

mass of the substance = m = 18.8865 gm

volume = V = 7.9 cm^3

density = d = ?

We know that,

$$D = \frac{m}{V}$$

$$D = \frac{18.8865}{7.9} = 2.39 \text{ gm / cm}^3$$

D = 2.4 gm / cm³ (considering significant figures and rounding off) **Ans.**

Problem 1.33: ***Calculate the volume of nitrogen gas produced by heating 800 grams of ammonia at 21°C and 823 torr pressure:***

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

Solution:

Data:

Pressure = P = 823 torr = $\frac{823}{760}$ = 1.083 atm

Moles of NH_3 = $\frac{800}{17}$ = 47.06

Temperature = T = 21°C = 21 + 27 = 294 K
Gas constant = R = 0.0821 atm.dm³ / mole.K
Volume of N_2 = V = ?

2 moles of NH_3 produce $\frac{47.06}{2}$ of N_2 = 23.53 of N_2

We know that PV = nRT

$$V = \frac{nRT}{P}$$

$$V = \frac{(23.53)(0.0821)(294)}{1.083}$$

$$V = 424.24 \text{ dm}^3$$ **Ans.**

Problem 1.34: ***Combustion of 0.5 gm of a hydrocarbon produced 1.515 gm CO_2 and 0.77 gm of H_2O. If the molecular mass of the compound is 58 a.m.u., determine its molecular formula.*** ***Karachi Board 2014***

Solution:

Data:

Mass of hydrocarbon = 0.5 gm
Mass of CO_2 = 1.515 gm
Mass of H_2O = 0.77 gm
Molecular mass of the compound = 58 a.m.u
Molecular formula = M.F. = ?

We know that:

Molecular formula = M.F. = n (Empirical formula)

where $n = \frac{\textit{Molecular formula mass}}{\textit{Empirical formula mass}}$

$\% = \frac{\textit{Mass of element}}{\textit{Mass of compound}} \times 100$

mass of element $= \frac{\textit{Mole of element in compound}}{\textit{Molecular weight of compound}} \times$ given mass of compound

Mass of C:

Molecular weight of $CO_2 = 12 \times 1 + 2 \times 16 = 12 + 32 = 44$ a.m.u.

Mass of C $= \frac{12}{44} \times 1.515 = 0.413$ gm

% of C $= \frac{0.413}{0.5} \times 100 = 82.63\ \%$

Mass of H:

Molecular weight of $H_2O = 2 \times 1 + 1 \times 16 = 2 + 16 = 18$ a.m.u.

Mass of H $= \frac{2}{18} \times 0.77 = 0.085$ gm

% of H $= \frac{0.085}{0.5} \times 100 = 17.11\ \%$

Mole ration and simple ratio:

Mole ratio of C $= \frac{82.63}{12} = 6.88$

Mole ratio of H $= \frac{17.11}{1} = 17.11$

Simple ratio of C $= \frac{6.88}{6.88} = 1$

Simple ratio of H $= \frac{17.11}{6.88} = 2.48 = 2.5$

Multiply both ratio by 2, we get:

Ratio of C $= 1 \times 2 = 2$

Ratio of H $= 2.5 \times 2 = 5$

$\therefore$ Empirical formula of compound is C_2H_5

Empirical formula mass $= 12 \times 2 + 1 \times 5 = 24 + 5 = 29$

$n = \frac{58}{29} = 2$

Molecular formula $= 2(C_2H_5) = C_4H_{10}$ **Ans.**

Problem 1.35: ***What volume of CO_2 measured at 20°C and 720 torr pressure will be produced by the reaction between 200 gm of Na_2CO_3 and HCl?***

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$

Solution: *Karachi Board: 2016*

$$\underset{\substack{(23\times2+12+16\times3)\\46+12+48\\106\text{ gm}}}{Na_2CO_3} + 2HCl \longrightarrow 2NaCl + \underset{\substack{(12+16\times2)\\12+32\\44\text{ gm}}}{CO_2} + H_2O$$

106 gm of Na_2CO_3 gives 44 gm of CO_2

1 gm of Na_2CO_3 gives $\frac{44}{106}$ gm of CO_2

200 gm of Na_2CO_3 gives $\frac{44}{106} \times 200$ gm of CO_2

Mass of CO_2 = 83 gm

Volume of CO_2 :

$T = 20°C + 273 = 293\ K$

$P = 720\text{ torr} = \frac{720}{760} = 0.947\text{ atm}$

Volume = ?

We know that $PV = nRT$

$PV = \frac{m}{M} RT$

$V = \frac{m}{PM} RT = \frac{(83)(0.0821)(293)}{(0.947)(44)} = \frac{1996.6}{41.668}$

$V = 48\ dm^3$ **Ans.**

Problem 1.36: ***Simplify the following by using rules of significant figures:***

$$\frac{92 \times 751 \times 273}{760 \times 297}$$

Karachi Board: 2016

Solution:

Step 1: $92 \times 751 \times 273 = 18862116 = 1.9 \times 10^7$ (up to 2 significant figures)

Step 2: $760 \times 297 = 225720 = 2.3 \times 10^5$ (up to 2 significant figures)

Step 3: $= \frac{1.9 \times 10^7}{2.3 \times 10^5}$

Step 4: $= 8.3 \times 10^2$ **Ans.**

Problem 1.37: ***An organic compound contains 40% C and 6.66% H by mass. Its molecular mass is double that of its empirical formula mass. Find its molecular mass.***

Solution: ***Karachi Board: 2017-2019***

Data:

C = 40%
H = 6.66%
O = 100 - (40 + 6.66) = 100 - 46.66 = 53.34%

Mole Ratios:

$C = \frac{40}{12} = 3.33$ mole $H = \frac{6.66}{1} = 6.66$mole $O = \frac{53.34}{16} = 3.33$ mole

Atomic Ratios:

$C = \frac{3.33}{3.33} = 1$ atom $H = \frac{6.66}{3.33} = 2$ atom $O = \frac{3.33}{3.33} = 1$ atom

So, Empirical Formula = CH_2O
Empirical Formula mass = 12 + 2 + 16 = 30
The given condition is molecular mass = 2 (Empirical Formula Mass)
Molecular mass = 2 (30) = 60

$n = \frac{60}{30} = 2$

Molecular Formula = $(CH_2O)_n$
Molecular Formula = $(CH_2O)_2$
Molecular Formula = $C_2H_4O_2$ **Ans.**

Problem 1.38: $CACO_3 \longrightarrow CaO + CO_2$

$CaCO_3$ is often used to generate CO_2 gas in industry. If 200g of $CaCO_3$ is strongly heated, what volume of CO_2 will be obtained at 30°C and 1200 torr pressure?

Solution: ***Karachi Board: 2017***

Data:

mass of $CaCO_3$ = 200gm
T = 30°C = 30 + 273 = 303 K
P = 1200 torr = $\frac{1200}{760}$ = 1.58 atm
Mass of CO_2 = ?

$$\underset{\substack{(40+12+48)\\100\text{ gm}}}{CaCO_3} \longrightarrow \underset{\substack{(12+32)\\44\text{ gm}}}{CaO} + CO_2$$

$$\underset{(40+12+48)\ 100\ gm}{CaCO_3} \quad \underset{(12+32)\ 44\ gm}{CaO} + CO_2$$

100 gm of $CaCO_3$ gives 44 gm of CO_2

1 gm of $CaCO_3$ gives $\frac{44}{100}$ gm of CO_2

200 gm of $CaCO_3$ gives $\frac{44}{100} \times 200$ gm of CO_2

Mass of CO_2 = 88 gm

Now for Volume, $PV = nRT$

$$V = \frac{nRT}{P}$$

$$V = \frac{mRT}{MP} \quad \left(\text{because } n = \frac{m}{M}\right)$$

$$V = \frac{(88)(0.0821)(303)}{(44)(1.58)}$$

$$V = \frac{2189.1144}{69.52}$$

$$V = 31.48\ dm^3$$ **Ans.**

Solution of Textbook Progress Test - 1

Q.01 ***(a) Explain (i) Empirical formula (ii) Molecular formula (iii) Mole.***
(b) Calculate the number of moles in 2400g of :
(i) CO_2 (ii) Oxygen Molecule (iii) $CaCO_3$ (iv) $MgBr_2$

Solution:

(a) See Q 17, Q 19 & Q 21 on page 12, 13 and 14.
(b) For solution see problem 1.29 on page 35.

Q.02 ***(a) What is Avogadro's Number?***
Calculate the number of atoms in 9.2 g of Na. (Atomic mass of Na = 23 a.m.u)
(b) Calculate the mass in gms of 3.01×10^{16} molecules of glucose ($C_6H_{12}O_6$)

Solution:

(a) See Q 24 on page 14.

$$\text{No. of Sodium atoms} = \frac{\text{Mass of Na}}{\text{Atomic mass of Na}} \times \text{Avogadro's No.}$$

No. of Sodium atoms $= \frac{9.2}{23} \times 6.02 \times 10^{23}$

No. of Sodium atoms $= 2.4 \times 10^{23}$ atoms **Ans.**

(b) (For solution see of Important Problem - Problem 1.11 on page 28)

Q.03 ***A compound of C, H and N contains 67.70% Carbon, 7.41% Hydrogen and 25.90% Nitrogen, the molecular mass of the compound was found to be 108.***

(i) Find the empirical formula of the compound.

(ii) Find the molecular formula of the compound.

Solution:

For solution see Important Problems - Problem 1.10 on page 27.

Q.04 ***(a) Determine the significant figures in the following:***
15.01, 7000, 3.200, 0.004

(b) Simplify the following according to the rules of significant figures:

(i) 1.41 × 3.546 ***(ii)*** $\frac{31.23 \times 4.56}{9.41395}$

Solution:

(a)

1. 15.01 ⟶ 4
2. 7000 ⟶ 1
3. 3.200 ⟶ 4
4. 0.004 ⟶ 1

(b) ***(i)*** $1.41 \times 3.546 = 4.999 = 5.0$

(ii) See example 1.3 on page 16.

Q.05 ***Express the following as the power of 10.***

(a) 6782 (b) 565.2 (c) 0.00019 (d) 70000 (e) 0.00000067

Solution :

1. 6782 ⟶ 6.782×10^3
2. 565.2 ⟶ 5.652×10^2
3. 0.00019 ⟶ 1.9×10^{-4}
4. 70000 ⟶ 7×10^4
5. 0.00000067 ⟶ 6.7×10^{-7}

Q.06 ***With the help of logarithm table, find the value of :***

(a) $(25.4)^3 \times (416.2)^{\frac{3}{2}}$ ***(b)*** 294×0.0006

(c) $0.18 \div 108$ ***(d)*** $\frac{57 \times 365 \times (566)^{\frac{1}{2}}}{78 \times 221 \times (356)^{\frac{2}{3}}}$

Solution:

(a) $(25.4)^3 \times (416.2)^{\frac{3}{4}}$

$= 3 \log 25.4 + \frac{3}{4} \log 416.2$

$= 3\,(1.4048) + \frac{3}{4}\,(2.6193)$

$= 4.2144 + 1.9644$

$= 6.178$

(b) 294×0.0006

$= \log 294 + \log 6 \times 10^{-4}$

$= \log 294 + \log 6 - 4 \log 10$

$= 2.4683 + 0.7781 - 4\,(1)$

$= -0.7536$

$= \bar{1} - 0.7536 - 1$

$= 0.2464 - 1 = \bar{1}.2464$

$=$ Anti log of $\bar{1}.2464 =$ ***0.1764*** ***Ans.***

(c) $0.18 \div 108$

$= \log 0.18 - \log 108$

$= -0.7447 - 2.0334 = -2.778$

$=$ anti log (-2.778)

$= 0.001667$ **Ans.**

(d) $\dfrac{57 \times 365 \times (566)^{\frac{1}{2}}}{78 \times 221 \times (356)^{\frac{2}{3}}}$

$= \log 57 + \log 365 + \frac{1}{2} \log 566 - \log 78 - \log 221 - \frac{2}{3} \log 356$

$= 1.7558 + 2.5622 + \frac{1}{2}\,(2.7528) - 1.8920 - 2.3443 - \frac{2}{3}\,(2.55)$

$= 1.7558 + 2.5622 + 1.3764 - 1.8920 - 2.3443 - 1.7009 = -0.2428$

$=$ Anti log $(-0.2428) = 0.5718$ **Ans.**

Q.07 ***Round off the following numbers into (a) four (b) three and (c) two significant digits: (i) 8.7483 (ii) 5.36748 (iii) 15.145 (iv) 188.55***

Solution:

	(i) 8.7483	*(ii)* 5.36748	*(iii)* 15.145	*(iv)* 188.55
4 Significant figures ⟶	8.748	5.368	15.14	188.6
3 Significant figures ⟶	8.75	5.37	15.1	189
2 Significant figures ⟶	8.8	5.4	15	1.9×10^2

Q.08 ***Acetic acid contains carbon, hydrogen and oxygen. 4.24g of sample of acetic acid on complete combustion gave 6.21g of CO_2 and 2.54 of H_2O. The molecular mass of acetic acid is 60. Find:***

(i) Empirical formula of Acetic Acid, and (ii) Molecular formula of acetic acid.

Solution:

To calculate masses of carbon and hydrogen for the masses of CO_2 and H_2O:

$$\text{Mass of Carbon} = \frac{1 \text{ mole of C}}{1 \text{ mole of } CO_2} \times 6.21\text{g } CO_2 = \frac{12\text{ g}}{44\text{ g}} \times 6.21 = 1.693 \text{ g C}$$

$$\text{Mass of Hydrogen} = \frac{2 \text{ moles of H}}{1 \text{ mole of } H_2O} \times 2.54\text{g } H_2O = \frac{2\text{ g}}{18\text{ g}} \times 2.54 = 0.282 \text{ g H}$$

To calculate percentage of carbon and hydrogen:

4.24 g of the compound contains 1.693 g C

1 g of the compound contains $\frac{1.693}{4.24}$ g C

$$\% \text{ of C} = \frac{1.693}{4.24} \times 100 = 39.92\ \%$$

4.24 g of the compound contains 0.282 g H

1 g of the compound contains $\frac{0.282}{4.24}$ g H

$$\% \text{ of H} = \frac{0.282}{4.24} \times 100 = 6.65\ \%$$

Total % of C and H = 39.92 + 6.65 = 46.57 %

% of O = 100 - 46.57 = 53.43 %

To calculate mole ratio of the elements, we divide the percentages by their atomic mass:

Mole Ratio of C	Mole Ratio of H	Mole Ratio of O
$\frac{39.92}{12} = 3.33$	$\frac{6.65}{1} = 6.6$	$\frac{53.43}{16} = 3.3$

To obtain the simplest ratio, the quotients are divided by the least ratio:

$$C = \frac{3.3}{3.3} = 1, \quad H = \frac{6.6}{3.3} = 2, \quad O = \frac{3.3}{3.3} = 1$$

Thus, the empirical formula of the compound = CH_2O Ans.

The empirical formula mass of CH_2O = 12 + 2 + 16 = 30

The value of the integer 'n' is calculated as follows:

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{60}{30} = 2$$

Molecular formula = $(\text{Empirical formula})_n$

= $(CH_2O)_2$

= $C_2H_4O_2$ Ans.

Q.09 ***Ethylene glycol is used as an antifreeze combustion of 6.38g of ethylene glycol gives 9.06g of CO_2 and 5.58g of H_2O. Ethylene glycol contains carbon hydrogen and oxygen and its molecular mass is 62. Find empirical and molecular formula.***

Solution:

To calculate masses of carbon and hydrogen for the masses of CO_2 and H_2O:

$$\text{Mass of Carbon} = \frac{1 \text{ mole of C}}{1 \text{ mole of } CO_2} \times 9.06 \text{ g } CO_2 = \frac{12 \text{ g}}{44 \text{ g}} \times 9.06 = 2.470 \text{ g C}$$

$$\text{Mass of Hydrogen} = \frac{2 \text{ moles of H}}{1 \text{ mole of } H_2O} \times 5.58 \text{ g } CO_2 = \frac{2 \text{ g}}{18 \text{ g}} \times 5.58 = 0.62 \text{ g H}$$

To calculate percentage of carbon and hydrogen:

6.38 g of the compound contains 2.470 g C

1 g of the compound contains $\frac{2.470}{6.38}$ g C

$$\% \text{ of C} = \frac{2.470}{6.38} \times 100 = 38.71\ \%$$

6.38 g of the compound contains 0.62 g H

1 g of the compound contains $\frac{0.62}{6.38}$ g H

$$\% \text{ of H} = \frac{0.62}{6.38} \times 100 = 9.71\ \%$$

Total % of C and H = 38.71 + 9.71 = 48.42 %

% of O = 100 − 48.42 = 51.58 %

To calculate mole ratio of the elements, we divide the percentages by their atomic mass:

Mole Ratio of C	Mole Ratio of H	Mole Ratio of O
$\frac{38.71}{12} = 3.2$	$\frac{9.71}{1} = 9.7$	$\frac{51.58}{16} = 3.2$

To obtain the simplest ratio, the quotients are divided by the least ratio:

$$C = \frac{3.2}{3.2} = 1; \quad H = \frac{9.7}{3.2} = 3; \quad O = \frac{3.3}{3.3} = 1$$

Thus, the empirical formula of the compound = CH_3O Ans.

The empirical formula mass of CH_3O = 12 + 3 + 16 = 31

The value of the integer 'n' is calculated as follows:

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{62}{31} = 2$$

Molecular formula = $(\text{Empirical formula})_n$

= $(CH_3O)_2$

= $C_2H_6O_2$ **Ans.**

Q.10 ***When dinitrogen pentaoxide (N_2O_5), a white solid, is heated it decomposes to nitrogen dioxide and oxygen.*** $2N_2O_{5(s)} \longrightarrow 4NO_{2(g)} + O_{2(g)}$
Find the volume of NO_2 and O_2 gases produced at S.T.P. when a sample of 54g of N_2O_5 is heated.

Solution:

See Problem 1.8 on page 26.

Q.11 ***Hydrogen cyanide is prepared from ammonia, air and natural gas (CH_4) by the following process:*** $2NH_{3(g)} + 3O_{2(g)} + 2CH_{4(g)} \longrightarrow 2HCN_{(g)} + 6H_2O_{(g)}$
If a reaction vessel contain 51g of NH_3. What is the maximum mass of HCN that could be made, assuming the reaction goes to completion?
Find also the volume of O_2 and CH_4 gases required for the reaction at S.T.P.

Solution:

$2NH_{3(g)} + 3O_{2(g)} + 2CH_{4(g)} \longrightarrow 2HCN_{(g)} + 6H_2O_{(g)}$
2 moles 3 moles 2 moles 2moles 6moles
2(17) = 34 grams 2(27) = 54 grams

(i) 34 grams of NH_3 forms $\longrightarrow$ 54 grams of HCN (as per equation)

1 gram of NH_3 forms $\longrightarrow$ $\frac{54}{34}$ grams of HCN

51 grams of NH_3 forms $\longrightarrow$ $\frac{54}{34} \times 51 = 81$ grams

Mass of HCN = 81 grams **Ans.**

(ii) 34 grams of NH_3 at S.T.P. requires $\longrightarrow$ 67.2 dm^3 Oxygen (as per equation)

1 gram of NH_3 at STP requires $\longrightarrow$ $\frac{67.2}{34}$ dm^3 Oxygen

51grams of NH_3 at S.T.P. requires $\longrightarrow$ $\frac{67.2 \times 51}{34} = 100.8$ dm^3

Volume of O_2 = 100.8 dm^3 **Ans.**

(iii) 34 grams of NH_3 at S.T.P. requires $\longrightarrow$ 44.8 dm^3 of CH_4

1 gram of of NH_3 at STP requires $\longrightarrow$ $\frac{44.8}{34}$ dm^3 of CH_4

51grams of NH_3 at S.T.P requires $\longrightarrow$ $\frac{44.8}{34} \times 51 = 67.2$ dm^3

Volume of CH_4 = 67.2 dm^3 **Ans.**

Q.12 ***Ammonia gas can be produced by heating together the solid NH_4Cl and $Ca(OH)_2$. If a mixture containing 100 g of each of these solids is heated, how many grams of NH_3 are produced? Also find the volume of NH_3 gas at S.T.P.***

$$2NH_4Cl_{(s)} + Ca(OH)_2 \xrightarrow{heat} 2NH_{3(g)} + CaCl_2 + 2H_2O$$

Solution:

$$2NH_4Cl_{(s)} + Ca(OH)_2 \xrightarrow{heat} 2NH_{3(g)} + CaCl_2 + 2H_2O$$

Molecular mass of $NH_4Cl = 14 + 4 + 35.5 = 53.5$

$$\text{Moles of } NH_4Cl = \frac{\text{Mass of } NH_4Cl}{\text{Molecular mass}} = \frac{100}{53.5} = 1.87 \text{ moles}$$

2 moles of NH_4Cl give 2 moles of NH_3 (as per equation)
1.87 moles of NH_4Cl give 1.87 moles of NH_3
Molecular mass of $Ca(OH)_2 = 40 + 32 + 2 = 74$

$$\text{Moles of } Ca(OH)_2 = \frac{\text{Mass of } Ca(OH)_2}{\text{Molecular mass}} = \frac{100}{74} = 1.35 \text{ moles}$$

1 mole of $Ca(OH)_2$ produces 2 moles of NH_3 (as per equation)
1.35 moles of $Ca(OH)_2$ produce $2 \times 1.35 = 2.70$ moles of NH_3

Since NH_4Cl gives least number of moles of NH_3. Therefore NH_4Cl will be the limiting reactant. So amount of NH_3 is calculated by NH_4Cl.

(a) Mass of NH_3 = Moles × molecular mass
= 1.87×17
Mass of NH_3 = 31.79 gm **Ans.**

(b) Volume of NH_3 = Moles × Molar Volume
= 1.87×22.4
Volume of NH_3 at S.T.P. = **41.89 dm^3** **Ans.**