# Chemistry Notes

## NDA Chemistry Syllabus & Scope

This document covers the key topics outlined in the official syllabus for the Chemistry section of the NDA examination.

- **Physical and Chemical changes.**
- **Elements, Mixtures and Compounds, Symbols, Formulae and simple Chemical Equations, Law of Chemical Combination (excluding problems).**
- **Properties of Air and Water.**
- **Preparation and Properties of Hydrogen, Oxygen, Nitrogen and Carbon dioxide, Oxidation and Reduction.**
- **Acids, bases and salts.**
- **Carbon—different forms.**
- **Fertilizers—Natural and Artificial.**
- **Material used in the preparation of substances like Soap, Glass, Ink, Paper, Cement, Paints, Safety Matches and Gun-Powder.**
- **Elementary ideas about the structure of Atom, Atomic Equivalent and Molecular Weights, Valency.**

---

## 1. Fundamental Concepts

### 1.1 Physical vs. Chemical Changes

- **Physical Change:** Alters a substance's form (shape, size, state) but not its chemical identity. It's often reversible.
  - **Examples:** Melting ice, boiling water, shredding paper, dissolving sugar.
- **Chemical Change:** Forms one or more new substances with different properties. It's generally irreversible.
  - **Signs:** Gas production (bubbles), color change, odor, temperature change, light/sound production. [1]
  - **Examples:** Burning wood, rusting iron, cooking an egg, digestion of food.

## 1.2 Elements, Compounds & Mixtures

| Category | Definition | Key Properties | Examples |
|---|---|---|---|
| **Element** | A pure substance of only one type of atom. Cannot be broken down chemically. | Has unique properties. | Iron (Fe), Carbon (C), Oxygen (O2) |
| **Compound** | A pure substance of two or more elements chemically bonded in a fixed ratio. | Properties are different from its elements. Separated only by chemical reactions. Fixed melting/boiling point. | Water (H2O), Salt (NaCl) |
| **Mixture** | Two or more substances physically combined in a variable ratio. | Components keep their properties. Separated by physical means (filtration, evaporation). Melts/boils over a range of temperatures. | Air, Seawater, Salad |



## 1.3 Symbols, Formulae & Equations

- **Symbols:** One or two-letter codes for elements (e.g., **H**, **Ca**, **Fe**). The first letter is always capitalized, the second is lowercase.
- **Formulae:** Represent compounds using symbols and subscripts (e.g., **H2O**, **Ca(NO3)2**).
- **Equations:** Describe chemical reactions.
  - **Reactants → Products**
  - Must be **balanced** to follow the Law of Conservation of Mass. [1]
  - **Balancing Tip:** Change coefficients (numbers in front), never subscripts.
  - **Example:** Unbalanced: Fe+H2O⟶Fe3O4+H2. Balanced: **3Fe+4H2O⟶Fe3O4+4H2**. [1]

### 1.4 Law of Chemical Combination

- **Conservation of Mass (Lavoisier):** Mass is not created or destroyed in a chemical reaction.
- **Definite Proportions (Proust):** A compound always contains the same elements in the same fixed ratio by mass.
  - **Example:** Pure water ($H_2O$) is always 11.1% hydrogen and 88.9% oxygen by mass.
- **Multiple Proportions (Dalton):** When two elements form multiple compounds, the mass ratios of one element combined with a fixed mass of the other are in simple whole numbers.
  - **Example:** In CO and $CO_2$, the masses of oxygen that combine with 12g of carbon are 16g and 32g, a 1:2 ratio.
- **Gay-Lussac's Law of Gaseous Volumes:** The volumes of reacting gases are in simple whole-number ratios.
  - **Example:** 2 volumes of $H_2$ + 1 volume of $O_2$ → 2 volumes of $H_2O$ (gas). The ratio is 2:1:2.

---

## 2. Chemistry of Air & Water

### 2.1 Properties of Air

- **Composition:** A homogeneous mixture of gases.
  - **Nitrogen ($N_2$):** ~78%
  - **Oxygen ($O_2$):** ~21%
  - **Argon (Ar):** ~0.93%
  - **Carbon Dioxide ($CO_2$):** ~0.04%
  - Also contains variable water vapor and trace gases.
- **Key Roles:**
  - **Oxygen:** Essential for respiration and combustion. [2]
  - **Nitrogen:** Acts as a diluent, controlling combustion. [2]
  - **Carbon Dioxide:** Used in photosynthesis; a greenhouse gas. [2]

### 2.2 Properties of Water ($H_2O$)

- **Structure:** A polar molecule due to its bent shape, leading to strong **hydrogen bonds**.
- **Key Properties:**
  - **Universal Solvent:** Dissolves many polar and ionic substances. [4]

- **High Specific Heat:** Absorbs a lot of heat before its temperature rises, regulating climate. [4]
- **Anomalous Expansion:** Reaches maximum density at 4°C. Ice is less dense than liquid water, so it floats. This insulates lakes and allows aquatic life to survive winter.
- **Amphoteric:** Can act as both an acid and a base. [4]

---

## 3. Key Gases & Reactions

### 3.1 Preparation and Properties of Key Gases

| Gas | Lab Preparation | Key Properties | Main Uses |
|---|---|---|---|
| **Hydrogen ($H_2$)** | $Zn + 2HCl \rightarrow ZnCl_2 + H_2$ | Lightest gas, highly flammable, 'pop' sound with flame. | Ammonia synthesis (Haber Process), rocket fuel. |
| **Oxygen ($O_2$)** | $2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2$ | Supports combustion, relights a glowing splint. | Respiration, welding, steel manufacturing. |
| **Nitrogen ($N_2$)** | $NH_4Cl + NaNO_2 \rightarrow N_2 + 2H_2O + NaCl$ | Inert (unreactive) due to strong triple bond. | Ammonia synthesis, inert atmosphere for food packaging. |
| **Carbon Dioxide ($CO_2$)** | $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$ | Denser than air, extinguishes flames, turns limewater milky. | Carbonated drinks, fire extinguishers, dry ice (refrigerant). |

### 3.2 Oxidation and Reduction (Redox)

- **Definitions:**
  - **Oxidation:** Loss of electrons OR gain of oxygen.
  - **Reduction:** Gain of electrons OR loss of oxygen.
  - **Mnemonic: OIL RIG** (Oxidation Is Loss, Reduction Is Gain).
- **Agents:**
  - **Oxidizing Agent:** Causes oxidation, gets reduced itself.
  - **Reducing Agent:** Causes reduction, gets oxidized itself.
- **Example:** $CuO + H_2 \rightarrow Cu + H_2O$

- CuO is **reduced** (loses oxygen) and is the **oxidizing agent**.
- H2 is **oxidized** (gains oxygen) and is the **reducing agent**. [1]

### 3.3 Acids, Bases, and Salts

- **Acids:** Taste sour, turn blue litmus red, pH < 7.
  - **Examples:** Hydrochloric acid (HCl), Acetic acid (CH3COOH in vinegar). [1]
- **Bases:** Taste bitter, feel soapy, turn red litmus blue, pH > 7.
  - **Examples:** Sodium hydroxide (NaOH), Ammonium hydroxide (NH4OH). [1]
- **Neutralization:** The reaction between an acid and a base.
  - **General Equation:** Acid+Base⟶Salt+Water [1]
  - **Example:** HCl+NaOH⟶NaCl+H2O [1]
- **Salts:** Ionic compounds formed from the cation of a base and the anion of an acid.

---

## 4. Carbon & Industrial Materials

### 4.1 Carbon—Different Forms (Allotropes)

| Allotrope | Structure | Key Properties |
|---|---|---|
| **Diamond** | Each carbon atom is bonded to four others in a rigid 3D tetrahedral lattice (sp3). | Extremely hard, electrical insulator, transparent. |
| **Graphite** | Each carbon atom is bonded to three others in flat hexagonal layers (sp2). Layers are held by weak forces. | Soft, slippery, electrical conductor (due to delocalized electrons). |

### 4.2 Fertilizers—Natural and Artificial

- **Natural (Organic):** Derived from organic matter (manure, compost). Slow-releasing and improves soil health.
- **Artificial (Synthetic):** Manufactured chemicals with precise NPK (Nitrogen, Phosphorus, Potassium) content. Fast-acting but can harm soil over time and cause nutrient runoff.

### 4.3 Preparation of Common Substances

- **Soap:** Made by **saponification**: the reaction of a fat/oil with a strong base like sodium hydroxide (NaOH).
- **Glass:** Made by melting **silica sand (SiO2)**, **soda ash (Na2CO3)**, and **limestone (CaCO3)** at high temperatures. [5]
- **Ink:** A mixture of a **colorant** (pigment/dye), a **binder** (resin), a **solvent**, and additives.
- **Paper:** Made from **cellulose fibers** (usually from wood pulp) by separating fibers from lignin and forming them into sheets.
- **Cement (Portland):** Made by heating **limestone** and **clay** in a kiln to form 'clinker', which is then ground with gypsum. [8]
- **Paints:** Consist of **pigment** (color), **resin** (binder), **solvent** (carrier), and additives.
- **Safety Matches:** The match head contains an oxidizing agent (**potassium chlorate, KClO3**) and fuel (sulfur). The striking surface contains **red phosphorus**.
- **Gunpowder:** A mixture of **potassium nitrate (KNO3)** (oxidizer), **charcoal** (fuel), and **sulfur** (fuel).

---

## 5. Atomic Structure & Quantification

### 5.1 Structure of the Atom (Bohr's Model)

- **Postulates:**
  1. Electrons revolve around the nucleus in fixed circular paths called **orbits** or **shells**.
  2. Each orbit has a fixed, **quantized energy level**.
  3. Electrons can jump between orbits by absorbing or emitting energy (photons).
- **Limitations:** Fails to explain spectra of multi-electron atoms, the Zeeman effect (splitting of spectral lines in a magnetic field), and violates the Heisenberg Uncertainty Principle.

### 5.2 Atomic, Molecular & Equivalent Weights

- **Atomic Weight:** The weighted average mass of an element's isotopes (in amu).
- **Molecular Weight:** The sum of the atomic weights of all atoms in a molecule's formula.
  - **Example ($Ca(OH)_2$):** $(1 \times 40) + (2 \times 16) + (2 \times 1) = 74$ amu. [11]
- **Equivalent Weight:** Equivalent Weight=n−factorMolar Mass
  - **Acid:** n-factor = number of replaceable $H^+$ ions (basicity). For $H_2SO_4$, n=2.
  - **Base:** n-factor = number of replaceable $OH^-$ ions (acidity). For $Ca(OH)_2$, n=2.
  - **Salt:** n-factor = total positive charge of the cation. For $Na_2CO_3$, n=2.

### 5.3 Valency

- **Definition:** The combining capacity of an atom, determined by its **valence electrons** (electrons in the outermost shell).
- **Metals:** Valency = number of valence electrons (they lose electrons).
  - **Example:** Sodium (Group 1) has 1 valence electron, so its valency is 1. [12]
- **Non-metals:** Valency = 8 - (number of valence electrons) (they gain electrons).
  - **Example:** Oxygen (Group 16) has 6 valence electrons, so its valency is 8 - 6 = 2. [12]
- **Periodic Table Trend:** Elements in the same group typically have the same valency. [12]