2. Introduction to analytical chemistry

Exercises

1. Choose correct option (Answer are given directly)

A. The branch of chemistry which deals with study of separation, identification, and quantitative determination of the composition of different substances is called as..

Ans. Analytical chemistry

B. Which one of the following property of matter is Not quantitative in nature?

Ans. Colour

C. SI unit of mass is ....

Ans. Kg

D. The number of significant figures in 1.50×10^4 g is...

Ans. 3

E. In Avogadro's constant 6.022×10^{23} mol^{-1}, the number of significant figures is...

Ans. 4

F. By decomposition of 25 g of $CaCO_3$, the amount of CaO produced will be

Ans. 14.0 g

G. How many grams of water will be produced by complete combustion of 12 g of methane gas

Ans. 27

H. Two elements A (At. mass 75) and B (At. mass 16) combine to give a compound having 75.8% of A. The formula of the compound is...

Ans. A_2B_3

I. The hydrocarbon contains 79.87 % carbon and 20.13 % of hydrogen. What is its empirical formula?

Ans. CH_3

J. How many grams of oxygen will be required to react completely with 27 g of Al? (Atomic mass: Al=27, 0 = 16)

Ans. 24

K. In $CuSO_4.5H_2O$ the percentage of water is...
(Cu = 63.5, S = 32, O = 16, H = 1)

Ans. 36%

L. When two properties of a system are mathematically related to each other, the relation can be deduced by

Ans. Plotting a graph

2. Answer the following questions

A. Define: Least count

Ans. Least count: The smallest quantity or value that can be measured by the measuring equipment or instrument is called its least count.

B. What do you mean by significant figures? State the rules for deciding significant figures.

Ans. The significant figures in a measurement or result are the number of digits known with certainty plus one uncertain digit.

Rules for deciding significant figures: (1) All non zero digits are significant. For example, 127.34 g contains five significant figures which are 1, 2, 7, 3 and 4.

(2) All zeros become significant, if they are placed between two non zero digits. For
example, 120.007 m contains six significant figures which are 1, 2, 0, 0, 0 and 7.

(3) Zeros on the left of the first non zero digit are not significant. Such a zero indicates the position of the decimal point.
For example, 0.025 has two significant figures, 2 and 5.
0.005 has only one significant figure, 5.

(4) All zeros placed at the end of a number are significant if they are on the right

side of the decimal point. They represent the accuracy or precision of the measuring scale.
For example, 243.0 has four significant figures which are 2, 4, 3 and 0.
Terminal zeros are not significant if there is no decimal point. For example, the measurement 400 g has one significant figure which is 4.

(5) In numbers written is scientific notation, all digits are significant.
For example, 2.035×10^2 has four significant figures which are 2, 0, 3 and 5.
The measurement, 3.25×10^{-5} has three significant figures viz. 3, 2 and 5.

C. Distinguish between accuracy and precision.

Ans.

Accuracy	Precision
1. Accuracy refers to the nearness of the observed value or the measured value to the true value.	1. Precision is the close ness between two or more measured values to each other.
2. Accuracy expresses the correctness of the measurement.	2. Precision the describes agreement between a result and its true value.
3. Accuracy depends upon the sensitivity or the least count of the measuring equipment.	3. High precision implies reproducibi lity of readings.
4. Accuracy can never be determined exact ly because the true value of a quantity can never be known exactly, instead an accepted value must be used to determine accuracy.	4. Precision is determined by simply replicating a measurement.
5. Larger the accuracy, smaller is the error.	5. Smaller the difference between the individual values of repeated measure ments, greater is the precision.
6. Accuracy is expressed in terms of either absolute or relative error.	6. Precision is expressed in terms of deviation.

D. Explain the terms percentage composition, empirical formula and molecular formula.

Ans. Percentage composition: The percentage by mass of each element in a compound is called per cent composition.

Empirical formula: The simplest ratio of atoms of the constituent elements in a molecule is called the empirical formula of that compound.

Molecular formula: Molecular formula of a compound is the formula which indicates the actual number of atoms of the constituent elements in a molecule.

E. What is a limiting reagent? Explain.

Ans. Limiting reagent: The reactant in a chemical reaction that limits the amount of product that can be formed is called the limiting agent. The reaction will stop when all of the limiting reactant is consumed.
A balanced chemical equation gives the ideal stoichiometric relationship among reactants and products. However, when a chemist carries out a reaction, reactants for the experiment are not necessarily present in exact stoichiometric amounts. This is because, the goal of the reaction is to produce the maximum quantity of a useful compound or product from the starting material. Many a times, a large excess of one reactant is supplied to ensure that the more expensive reactant is completely converted into the desired product. Thus, the reactant which is present in lesser amounts gets consumed after some time and subsequently, no further reaction takes place.

F. What do you mean by SI units? What is the SI unit of mass?

Ans. In 1960, the General Conference of weight and measures adopted an International System of
Units, called SI units (French name Systeme internationale d'Unites) which has seven fun damental units. The SI unit of mass is kilogram (kg).

G. Explain the following terms

(a) Mole fraction

(b) Molarity

(c) Molality

Ans. Mole fraction (x): The mole fraction of any component of a solution is defined as the ratio of number of moles of that component present in the solution to the total number of moles of all the components of the solution.

$$Mole\ fraction = \frac{Number\ of\ moles\ of\ a\ component}{Total\ number\ of\ moles\ of\ solute}$$

Number of moles of a substance

$$= \frac{Mass\ of\ substance}{Molar\ mass\ of\ the\ substance} = \frac{W}{M} mol$$

If a solution contains n, moles of solvent and n_2 moles of solute, then the total number of moles present in the solution = $n_1 + n_2$.

Mole fraction of the Solvent $\times_1$

$$\frac{n_1}{n_1 + n_2}$$

Mole Fraction of the solute $\times_2$

$$\frac{n_2}{n_1 + n_2}$$

Mole fraction is independent of temperature and has no units.

(b) Molarity (M): It is defined as the number of moles of a solute present in 1 litre of a solution. If n moles of a solute are present in V lit. of a solution then,

$$Molarity\ (M) = \frac{Number\ of\ moles\ of\ solute}{Volume\ of\ solution\ in\ lit.}$$

$$= \frac{n}{V} mol\ L^{-1}$$

$$Molarity = \frac{Mass\ of\ solute}{Molar\ mass\ of\ solute \times Volume\ of\ solution\ in\ L.}$$

$$= \frac{Mass\ of\ solute \times 1000}{Molar\ mass\ of\ solute \times Volumn\ of\ solution\ in\ cm^3}$$

The unit of molarity is mol litre^{-1} (mol L^{-1})
Molarity changes with temperature.

(c) Molality (m): It is defined as the number moles of a solute dissolved in 1 kg (or 1000 gram) of a solvent.
Molality (m)

$$= \frac{Number\ of\ moles\ os\ a\ solute}{Mass\ of\ a\ solvent\ in\ kg}$$

$$= \frac{Mass\ of\ a\ solute}{Molar\ mass\ of\ solute \times Molar\ mass\ of\ solvent\ in\ kg}$$

$$= \frac{Mass\ of\ a\ solute \times 1000}{Molar\ mass\ of\ solute \times Molar\ Mass\ of\ solvent\ in\ g}$$

The unit of molality is mol kg^{-1} and denoted by m.
Molality is independent of temperature, since it involves mass of solute and mass of solvent which are independent of temperature.

H. Define: Stoichiometry

Ans. Stoichiometry: The study of quantitative relations between the amount of reactants and products is called stoichiometry.

I. Why there is a need of rounding off figures during calculation?

Ans. The final result of a calculation often contains figures that are not significant. When this occurs the final result is rounded off.

J. Why does molarity of a solution depend upon temperature?

Ans. Molarity of a solution depends upon temperature since it involves volume of the solution which is temperature dependent.

K. Define Analytical chemistry. Why is accurate measurement crucial in science?

Ans. Analytical chemistry: The branch of chemistry which deals with the study of separation, identification, qualitative and quantitative determination of the compositions of different substances, is called analytical chemistry.

Accurate measurements are important because exact amounts of reagents or chemicals are required for reactions to take place. Measurements that are not accurate, provide incorrect data which can lead to wrong or even dangerous conclusions or results.
For example, if a lab experiment requires a specific amount of a chemical, measuring the wrong amount may result in an unsafe or unexpected outcome. Due to all these reasons, accurate measurement is crucial in science.

3. Solve the following questions.

A. How many significant figures are in each of the following quantities?

a. 45.26 ft

b. 0.109 in

c. 0.00025 kg
d. 2.3659 x 10^{-8} cm

e. 52.0 cm^3

f. 0.00020 kg

g. 8.50 x 104 mm

h. 300.0 cg

Solution: (a) 4 (b) 3 (c) 2 (d) 5 (e) 3 (f) 2 (g) 3 (h) 4.

B. Round off each of the following quantities to two significant figures :

(a) 25.55 mL

(b) 0.00254 m

(c) 1.491 x 10^5 mg

(d) 199 g.

Solution: (a) 26 mL
[Note: The last two digits being 55, we first convert first two digits from 25 to 26. For two significant figures the answer is 26 mL.
(b) 2.5 x 10^{-3} m
[Note: Since the third digit 4 is less than 5 and we require two significant figures, we drop the third digit 4 and write 2.5 x 10^{-3} m]

(c) 1.5 x 10^5 mg
(d) 2.0 x 10^2 g

C. Round off each of the following quantities to three significant figures:

a. 1.43 cm^3

b. 458 × 10^2 cm

c. 643 cm^2

d. 0.039 m

e. 6.398 x 10^{-3} km

f. 0.0179 g

g. 79,000 m

h. 42,150

i. 649.85;
j. 23,642,000 mm

k. 0.0041962 kg

Solution: (a) 1.43 cm^3

(b) 458 x 10^2 cm

(c) 643 cm^2

(d) 3.90 × 10^{-2} m

(e) 6.40 x 10-3 km

[Note: In the figure 6.398 x 10^{-3}, the fourth digit is more than 5, hence third digit is increased by 1 which makes second digit 4 and final figure with three significant figures becomes 6.40 x 10^{-3} km.]

(f) 0.0179 or 1.79 × 10^{-2}g

(g) 790 x 10^2 or 7.90 × 104 m

(h) 4.22 x 104

(i) 650 (j) 2.36×10^7 mm

(K) 4:20 10^{-3}kg

D. Express the following sum to appropriate number of significant figures:

a. 2.3×10^3 mL + 4.22×10^4 mL + 9.04×10^3 mL + 8.71×10^5 mL;

b. 319.5 g - 20460 g - 0.0639 g - 45.642 g - 4.173 g

Solution:

(a) 2.3×10^3 mL +4.22×10^4 mL + 9.04×10^3 mL +8.71×10^5 mL

$= (0.23 + 4.22 + 0.904 + 87.1) \times 10^4$

$= 92.454 \times 10^4$ mL

$= 92.5 \times 10^4$ mL

$= 9.2 \times 10^5$ mL

(b) 319.5 g - 20460 g - 0.0639 g - 45.642 g -4.173 g = -20190.38 g

4. Solve the following problems.

A. Express the following quantities in exponential terms.

a. 0.0003498

b. 235.4678

c. 70000.0

d. 1569.00

Solution:

(a) 3.498×10^{-4}

(b) 2.354678×10^2

(c) 7.00000×10^4

(d) 1.56900×10^3

B. Give the number of significant figures each of the following:

(a) 1.230×10^4

(b) 0.002030

(c) 1.23×10^4

(d) 1.89×10^{-4}.

Solution: (a) 4 (b) 4 (c) 3 (d) 3

C. Express the quantities in above (B) with or without exponents as the case may be.

Solution: (a) 12300

(b) 2.030×10^{-3}

(c) 12300

(d) 0.000189

D. Find out the molar masses of the following compounds:

(a) Copper sulphate crystal ($CuSO4.5H_2O$)

(b) Sodium carbonate, decahydrate ($Na_2CO3.10H_2O$)

(c) Mohr's salt [$FeSO (NH4)_2SO4.6H_2O$]
(At. mass: Cu = 63.5; S =32; O=16; H = 1; Na = 23; C = 12; Fe = 56; N = 14)

Solution: (a) Molar mass of Copper sulphate crystal ($CuSO_4.5H_2O$) - Atomic mass of Cu + Atomic mass of S +4 x Atomic mass of O +5

= (2x Atomic mass of H+ Atomic mass of O) = $63.5+32+4 \times 16+5(2 \times 1+16)$

= 63.5+32 +64 +5 (18)

= 249.5 g/mol

(b) Molar mass of Sodium carbonate, decahydrate ($Na_2CO_3.10H_2O$) = 2 x Atomic mass of Na + Atomic mass of C+3 x Atomic mass of O+10

(2 x Atomic mass of H+ Atomic mass of O)

= 2 x 23 +12 + 3 x 16+10 (2 x 1+16)

= 46 +12 +48 + 10 (18)

= 286 g/mol

(c) Molar mass of Mohr's salt [$FeSO_4(NH_4)_2SO_4.6H_2O$]

= Atomic mass of Fe + Atomic mass of S +4 x Atomic mass of O+2
(Atomic mass of N + 4 x Atomic mass of H) + Atomic mass of S +4 x Atomic mass of O+6M
(2 x Atomic mass of H+ Atomic mass of O)

= 56 +32 + 4 x 16+ 2(14+4 × 1) +32 +4 x 16+6 (2×1+16)

= 56 +32 +64 + 2(18) + 32 +64 +6 (18)

= 392 g/mol

E. Work out the percentage composition of constituents elements in the following compounds:

a. Lead phosphate [$Pb_{3,}(PO_4)_2$],

b. Potassium dichromate (K_2Cr_2O),

c. Macrocosmic salt Sodium ammonium hydrogen phosphate, tetrahydrate ($NaNH_4$ $HPO_4.4H_20$)
(At. mass : Pb = 207; P= 31; O = 16; K = 39; Cr= 52; Na = 23; N = 14)

Solution:

(a) Percentage composition of the constituent elements in [$Pb_3(PO_4)_2$]
Molecular mass of Lead phosphate [Pb_3 $(PO_4)_2$] = 3 x Atomic mass of Pb +2 (Atomic mass of P+4 x Atomic mass of O) = 3 x 207 +2 (31 +4 x 16) = 621 +2(31 +64) = 811 g/mol

(1) To determine the percentage composition of Pb Mass of Pb in $Pb_3(PO_4)_2$ = 3 × 207 = 621

$$= \frac{\text{Mass of Pb in } Pb_3(PO_4)_2}{\textit{Molecular mass of } Pb_3(PO_4)_2} \times 100$$

$$= \frac{621}{811} \times 100 = 76.57\%$$

(2) To determine the percentage composition of P = Mass of P in $Pb_3(PO_4)_2$ = 2 x 31 = 62

$$= \frac{\text{Mass of P in } Pb_3(PO_4)_2}{Molecular\ mass\ of\ Pb_3(PO_4)_2} \times 100$$

$$= \frac{62}{811} \times 100 = 7.64\%$$

(3) To determine the percentage composition of O = Mass of O in $Pb_3(PO_4)_2$ = 2 (4 x 16) = 128

$$= \frac{\text{Mass of O } Pb_3(PO_4)_2}{Molecular\ mass\ of\ Pb_3(PO_4)_2} \times 100$$

$$= \frac{128}{811} \times 100 = 15.78\%$$

(b) Percentage composition of the constituent elements in $[K_2Cr_2O_7]$

Molecular mass of $[K_2Cr_2O_7]$

= 2 x Atomic mass of K + 2 x Atomic mass of Cr +7 x Atomic mass of O

= 2 x 39+2 x 52 + 7 x 16 = 294

(1) To determine the percentage composition of K

= Mass of K in $K_2Cr_2O_7$ = 2 x 39 = 78

$$= \frac{\text{Mass of K in } K_2Cr_2O_7}{Molecular\ mass\ of\ K_2Cr_2O_7} \times 100$$

$$= \frac{78}{294} \times 100 = 26.53\%$$

(2) To determine the percentage composition of Cr

= Mass of Cr in $K_2Cr_2O_7$ = 2 x 52 = 104

$$= \frac{\text{Mass of Cr in } K_2Cr_2O_7}{Molecular\ mass\ of\ K_2Cr_2O_7} \times 100$$

$$= \frac{104}{294} \times 100 = 35.37\%$$

(3) To determine the percentage composition of O
$= \text{Mass of O in } K_2Cr_2O_7 = 7 \times 16 = 112$

$$= \frac{\text{Mass of O in } K_2Cr_2O_7}{Molecular\ mass\ of\ K_2Cr_2O_7} \times 100$$

$$= \frac{112}{294} \times 100 = 38.10\%$$

F. Find the percentage composition of constituent green vitriol crystals ($FeSO_4.7H_2O$). Also find out the mass of iron and the water of crystallisation in 4.54 kg of the crystals. (At. mass : Fe = 56; S = 32; O=16)

Solution:
(A) Percentage composition of the constituent elements in $FeSO_4.7H_2O$
Molecular mass of $FeSO_4.7H_20$

= Atomic mass of Fe + Atomic mass of S+ 4 x Atomic mass of O+7(2 x Atomic mass of H+
Atomic mass of O)

$= 56+32 +4 \times 16 +7 (2 \times 1+16)$

= 278 g/mol

(1) To determine the percentage composition of Fe = Mass of Fe in $FeSO_4.7H_2O$ = 56

$$= \frac{\text{Mass of Fe in } FeSO_4.7H_2O}{Molecular\ mass\ of\ FeSO_4.7H_2O} \times 100$$

$$= \frac{56}{278} \times 100 = 20.14\%$$

(2) To determine the percentage composition of O = Mass of O in $FeSO_4.7H_2O$= 11 x 16 = 176

$$= \frac{\text{Mass of O in } FeSO_4.7H_2O}{Molecular\ mass\ of\ FeSO_4.7H_2O} \times 100$$

$$= \frac{176}{278} \times 100 = 63.31\%$$

(3) To determine the percentage composition of S = Mass of S in $FeSO_4.7H_2O$ = 32

$$= \frac{\text{Mass of S in } FeSO_4.7H_2O}{Molecular\ mass\ of\ FeSO_4.7H_2O} \times 100$$

$$= \frac{32}{278} \times 100 = 11.51\%$$

(4) To determine the percentage composition of H =Mass of H in $FeSO_4.7H_2O$ = $14 \times 1 = 14$

$$= \frac{\text{Mass of H in } FeSO_4.7H_2O}{Molecular\ mass\ of\ FeSO_4.7H_2O} \times 100$$

$$= \frac{14}{278} \times 100 = 5.04\%$$

(B) To find out the mass of iron and the water of crystallisation in 4.54 kg of the crystals.

Weight of crystals = 4.54 kg

Mass of iron = ?

278 8 of $FeSO_4.7H_2O$ contains 56 g of Fe

∴ 4.54 kg of $FeSO_4.7H_2O$ contains

$$\frac{4.54 \times 56}{278} = 0.915\ kg\ of\ fe$$

Mass of iron in 4.54 kg 0.915 kg Mass of water of crystallisation =?

278 g of $FeSO_4.7H_2O$ contains $7H_2O$ molecules i.e 7 x 18 g of H_2O = 126 g of H_2O

∴ 4.54 kg of $FeSO_4.7H_2O$ contains

$$\frac{4.54 \times 126}{278}$$

= 2.058 kg of water of crystallisation Mass of water of crystallisation = 2.058 kg

G. The red colour of blood is due to a compound called "haemoglobin". It contains 0.335 % of iron. Four atoms of iron are present in one molecule of haemoglobin. What is its molecular weight ?

Solution: Given:

Atomic mass of Fe = 55.84

Percentage of iron in haemoglobin = 0.335%

One molecule of haemoglobin contains 4 atoms of iron.

Since, 1 atom of Fe = 55.84 g

4 atoms of Fe = 223.36

0.335 g of Fe is present in 100 g of haemoglobin

∴ 223.36 g of Fe is present in

$$\frac{223.36 \times 100}{0.335} ?\ g$$

= 66674.6 g/mol of haemoglobin

Molecular weight of haemoglobin = 66674.6 g/mol

H. A substance, on analysis, gave the following percent composition: Na = 43.4 %, C = 11.3 % and O = 45.3 %. Calculate the empirical formula. (At. mass Na = 23 u, C = 12 u, O = 16 u).

Solution: Given: Na = 43.4%, C = 11.3% and O= 45.3%. To calculate the moles of the constituent elements

$$Moles\ of\ Na = \frac{\%\ of\ Na}{Atomic\ mass\ of\ Na} = \frac{43.3}{23}$$

=1.89

$$Moles\ of\ C = \frac{\%\ of\ c}{Atomic\ mass\ of\ C} = \frac{11.3}{12}$$

=0.941

$$Moles\ of\ O = \frac{\%\ of\ O}{Atomic\ mass\ of\ O} = \frac{45.3}{16}$$

= 2.83

Hence, the ratio of number of moles of Na: C : O is

$$\frac{1.89}{0.941} = 2 : \frac{0.941}{0.941} = 1 : \frac{2.83}{0.941} = 3$$

Hence the empirical formula is $Na_2\ CO_3$.

I. Assuming the atomic weight of a metal M to be 56, find the empirical formula of its oxide containing 70.0% of M.

Solution : Given : Atomic weight of M = 56

Percentage of M = 70.0%

Since, the oxide contains 70.0% of M, the amount of oxygen will be 30.0%

The atomic weight of Oxygen = 16

$$Moles\ of\ M = \frac{\%\ \ of\ M}{Atomic\ mass\ of\ M} = \frac{70.0}{56}$$

=1.25

$$Moles\ of\ O = \frac{\%\ of\ O}{Atomic\ Mass\ of\ O} = \frac{30.0}{16}$$

= 1.875

Hence, the ratio of the number of moles of the metal with oxygen would be,

$$\frac{1.25}{1.25} = 1\ and\ \frac{1.875}{1.25} = 1.5$$

i.e. 2:3

Hence, the empirical formula of the compound would be M_2O_3.

J. 1.00 g of a hydrated salt contains 0.2014 g of iron, 0.1153 g of sulphur, 0.2301 g of oxygen and 0.4532 g of water of crystallisation. Find the empirical formula.

Solution : Given :

Iron=0.2014 g

Sulphur=0.1153 g

Oxygen=0.2301 g

Water of crystallisation = 0 .4532 g

Wt. of hydrated salt= 1.00 g

To calculate the percentage of the different elements.

Percentage of Fe in the salt

$$= \frac{Wt.\ of\ fe}{Wt.\ of\ the\ hydrated\ salt} \times 100$$

$$= \frac{0.2014}{1.00} \times 100 = 20.14\%$$

Percentage of S in the salt

$$= \frac{Wt.of\ S}{Wt.\ of\ the\ hydrated\ salt} \times 100$$

$$= \frac{0.1153}{1.00} \times 100 = 11.53\%$$

Percentage of O in the salt

$$= \frac{Wt.of\ O}{Wt.\ of\ the\ hydrated\ salt} \times 100$$

$$= \frac{0.2301}{1.00} \times 100 = 23.01\%$$

Percentage of H_2O in the salt

$$= \frac{wt.\ of\ H_2O}{wt.of\ the\ hydrated\ salt} \times 100$$

$$= \frac{0.4532}{1.00} \times 100 = 45.32\%$$

To calculate the moles of each element

$$Moles\ of\ Fe = \frac{\%\ of\ Fe}{Atomic\,mass\ of\ Fe} = \frac{20.14}{56} = 0.360$$

$$Moles\ of\ S = \frac{\%\ \ of\ S}{Atomic\ mass\ of\ S} = \frac{11.53}{32} = 0.360$$

$$Moles\ of\ O = \frac{\%\ \ of\ O}{Atomic\ mass\ of\ O} = \frac{23.01}{16} = 1.438$$

$$Moles\ of\ H_2O\ = \frac{\%\ \ of\ H_2O}{Atomic\ mass\ of\ H_2O} = \frac{45.32}{18} = 2.518$$

Hence, the ratio of number of moles of Fe: S : O: H_2O : is

$$\frac{0.360}{0.360} = 1 : \frac{0.360}{0.360} = 1 : \frac{1.438}{0.360} = 3.99 : \frac{2.518}{0.360} = 7$$

Hence the empirical formula is $FeSO_4 7H_2O$.

K. An organic compound containing oxygen, carbon, hydrogen and nitrogen contains 20% carbon, 6.7 % hydrogen and 46.67 % nitrogen. Its molecular mass was found to be 60. Find the molecular formula of the compound.

Solution: Given:

Carbon = 20%

Hydrogen = 6.7%

Nitrogen = 46.67%

Molecular mass = 60

The total percentage of the constitution element

= % Carbon + % Hydrogen + % Nitrogen = 20 +6.7+46.67
= 73.37%

This is less than 100%. Hence the compound contains adequate oxygen so that the total percentage of elements is 100%.
Hence, the percentage of oxygen = 100 - 73.37 = 26.63%
To calculate the moles of the constituent elements

$$Moles\ of\ C = \frac{\%\ of\ N}{Atomic\ mass\ of\ N} = \frac{20}{12} = 1.66$$

$$Moles\ of\ H = \frac{\%\ of\ H}{Atomic\ mass\ of\ H} = \frac{6.7}{1} = 6.7$$

$$Moles\ of\ N = \frac{\%\ of\ N}{Atomic\ mass\ of\ N} = \frac{46.67}{14} = 3.33$$

$$Moles\ of\ O = \frac{\%\ of\ O}{Atomic\ mass\ of\ O} = \frac{26.63}{16} = 1.66$$

Hence, the ratio of the number of moles of C : H : N : O is

$$\frac{1.66}{1.66} = 1 : \frac{6.7}{1.66} = 4.03 : \frac{3.33}{1.66} = 2.00 : \frac{1.66}{1.66} = 1$$

Hence, the empirical formula is CH_4N_2O
Empirical formula mass

= Atomic mass of C = 4 × Atomic mass of H + 2 ×

= Atomic mass of N + Atomic mass of O

= 12 + 4 x 1 + 2 x 14 + 16 = 60
Molar mass = Empirical mass
(Since molar mass = Molecular mass)
Molecular formula = Empirical formula = CH_4N_2O

L. A compound on analysis gave the following percentage composition by mass : H = 9.09; O=36.36; C = 54.55. Mol mass of compound is 88. Find its molecular formula.
Solution: Given:
Carbon = 54.55%
Hydrogen = 9.09%
Oxygen = 36.36%
Molecular mass = 88

$$Moles\ of\ C = \frac{\%\ of\ C}{Atomic\ mass\ of\ C} = \frac{54.55}{12} = 4.54$$

$$Moles\ of\ H = \frac{\%\ of\ H}{Atomic\ mass\ of\ H} = \frac{9.09}{1} = 9.09$$

$$Moles\ of\ O = \frac{\%\ of\ O}{Atomic\ mass\ of\ O} = \frac{36.36}{16} = 2.27$$

Hence, the ratio of the number of moles of C: H : N : O is

$\frac{4.54}{2.27} = 2 : \frac{9.09}{2.27} = 4 : \frac{2.27}{2.27} = 1$
Hence, the empirical formula is CH_4N_2O
Empirical formula mass

= 2 x Atomic mass of C + 4 x Atomic mass of H + Atomic mass of O = 2 × 12 + 4 × 1 + 16 = 44
$r = \frac{Molar\ mass}{Empirical\ formula\ mass} = \frac{88}{44} = 2$
Molecular formula = r × Empirical formula Molecular formula = 2 × C_2H_4O
= $C_4 H_8 O_2$

M. Carbohydrates are compounds containing only carbon, hydrogen and oxygen. When heated in the absence of air, these compounds decompose to form carbon and water. If 310 g of a carbohydrate leave a residue of 124 g of carbon on heating in absence of air, what is the empirical formula of the carbohydrate?

Solution : Given :

Amount of carbohydrate=310 g Amount of carbon residue obtained on heating = 124 g
Amount of H_2O formed Amounts of carbohydrate-Amount of carbon as residue = 310 - 124 = 186 g
Since 18 g of H_2O contains 2 g of H
186g of H_2O will Contain
$\rightarrow \frac{186 \times 2}{18} = 20.66g\ of\ H$
Since 18 g of H_2O contains 16 g of O
186g of H_2O will Contains
$\rightarrow \frac{186 \times 16}{18} = 165.33g\ of\ O$
To determine the moles of the C, H and O in the compound.
$Moles\ of\ C = \frac{\%\ of\ C}{Atomic\ mass\ of\ C} = \frac{124}{12} = 10.33$
$Moles\ of\ H = \frac{\%\ of\ H}{Atomic\ mass\ of\ H} = \frac{20.66}{1} = 20.66$
$Moles\ of\ O = \frac{\%\ of\ O}{Atomic\ mass\ of\ O} = \frac{165.33}{16} = 10.33$
Hence, the ratio of the number of moles of C : H : O is
$\frac{10.33}{10.33} = 1 : \frac{20.66}{10.33} = 2 : \frac{10.33}{10.33} = 1$
Hence, the empirical formula is CH_2O.

N. Write each of the following in exponential notation:

a. 3,672,199

b. 0.000098

c. 0.00461

d. 198.75

Solution: a. 3,672,199 x 10^6

b. 9.8 x 10^{-5}

c. 4.61 x 10^{-3}

d. 1.9875 x 10^2

O. Write each of the following numbers in ordinary decimal form:

a. 3.49 × 10^{-11}

b. 3.75 × 10^{-1}

c. 5.16 × 10^4

d. 43.71 × 10^{-4}

e. 0.011 × 10^{-3}

f. 14.3 × 10^{-2}

g. 0.00477 × 105

h. 5.00858585

Solution:

a. 0.0000000000349

b. 0.375

c. 51600

d. 0.004371

e. 0.000011

f. 0.143

g. 477

h. 5.00858585

P. Perform each of the following calculations. Round off your answers to two digits.

$$(a)\ \frac{1}{3.40 \times 10^{24}}$$

$$(b)\ \frac{33}{9.00 \times 10^{-4}}$$

$$(c)\ \frac{1.4 \times 10^{9}}{(2.77 \times 10^{3})(3.76 \times 10^{5})}$$

$$(d)\ \frac{(4 \times 10^{-3})(9.9 \times 10^{-7})}{(789)(1.002 \times 10^{-10})(0.3 \times 10^{2})}$$

Solution:

$$(a)\ \frac{1}{3.40 \times 10^{24}} = 0.2941 \text{ x } 10^{-24} = 2.9 \times 10^{-25}$$

$$(b)\ \frac{33}{9.00 \times 10^{-4}} = 3.66 \text{ x } 10^{4} = 3.7 \text{ x } 10^{4}$$

$$(c)\ \frac{1.4 \times 10^{9}}{(2.77 \times 10^{3})(3.76 \times 10^{5})} = \frac{1.4 \times 10^{9}}{10.4152 \times 10^{8}}$$

$= 0.1344 \text{ x } 10 = 1.344 = 1.3$

$$(d)\ \frac{(4 \times 10^{-3})(9.9 \times 10^{-7})}{(789)(1.002 \times 10^{-10})(0.3 \times 10^{2})}$$

$0.1669 \text{ x } 10^{-2} = 1.7 \text{ x } 10^{-3}$

Q. Perform each of the following calculations. Round off your answers to three digits.

a. $(3.26\ 10^{4})\ (1.54\ 10^{6})$

$(\mathbf{b}).\ (8.39\ 10^{7})\ (4.53\ 10^{9})$

$$(c)\ \frac{8.94 \times 10^{6}}{4.35 \times 10^{4}}$$

$$(d)\ \frac{(9.28 \times 10^{9})(9.9 \times 10^{-7})}{(511)(2.89 \times 10^{-6})}$$

Solution:

(a) $(3.26 \text{ x } 10^4)\ (1.54 \times 10^6)$
$= 5.0204 \text{ x } 10^{10} = 5.02 \text{ x } 10^{10}$

(b) $(8.39 \text{ x } 107)\ (4.53 \times 10°) = 38.0067 \text{ x } 10^{16} = 3.80 \times 10^{17}$

$(c)\ \dfrac{8.94 \times 10^6}{4.35 \times 10^4} = 2.055 \times 10^2$
$= 2.06 \times 10^2$

$(d)\ \dfrac{(9.82 \times 10^9)(9.9 \times 10^{-7})}{(511)(2.98 \times 10^{-6})}$
$= \dfrac{91.872 \times 10^2}{1522.78 \times 10^{-6}}$
$= 0.06033 \times 100^8$
$= 6.03 \times 10^6$

R. Perform the following operations:

a. $3.971 \text{ x } 10^7 + 1.98 \times 10^4$;

b. $1.05 \text{ x } 10^{-4} - 9.7 \times 10^{-5}$;

c. $4.11 \text{ x } 10^{-3} + 8.1\ 10^{-4}$;

d. $2.12 \text{ x } 10^6 - 3.5 \times 10^5$.

Solution:

(a) $3.971 \text{ x } 10^7 + 1.98 \text{ x } 10^4$
$= 3971 \times 10^4 + 1.98 \text{ x } 10^4$
$= (3971 + 1.98) \times 10^4$
$= 3972.98 \text{ x } 10^4$
$= 3.97298 \text{ x } 10^7$

(b) $1.05 \text{ x } 10^{-4} - 9.7 \text{ x } 10^{-5}$
$= 1.05 \text{ x } 10^{-4} - 0.97 \times 10^{-4}$
$= (1.05-0.97) \times 10^{-4}$
$= 0.08 \text{ x } 10^{-4} = 8.0 \times 10^{-6}$

(c) $4.11 \text{ x } 10^{-3} + 8.1 \text{ x } 10^{-4}$
$= 4.11 \times 10^{-3} + 0.81 \times 10^{-3}$
$= (4.11 + 0.81) \times 10^{-3}$
$= 4.92 \text{ x } 10^{-3}$

(d) $2.12 \times 10^6 - 3.5 \times 10^5$
$= 21.2 \times 10^5 - 3.5 \times 10^5$
$= (21.2 - 3.5) \times 10^5$
$= 17.7 \times 10^5 = 1.77 \times 10^6$

S. A 1.000 mL sample of acetone, a common solvent used as a paint remover, was placed in a small bottle whose mass was known to be 38.0015 g. The following values were obtained when the acetone filled bottle was weighed: 38.7798 g, 38.7795 g and 38.7801 g. How would you characterise the precision and accuracy of these measurements if the actual mass of the acetone was 0.7791 g ?

Solution: Given:

Volume of acetone taken=1.000 mL
Mass of bottle = 38.0015 g Actual mass of acetone = 0.7791 g
To determine the mean values of the weight of acetone (Observed value):
0.7783 g

Weight of acetone + bottle	Weight of bottle	Weight of acetone	Mean of the values of weight of acetone (Observed value)
38.7798 g	38.0015 g	0.7783 g	
38.7795 g	38.0015 g	0.7780 g	0.7789g
38.7801 g	38.0015 g	0.7786 g	

Weight of acetone + bottle	Weight of bottle	Weight of acetone	Mean of the values of weight of acetone (Observed value)
38.7798 g	38.0015 g	0.7783 g	
38.7795 g	38.0015 g	0.7780 g	0.7789g
38.7801 g	38.0015 g	0.7786 g	

Absolute error =Observed value - True value
= 0.7783-0.7791= -0.008

$$Relative\ error = \frac{-0.008}{0.7791} \times 100\% = -0.1027$$

Accuracy of the measurements is 0.1027%.
To determine the average deviation of the measurements:

Readings	**Weight of acetone**	**Mean of the values of weight of acetone**	**Deviation**
1	0.7783 g		0.000
2	0.7780 g	0.7783g	0.0003
3	0.7786 g		0.0003
Mean absolute deviation			$\pm$ 0.0002

Readings	Weight of acetone	Mean of the values of weight of acetone	Deviation
1	0.7783 g	0.7783g	0.000
2	0.7780 g		0.0003
3	0.7786 g		0.0003
Mean absolute deviation			± 0.0002

$$Relative\ Deviation = \frac{Mean\ absolute\ deviation}{Mean} \times 100\%$$

$$= \frac{0.0002}{0.7783} \times 100\% = 0.0257\%$$

Precision of the measurements = 0.0257%

T. Your laboratory partner was given the task of measuring the length of a box (approx 5 in) as accurately as possible, using a metre stick graduated in milimeters. He supplied you with the following measurements:
12.65 cm, 12.6 cm, 12.65 cm, 12.655 cm, 126.55 mm, 12 cm.

a. State which of the measurements you would accept, giving the reason.
(Ans.: 12.6 cm)

b. Give your reason for rejecting each of the others.

Solution:
The measurement 12.6 is acceptable.

Reason: (a) 5 inches is approximately 12.7 cm. The value 12.6 is closer to this value, hence this measurement is acceptable.

(b) Since the length of the box has been measured using a metre stick graduated in milimeters.
The least count of the scale is 0.1 cm. The other measurements cannot be obtained using a scale with a least count of 0.1 cm, hence the other measurements can be rejected.

U. What weight of calcium oxide will be formed on heating 19.3 g of calcium carbonate ?
(At. wt.: Ca = 40; C = 12; O=16)

Solution : Given :
Weight of calcium carbonate = 19.3 g
The balanced chemical equation is,

$$\underset{100g}{CaCO_{3(s)}} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$$

Since 100 g of $CaCO_3$ produces 56 g of CaO

19.3 g of $CaCO_3$ will produce

$$= \frac{19.3 \times 56}{100} = 10.8\, of\ CaO$$

V. The hourly energy requirements of an astronaut can be satisfied by the energy released when 34 grams of sucrose are "burnt" in his body. How many grams of oxygen would be needed to be carried in space capsule to meet his requirement for one day ?

Solution: The balanced chemical equation for the burning of sucrose is,

$$\underset{342g}{C_{12}H_{22}O_{11(s)}} + \underset{\substack{12 \times (32) \\ = 384g}}{12O_{2(g)}} \rightarrow 12CO_{2(g)} + 11H_2O_{(l)}$$

342 g of sucrose requires 384g of oxygen

∴ 34 g of sucrose will require

$$\frac{34 \times 384}{342} = 38.1754 g\ of\ oxygen$$

The hourly requirement of oxygen is 38.175 g

Therefore, the requirement of oxygen for one day will be 38.1754 × 24

=916.209 g

=916.21g

The oxygen requirement for one day = 916.21 g.