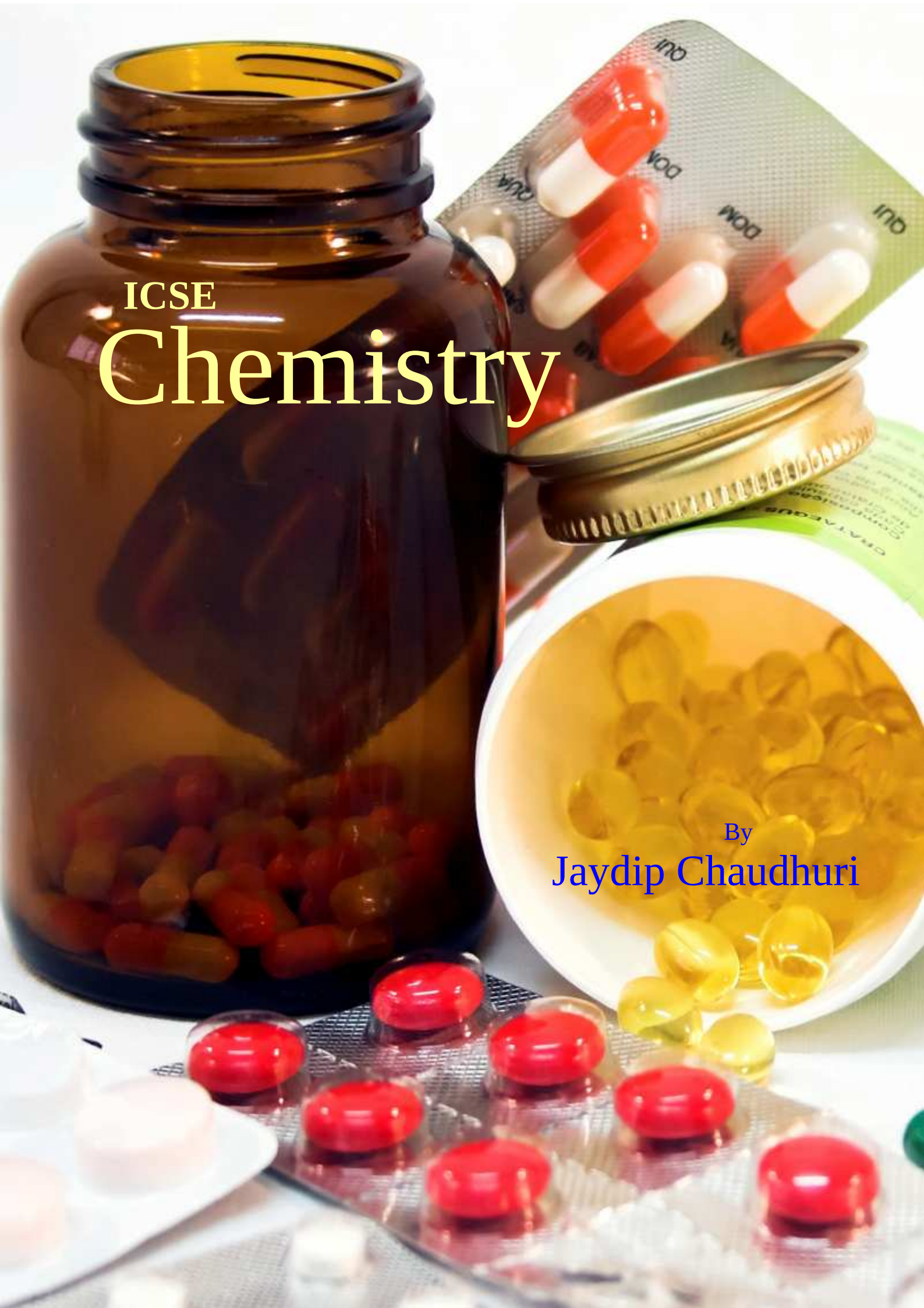
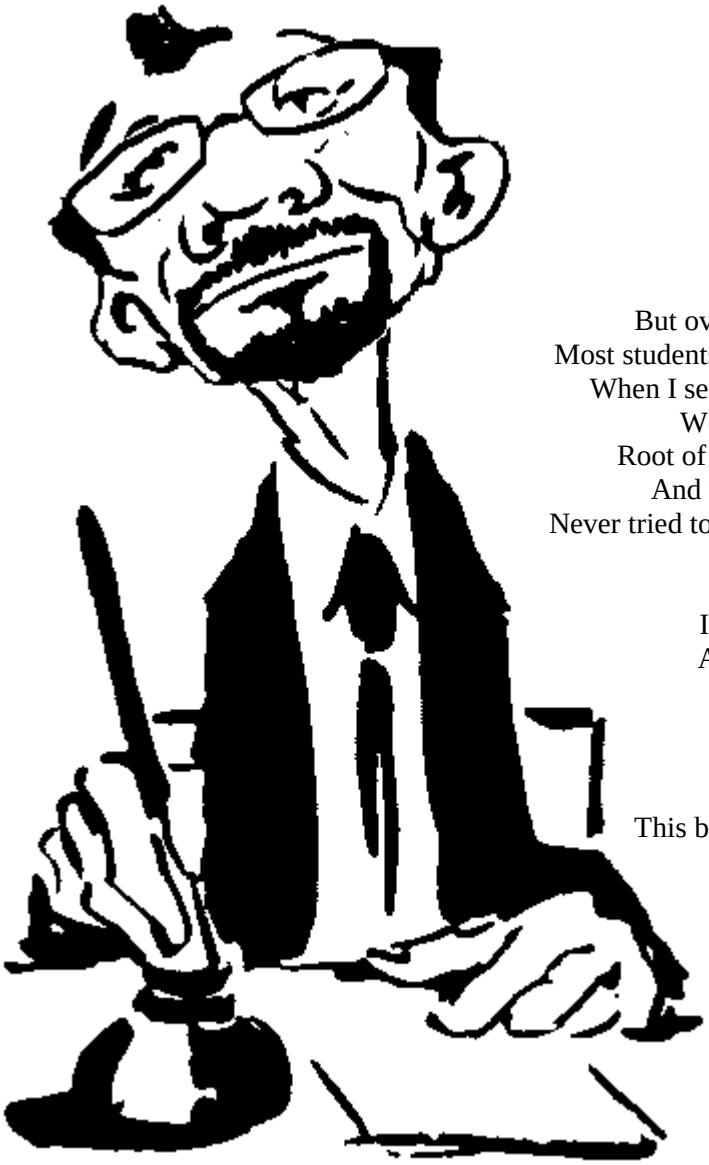


ICSE Chemistry

By
Jaydip Chaudhuri

Forewords …



There were absolutely no need
To have another textbook like this
As there are plenty for the affluent

Besides, writing a book is a
Good source of income.
Every year if nothing changes,
Syllabus changes will support the sale

But over the years, in general, I have observed
Most students do not welcome chemistry as a subject
When I searched for the reason, I realized the way
We teach chemistry at school level creates
Root of the fear, which remains rest of their life
And the fear is created because most of them
Never tried to understand the basic rules of chemistry

This book caters to that,
I have tried to explain in a different way,
All the principals and remembering rules
So that everyone understands the basics
Of every chemical reactions

World of knowledge is free
This book will remain free to download for all
Even if it finds its publisher
Because I always wanted you to enjoy
Every lesson of chemistry and I mean it

My effort will be successful
If you all find it as a simple
And comfortable read
And learn the language of chemistry

June 1st, 2009

This book is dedicated to

My mother, **Smt. Ena Chaudhuri**,
Who still nurtures a dream of starting a school of different kind!
Hope this small effort will satisfy her

Jaydip Chaudhuri
Department of Chemistry, Sarala Birla Academy, Bangalore-83
Formerly at The Doon School, Dehradun, and
St. Paul's School, Jalapahar, Darjeeling

ICSE: Chemistry: Contents

- **Analytical Chemistry**
  - Effect of heat on carbonates and bicarbonate
  - Effect of heat on nitrates
  - Action of alkali (sodium hydroxide) on metal cations
  - Action of ammonia on metal cations

- **Organic Chemistry**
  - History of organic origin
  - Nomenclature
  - Hydrocarbons-alkanes, alkenes and alkynes
  - Substituted hydrocarbons-haloalkanes: reaction pathways
  - Alcohol, aldehyde and carboxylic acids
  - Preparations of various organic compounds

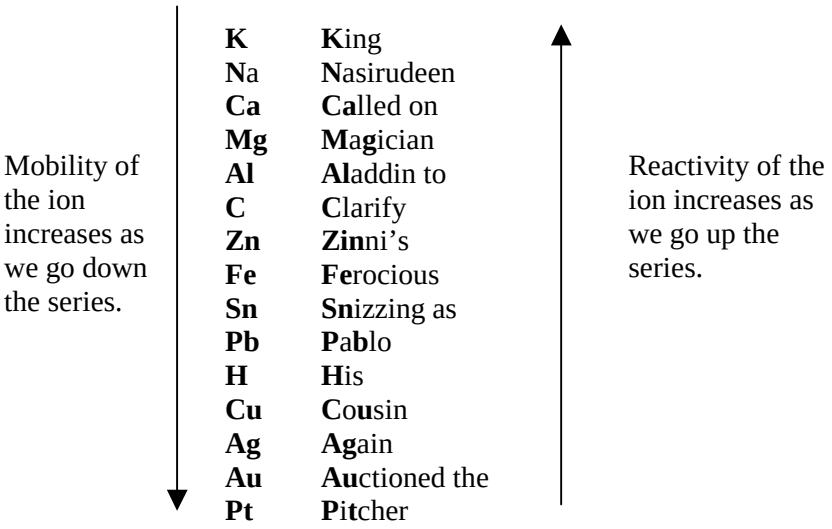
- **Metallurgy**
  - Reactivity series and three groups of metals
  - Electrolysis method of active metals
  - Carbon reduction method of less active metals
  - Purification of inert metals
  - Alloys and their usage

Chapter-1

Revisions Of Basic Chemistry

Symbols of Elements
Formula and Equations
Word Equation
Chemical Equations
Balancing of Chemical Equations
Types of reactions

Remember the reactivity series:



Types of Reaction:

Basically there are four basic types of reactions

1. **Addition (Composition/Association) Reaction**

   A+ B ⟶ AB

   Example of this type of reaction is: $2H_2 + O_2 \longrightarrow 2H_2O$

   If you consider H_2 as A and O_2 as B in the reactant side, then observe that they joined together in the product side to form H_2O

2. **Dissociation (Decomposition/Fragmentation) Reaction**

   AB ⟶ A + B

   Example of this type of reaction is: $2H_2O_2 \longrightarrow 2H_2O + O_2$

   Here H_2O_2 as reactant after the reaction has broken into two products water and oxygen gas, O_2.

3. **Substitution (replacement) Reaction**

   AB + C ⟶ CB + A

   Example of this type of reaction is: $CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu$

   Here in this example Zn has substituted or replaced Cu like in the model where C substitutes A.

4. **Double Decomposition (double substitution) Reaction**:

   AB+ CD ⟶ AD + CB

   Example of this type of reaction is: $H_2SO_4 + 2NaCl \longrightarrow Na_2SO_4 + 2HCl$

   If you consider H^+ as A and SO_4^{2-} as B and Na^+ as C and Cl^- as D in the reactant side, then you will observe that in the product side it has changed its position accordingly

Chapter-2

Oxidation Vs. Reductions

What is Oxidation and Reduction?

Oxidation …

- In terms of Oxygen /Hydrogen
- In terms of Electron loss
- In terms of Oxidation Number

Oxidation and Reduction

Oxidation and reduction can be defined in many ways; here are three simple definitions appropriate for you, in terms of oxygen/hydrogen, oxidation number and electron loss/gain

Oxidation and reduction in terms of oxygen or hydrogen:

Addition of oxygen: addition of oxygen or electronegative elements like oxygen (Cl, Br, N as example) is called as oxidation. Similar way removal of oxygen or electronegative elements like Cl is called reduction. [$2Cu + O_2 \longrightarrow 2CuO$]

Oxidation in terms of hydrogen: similar way removal of hydrogen is called oxidation and addition of hydrogen is called reduction. [$CuO + H_2 \longrightarrow Cu + H_2O$]

So the rule:
Addition of oxygen or oxygen like elements is oxidation and removal of oxygen or oxygen like atoms are reduction. If

Oxidation in terms of oxidation number:

Every element when they form compound remain in some oxidation (+n or –n) state (a similar old fashioned term is valance of an element) and if after the reaction any particular element has increased its oxidation state is called has undergone oxidation.

So increase in oxidation number indicates an oxidation in an element whereas in the similar way if a decrease in oxidation state occurs indicates at reduction of that particular element

Example: [$CuSO_4 + Fe \longrightarrow FeSO_4 + Cu$]
Every element in it elemental form remains in its ‘0’oxidatio state. So in the above equation Cu and Fe are in 0 oxidation state. Again the total of all the oxidation state in a compound is zero, so the oxidation number of S, O and Cu in copper sulphate added together is zero. And if so

Oxidation in terms of electron loss or gain:

s

Chapter-4

Acids, Bases And Salts

What is Acid and Acidic behavior?
Reactions of Acids
Base, and alkali, general behavior
Reactions of Bases
Salts, types of salts
General method of preparation of salts

Acids and Bases Reaction rules:

- Alkali + Ammonium (NH_4^+) salt $\longrightarrow$ salt + water + ammonia
- Alkali + amphoteric Metals (Al, Zn, Pb) $\longrightarrow$ sodium/potassium salt of metaloate + H_2
- Acid [$H^+_{(aq)}$] + base (metal oxide/hydroxide) $\longrightarrow$ salt + water
- Acid + carbonate/bicarbonate (CO_3^{2-} / HCO_3^-) $\longrightarrow$ salt + water + carbon dioxide
- Acid + sulphite / bisulphite (SO_3^{2-} / HSO_3^-) $\longrightarrow$ salt + water + sulphur dioxide
- Acid + sulphide (S^{2-}) $\longrightarrow$ salt + hydrogen sulphide
- Acid + active metal $\longrightarrow$ salt + hydrogen gas

Comparative study of three acids: $HCl_{(aq)}$, $H_2SO_{4\ (aq)}$, $HNO_{3\ (aq)}$

When working with acids, remember the general rules of acids and bases, and remember an acid always behaves as acid only in aqueous solution, so checkout whether the acid is given as $HCl_{(aq)}$, $H_2SO_{4\ (aq)}$, $HNO_{3\ (aq)}$ or not..

Acid + [O^{2-} /OH^-] $\longrightarrow$ **salt + H_2O**
Acid + [CO_3^{2-} / HCO_3^-] $\longrightarrow$ **salt + H_2O + CO_2**
Acid + [SO_3^{2-} / HSO_3^-] $\longrightarrow$ **salt + H_2O + SO_2**
Acid + [S^{2-}] $\longrightarrow$ **salt + H_2S**
Acid + Active Metal * $\longrightarrow$ **salt + H_2**

Points to remember:

- Cu, Hg, Ag, Au, and Pt are not considered as active metal.
- While reaction, divide the reactions into cationic [$H^+_{(aq)}$] and anionic part and then work in your brain about the product.
- Remember only very cold and very dilute 1% HNO_3 behaves like acid otherwise it works as oxidant.

Oxidising character of H_2SO_4 and HNO_3

Basic Principle to understand the nature of reactions
Easy to Remember:

$2SO_2 + 2H_2O + O_2 \rightleftharpoons 2H_2SO_{4\ (l)}$
$4NO_2 + 2H_2O + O_2 \rightleftharpoons 4HNO_{3\ (l)}$

[Not only so, NO_2 is again formed from NO;
So sometimes it behaves as: $4NO + 2H_2O + 3O_2 \rightleftharpoons 4HNO_{3\ (aq)}$]

So when concentrated acids are kept they have the tendency to go backwards (attain an equilibrium, a reversible behaviour). And the oxygen in them gets added to the other elements etc and thus oxidising them. For sake of discussion lets take an example how we can use the above fact to understand a reaction in a simple and convincing way:

Lets see the reaction of carbon with conc. Sulphuric acid [represented as H_2SO_4 (l)]
$H_2SO_4 + C \longrightarrow [SO_2 + O_2 + H_2O] + C \longrightarrow [SO_2 + H_2O] + [C + O_2]$
Find here whenever we are finding H_2SO_4 as concentrated acid and if we start thinking its origin, we will realise that the presence of active oxygen that further reacts with carbon to form its oxide. So in the above equation I have broken it according to our thought process, and if you do so, you are going to understand what products are going to be formed at the end of the reaction. Further the product carbon dioxide is an acidic oxide (non-metal oxide are acidic in nature) so it doesn't react with any of the reactants if it is given in excess also.

So the rule of the thumb is:
Analyse each reaction simple way and learn it stepwise:
Dissociate the acid in its oxidising form mentally

- Predict the product formed with the given reagent
- In case of metal (product is metal oxide, a base, that again reacts with acid) see further reaction possibilities

A simple illustration of the above statements:
Note that the square brackets, [ ], in the following equations are given just for your understanding of active reactants at that step.

Step 1: $Zn + 3\mathbf{HNO_3} \longrightarrow Zn + [\mathbf{½O_2 + 2NO_2 + H_2O}] + HNO_3$

Step 2: $[\mathbf{Zn + ½O_2}] + 2NO_2 + H_2O + HNO_3 \longrightarrow [\mathbf{ZnO}] + 2NO_2 + H_2O + HNO_3$

Now base, zinc oxide again reacts with the rest of the acids that is formed (HNO_3 only behaves as acid in presence of water, i.e. in aqueous solution) in presence of little moisture produced above, to give the final product in third step.

Step 3: $NO_2 + H_2O + [\mathbf{ZnO + HNO_3}] \longrightarrow NO_2 + H_2O + \mathbf{Zn(NO_3)_2}$

Reaction of sulphuric acid as oxidising agent is as follows**:**

With non-metal:

$S + 2H_2SO_4 \longrightarrow [2SO_2 + 2H_2O] + SO_2$

$C + H_2SO_4 \longrightarrow [SO_2 + H_2O] + CO_2$

With metals:

$Zn + 2H_2SO_4 \longrightarrow [SO_2 + H_2O] + ZnO + H_2SO_4 \longrightarrow ZnSO_4 + 2H_2O + SO_2$

$Cu + 2H_2SO_4 \longrightarrow [SO_2 + H_2O] + CuO + H_2SO_4 \longrightarrow CuSO_4 + 2H_2O + SO_2$

Reaction of nitric acid as oxidant is little more complicated than H_2SO_4, as NO_3^- ion reacts in two different ways depending on the concentration of hydronium ion present (or simply H^+ in aqueous solution). In presence of more acid it produces NO and in less acid the end product is NO_2

Teaching notes: two redox potentials of NO_3^- are as follows:

$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$ $\quad E^o = 0.78V$

$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO + 2H_2O$ $\quad E^o = 0.96V$

Note here in more acidic medium, that is with more hydronium ion $[H^+_{(aq)}]$ NO_3^- produces NO, where as in the less acidic medium it produces NO_2.

I prefer to teach this as (in simple terms): if there are more $H^+_{(aq)}$ ions it eats up more oxygen from NO_3^- and produces NO. HNO_3 becomes more acidic when it is in aqueous medium that is 60-40% dilute has more hydronium ion than that of concentrated one, so in the more concentrated solution NO_3^- in HNO_3 produces NO_2 where as it produces NO when it is diluted further.

Reaction of Concentrated Nitric Acid as oxidising agent:

It gives similar product like that of sulphuric acid. When concentrated Nitric acid is given (which has less hydronium, $H^+_{(aq)}$ ion).

With non metal:

$C + HNO_3 \longrightarrow CO_2 + [NO_2 + H_2O]$

$S + 6HNO_3 \longrightarrow [4NO_2 + 2H_2O] + SO_2 + 2HNO_3 \longrightarrow [6NO_2 + 3H_2O] + SO_3$

$2P + 10HNO_3 \longrightarrow [10NO_2 + 5H_2O] + P_2O_5$

A small note: As all three non-metal oxides are acidic oxides and are water-soluble and produces carbonic acid, sulphuric and phosphoric acid respectively, you may add up water with above non-metal oxides to write the acidic products as end products. So statements like [$C + HNO_3 \longrightarrow H_2CO_3 + NO_2$] is equally correct

With metal

$Zn + HNO_3 \longrightarrow [NO_2 + H_2O] + ZnO + HNO_3 \longrightarrow Zn(NO_3)_2 + 2H_2O + NO_2$

$Cu + HNO_3 \longrightarrow [NO_2 + H_2O] + CuO + HNO_3 \longrightarrow Cu(NO_3)_2 + 2H_2O + NO_2$

Reaction of Dilute (40-60%) Nitric Acid as oxidising Agent:

When diluted little more, it undergoes a different reaction, so with moderate dilute nitric acid it produces NO, which has more H^+ than the previous one.

But also a different short of product with less active metals in less concentrated, solution

The reaction goes by the following general way: (where M stands for metal, and metal oxides are generally bases so it reacts with dilute acid, a acid-base reaction)

$3\mathbf{M} + 8HNO_3 \longrightarrow [2NO + H_2O] + 3\mathbf{MO} + 6HNO_3$

$\longrightarrow 3\mathbf{M}(NO_3)_2 + 3H_2O + [H_2O + 2NO]$

Example:

$3Zn + 8HNO_3 \longrightarrow 3Zn(NO_3)_2 + 4H_2O + 2NO$

$3Fe + 8HNO_3 \longrightarrow 3Fe(NO_3)_2 + 4H_2O + 2NO$

$3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$

Aqua Regia (King of All Acids)

Even concentrated HNO_3 oxidises concentrated HCl in concentrated solution to form nitrocyl chloride, NOCl. A mixture of 3 portions of concentrated HCl with 1 portion concentrated HNO_3 is called aqua regia or royal water, which even dissolves gold and platinum like inert metals.

Au + Aqua regia $\longrightarrow NOCl + H_2O + AuCl_3$

Pt + Aqua regia $\longrightarrow NOCl + H_2O + PtCl_4$

Dehydrating nature of H_2SO_4

When moist sugar is mixed up with concentrated sulphuric acid it forms a spongy mass, this shows dehydrating nature of H_2SO_4. Reaction goes as

$C_6H_{12}O_6 + H_2SO_4 \longrightarrow 6C + 6H_2O$ [dehydrating nature]

$C + H_2SO_4 \longrightarrow CO_2 + [H_2O + SO_2]$ [oxidising action of sulphuric acid]

Which produces a spongy mass of carbon puffed by CO_2 and SO_2 produced from oxidising reaction, which follows dehydration. This property of H_2SO_4 is utilised in carbon monoxide preparation from organic acids

$HCOOH + H_2SO_4 \longrightarrow CO + H_2O$ [from formic acid]

$HOOC\text{-}COOH + H_2SO_4 \longrightarrow CO + CO_2 + H_2O$ [from oxalic acid]

Other three substances, NH_3, SO_2 and H_2S

Ammonia as base: ammonia behaves as base as when in aqueous solution, it dissociates as [$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$] and thus the OH^- produced behaves as alkali

Ammonia as a reducing agent: ammonia behaves

Ammonia as complex creator:

Test for ammonia

Sulphur dioxide as additive

Sulphur dioxide acts both as oxidising and reducing as [$S + O_2 \longrightarrow SO_2 \longleftarrow SO_3$]

Sulphur dioxide as oxidising agent

Sulphur dioxide as reducing agent

Bleaching comparison

Thermal decomposition of metal salts

Metal carbonate

Metal nitrates

Other salts

Chapter-5

Chemical Bonding

Ionic or electrovalent bonds
Covalent bonds
Polarity in covalent bonding
Coordination or dative bonding

Chapter-4

Stoichiometry

Molecular weight
Percentage composition
Empirical formula
Molecular formula
Mole and Avogadro's number
Gay Lussac's Law
Avogadro's hypothesis
Mole concepts
Mole, mass, volume relationships
Various mole-mass-volume calculations

Chapter-3

Periodic Trends

What is Acid and Acidic behavior?
Reactions of Acids
Base, and alkali, general behavior
Reactions of Bases
Salts, types of salts
General method of preparation of salts

Chapter-6

Electrolysis

Electrolysis and Electrolytes
Electrolysis in molten state
Electrolyte of Aqueous solutions
Application of Electrolysis

Chapter-7

Inorganic Chemistry

Comparative study of acids
- Hydrochloric acid
- Sulphuric acid
- Nitric acid

Ammonia and its reactions
Hydrogen sulphide
Sulphur Dioxide

Chapter-8

Analytical Chemistry

Thermal Decomposition:
- Effect of heat on carbonates
- Effect of heat on nitrates

Analysis of Metal Cations:
- With Sodium hydroxide solution
- With dilute ammonia solution

Identification of Gases

Chapter-9

Organic Chemistry

Chapter-10

Metallurgy

What is Acid and Acidic behavior?
Reactions of Acids
Base, and alkali, general behavior
Reactions of Bases
Salts, types of salts
General method of preparation of salts

THE PERIODIC TABLE

Period	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
1	1 H Hydrogen 1							2 He Helium 4
2	3 Li Lithium 7	4 Be Beryllium 9	5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
3	11 Na Sodium 23	12 Mg Magnesium 24	13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulphur 32	17 Cl Chlorine 35.5	18 Ar Argon 40
4	19 K Potassium 39	20 Ca Calcium 40	21 Sc Scandium 45	22 Ti Titanium 48	23 V Vanadium 51	24 Cr Chromium 52	25 Mn Manganese 55	26 Fe Iron 56	27 Co Cobalt 59	28 Ni Nickel 59	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 70	32 Ge Germanium 73	33 As Arsenic 75	34 Se Selenium 79	35 Br Bromine 80	36 Kr Krypton 84
5	37 Rb Rubidium 85	38 Sr Strontium 88	39 Y Yttrium 89	40 Zr Zirconium 91	41 Nb Niobium 93	42 Mo Molybdenum 96	43 Tc Technetium (99)	44 Ru Ruthenium 101	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 108	48 Cd Cadmium 112	49 In Indium 115	50 Sn Tin 119	51 Sb Antimony 122	52 Te Telurium 128	53 I Iodine 127	54 Xe Xenon 131
6	55 Cs Caesium 133	56 Ba Barium 137	57 La Lanthanum 139	72 Hf Hafnium 178	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 186	76 Os Osmium 190	77 Ir Iridium 192	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 201	81 Ti Thallium 204	82 Pb Lead 207	83 Bi Bismuth 209	84 Po Polonium (210)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Unq Unniquadium (261)	105 Unp Unnilpentium (262)	106 Unh Unnilhexium (263)												

Key

Atomic Number
Symbol
Name
Molar mass in g mol^{-1}

► Lanthanide elements	58 Ce Cerium 140	59 Pr Praseodymium 141	60 Nd Neodmium 144	61 Pm Promethium (147)	62 Sm Samarium 150	63 Eu Europium 152	64 Gd Gadolinium 157	65 Tb Terbium 159	66 Dy Dysprosium 163	67 Ho Holmium 165	68 Er Erbium 167	69 Tm Thulium 169	70 Yb Ytterbium 173	71 Lu Lutetium 175
►► Actinide elements	90 Th Thorium 232	91 Pa Protactinium (231)	92 U Uranium 238	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (245)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (253)	101 Md Mendelevium (256)	102 No Nobelium (254)	103 Lr Lawrencium (257)

About the Writer

Writer, Mr. Jaydip Chaudhuri, is a teacher by profession, and a technocrat by trade. Born in Jalpaiguri, a small town in 'Duars' in North Bengal has done his schooling from various Ramakrishna Missions spread over Bihar and West Bengal. He has taken his Masters (M.Sc) in chemistry in physical chemistry from North Bengal University. And started taking lesson in computer science in the same place. But left the course half done to take up a teaching profession at St. Pauls' school, Jalapahar, Darjeeling, a school which ranked 6th by the times magazine in the list of top public school of India. There after He has moved on to The Doon school, Dehradun, one of the premier institution of excellence, in the public school world. Has taught in various other places like British International School, Andhra Pradesh, Banasthali Vidyapith, Jaipur, Baa atoll Education centre, at Republic of Maldives and at present working at Sarala Birla Academy, Bangalore-83. Besides Chemistry he has a keen interest in computer science, which he learnt in a era when Mainframes and minis used to rule the world of computer and personal computer or PC was a dream. He has a technical degree in his pocket in computer science and application (MCA). Besides teaching he loves cartooning, wood curving, clay sculpting and various other maddening activities. Other than these he has the University quiz championship in his credit, and the university award for self composed poetry, in Bengali, his mother tongue