Topic 1

Atoms, Molecules & Stoichiometry

Definition

Atom

- smallest particle into which an element can be divided without losing its identity.
- Eg. Na, C, N etc.

Molecule

- group of atoms (held by covalent bonds) which is capable of independent existence.
- Eg. NH_3, H_2O, O_2

Definition

Isotopes

- atoms of the same element that have the same number of protons but different number of neutrons (same atomic number but different mass number/nucleon number)

Relative Atomic Mass (RAM)

- **Definition:** the **ratio** of the average mass of one atom of the element to 1/12 the mass of an atom of ^{12}C, isotope, expressed on the ^{12}C scale.

- $$\mathbf{Ar} = \frac{\textbf{mass of one atom of an element}}{\mathbf{1/12 \times} \textbf{ mass of one atom of } \mathbf{^{12}C}}$$

Relative Molecular Mass (RMM)

- the **ratio** of the average mass of one molecule of the substance to 1/12 the mass of an atom of ^{12}C isotope, expressed on the ^{12}C scale.
- **Mr = <u>mass of one molecule in a sub</u>**

  1/12 x mass of one atom of ^{12}C

Eg. Mr of $CaCO_3$ = 40.1 + 12.0+ 3(16.0)

= 100.1

Relative Isotopic Mass (RIM)

- the **ratio** of the average mass of one atom of the isotope to 1/12 the mass of an atom of ^{12}C isotope, expressed on the ^{12}C scale.
- **Ar =<u>mass of one atom of the isotope</u>**

  1/12 x mass of one atom of ^{12}C

The Mole Concept

- **Mole** is the unit of the amount of substance.
- One mole of a substance contains as many particles of that substance as there are atoms of carbon in 12 grams of ^{12}C.
- N/T : When mole is used, the particles must be stated (atoms, molecules, ions or electrons)

The Avogadro Constant, L

- **L = number of entities in sample/amount of substance of sample**
- L has been determined experimentally to have a value of **6.02×10^{23}** per mole.
- One mole of any substance is the amount of substance containing a number of particles equal to the Avogadro constant.

The Avogadro Constant, L

- Eg. 1 mole of CO_3^{2-} ions = 6.02×10^{23} ions
- 1 mole of electrons = 6.02×10^{23} electrons

The Avogadro Constant, L

- 1 mole of any substance has a mass in grams numerically equal to its A_r or M_r.
- **No. of moles = mass in grams A_r / M_r**
- **No. of particles = no. of moles x L**

Questions

- 1.What is the mass of one mole of aspirin, $C_9H_8O_4$?
- 2. How many moles of aspirin are there in 1.00 g of this substance?
- 3. What is the mass, in grams, of 0.433 mole of aspirin?

Questions

- 4. How many aspirin molecules are there in 1.74g of this substance?
- 5. What is the mass, in grams, of 1.00×10^{23} molecules of aspirin?
- 6. How many carbon atoms are there in 1 mole of aspirin?

Mass Spectra

- a mass spectrum is a plot of relative abundance against m/e. It shows where the ion appears and how many ion appears.
- the mass spectrum of an element provides the following information:-

Mass Spectra

- **Number of isotopes present** - from the **number of peaks** or lines.
- **Isotopic mass** and hence, identity of the isotope - from **m/e value** of each peak
- **Relative abundance** of each isotope - from the **height of each peak**

Mass Spectra

- The relative atomic mass of an element is the weighed average of the isotopic masses according to their relative abundances.
- Ar = $\sum \frac{\text{(isotopic mass x percentage adundance)}}{100}$

Example 1

- Chlorine consists of 2 isotopes ^{35}Cl and ^{37}Cl. The relative abundance of the isotopes are 75% to 25% relatively. Calculate the relative atomic mass of chlorine atom.

Example 2

- Naturally occurring gallium, Ga, is a mixture of two isotopes of mass numbers 69 and 71. What is the percentage abundance of each isotope? [Ar of Ga = 69.7]

Example 3

- Calculate the weight of silicon using the following data for the percent natural abundance and mass of each isotope:

  92.23% ^{28}Si; 4.67% ^{29}Si; 3.10% ^{30}Si.

Example 4

- Thallium has two stable isotopes, ^{203}Tl and ^{205}Tl. Knowing that the atomic weight of thallium is 204.4, which isotope is the more abundant of the two?

Example 5

- Calculate the atomic mass of magnesium, given the following:-

  ^{24}Mg, 78.99%

  ^{25}Mg, 10.00%

  ^{26}Mg, 11.01%

Example 6

- Copper exists as two isotopes: ^{63}Cu and ^{65}Cu.

  What are the percent abundances of the isotopes?

Empirical Formula

- simplest formula which shows the ratio of the atoms of the different elements in the compound
- Eg. Calculate the empirical formula of a compound that has the composition C: 12.8% H: 2.1%, Br: 85.1%
- Calculate the empirical formula of a compound that has the composition:

  48.8% C, 13.5% H and 37.7% N

Molecular Formula

- shows the actual number of atoms of each element present in **one** molecule of a compound.
- For example: If the empirical formula is CH_2 and the molecular mass is 56, then obviously the molecular formula is calculated as $(CH_2)n = 56, 14n = 56$, therefore $n = 4$. So the molecular formula is C_4H_8.

Volume of Solutions and Gases

- 1 mole of any gas occupies a volume of $22.4 dm^3$ at s.t.p or $24 dm^3$ at r.t.p
- ↳(This is the molar volume of gases)
- [s.t.p refers to 0°C, 1 atm pressure]
- [r.t.p refers to 25 °C , 1 atm pressure]

Concentration of Solutions

- the **concentration** of an aqueous solution may be expressed either as
- a) mass of solute per dm^3(units : **gdm^{-3}**)
- b) mole of solute per dm^3 (units : **$moldm^{-3}$**)
- N/T: When a given volume of solution is diluted, the number of moles of solute remains unchanged after dilution.

Example 1

- If $10.0cm^3$ of a $3.00moldm^{-3}$ sulfuric acid is diluted with water to give $250cm^3$, what is the concentration of the diluted solution in $moldm^{-3}$?
- Calculate the volume of O_2 that is needed to oxidize $20dm^3$ of NH_3 to NO(g)

Example 2

- Calculate the concentration in moldm^{-3} of the solution obtained by dissolving 4.5g of glucose, $C_6H_{12}O_6$ in water to make 250cm^3 of solution.
- Calculate the volume of CO_2 produced at s.t.p by decomposing 15g of $CaCO_3$.

Calculation using Combustion Data

- the molecular formula of hydrocarbons can be determined by combustion in excess oxygen to from CO_2 and H_2O.
- a **gaseous** hydrocarbon, C_xH_y explodes with excess O_2 according to the general equation:-
- **$C_xH_{y(g)} + (x + y/4)O_{2(g)} \rightarrow xCO_{2(g)} + (y/2)H_2O_{(l)}$**

Example 1

- 1. $10cm^3$ of a gaseous hydrocarbon required $20cm^3$ of oxygen for complete combustion $10cm^3$ of carbon dioxide was produced. Calculate the molecular formula of the hydrocarbon.[All gases were measured under the same conditions].

Example 2

- 2. $150cm^3$ of oxygen were added to $20cm^3$ of a gaseous hydrocarbon. After explosion and cooling, the gaseous mixture occupied $130cm^3$ and after absorption by KOH, $90cm^3$ of oxygen remained. Calculate the formula of the hydrocarbon. [All volumes being measured at r.t.p]

Example 3

- 3. Complete combustion of a hydrocarbon yields 2.64g of carbon dioxide and 0.54g of water. What is the empirical formula of the hydrocarbon? If the relative molecule mass of the hydrocarbon is 78, what is its molecular formula?

Reacting Masses

- Excess reagents are those which are in excess of the stoichiometric amount required for the reaction (as indicated by the balanced equation).
- They are not completely consumed at the end of the reaction.

Example 1

- Determine the mass of zinc obtained from the reduction of 50g of ZnO by 50g of charcoal.

Example 2

- To determine the sulfur content in tomato, 20.0g of tomato were digested in concentrated nitric acid and the SO_4^{2-} ions produced were precipitated as $BaSO_4$. 0.156g of $BaSO_4$ was collected. What was the percentage, by mass, of sulfur in the tomato?

Reacting masses

- The limiting reagent is completely consumed at the end of the reaction and it determines the yield of the reaction.
- The theoretical yield is the maximum amount of a product that can be obtained in a reaction from the given amounts of reactants.

Reacting masses

- The actual yield, however, may be much less due to incomplete reaction or product loss during the reaction.
- Percentage yield is a measure of the efficiency of the reaction.
- Percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100$

Example 1

- Calculate the percentage yield when 31g of methyl salicylate are obtained from 50g of salicylic acid and an equimolar amount of methanol.

  $C_7H_6O_3$ + CH_3OH → $C_8H_8O_3$ H_2O

Example 2

- Sorbitol, $C_6H_8(OH)_6$, is a key component of “Fisherman’s Friend” extra strong lozenges. If each lozenge contains 91% by mass, of sorbitol, what chemical amount (moles) of sorbitol is present in a 25g packet of these lozenges?