Chapter

1

BASIC CONCEPTS

Formula of mass spectrograph:

(The formula for mass charge ratio for mass spectrograph is $m/e = \frac{H^2 r^2}{2E}$, where 'H' is the strength of magnetic field, E is strength of electrical field and r is the radius of curvature of positive ion.

EQUATIONS TO SOLVE THE NUMERICALS

(1) Empirical and Molecular Formula

(i) Average atomic mass of an element

$$= \frac{\text{Sum of multiplication of isotopic mass and relative abundance}}{100}$$

(ii) % composition of a element in a compound

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

(iii) The % of C, H and O in an organic compound is determined by combustion analysis. The formulas are as follows: **(Faisalabad 2013)**

$$\% \text{ of carbon} = \frac{\text{Mass of } CO_2}{\text{Mass of organic compound}} \times \frac{12 \times 100}{44}$$

$$\% \text{ of hydrogen} = \frac{\text{Mass of } H_2O}{\text{Mass of organic compound}} \times \frac{2 \times 100}{18}$$

$$\% \text{ of oxygen} = 100 - (\% \text{ of C} + \% \text{ of H})$$

(iv) Molecular formula = n(empirical formula)

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

(2) Concept of Mole and Avogadro's Number

(i) 1 gram atom of an element $= \frac{\text{Mass of element}}{\text{Atomic mass}}$

(ii) 1 gram molecular mass of a compound $= \frac{\text{Mass of the compound}}{\text{Molar mass}}$

(iii) 1 gram formula mass $= \frac{\text{Mass of the ionic compound}}{\text{Formula mass}}$

(iv) $1 \text{ gram ion} = \frac{\text{Mass of the ion}}{\text{Ionic mass}}$

(v) Number of atoms of an element = Number of gram atoms $\times N_A$

(vi) Number of molecules of a compound = Number of gram mole $\times N_A$

(vii) Number of formula units in an ionic compound = Number of gram formula $\times N_A$

(viii) Number of ions = Number of gram ions $\times N_A$

(ix) $\text{Number of atoms of an element} = \frac{\text{Mass of element} \times N_A}{\text{Atomic mass}}$

(x) $\text{Number of molecules of a compound} = \frac{\text{Mass of compound} \times N_A}{\text{Molar mass}}$

(xi) Number of formula units in an ionic compound $= \frac{\text{Mass of the ionic compound}}{\text{Formula mass}} \times N_A$

(xii) $\text{Number of ions} = \frac{\text{Mass of the ions}}{\text{Ionic mass}} \times N_A$

(xiii) Number of atoms of an element in a molecule = Number of molecules $\times$ number of atoms of that element in molecule.

(xiv) Volume of a gas at S.T.P. = Number of moles of gas $\times$ 22.414 dm^3

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

METHODS TO SOLVE THE NUMERICAL PROBLEMS

(1) Determination of average atomic mass of an element from the % relative abundance and isotopic masses

The % relative abundance of each isotope is multiplied with isotopic mass. These factors are added up for all the isotopes and divided by 100.

(2) Determination of % of an element in a compound

The mass of that element in the compound is divided by the molar mass of the compound and multiplied by 100.

(3) Determination of empirical formula

The % of each element is divided by the atomic mass to get the mole ratios. The mole ratios are divided by the smallest value to get the atomic ratios. If the atomic ratios are whole numbers, then well and good, otherwise multiply with a suitable digit to get the whole numbers. These whole numbers give the empirical formula.

(4) Determination of molecular formula from empirical formula

For this purpose, we should know the molar mass of the compound. Molar mass is divided by empirical formula mass to get the 'n' factor.

n is multiplied with empirical formula to get the molecular formula.

(5) Calculation of mole of a substance

Number of moles of elements are obtained by dividing the mass of the element with atomic mass.

In case of molecular compounds, the mass of the substance is divided by molar mass to get the number of moles of the compound.

(6) Calculation of number of atoms

To calculate the number of atoms of an element, divide the mass of the element by atomic mass and multiply with N_A.

(7) Stoichiometric calculation the number of molecules

To calculate the number of molecules of a compound divide mass of the compound by molar mass and multiply with N_A.

(8) Stoichiometric calculations

In stoichiometric calculations, the mass of the given substance is converted into number of moles. These moles are compared with the moles of that substance whose amount is required. For the purpose of comparison, we take the help of balanced chemical equation.

(9) Calculation of limiting reagent

To calculate the limiting reagent, we first of all calculate the number of moles of all the reactants whose masses are given. These number of moles are compared with number of moles of the required substance. That substance among the reactants, which gives lesser number of moles of the required product is the limiting reagent. The less number of moles of the required product is multiplied by molar mass to get its mass.

(10) Calculation of % yield

In order to calculate the % yield of a chemical reaction we need the actual yield. This is mostly given in the numerical. The theoretical yield is calculated from the balanced chemical equation according to the disciplines of stoichiometry.

TABLES

Natural abundance of some common isotopes

Element	Relative abundances in %	
Hydrogen	$^{1}_{1}H$ = 99.985	$^{2}_{1}H$ = 0.015
Carbon	$^{12}_{6}C$ = 98.893	$^{13}_{6}C$ = 1.107
Nitrogen	$^{14}_{7}N$ = 99.634	$^{15}_{7}N$ = 0.366
Oxygen	$^{16}_{8}O$ = 99.759	$^{17}_{8}O$ = 0.037, $^{18}_{8}O$ = 0.204
Sulphur	$^{32}_{16}S$ = 95.0	$^{33}_{16}S$ = 0.76, $^{34}_{16}S$ = 4.22, $^{36}_{16}S$ = 0.014
Fluorine	$^{19}_{9}F$ = 100	———
Chlorine	$^{35}_{17}Cl$ = 75.53	$^{37}_{17}Cl$ = 24.47
Bromine	$^{79}_{35}Br$ = 50.54	$^{81}_{35}Br$ = 49.49
Iodine	$^{117}_{53}I$ = 100	———

Atomic masses and abundances of several naturally occurring isotopes

Isotope	Mass number	% natural abundance	Relative atomic mass	Average atomic mass of elements
H – 1	1	99.985	1.007825	
H – 2	2	0.015	2.0140	1.00794
C – 12	12	98.893	12 (by definition)	
C – 13	13	1.10	13.003355	12.011
O – 16	16	99.759	15.994915	
O – 17	17	0.038	16.999131	
O – 18	18	0.200	17.999160	15.9994
Cu – 63	63	69.17	62.939598	
Cu – 65	65	30.83	64.927793	63.546
Cs – 133	133	100	132.905329	132.905
Ur – 235	235	0.720	235.043924	
Ur – 238	238	99.280	238.050784	238.0289

DEFINITIONS

(May be used in short questions with examples)

1. % yield:

That yield which is obtained by dividing the actual yield with theoretical yield and multiplying with 100 is called % age. It is calculated for knowing the efficiency of a chemical reaction. Formula; $\%\ \text{yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$

2. Actual yield:

The actual amount of the product which is obtained in a chemical reaction is called actual yield. It is an experimental quantity and is mostly less than the theoretical yield. Theoretical yield is calculated from the balanced chemical reaction. We take the help of stoichiometry for calculating theoretical yield.

3. Atom: **(Rwp 2011)**

The smallest particle of an element which may or may not exist independently is called an atom. The atoms of O, Cu and Au are made up of protons, neutrons and electrons. No doubt, other fundamental particles are also there.

4. Atomic-mass-unit:

It is the mass of 1/12th of one atom of carbon with lightest isotope C – 12. Its value is 1.661×10^{-24} kg. It is calculated with help of Avogadro's number.

5. Average atomic mass:

It is the average of atomic masses of all the isotopes of an element. Every isotope has its own at mass. The average atomic mass is a fractional quantity.

6. Avogadro's number: **(Lahore 2014, Sahiwal 2014)**

It is the number of atoms, molecules, formula units or ions present in one mole of the element, a compound, or an ionic substance is called Avogadro's number. Its value is 6.02×10^{23}.

Formula applied:

$$\text{Average At. mass} = \frac{(\text{mass of } Ne^{20} \times \% \text{ abundance}) + (\text{mass of } Ne^{21} \times \% \text{ abundance}) + (\text{mass of } Ne^{22} \times \% \text{ abundance})}{100}$$

Putting the values

$$\text{Average atomic mass of Neon} = \frac{20 \times 90.92 + 21 \times 0.26 + 22 \times 8.82}{100}$$

$$= \frac{1818.4 + 5.46 + 194.04}{100}$$

$$= \frac{2017.9}{100} = \boxed{20.18 \text{ a.m.u}} \quad \text{Ans.}$$

Therefore the average atomic mass of neon is 20.18 a.m.u

7. Branches of chemistry:

Some important branches of chemistry are as follows:

(i) Physical chemistry (ii) Inorganic chemistry
(iii) Organic chemistry (iv) Analytical chemistry
(v) Bio-Chemistry
(vi) Applied chemistry or Industrial chemistry

The average atomic mass of three isotopes of Ne is as follows.

8. Chemistry:

That branch of science which deals with the structure of matter, composition of matter, changes of matter and laws and principles which govern these changes is called chemistry.

9. Empirical formula: **Lahore (2007)**

That formula of a substance which gives the simple ratio of the elements present in the molecule of a substance. The empirical formula of H_2O_2 is HO, of Na_2O_2 is NaO and of $C_6H_{12}O_6$ is $C_1H_2O_1$.

10. Gram atom:

The atomic mass of an element expressed in grams is called the gram atom of an element. 12 g of carbon, 56 g of Fe and 238 g of U are gram atoms of carbon, iron and uranium respectively.

11. Gram formula: **(Gujranwala 2009)**

The formula mass of an ionic substance expressed in grams is called as gram formula of the substance. 58.5 g of NaCl is gram formula of NaCl. It is not its molecular formula. NaCl does not have molecules.

12. Gram ion:

The ionic mass of an ionic substance expressed in grams is called as gram ion. 17 g is gram ion of $OH^{\ominus}$. Similarly 96 g is g ion of SO_4^{-2}.

13. Gram molar mass: **(Bahawalpur 2008, Gujranwala 2009)**

The molar mass of a substance expressed in grams is called gram molar mass. 342 g is gram molar mass of glucose. 98 g is gram molar mass of H_2SO_4.

14. Heteronuclear diatomic molecule: **(D.G. Khan 2011)**

A molecule having two different atoms of two elements is called heteronuclear diatomic molecule. H – Cl, H – Br, H – I, CO – NO etc are heteronuclear diatomic molecules.

15. Homonuclear diatomic molecule: **(D.G. Khan 2011)**

A molecule which is consisted of two atoms and both are same is called homonuclear diatomic molecule. H_2, O_2, N_2, Cl_2, Br_2, I_2 etc are homonuclear diatomic molecules.

16. Ion: **(Sarg. 2011)**

A positively or negatively charged atom or group of atoms is called an ion. For example $H^{\oplus}$, SO_4^{-2}, $OH^{\ominus}$, CO_3^{-2} etc. are various ions.

17. Isobars:

Those atoms which have the same mass numbers but different atomic numbers. ${}^{36}_{16}S$ and ${}^{36}_{18}Ar$ are isobars of each other.

18. Isoelectronic species:

Those species *i.e.*, atoms, ions or molecules which have the same number of electrons are called isoelectronic species. $Na^{\oplus}$, Mg^{2+}, Al^{3+}, Si^{4+} are isoelectronic species. Similarly C^{-4}, N^{-3}, O^{-2} and F^{-1} are isoelectric to each other.

19. Isotones:

Atoms of the element having same number of neutrons are called isotones. ${}^{14}_{6}C$ and ${}^{15}_{7}N$ have both 8 neutrons and are isotones to each other.

20. Isotopes:

The atoms of an element which have same atomic number, but different mass numbers are called isotopes. ${}^{16}_{8}O$, ${}^{17}_{8}O$, ${}^{18}_{8}O$ are isotopes of oxygen.

21. Limiting reactant:

That reactant which is present in lesser amount and controls the amount of the products formed is called limiting reactant. It is finished earlier.

22. Macromolecule:

Molecules of high molar masses usually more than 10,000 are called macromolecules. The molecules of PVC, starch, and cellulose are macromolecules.

23. Mass spectrometry:

It is a technique in which gas molecules are converted to gaseous ions, which are separated on the basis of their mass to change ratio. It may be for isotopes of an element or to see the fragmentation pattern of a molecule. The isotopes of Ne can be separated by it.

24. Mass spectrum: **(Sarg. 2014)**

It is a graphical representation of the masses and the relative abundances of molecular ions. The positively charged fragments are formed from it by the electron bombardment. It shows peaks. The % of fragments is calculated from the base peak.

25. Molar volume: **Rwp (2012), (D. G. Khan 2014)**

It is the volume of one mole of an ideal gas at standard temperature and pressure. Its value is 22.414 dm^3. H_2, He, CH_4 has 22.4 dm^3 of their volumes, when we take 2 g, 4 g and 16 g of them respectively at S.T.P.

26. Mole: **D.G. Khan (2013), (Lahore 2014)**

The atomic mass of an element, molar mass of a compound, formula mass of an ionic substance and ionic mass of ionic substance expressed in grams is called one mole of the substance. 2 g of H_2, 12 g of C, 17 g of $OH^{\ominus}$, 58.5 g of NaCl are one mole of each. 100 g of diamond will be $\frac{100}{2}$ = 8.33 moles.

27. Molecular formula: **Rwp (2012)**

That formula of a substance which gives us the kinds and total number of atoms present in the molecule of a substance. $KMnO_4$ is molecular formula of potassium per managanate.

28. Molecular ion: **(Sahiwal 2014)**

Any molecular species having positive or negative charge is called molecular ion. $MnO_4^{(2-)}$, $Cr_2O_7^{(2-)}$ are molecules ions. CH_4 is a molecular ion.

29. Molecule: **Bahawalpur (2008), Rwp (2011), (D.G. Khan 2014)**

The smallest particle of a substance which can exist independently is called a molecule. CO_2, NH_3, H_2O show one molecule of each of them.

30. Polyatomic molecule:

A molecule having more than two atoms is called polyatomic molecule. $C_{12}H_{22}O_{11}$ is polyatomic molecule of sugar.

31. Relative abundance of an isotope:

The percentage of an isotope of an element relative to other isotope of the same element is called relative abundance of isotope. ^{35}Cl is 75.53% and ^{36}Cl is 24.47% in nature.

32. Relative atomic mass: **D.G. Khan (2013)**

It is the mass of one atom of an element compared with the mass of one atom of carbon taken as 12. The relative atomic mass of H, O, and U are 1.0794, 15.9994 and 238.024 amu respectively.

33. Stoichiometric amounts:

The amounts of reactants and products in a balanced chemical equation are called stoichiometric amounts. 12 g of C, 32 g of O_2 and 44 g of CO_2 are stoichiometric amounts in the reaction $C + O_2 \longrightarrow CO_2$.

34. Stoichiometric calculations: **Faisalabad (2008)**

Those calculations which are based on stoichiometry are called stoichiometic calculations. These calculation can be done on the basis of mole-mole, mole-wt. mole-volume etc.

35. Stoichiometry: **D.G. Khan (2013)**

That branch of chemistry which deals with the quantitative relationship between reactants and products in a balanced chemical equation is called stoichiometry.

36. Structural formula:

That formula of a substance which gives us the relative position of atoms and groups in the molecule of a substance along with its bond lengths and bond angles is called structural formula. The structural formula of CH_4 is tetrahedral having certain bond lengths and six bond angles as 109.5°.

37. Theoretical yield:

The amount of the product calculated from balanced chemical equation is called theoretical yield. It is calculated from the balanced chemical equations by the basic principles of stoichiometry. In $2H_2 + O_2 \longrightarrow 2H_2O$, 1g of H_2 combines with 16 g of O_2 to give 18 g of H_2O. This 18 g of H_2O is theoretical yield of H_2O.

38. Yield:

The amount of product obtained in a chemical reaction is known as yield of reaction or yield of the product. The yield is of two types i.e., theoretical and actual. Theoretical yield is calculated from balanced chemical equation, but actual is a experimental quantity.

ANSWERS TO THE SHORT QUESTIONS

Atoms, Ions and Molecules

Q.1 What is atomic mass unit?

ایٹم کا ماس یونٹ کیا ہوتا ہے؟ -1

(Multan Board 2005, Sargodha 2008, Fd.abad 2009, Sarg. 2009, Gujranwala 2011)

Ans: It is a unit of mass used for atoms and molecules (ایٹمز اور مالیکیولز کے لئے کمیت کی اکائی ہے) and is equal to the 1/12 of the mass of an atom of carbon –12. It is obtained by dividing the unity (ایک) by Avogadro's number (6.02×10^{23}).

One a.m.u. = 1.6603×10^{-27} kg = 1.6603×10^{-24} g.

Q.2 Whenever an electron is removed from the atom a cation is produced, and the formation of the cation is an endothermic process. Comment.

ایک ایٹم سے جب الیکٹران نکالتے ہیں تو کیٹائن بنتا ہے۔ کیٹائن کا بننا انرجی کو جذب کرنے کا ایک عمل ہے۔ اس پر اپنی رائے دیں۔ -2

Ans: The number of electrons and protons in an atom are equal. When the electron is removed from the atom, energy has to be supplied (دینی پڑتی ہے). So, it is an endothermic process (حرارت جذب کرنے والا عمل). The ion develops the positive charge and is called cation (مثبت بار والا آئن).

Q.3 What do you mean by molecular ions?

مالیکیولر آئن سے کیا مراد ہے؟ -3

(Azad Jammu & Kashmir Board 2005, Sarg. 2009, Sarg. 2010, DG. Khan 2012, Multan 2012, B.pure 2012, B. Pure 2013, Lahore 2014, Rwp. 2014, D.G. Khan 2014)

Ans: Any molecular species (مالیکیول کی طرح کی شے) having positive or negative charge is called molecular ion (مالیکیول کی طرح کا آئن). They are mostly produced when a beam of electrons (الیکٹرانز پر مشتمل شعاع), having energy between 10 to 15 eV is bombarded

(بوچھاڑ کرنا) on molecules of a compound in the vapour phase (بخاراتی حالت میں). The examples may be $CO^{\oplus}$, $N_2^{\oplus}$, $C_2H_4^{\oplus}$, $O_2^{\oplus}$, $CH_4^{\oplus}$.

Q.4 The atomic masses may be in fractions. Why? (Lahore 2004, AJK 2005, Multan 2008, Lahore 2008, Multan 2008, Lahore 2008, Sarg. 2009, B.Pur 2009)

-4 کسی ایٹم کے ایٹمی وزن کی ایک کسری مقدار ہونے کی کیا وجہ ہوتی ہے؟

Ans: Most of the elements have isotopes (آئسوٹوپس). Each isotopes contributes its atomic masses. Hence, the average of atomic masses of isotopes will be definitely in fractions (کُل کا کوئی جزو). Anyhow, the monoisotopic elements have also fractional atomic masses.

Isotopes and their Identification

Q.5 Why positively charged ions of isotopes are passed through magnetic field in the mass spectrometer?

-5 آئسوٹوپس کے مثبت چارج والے آئنز کو ماس سپکٹرومیٹر کے مقناطیسی میدان سے کیوں گزارا جاتا ہے؟

Ans: The positively charged ions bend perpendicular (عمود، جھکنا) to the joining lines of the two poles, when passed through the magnetic field (مقناطیسی میدان). In this way, magnetic field gives semicircular path (آدھا گول راستہ) to ions, scatters (بکھیر دینا) them on the basis of m/e values and compels (مجبور کرنا) them to fall on the electrometer. Electrometer records them.

Q.6 What is the function of electrometer in separation of isotopes in mass spectrometer? (Gujranwala 2008, Fd.Abad 2009, M.pure 2012, Multan 2013)

-6 ماس سپکٹرومیٹر آئسوٹوپس کو علیحدہ کرتا ہے۔ اس میں electrometer کا کیا کام ہے؟

Ans: When positively charged ions of different isotopes fall upon the electrometer (الیکٹران کے چارج کو ریکارڈ کرنے والا), then current is produced proportional (تناسب) to the number of ions falling upon that. In this way, the relative abundance (اضافی کثرت) of these isotopes can be recorded, in the form of peaks on the graph.

Q.7 What is mass spectrum (کمیت کے حوالے سے حاصل شدہ سپکٹرم) or mass spectrograph? (Guj. 2013)

-7 ماس سپکٹرم یا ماس سپکٹروگراف کیا ہوتا ہے؟

Ans: It is a graph which is plotted between m/e of the positive ions on x-axis and the relative abundance (اضافی کثرت) of the isotopes (% age) on y-axis. This graph is plotted with the electrometer and system is computerized.

Q.8 How does the change of either electric field or magnetic field help us to record the isotopic separation by mass spectrometer? (Multan 2013)

-8 ماس سپکٹرومیٹر میں برقی اور مقناطیسی میدانوں کو تبدیل کر کے ہم کس طرح آئسوٹوپس کو الگ الگ کر سکتے ہیں؟

Ans: Since $\frac{m}{e} = \frac{H^2r^2}{2E}$, when the magnetic field H increases, radius of curvature (گولائی کا نصف قطر) r decreases and a particular ion falls at different position on

electrometer. Similarly, the increase of electrical field E increases r. The change of r means that we can do the separation of ions (گولائی کے نصف قطر میں تبدیلی آئنز کو علیحدہ کر سکتی ہے).

Q.9 Why the isotopes have the same chemical properties?

9- آئسوٹوپس کی کیمیائی صفات ایک جیسی کیوں ہیں؟

(Rwp-2007, Rwp. 2009, Lahore 2012)

Ans: The isotopes of an element have same the number of electrons in different orbitals (مختلف آربیٹالز). They have the same number of unpaired electrons (بغیر جوڑا بنے الیکٹرانز) in the outermost (سب سے باہر والے) orbitals. The number of unpaired electrons in the outermost orbitals determine (فیصلہ کرنا) the chemical properties of elements.

Q.10 One hundred ions of $NO_3^{\ominus}$ and fifty ions of SO_4^{-2} have equal number of charges, but they have unequal masses and unequal number of atoms in them individually. Justify it.

10- ایک سو $NO_3^{\ominus}$ آئنز اور پچاس عدد SO_4^{-2} آئنز میں چارجز کی تعداد برابر ہے لیکن ان کے ماسز اور ایٹمز کی تعداد برابر نہیں ہے۔ اس کو صحیح ثابت کریں۔

Ans: 100 $NO_3^{\ominus}$ ions have 100 negative charges. 50 SO_4^{-2} have 100 negative charges. Their ionic masses are respectively (بالترتیب) 62 and 96 g/mole. So even if the number of ions are same, then they have unequal masses (ماسز برابر نہ ہوں گی). Each ion has different number of atoms in them, so there will be 400 atoms in 100 NO_3^{-1} and 250 atoms in 50 SO_4^{-2}.

Q.11 In the mass spectrum of isotopes of oxygen, the highest peak is due to $^{16}_{8}O$, the second highest is of $_8O^{18}$ while $_8O^{17}$ has the smallest peak. Why?

11- آکسیجن کے ماس سپکٹرم میں $^{16}_{8}O$ کی peak کی بلندی سب سے زیادہ، $_8O^{18}$ کی دوسرے نمبر پر اور $_8O^{17}$ کی سب سے چھوٹی ہے۔ کیوں؟

Ans: The relative abundance of various (مختلف) isotope is determined by the height of the peak (چوٹی کی بلندی) in mass spectrometer. $_8O^{16}$ has 99.759 % of relative abundance. $_8O^{18}$ has 0.204 % while $_8O^{17}$ has 0.037 % of relative abundance. So, the height of the peak due to $_8O^{17}$ will be smallest (اس آئن کی چوٹی کی بلندی سب سے کم ہو گی جس کی % سب سے کم ہو گی).

Q.12 The ratio of heights of the peaks for the isotopes of chlorine is 3:1, but in case of bromine two peaks of equal heights are obtained. Why?

12- Cl کے آئسوٹوپس کی peaks کی بلندیاں 1 : 3 کی نسبت سے ہیں جبکہ Br_2 کے لیے برابر ہیں۔ کیوں؟

Ans: The height of the peak depends upon the relative abundance of isotopes (آئسوٹوپس کی اضافی کثرت) of that element. Chlorine has two isotopes $_{17}Cl^{35}$ = 75.53 % and $_{17}Cl^{36}$ = 24.47 %. The intensities of these two peaks (دو چوٹیوں کی بلندی کی شدت) are in the ratio of 3:1.

In the case of bromine the relative abundance are 50.54 % for $_{35}Br^{80}$ and 49.46 % for $_{35}Br^{81}$. These two percentages are almost 50:50.

Q.13 What is the reason for two equally strong peaks in the mass spectrum for bromine ; while for iodine only one peak at 127 a.m.u is indicated? (Bahawalpur Board 2007, B.P. 2008)

-13 Br_2 کے ماس سپکٹرم میں دو عدد peaks کی بلندیاں برابر ہیں۔ جبکہ I_2 کی صرف ایک ہی peak ہے۔ کیا وجہ ہے؟

Ans. Bromine has two isotopes, which are almost equally abundant (کثرت کا برابر ہونا). Therefore, mass spectrometer gives two equally strong peaks. Iodine is mono-isotopic (ایک ہی آئسوٹوپ ہے), so only one peak is obtained in the mass spectrum.

Q.14 No individual neon atom in the sample of the element has a mass of 20.18 a.m.u. Why? (Mirpur-2006, Model Paper-2006-07, F.Abad 2007, B.P. 2008, Multan 2012, Bahawalpur 2012, F. Abad 2012, B. Pure 2013, Guj. 2013, Lhr 2014, Guj. 2014)

-14 Ne کے کسی ایٹم کا ایٹمی وزن 20.18 amu نہیں ہوتا۔ کیوں؟

Ans. Neon has three isotopes of atomic masses 20, 21 and 22 with relative abundances (اضافی کثریت) as 90.92%, 0.26% and 8.82%.

The relative atomic mass of neon, comes out to be 20.18 a.m.u. So 20.18 a.m.u. is the average atomic mass (اوسط ایٹمی کمیت) of all the three isotopes and there is no atom of Ne with this atomic mass.

Empirical And Molecular Formula

Q.15 Define empirical formula and how it is related to molecular formula?

(Faisalabad Board 2004, Lahore 2007, Multan 2008, Multan 2008, B.Pur 2009, Multan 2011, F. Abad 2012, Guj. 2013, D.G. Khan 2013, Multan 2013, D.G. Khan 2014, Rwp. 2014, Multan 2014, Guj. 2014, F. Abad 2014, B. Pur 2014)

-15 ایمپریکل فارمولا کی تعریف کریں۔ یہ مالیکیولر فارمولا سے کس طرح تعلق رکھتا ہے؟

Ans: The simplest (سادہ ترین) formula of a substance which tells us the ratio of atoms (ایٹمز کی نسبت) in the molecule of a substance is called empirical formula.

M.F. = n(E.F.).

E.F. of benzene is CH, but M.F is C_6H_6. Therefore M.F. = 6(E.F.)

H_2O, CO_2, H_2SO_4, $KMnO_4$ have same molecular are empirical formulas.

Q.16 One mole of H_2SO_4 should completely react with two moles of NaOH. How does Avogadro's number help to explain it?(Fed-2006, F.D-2006)

-16 H_2SO_4 کا ایک مول NaOH کے دو مولز سے ری ایکشن کرتا ہے۔ ایوگیڈروز کا نمبر کس طرح اس کو سمجھنے میں ہماری مدد کرتا ہے۔

Ans: The balanced chemical equation between H_2SO_4 and NaOH.

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

One mole of H_2SO_4 releases (آزاد کرنا) two moles of H^+ in the solution. It needs two moles of OH^- ions for complete neutralization (مکمل تعدیل کے لئے).

Q.17 NaCl has 58.5 amu as formula mass and not the molecular mass. Justify it. (Rwp. 2005, Rwp. 2007, Multan 2009, Sarg. 2009)

-17 NaCl کا فارمولا ماس 58.5 amu ہے۔ یہ اس کا مالیکیولر ماس نہیں کہلاتا صحیح ثابت کریں۔

Ans: NaCl is a ionic compound. it has no molecules in the crystal structure (قلمی ساخت میں مالیکیولز نہیں ہوتے). So, 58.5 amu cannot be called as its molecular mass.

Its formula is NaCl because for one $Na^{\oplus}$, there is one $Cl^{\ominus}$ in the crystal. Here, 58.5 amu is its formula mass.

Q.18 Molecular formula is multiple of empirical formula. Give an example. **(Lahore Board 2005, Lahore 2012, Multan 2013)**

-18 مالیکیولر فارمولا اِمپریکل فارمولا کا سادہ حاصل ضرب ہے۔ ایک مثال سے واضح کریں۔

Ans: The empirical formula is the simplest whole number ratio of atoms of different elements present in a compound. Molecular formula tells us the actual number of atoms of each element in a molecule. Hence the empirical formula has to be multiplied (ضرب دینا) with a suitable digit (مناسب ہندسے سے) to get the molecular formula.

Benzene, $C_6H_6 = 6(CH)$, Ethane, $C_2H_6 = 2(CH_3)$

Concept of Mole and Avogadro's Number

Q.19 Calculate the mass in grams of 10^{-3} moles of water. **(Rawalpindi Board 2005), (D.G. Khan 2011), (Rwp. 2011)**

-19 10^{-3} مولز پانی کا وزن معلوم کریں۔

Ans: Mass of water = No. of moles × molar mass

$= 10^{-3} \times 18\ g = 1.8 \times 10^{-2}\ g$

$= 0.018\ g$

Q.20 Mg atom is twice heavier than that of carbon atom. How?

(Rawalpindi 2005, Lahore 2007, Rawalpindi 2008, Rwp. 2008, Rwp. 2010), (Lahore 2011, Gujranwala 2011, Rwp. 2013, Sarg. 2014, Lhr. 2014, Guj. 2014)

-20 Mg کا ایک ایٹم Na کے ایک ایٹم سے دگنا بھاری ہے۔ کیسے؟

Ans: The atomic mass of Mg is 24 g mol^{-1} which is twice (دوگنا) in mass as compared to the atomic mass of C *i.e.* 12 g mol^{-1}. So Mg atom is twice heavier (بھاری ہونا) than that of carbon.

Q.21 180 grams of glucose and 342 grams of sucrose have same number of molecules, but different number of atoms present in them. Justify it.

(Lahore-2006, Faisalabad 2008, Bahawalpur 2008, Guj 2012, F. Abad 2014, Lhr 2014)

-21 180 گرام گلوکوز اور 342 گرام چینی میں مالیکیولز کی تعداد برابر ہے لیکن ان میں ایٹمز کی تعداد مختلف ہے۔ اس کو صحیح ثابت کریں۔

Ans: 180 grams of glucose ($C_6H_{12}O_6$), and 342 grams of sucrose ($C_{12}H_{22}O_{11}$) are one mole of each. One mole of various (مختلف) substances contain equal number of molecules i.e. 6.02×10^{23}.

One molecule of $C_6H_{12}O_6$ has 24 atoms. The total number of atoms of glucose in one mole is $24 \times 6.02 \times 10^{23}$. One molecule of $C_{12}H_{22}O_{11}$ has 45 atoms. The total number of atoms of sucrose in one mole of sucrose is $45 \times 6.02 \times 10^{23}$. It means that one mole of both glucose and sucrose will have different number of atoms.

Q.22 What is the number of $H^{\oplus}$ ions in 9.8 g of H_3PO_4? **(Fd.Abad 2009)**

-22 H_3PO_4 9.8 g میں $H^{\oplus}$ کی تعداد کیا ہے؟

Ans: When one molecule of H_2SO_4 ionizes (آئنز بناتا ہے), it produces two $H^{\oplus}$ and one $SO_4^{(2-)}$ ion. Hydrogen ion contains +1 charge while sulphate ion has –2 charge. The ions produced by complete ionization (مکمل آئنز میں تبدیلی) of 4.9 grams of H_2SO_4 in water will have equal +ve and –ve charges but the number of $H^{\oplus}$ ions is twice than number of negatively charged sulphate ions.

Similarly 1 mg of K_2CrO_4 will have thrice the number of ions ($2K^+ + CrO_4^{(-2)}$). If the number of formula units is X then ions will be 3X.

Q.28 96 gm of SO_4^{-2} has Avogadro's number of SO_4^{-2} ions, twice the Avogadro's numbers of negative charges, $4N_A$ as oxygen atoms and 5 N_A as total number of atoms. How?

-28 96 گرام $SO_4^{(-2)}$ میں N_A $SO_4^{(-2)}$ ہیں۔ $2N_A$ منفی چارجز ہیں $4N_A$ آکسیجن کے ایٹمز ہیں اور $5N_A$ کل ایٹمز کی تعداد ہے۔ کیسے؟ یاد رکھیں N_A کا مطلب ایوگیڈروز نمبر ہے۔

Ans: The ionic mass of $SO_4^{(-2)}$ is 96 a.m.u. So, in 96 gms of $SO_4^{(-2)}$, there is one mole of $SO_4^{(-2)}$ and one mole of the species have Avogadro's number of particles. i.e., 6.02×10^{23}.

Each $SO_4^{(-2)}$ ion has two negative charges, so total negative charges are $2N_A$.

Each $SO_4^{(-2)}$ ions has four oxygen atoms, so, there are total $4N_A$ oxygen atoms in 96 gms of $SO_4^{(-2)}$. Each $SO_4^{(-2)}$ has five atoms. So, one mole of $SO_4^{(-2)}$ has total $5N_A$ atoms.

Q.29 One mole of H_2O has two moles of bonds, three moles of atoms, ten moles of electrons and twenty-eight moles of the total fundamental particles present in it. Justify.

-29 ایک مول پانی میں دو مولز بانڈز ہیں۔ تین مولز ایٹمز ہیں۔ دس مولز الیکٹرانز ہیں اور 28 مولز ٹوٹل بنیادی ذرات ہیں۔ ثابت کریں۔

Ans: The molecule of H – O – H has two bonds in it. Therefore, one mole of H_2O contains two moles of bonds and three moles of atoms. Similarly, there are eight electrons in oxygen and one electron in each of the two H atoms. One molecule of H_2O has 10 electrons. So one mole of water contains 10 moles of electrons. There are 28 moles of all fundamental particles (بنیادی ذرات) in one mole of water 10 moles of electrons, 10 moles of protons, 8 moles of neutrons.

Q.30 Prove that one mole of each N_2, CO_2 and H_2 contain equal number of molecules. (Multan 2004, Sargodha 2008, Lahore 2008, Lahore 2009, Multan 2009)

-30 ثابت کریں کہ N_2, CO_2 اور H_2 کے ایک ایک مول میں مالیکیولز کی تعداد برابر ہے۔

Ans: This is according to Avogadro's law that one mole of a substance has 6.02×10^{23} molecules in it. So, 28 g of H_2, 44 g of CO_2 and 2 g of H_2 have 6.02×10^{23} molecules in each.

Q.31 N_2 and CO have same number of electrons, protons and neutrons. Justify. (B.Pur-2006, Rwp-2007, B.Pur-2007, Guj. 2008, Faisalabad 2010, Sarg. 2011, M. Pure 2012, Guj. 2012, D. G Khan 2012, Guj. 2013, Faisalabad 2013, D.G. Khan 2013, B. Pur 2014, Guj. 2014, B. Pur 2014)

Ans: The molar mass of H_3PO_4 is 98 amu 9.8 g of H_3PO_4 is 0.1 moles. 1 molecule of H_3PO_4 has $3H^{\oplus}$. Hence the number of H^+ ions in 0.1 moles of H_3PO_4 is 1/10th of Avogadro's number multiplied with 3 *i.e.*, $3 \times 6.02 \times 10^{22} = 1.806 \times 10^{23}$.

Q.23 What is the mass and number of molecules of CO_2 in 0.224 dm^3 of CO_2 at S.T.P?

-23 کاربن ڈائی آکسائیڈ کے 0.224 dm^3 کا S.T.P پر کتنا وزن اور کتنے مالیکیولز کی تعداد ہوتی ہے؟

Ans: 0.224 is 1/100th of one molar volume at S.T.P. Hence the number of molecules will be 1/100th (سوواں حصہ) of Avogadro's number *i.e.*, 6.02×10^{21}, and mass will be 44/100 = 0.44 g.

Q.24 Define Avogadro's number? How does it relate to the masses of chemical substances? (Gujranwala 2005, Rwp. 2009, B.P 2012, D.G. Khan 2013, B. Pur 2014, Multan 2014)

-24 ایوگیڈروز نمبر کی تعریف کریں۔ یہ کیمیکلز کے کمیت کے ساتھ کس طرح منسلک ہے؟

Ans: It is the number of atoms, molecules or ions in one gram mole of an element, compound and ion. One gram mole (مولر ماس کو گرام میں لینے سے) of the substance is the atomic mass, molar mass or ionic mass taken in grams. It means that the number of the species (چیزوں) is related with the masses (کمیتیں) of the species. 23 g of Na and 238 g of U have equal number of atoms in them.

Q.25 What is the number of covalent bonds in 8 g of CH_4? (B.P. 2008)

-25 8 گرام CH_4 میں کوویلنٹ بانڈز کی تعداد کیا ہے؟

Ans: 8 g of CH_4 is 0.5 moles of CH_4. It has 3.01×10^{23} molecules of CH_4. Each molecule has four bonds, so the total number of bonds is $4 \times 3.01 \times 10^{23} = 12.04 \times 10^{23} = 1.204 \times 10^{24}$.

Q.26 Two grams of H_2, 16g of CH_4 and 44g of CO_2 occupy separately the volumes of 22.414 dm^3 at STP although the sizes and masses of molecules of three gases are very different from each other. Give reason. (Model Paper-2006-07, Lahore 2012)

-26 کیا وجہ ہے کہ 2 گرام H_2، 16 گرام CH_4، 44 گرام CO_2 کی S.T.P پر 22.414 لیٹرز کی برابر جسامت رکھتی ہیں۔ حالانکہ ان گیسوں کے مالیکیولز کی سائنز اور کمیتیں مختلف ہیں۔

Ans: One mole of an ideal gas at S.T.P occupies (جگہ گھیرتا) a volume of 22.414 dm^3. Sizes and masses of molecules of different gases do not affect the volume. Normally (عام طور پر) it is known that in the gaseous state, the distance between the molecules is 300 times greater than their diameter (قطر). Therefore two grams of H_2, 16g of CH_4 and 44g of CO_2 (1 mole of each gas) separately (الگ الگ) occupy a volume of 22.4 dm^3. This is called molar volume (V_m).

Q.27 4.9 g of H_2SO_4, when completely ionized in water have equal number of positive and negative charges, but number of positively charged ions are twice the number of negatively charged ions. Give reason. (Lahore 2012, Sarg. 2014)

-27 4.9 گرام H_2SO_4 جب پانی میں مکمل طور پر آئنز میں تبدیل ہوتا ہے تو مثبت اور منفی چارجز کی تعداد برابر ہوتی ہے لیکن مثبت آئنز کی تعداد منفی آئنز کی تعداد سے دگنی ہے۔ سبب بتائیں۔

Ans: When one molecule of H_2SO_4 ionizes (آئنز بناتا ہے), it produces two $H^{\oplus}$ and one $SO_4^{(2-)}$ ion. Hydrogen ion contains +1 charge while sulphate ion has –2 charge. The ions produced by complete ionization (مکمل آئنز میں تبدیلی) of 4.9 grams of H_2SO_4 in water will have equal +ve and –ve charges but the number of $H^{\oplus}$ ions is twice than number of negatively charged sulphate ions.

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Ans: This is according to Avogadro's law that one mole of a substance has 6.02×10^{23} molecules in it. So, 28 g of H_2, 44 g of CO_2 and 2 g of H_2 have 6.02×10^{23} molecules in each.

Q.31 N_2 and CO have same number of electrons, protons and neutrons. Justify. (B.Pur-2006, Rwp-2007, B.Pur-2007, Guj. 2008, Faisalabad 2010, Sarg. 2011, M. Pure 2012, Guj. 2012, D. G Khan 2012, Guj. 2013, Faisalabad 2013, D.G. Khan 2013, B. Pur 2014, Guj. 2014, B. Pur 2014)

-31 N_2, CO میں $e^{\ominus}$, $p^{\oplus}$ اور نیوٹرانز کی تعداد برابر ہے۔ صحیح ثابت کریں۔

Ans: No. of electrons in N_2 = 7 + 7 = 14, number of protons in N_2 = 7 + 7 = 14 and number of neutrons (14 – 7) = 7 + 7 = 14.

In CO, number of electrons in C = 6, number of electrons in O = 8, total number of electrons = 6 + 8 = 14.

Number of protons in C = 6, number of protons in O = 8, total number of protons = 6 + 8 = 14.

Number of neutrons in C = 6, number of neutrons in O = 8, total number of neutrons = 6 + 8 = 14.

Q.32 Calculate the mass in kg of 2.6×10^{23} molecules of SO_2. (Faisalabad 2010)

-32 2.6×10^{23} کے SO_2 مالیکیولز کا وزن دریافت کریں۔

Ans: 6.02×10^{23} molecules of SO_2 have mass = 64 gm

1 molecule of SO_2 has mass = 64 gm

6.02×10^{23} molecules of SO_2 have mass = $\frac{64}{6.02 \times 10^{23}}$

2.6×10^{23} molecules of SO_2 have mass = $\frac{64 \times 2.6 \times 10^{23}}{6.02 \times 10^{23}}$

$= \frac{64 \times 2.6}{6.02} = 27.641g$

Q.33 One mole of H_2SO_4 should completely react with 2 moles of NaOH. Justify it. (Rwp. 2009)

-33 1 مول H_2SO_4 اور 2 مول NaOH آپس میں مکمل طور پر ری ایکشن کر لیتے ہیں۔ صحیح ثابت کریں۔

Ans: According to balanced equation. 1 mole of H_2SO_4 give $2N_A$ H^+ ions. So 2 moles of NaOH are needed to give $2N_A$ $AH^{\ominus}$.

Stoichiometry, Limiting Reagent and Yield

Q.34 How can the efficiency of a chemical reaction be expressed?
(Gujranwala Board 2005, Lahore 2007, Lahore 2014)

-34 ایک ری ایکشن کی کارکردگی کیسے ظاہر کی جاسکتی ہے؟

Ans: The efficiency (کارکردگی) of a chemical reaction can be expressed (ظاہر کرنا) by the percentage yield (پیداوار%) of the chemical reaction. Percentage yield depends upon the ratio of actual yield (اصلی پیداوار) and theoretical yield (علمی پیداوار)

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 10$$

Q.35 11 g of carbon is reacted with 32 g of oxygen to give CO_2. Which is the limiting reactant. (Multan Board 2005, Multan 2008, B. Pur 2009, F. Abad 2013)

$$C + O_2 \longrightarrow CO_2$$

-35 11 گرام کاربن کو 32 گرام آکسیجن سے ری ایکشن کرنے کو کہا جاتا ہے۔ اِس میں کونسا Limiting ری ایکٹنٹ ہے؟

Ans: According to the balanced chemical equation, 12 g of carbon should completely react (مکمل طور پر تعامل کرنا چاہیے) with 32 g of oxygen to gives 44 grams of CO_2. So 32

grams of oxygen will be in excess (فالتو ہونا) in comparison (مقابلتاً) to 11 grams of carbon. So carbon is the limiting (کم رہنے والا) reactant.

Q.36 Concept of limiting reactant is not applicable to the reversible reactions. Explain it. **(Lahore Board 2005, Faisalabad 2007, Fd.Abad 2009)**

-36 Limitingری ایکٹنٹ کا ادراک اُن ری ایکشنز پر لاگو نہیں ہوتا جو پلٹا کھا سکتے ہیں۔ کیوں؟

Ans: In the case of reversible reactions (پلٹا کھانے والے تعاملات), certain amounts of the reactants are left behind at the equilibrium stage. In the case of reactions having one of the substance as limiting one of the substance has to be consumed completely. So, the reversible reactions donot help us to understand (سمجھنا) the concept (ادراک) of limiting reactant (ری ایکشن میں عمل کرنے والا جو کم رہ جائے).

Q.37 Distinguish between actual and theoretical yield. Calculate efficiency of a reaction. **(B.Pur Board 2005, Multan-2006, Mirpur-2006, Multan 2007, Rwp. 2009, Lahore 2010, B. Pure 2013, Multan 2014, B. Pur 2014)**

-37 کسی تعامل میں حقیقی اور علمی پیداوار میں پہچان کریں۔ ایک ری ایکشن کی ایفی شنسی کیا ہوتی ہے؟

Ans: The amount (مقدار) of the product that is actually (حقیقتاً) obtained in a chemical reaction is called actual yield. The amount of product calculated from balanced chemical equation is called theoretical yield.

(جو لکھی ہوئی کیمیائی مساوات سے پیداوار نکالی جاتی ہے وہ علمی پیداوار کہلائے گی۔)

The efficiency (کارکردگی) of the chemical reaction is calculated from the percentage yield

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

Q.38 What is limiting reagent? How it helps to control the reaction?
(Lah 2005, Guj. 2006, B. Pur-2006, Rwp-2007, F. Abad-2007, Guj. 2009, Multan 2009, Sarg. 2010, Guj. 2010, Rwp. 2010, Faisalabad 2011, Rwp. 2013, Sarg. 2014, F. Abad. 2014, Guj. 2014)

-38 Limitingری ایکٹنٹ کیا ہوتا ہے؟ یہ کسی ری ایکشن کو کس طرح کنٹرول کرتا ہے؟

Ans: A limiting reactant is that one which is in lesser quantity and it is consumed earlier (پہلے ختم ہو جاتا ہے). Whenever, it is consumed then the further formation of the product stops, although the excess reagent is lying in the vessel. If the limiting reagent is not available (میسر نہیں ہے) to the excess reagent then product cannot be formed further.

Q.39 Why the experimental yield is mostly less than the theoretical yield?
(Mirpur 2004, Sargodha 2005, Model Paper-2006-07, B.P-2007, Guj. 2008, B.P. 2008, Rwp. 2010, Multan 2011, Bahawalpur 2011, Multan 2011, F. abad 2012, Guj. 2012, Rwp. 2012, Guj. 2013, Multan 2013, D.G. Khan 2014, B. Pur 2014)

-39 تجرباتی پیداوار اکثر علمی پیداوار سے کیوں کم ہوتی ہے؟

Ans: Experimental yield is mostly less than theoretical yield due to the following reasons:

(1) Mechanical loss of products due to:
   (a) filtration (b) separation by distillation
   (c) separating by separating funnel (علیحدہ کرنے والی قیف)

(d) washing (e) drying (f) crystallization
(2) Side reaction. (3) Reversibility of reaction.

Q.40 Law of conservation of mass (قانون بقائے مادہ) has to be obeyed in stiochiometric calculations. (Lahore 2013)

-40 سٹائیکیو میٹری کے اصولوں کے مطابق حساب کرنے کے دوران قانون بقائے مادہ کا کیوں خیال رکھنا پڑتا ہے؟

Ans: Total mass of reactants must be equal to total mass of products in a chemical reaction. So, the calculation (حساب لگانا) can be done for relative amounts of reactants and products in a chemical reaction.

Q.41 Define storchiometry. What are its basic assumptions?
(Faisalabad 2010, Guj. 2014, Lahore 2014, Lahore 2014)

-41 سٹائیکیو میٹری کی تعریف کریں۔اس کے بنیادی مفروضے کیا ہیں؟

Ans: The branch of chemistry which deals with quantitative relationships (مقداری تعلقات) between reactants and products in a balanced chemical equation (کیمیائی تعامل کی متوازن مساوات) is called stoichiometry.

To perform stoichiometric calculations following assumptions are necessary:

(i) All the reactants are completely converted into products.
(ii) No side reaction is taking place.
(iii) Law of conservation of mass and law of definite proportions are obeyed.

Q.42 The reaction of combustion in atmosphere consumes O_2, which is in excess. The O_2 or material being burnt?
(D. G. Khan 2012, Sarg. 2014, B. Pur 2014, B. Pur 2014, D.G. Khan 2014, Rwp. 2014)

-42 فضا میں چیزوں کے جلنے کا عمل O_2 کی موجودگی میں ہوتا ہے۔جو زیادہ مقدار میں ہوا میں موجود ہے۔بتایئے O_2 یا ملنے والا میٹریل limiting reactant ہے؟

Ans: Since O_2 is always excess and is left over in the atmosphere. A small part of total O_2 can burn the whole material. So burning material is limiting reactant. This is one of the best example of a reaction which is frequent in our surrounding in which one substance is limiting. One of the reactants should be taken in large excess to consume other material completely.

Chapter 2

EXPERIMENTAL TECHNIQUES IN CHEMISTRY

DEFINITIONS

(May be used in short questions with examples)

(1) Analysis:

The process of determination of composition of a substance quantitatively or qualitatively is called analysis. The analysis can be volumetric or grammetric. Acid-base titration is quantitative while salt analysis is qualitative analysis.

(2) Analyte:

That sample of the substance which is being analysed is called analyte. Acid or base whose molality is being determined by volumetric analysis is analyte.

(3) Analytical chemistry:

That branch of chemistry which deals with the quantitative and qualitative analysis is called analytical chemistry. Quantitative analysis is volumetric and grammetric. Qualitative analysis is salt analysis.

(4) Chromatographic tank:

That vessel in which the mobile phase is stored is called chromatographic tank.

(5) Crystal:

It is a discrete solid particle which is bounded by definite faces. These faces intersect at definite angles and show certain symmetry characteristics. Unit cell represents the picture of a crystal.

(6) Crystallization: **(Guj. 2008, F. Abad 2008, Lahore 2014)**

It is the removal of a solid from solution by increasing its concentration above the saturation point in such a way that the excessive solid separates out in the form of crystals. The crystalline substance is though to be pure. Sugar, we eat is in the form of crystals.

(7) Distribution coefficient:

It is a constant which is a ratio of concentration of a solute in two solvents under the given conditions. It is a constant quantity under the given conditions for a system.

(8) Distribution law: **(D. G. Khan 2012, D.G. Khan 2014, Rwp. 2014, B. Pur 2014)**

According to this law a substance is distributed between two immiscible liquids in such a way that its concentration in two liquids is constant. It is independent of the amount of the solvent added. It gives distribution coefficient and is represented by K_D.

(9) Filter medium: **(Rwp. 2012)**

That porous material which is used for filtration of a solid substance from a liquid is called filter medium. Filter paper is the best example of a filter medium.

(10) Filter:

Any water insoluble porous material which has a reasonable degree of rigidity and can be used to separate the components from each other is called filter. Filter paper is a best filter.

(11) Filtrate: **(Rwp. 2012)**

That liquid which is collected after passing through the filter medium is called filtrate. It is collected in a beaker or flask in the laboratory.

(12) Fluted filter paper:

That filter paper which has a fan-like arrangement with alternate elevations and depressions at various folds, and is used to increase the rate of filtration is called fluted filter paper.

(13) Gooch crucible: **(Lahore 2012)**

A crucible which is made up of ceramic material having a perforated base and covered with a filter paper or asbestos material is known as Gooch crucible.

(14) Mobile phase:

A phase which is consisted of a single solvent or a mixture of solvents and is used for the separation of components in chromatography is called mobile phase.

(15) Mother liquor:

The solution which remains behind after the formation of the crystals is called mother liquor. Molasses from sugar industry is a best example of mother liquor.

(16) Partition chromatography: **(Lahore 2011, Rwp. 2013, Multan 2014, Guj. 2014, B. Pur 2014)**

That type of chromatography which involves the partitioning of the components between the two liquids.

(17) Partition coefficient: **(Sarg. 2014, B. Pur 2014)**

The ratio of the amounts of the solute dissolved in two immiscible liquids at equilibrium position is called partition coefficient. It is same as distribution coefficient and is represented by K_D.

(18) Quantitative analysis: **(Multan 2011)**

That branch of analysis in which the components of the sample are analysed quantitatively is called quantitative analysis. Volumetric and grammetric analysis are two major types of it.

(19) Residue:

That solid substance which is left behind on the filter medium during filtration is called residue. It cannot pass through the pores of filter paper.

(20) Sintered glass crucible: **(Lahore 2012)**

It is a glass crucible with a sintered glass disc sealed into the bottom.

(21) Solvent extraction:

It is a method of extracting of a desired component from the solutions by shaking it with second liquid in which the component is more soluble. This second liquid is immiscible with the first liquid. Separating funnel may be used to separate two layers.

(22) Stationary phase:

A stationary phase may be consisted of solid or a liquid supported on a solid or a gel. It may be packed in a column. In column chromatograph, silver gel is stationary phase.

(23) Sublimand: **(Lahore 2014)**

The solid substance which is being sublimed is called sublimand. Naphthalene can be sublimed and is called sublimand.

(24) Sublimate: (Lahore 2014)

That pure solid substance which is obtained after sublimation is called sublimate.

(25) Sublimation:

(Lahore 2009, Multan 2009, B. Pure 2013, Lahore 2014, Lahore 2014, Sarg. 2014, Rwp. 2014, D.G. Khan 2014)

The process of vaporization of a solid directly on heating without passing through the liquid phase and the condensation of these vapours on cooling to be solid, without passing through the liquid phase, is called sublimation.

(26) Vacuum desiccator:

A desiccator which is connected to the vacuum pump is called vacuum desiccator. It creates low pressure and causes water vapours to leave the substance and make it dry.

ANSWERS TO THE SHORT QUESTIONS

Purification Techniques

Q.1 **Mention various experimental techniques which are used for the purification of substances?** **(Lahore 2007)**

-1 کسی چیز کو صاف کرنے کے مختلف تجرباتی طریقوں کا ذکر کریں۔

Ans: The techniques (مروجہ طریقہ کار) are as follows:

(i) Filtration (ii) Crystallization (iii) Sublimation (iv) Solvent extraction

(ٹھوس کی بخارات میں تبدیلی، مکمل تسعید)

It depends upon the nature of the substances, that which technique is to be used.

Q.2 How do you justify that qualitative and quantitative analysis are discussed in analytical chemistry? (Multan 2011)

-2 آپ کس طرح ثابت کریں گے کہ صفاتی اور مقداری تجزیہ کو تجزیاتی کیمیا میں زیر بحث لایا جاتا ہے۔

Ans: It is that branch of chemistry which gives up analysis (تجزیہ) of elements and compounds. In qualitative analysis (صفاتی تجزیہ), we come to know about nature of the elements and in quantitative analysis (مقداری تجزیہ) gives us the quantities of different elements in the compound.

Q.3 Define sublimation with an example? (Rwp. 2005, Lhr. 2008, Multan 2008, (Sarg. 2009, Lahore 2009, Multan 2009, Rwp. 2009, Rwp. 2010, Bahawalpur 2011, D. G. Khan 2012, F. Abad 2012, Lahore 2013, Guj. 2013, Lahore 2014)

-3 عمل تسعید کی تعریف کریں اور ایک مثال دیں۔

Ans: The vapourisation (بخارات میں تبدیلی کا عمل) of a solid directly on heating without passing through the liquid phase and the condensation of these vapours on cooling to solid without passing through liquid phase is called sublimation. Naphethalene, iodine, NH_4Cl, benzoic acid and camphor (کافور) undergo sublimation. We can do the separation of solids without using solvents.

Q.4 How desiccator is used to dry the crystals? (Multan 2008, B.Pur 2009, Lahore 2012, Rwp. 2014, Sahiwal 2014)

-4 قلموں کو خشک کرنے کے لیے ڈیسی کیٹر کیسے استعمال کیا جاتا ہے؟

Ans: The prepared crystals are wet and they need drying. In a desiccator (خشک کرنے والا), the crystals are spread on the watch glass and placed in a desiccator for several hours. Some drying agents (خشک کرنے والے) like anhydrous $CaCl_2$, silica gel or P_2O_5 are used.

Q.5 How does a Gooch crucible increase the rate of filtration? (Gujranwala Board 2005, Multan 2007, Sarg. 2009, Rwp. 2011, Multan 2012, Sarg. 2014, Sahiwal 2014)

-5 گوچ کی کٹھالی کس طرح فلٹریشن کی رفتار کو بڑھاتی ہے؟

Ans: This crucible is made up of porcelain (مٹی کا بنا ہوا). It has perforated base (پیندے میں سوراخ ہوں) covered with a filter paper or asbestos mate. Filtration can be done quickly if this crucible is placed in a suction (ہوا کا کھینچنا) of filtering apparatus.

Q.6 Concentrated HCl and $KMnO_4$ solutions cannot be filtered by Gooch crucible. Give reason. (Gujranwala 2011, Bahawalpur 2011, F. Abad 2012, B. Pure 2013)

-6 زیادہ ارتکاز والے HCl اور $KMnO_4$ کے سولیوشنز گوچ کٹھالی سے فلٹر نہیں ہو سکتے وجہ بتائیں۔

Ans: Conc. HCl and the oxidizing agents like $KMnO_4$ react with filter paper. For this purpose, the perforation (سوراخ) of Gooch crucible is covered with asbestos mate. In this way, the above solutions can be filtered.

Crystallization

Q.7 Which solvents are mostly used in crystallization. (Model Paper-2006-07, Rawalpindi 2007, Faisalabad 2007, Rwp 2011, Guj. 2013)

-7 قلم کاری کے لیے کون سے سالونٹ مستعمل ہیں؟

Ans: The most commonly (کثرت سے ہونے والے) used solvents are:

(i) Water (ii) Rectified spirit (iii) Absolute alcohol (iv) Ether
(v) Acetone (vi) Chloroform (vii) CCl_4 (viii) Acetic acid (ix) Petroleum ether.

Q.8 Give the main characteristics of the solvent used for crystallization.
(Sargodha 2005, Federal-2006, Sargodha 2008, Lahore 2009, Fd.Abad 2009, Guj. 2010, Faisalabad 2010, B. pure 2012, D. G. Khan 2012, Guj 2012. M. Pure 2012, D.G. Khan 2013, Lahore 2014)

-8 قلموں کے بنانے میں کسی سالونٹ کی کیا صفات ہونی چاہئیں۔

Ans:
(i) The solvent should dissolve a large amount of solute at high temperature.
(ii) The solvent should have no chemical reaction with solute.
(iii) It should not dissolve the impurities (کثافتیں).
(iv) It should be cheap (سستا).
(v) It should not be inflammable (جلدی سے آگ نہ پکڑنے والا).

Q.9 Mention the major steps involved in the crystallization.
(Model Paper-2006-07, Rwp-2007, Multan 2007, Lahore 2007, Sargodha 2008, 2011, Faisalabad 2013, F. Abad 2014)

-9 قلمیں بنانے میں کونسے اہم اقدام کارفرما ہوتے ہیں؟

Ans: (i) Preparing the saturated solution (سیر شدہ سولیوشن). (ii) Filtering the impurities.
(iii) Cooling of the filtrate (فلٹر کیا ہوا مائع). (iv) Collection of crystals.
(v) Drying of crystals.

Q.10 How the decolourization of undesirable colours and dehydration is carried out for freshly prepared crystalline substances? (Guj. 2008, B.P. 2008)
(Lhr-2006, Multan-2006, Rawalpindi 2007, Multan 2007, B.Pur 2007, Rwp. 2010, Federal 2013, D.G. Khan 2014, B. Pur 2014, Multan 2014)

-10 تازہ تیار شدہ قلمی میٹریل کو بے رنگ کرنے اور پانی سے پاک کرنے کے لئے کیا کرنا پڑتا ہے؟

Ans: The decolorization (رنگ اتارنا) of undesirable colours (نامناسب رنگ) is carried out by boiling the substance with sufficient amount of powdered animal charcoal in the solvent. Hot solution is filtered. In this way charcoal absorbs the coloured impurities and the pure decolorized (اڑے ہوئے رنگ والے) substance crystallizes on cooling. The dehydrating agents employed are conc. H_2SO_4, P_2O_5 or silica gel.

Solvent Extraction

Q.11 What is solvent extraction? (Lahore 2008, Lahore 2010, Sarg. 2011, Mirpur 2012, Guj. 2013)

-11 سالونٹ کی مدد سے سولیوٹ کو کیسے باہر نکالا جاتا ہے؟

Ans: This is a technique (طریقہ کار) in which a solute is separated (الگ کرنا) from the solution. For this purpose, the solution is shaken (ہلانا) with another solvent in which the solute is more soluble. Anyhow, the added solvent should not be miscible with the solution.

Q.12 What is ether extraction?

-12 ایتھر کی مدد سے کیمیائی مرکبات کو سالونٹ سے کیسے نکالا جاتا ہے؟

Ans: Some organic products are prepared in aqueous medium. We have to remove this organic compound from water. For this purpose, ether is added. Two separate layers are produced (دو الگ تہیں بنتی ہیں) in the separating funnel. The ether layer contains the organic compound. This ether layer is separated and ether is evaporated (بخارات میں تبدیل ہونا).

Chromatography

Q.13 What is R_f value? Give its units.
(Multan Board 2005, D.G. Khan-2006, Multan 2007, Lahore 2009, B.Pur 2009, Faisalabad 2010, Faisalabad 2011, Multan 2011, Lahore 2012, Guj. 2013, Multan 2013)

-13 R_f کی قیمت کیا ظاہر کرتی ہے؟ اس کی یونٹس بتائیں۔

Ans: R_f stands for (نمائندگی کرنا) retardation factor (ایسا فیکٹر جو رکاوٹ کو ماپے). It is different for each component which is separated by chromatography.

$$R_f = \frac{\text{Distance travelled by a component from the original spot}}{\text{Distance travelled by the solvent from the original spot}}$$

It has no units.

Q.14 Give the main uses of paper chromatography.
(B.Pur-2006, Guj. 2009, Lahore 2010, B.Pur 2012, Multan 2013, Lahore 2014, Lahore 2014, D.G. Khan 2014)

-14 پیپر کروميٹوگرافی کے اہم استعمالات بتائیں۔

Ans:
(i) For the separation and purification (صاف کرنے کا عمل) of coloured organic compounds.
(ii) For checking the purity (صفائی) of the compounds.
(iii) In qualitative and quantitative analysis.
(iv) For the separation, purification and identification (پہچاننا) of products of reactions.

Q.15 Differentiate between stationary and mobile phase?
(Lahore Board 2005, Mirpur-2006, Federal-2006, Multan 2009, Faisalabad 2013, Guj. 2014)

-15 حرکت پذیر اور ساکن فیز میں کیسے فرق کریں گے؟

Ans: The solvent or the mixture of solvents used for the separation of components in chromatography is called mobile phase (حرکت میں رہنے والا فیز). The phase over which mobile phase flows is stationary (ساکن) one. Water, ethyl alcohol etc. are some important mobile phases while silica gel and filter paper are some important stationary phases.

Q.16 What is the distribution coefficient? To which technique it is applicable?
(Azad Jammu & Kashmir Board 2005, Guj. 2009, Lahore. 2010, D.G. Khan 2011, Gujranwal 2011, Guj 2012, D.G. Khan 2013, Multan 2013, B. Pur 2014, Guj. 2014, Guj. 2014)

-16 سولیوٹ کا سالیوشن میں تقسیم کا مستقلہ کیا ہوتا ہے؟ یہ کس ہنر مندی میں استعمال ہوتا ہے؟

Ans: It is the ratio of the amounts of solute dissolved in the immiscible liquids (مائعات جو حل نہ ہو سکیں) at equilibrium.

$$\text{Distribution coefficient } (K_D) = \frac{\text{concentration of solute in organic phase}}{\text{concentration of solute aqueous phase}}$$

This technique is used in the solvent extraction of certain soluble compounds.

Q.17 How naphthalene can be purified? (Guj. 2008)

-17 نیفتھالین کو کس طرح صاف کیا جا سکتا ہے؟

Ans: Naphthalene can be directly converted from solid to vapour state, i.e., by the sublimation. The impurities are left behind (کثافتیں پیچھے جاتی ہیں) because they do not sublime. Inverted funnel can be used.

Q.18 **In solvent extraction technique, repeated extractions using small portions of solvent are more efficient than using a single extraction but larger volume of solvent. Why?** **(Rwp. 2008, Sarg. 2010, Lahore 2011, Sarg. 2014)**

-18 جب ایک نامیاتی سالونٹ سے ہم کسی سولیوٹ کو دوسرے سالونٹ کی مدد سے الگ کرتے ہیں تو نامیاتی سالونٹ کے چھوٹے چھوٹے حصے لے کر کام کرنے سے سولیوٹ زیادہ نکالا جاسکتا ہے بجائے کہ سارا نامیاتی سالونٹ ایک ہی مرتبہ استعمال کر لیا جائے۔ کیسے؟

Ans: It is due to constant value of distribution coefficient (تقسیم کا عددی سر) of a solute in two solvents, which are insoluble. Say an organic solute is 1g, and is present in 1000 ml of H_2O. We have 1000 mL of ether for extraction. If we use 1000 mL ether in one installment, 67% of 1g of solute is extracted if K_D is 2 in the favour of ether. But by using two installments of 500 mL each 75% of 1 g is extracted and so on.

Q.19 **Why is there a need to crystallize a crude product?** **(Guj. 2010, Lahore 2014)**

-19 ناخالص پراڈکٹ کو صاف کرنے کی کیا ضرورت ہے؟

Ans: Impurities are mostly present in the crude product (ناخالص پراڈکٹ). By using a suitable solvent, in which the required substance under preparation is soluble is used to get the crystals of that substance. The crystals are a pure substance.

Q.20 **Iodine is more soluble in water in presence of KI. Give reason.** **(Faisalabad 2011)**

-20 I_2 کو پانی میں حل پذیری کے لئے KI کی ضرورت ہوتی ہے۔ سبب بتائیں۔

Ans: To dissolve I_2 in water a dilute solution KI should be prepared first of all. I_2 combines with $I^{\ominus}$ of KI to give $I_3^{\ominus}$ ion. This ion $I_3^{\ominus}$ is soluble in water. I_2 is not soluble in H_2O.

Chapter

3

GASES

EQUATIONS TO DO THE NUMERICAL PROBLEMS

(1) $PV = K \qquad P_1V_1 = P_2V_2$ (Boyle's law)

(2) $\frac{V}{T} = K \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2}$ (Charles's law)

(3) $K = C° + 273.16$

(4) $C° = 5/9\ [F° - 32]$

(5) $F° = 9/5\ [°C] + 32$

(6) $V_T = V\left(1 + \frac{T}{273}\right)$ (Charles's law)

(7) $PV = nRT$ (General gas equation for n-moles of an ideal gas)

(8) $PV = RT$ (General gas equation for one mole of an ideal gas)

(9) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ (General gas equation)

(10) $d = \frac{PM}{RT}$ (General gas equation to calculate the density of an ideal gas)

(11) $P_t = p_A + p_B + p_C$ (Dalton's law of partial pressures)

(12) $p_A = X_A P_t,\ p_B = X_B P_t,\ p_c = X_c P_t$ or $p_i = X_i P_t$

(13) $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$ (Graham's law of diffusion in terms of densities of gases)

(14) $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$ (Graham's law of diffusion in terms of molar mass of gases)

(15) $PV = \frac{1}{3} mN\bar{c}^2$ (kinetic equation of gases)

(16) $\bar{c}^2 = \frac{n_1c_1^2 + n_2c_2^2 + n_3c_3^2 + \ldots\ldots\ldots\ldots + n_n c^2_n}{n_1 + n_2 + n_3 + \ldots\ldots + n_n}$ (Mean square velocity)

(17) $c_{r.m.s.} = \sqrt{\frac{n_1c_1^2 + n_2c_2^2 + n_3c_3^2 + \ldots\ldots\ldots\ldots + n_nc^2_n}{n_1 + n_2 + n_3 + \ldots\ldots + n_n}}$ (Root mean square velocity of a gas)

(18) $c_{r.m.s.} = \sqrt{\frac{3RT}{M}}$ (Root mean square velocity of a gas related with temperature and molar mass of a gas)

(19) $\frac{PV}{RT} = Z$ (Compressibility factor)

(20) $\left(P + \frac{a}{V^2}\right)(V - b) = RT$ (Van der Waal's equation for one mole of a real gas)

(21) $\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$ (Van der Waal's equation for n moles of a real gas)

METHODS TO SOLVE VARIOUS NUMERICAL PROBLEMS

(1) If temperature and number of moles of an ideal gas are constant, the following equation is applied. It is deduced from Boyle's law

$$P_1V_1 = P_2V_2$$

(2) When the pressure and number of moles of an ideal gas are constant, then the following equation is applied. It is deduced from Charles's law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

(3) If we want to calculate the volume of a gas at any temperature at constant pressure and number of moles, then following relationship is given by Charles

$$V_T = V_0\left(1 + \frac{T}{273}\right)$$

V_0 is the volume of that gas at 0°C.

(4) If none of the parameters is constant to solve the numericals of a gas, then we use

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

(5) In order to calculate the value of general gas constant "R", we use the Avogadro's law, Boyle's law and Charles's law

$$R = \frac{PV}{nT}$$

(6) In order to calculate the number of moles of an ideal gas, we should know the P, V and T along with the suitable values of general gas constant R

$$n = \frac{PV}{RT}$$

(7) If we want to calculate the number of molecules of gas, then multiply the number of moles with N_A. The number of moles are calculated from point (6) given above.

(8) To determine the density of a gas, use the following relationship

$$d = \frac{PM}{RT}$$ **(Bahawalpur 2008)**

Be careful in selecting the units of P and M.

(a) If M is in g $mole^{-1}$, P is in atm and R is in 0.0821 dm^3 atm K^{-1} mol^{-1}, then 'd' comes out to be in g dm^{-3}.

(b) If M = kg mol^{-1}, P = Nm^{-2} and R = 8.3143 JK^{-1} mol^{-1}, then "d" comes out to be in kg m^{-3}.

(9) To determine the mass of the given gas, use the following relationship

$$m = \frac{PVM}{RT}$$

(10) To calculate the partial pressure of a gas, multiply the mole fraction with a total pressure of the mixture

$$p_i = X_i P_t$$

The mole fraction of a gas is ratio of number of moles of that gas to total number of moles of mixtures

$$X_i = \frac{n_i}{n_t}$$

(11) To get the pressure of the dry gas, subtract the aqueous tension from the moist gas

$$P_{dry} = P_{moist} - P_{(aq\ tension)}$$

Aqueous tension is the pressure of vapours of water at a given temperature.

(12) The comparison of rate of diffusion of gases can be done by knowing the densities of gases

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

or, we should know the molar masses of gases.

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

(13) To calculate the root mean square velocity, we should know the temperature and molar mass of the gas

$$C_{r.m.s.} = \sqrt{\frac{3RT}{M}}$$

(14) If we know the Van der Waal's constants "a" and "b" and the gas is non-ideal, the following relationship is used to calculate the pressure of a real gase

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT.$$

DEFINITIONS

(May be used in short questions with examples)

(1) Absolute scale of temperature: **(D.G. Khan 2014)**

It is that temperature scale which starts from –273.16°C as zero. This is also called Kelvin scale of temperature. For example 0K is 273.16°C and 100 K is 373.16°C.

(2) Absolute zero: **(Gujranwala-2006, Multan 2014, B. Pur 2014)**

It is hypothetical temperature at which the volumes of all the gases become zero. Its value is –273.16°C. This temperature can never be achieved. It is theoretically achieved value by Charles's law.

(3) Aqueous tension:

The pressure of vapours of water at a particular temperature is called aqueous tension. Water vapours are always present in the air and exert pressure.

(4) Avogadro's law: **(Federal Board 2013, Lahore 2014)**

Equal volumes of all the gases at same temperature and pressure contain equal number of molecules. 10 mL of H_2, O_2, CH_4 separately at 0°C and 1 atm pressure contain equal number of molecules of each gas in their vessels.

(5) Boyle's law: **(Guj. 2013, Lahore 2014)**

The volume of given amount of a gas is inversely proportional to the pressure of the gas at a constant temperature. Mathematically $PV = K$ or $P_1V_1 = P_2V_2$ at const. T and number of moles.

(6) Charles's law: **(Lahore 2014, D.G. Khan 2014, Sahiwal 2014)**

The volume of the given amount of a gas is directly proportional to the absolute temperature of the gas, at constant pressure. Mathematically $\frac{V}{T} = K$ or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ at constant P and number of moles.

(7) Critical pressure: **(Sarg. 2010, D.G. Khan 2014)**

It is the minimum pressure which is required to liquefy a gas at its critical temperature. It is different for different gases and is denoted by P_c.

(8) Critical temperature: **(Sarg. 2010, D.G. Khan 2014, Rwp. 2014)**

The temperature of a gas above which a gas cannot be liquefied, no matter how great the pressure is applied, is called critical temperature. It is different for different gases and is denoted by T_c.

(9) Critical volume: **(Rwp. 2014)**

The volume which is occupied by one mole of a gas at critical temperature and critical pressure is called critical volume. It is different for different gases and is denoted by V_C.

(10) Dalton's law of partial pressure: **(Bahawalpur 2011)**

Total pressure of mixtures of ideal gases is equal to the sum of individual partial pressures at a given temperature. So $P_t = P_{N_2} + P_{O_2} + P_{others}$ in the air.

(11) Diffusion: **(Faisalabad 2013, B. Pure 2013, Sarg. 2014, B. Pur 2014)**

The spontaneous mixing of the molecules of different gases by random motion and collision to form homogeneous mixture is called diffusion. The gases of balloon diffuse in air after its burst.

(12) Effusion: **(Faisalabad 2013, B. Pure 2013, Sarg. 2014, B. Pur 2014)**

The passage of gas molecules one by one without collision through a pinhole in a container into an evacuated space is called effusion.

(13) Gas laws:

Gas laws are the relationships between the volume of the given amount of the gas and prevailing conditions of temperature and pressure. Boyle's law, Charles's law and pressure temperature law are gas laws.

(14) Graham's law of diffusion: **(Bahawalpur 2008)**

(i) The rate of diffusion or effusion of a gas is inversely proportional to the square root of the density of the gas. $r \propto \frac{1}{\sqrt{d}}$ or $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$

(ii) The rate of diffusion or effusion of a gas is inversely proportional to the square root of the molecular masses of the gas. $r \propto \frac{1}{\sqrt{M}}$ or $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$

(15) Ideal gas:

That gas which obeys gas laws like Boyle's law, Charles's law and Avogadro's law is called ideal gas. The ideal gas should obey the general gas equation i.e., PV = nRT.

(16) Isotherm:

A graph between pressure and volume of the gas at constant temperature and the number of moles is called isotherm. It is a parabolic curve. It is in the shape of a curve.

(17) Joule-thomson effect: **(Lahore 2011, Lahore 2012)**

The phenomenon of the change of temperature when a gas expands adiabatically from or region of high pressure to a region of low pressure is called Joule-Thomson effect. We can liquefy gas by this phenomenon.

(18) Liquefaction:

The process of conversion of a gaseous substance into the liquid state is called liquefaction of the gas. There are various methods for this process.

(19) Mean square velocity: **(Guj. 2014)**

It is the average of the squares of all the possible velocities of gas molecules.

$$\overline{c}^2 = \frac{c_1^2 + c_2^2 + c_3^2 + ... + c_n^2}{n}$$

(20) Mole fraction of gas:

It is ratio of number of moles of a gas to the total number of moles of all the gases in the mixture.

$$X_{N_2} \text{ (in air)} = \frac{n_{N_2}}{n_{N_2} + n_{O_2} + n_{others}}$$

(21) Non-ideal gas:

That gas which obeys the gas laws approximately is called a non-ideal gas. The general gas equation $pV = nRT$ is obeyed approximately.

(22) Partial pressure:

The pressure which is exerted by an individual gas in a gaseous mixture is called partial pressure of that gas.

$$p_{N_2} = X_N P_t$$

(23) Permanent gases:

Those gases which have low critical temperature are called permanent gases.

(24) Plasma state:

A fourth state of matter which is mostly consisted of gaseous charged particles is called plasma. 99% of the universe is made up of charged particles scattered in the vacuum and is called plasma.

(25) Root mean square velocity:

It is a square root of mean square velocity of a gas.

$$C_{rms} = \sqrt{\frac{3RT}{M}}$$

It is directly proportional to the square root of absolute temperature and inversely proportional to square root of molar mass of gas.

(26) Second definition of Charles's law:

The volume of the given mass of a gas increases or decreases by $\frac{1}{273}$ of its volume at 0°C for every 1°C rise or fall of temperature at constant pressure. This statement convinces us that at –273.16°C, the volume of gases will be zero.

(27) Triple point:

The temperature where three states of a substance coexist is called the triple point.

ANSWERS TO THE SHORT QUESTIONS

Boyle's Law

Q.1 Why is the Boyle's law applicable only to the ideal gases?
(Fd. 2009, F. Abad 2012, Guj. 2013)

-1 بوائل کا قانون صرف آئیڈیل یا مثالی گیسوں پر ہی لاگو کیوں ہوتا ہے؟

Ans: Boyle's law is applicable (لاگو ہوتا) to those gases which have no forces of attractions among the molecules. Such gases are ideal (مثالی). So Boyle's law is applicable to only ideal gases. Its formula is PV = K when n and T are constant.

Q.2 When a gas obeys the Boyle's law, the isotherms for the gas can be plotted. How is it true? **(Guj. 2013)**

-2 جب ایک گیس بوائل کے قانون کے مطابق کام کرتی ہے۔ تو اس کے لئے Isotherms پلاٹ کیے جاسکتے ہیں۔ یہ کیسے صحیح ہے؟

Ans: Isotherms are the graphs between pressure and volume at constant temperature and number of moles. This condition is fulfilled by Boyle's law. The word isotherm means "same temperature (مستقل درجہ حرارت)". They are curves. At higher temperature the curves go away from the axis.

Q.3 What are isotherms? What happens to the positions of isotherms when they are plotted at high temperature for a particular gas? **(Lahore 2014)**

-3 آئسوتھرمز کیا ہوتے ہیں؟ جب زیادہ درجہ حرارت پر ان کو پلاٹ کیا جائے تو ان کی پوزیشن کو کیا ہوتا ہے؟

Ans. Isotherms are the graphs between pressure and volume, when temperature is constant. These graphs are plotted keeping in view the Boyle's Law. There are curves.

When the isotherms are plotted at higher temperatures, then they go away from the axis (axis سے دور ہو جاتے ہیں). The reason is that, the volumes of the gases increase at high temperatures. In this way the points in the graph paper go away from the axis.

Q.4 The product of pressure and volume at constant temperature and number of moles is a constant quantity. Why?
(Multan Board 2004, Sarg. 2009, Fd.Abad 2009)

-4 گیس کے دباؤ اور جسامت کا حاصل ضرب مستقل درجہ حرارت ایک مستقل مقدار ہے۔ کیوں؟

Ans: When the temperature and number of moles of a gas are constant, then the increase of pressure decreases the volume in such a way that PV remains constant (PV = K). By doubling (دُگنا کرنا) the pressure the volume becomes half. We can say that,

$P_1V_1 = P_2V_2 = P_3V_3$, at constant temperature and number of moles.

Q.5 Why do we get a straight line when pressures are plotted against inverse of volumes? This straight line changes its positions in the graph by varying the temperature. Justify it. **(B.Pur 2009, Guj. 2011, D.G. Khan 2014)**