Chemistry definitions

C1, C2, C3 :Particulate nature of matter, Experimental techniques and atoms,elements and compounds (according to syllabus guide)

- **-physical properties**: any property that can be measurable and can be observed without chemical reaction taking place and without change in composition of matter. It doesn’t change the chemical nature of matter.
- **-melting point**: the temperature at which a pure substance turns into a liquid.
- **-freezing point**: the temperature at which a pure substance changes to a solid from liquid/ liquid is cooled down.
- **-boiling point**: the temperature at which the saturated pressure of a liquid is equal to the surrounding atmosphere and it increases with pressure and it occurs throughout the liquid.
- **-volatile liquid**: a liquid which evaporates easily and has a relatively low boiling point. They have equilibrium vapour pressure.
- **-sublimation**: a few solids change directly from solid to gas on heating and the reverse is called deposition or reverse sublimation.
- **-evaporation**: when liquids change into gases over a range of temperatures and it occurs on the surface of the liquid and the opposite is condensation.
- **-pure substance**: consists of only one substance and no contaminating impurities.
- **-mixture**: more than one substance present and substances may be in different physical states and solutions, suspensions and colloids are types of mixtures.
- **-atom**: the smallest particle of a chemical element that can exist.
- **-molecule**:a group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction.
- **-ions**: an atom or molecule with a net electric charge due to the loss or gain of one or more electrons.
- **-decantation** : a process carried out to pour of a liquid once the solid of the solution has settled.
- **-filtration**: separation of insoluble solid from a liquid by collecting the insoluble solid as residue on the filter paper and purified liquid as filtrate.

- **-Buchner funnel**: is used to increase the filtration process as a vacuum pump is connected to the side arm flask which speeds up the flow of liquid through the funnel.
- **-centrifugation**: is a separating technique where the mixture is spun at a high speed in a centrifuge so that the solid deposits at the bottom of the tube and liquid can carefully be decanted.
- **-distillation**: is a method for separating the solvent from a solution. The more volatile liquid is condensed and collected as distillate.
- **-fractional distillation**: is a process in which the volatile components having different boiling points of a mixture are split from one another by heating the mixture in a column and collecting and condensing the vapours drawn at different levels of the fractionating column.
- **-chromatography**: used to separate a mixture of solids by passing it in solution or suspension through a medium in which the components move at different rates.
- **-retention factor** : the relation of the distance moved by a particular spot to the distance moved by the solvent front.
- **-solution**: combination of a solute and solvent
- **-solute**: the substance that dissolves in the liquid.
- **-solvent**: the liquid in which the solute dissolves.
- **-concentrated**: a solution containing a high proportion of solute
- **-dilute**: solution containing less amount of solute in solvent
- **-concentration**: of a solution is the mass of solute dissolved in a particular volume of solvent(1dm^3)
- **-saturated solution**: a point when no more of the solid will dissolve in the solution at the temperature given.
- **-diffusion**: is the random movement of particles from a region of higher concentration to a region of lower concentration causing the particles to evenly spared out.
- **-matter**: anything that has mass and takes up space(volume). Three physical states of matter are solid, liquid and gas.
- **-elements**: are pure substances that cannot be chemically broken down into simpler substances
- **-compounds**: are pure substances made of two or more elects chemically bonded together.
- **-chemical reaction**: in a chemical reaction new chemical substances are formed and the process is not easily reversed and energy is often given out.
- **-physical change**: the substances involved do not change identity and they can easily be returned to their original form by physical processes

- **-lattice**: the highly structured ordered microscopic arrangements in solids which produces regular crystal structures
- **-nucleus**: the positively charged part of the atom in the centre and contains almost all of the mass of the atom.
- **-electron**: subatomic particle consisting of a negative electrical charge and hardly has any mass.
- **-proton**: subatomic particle consisting of a positive electrical charge and mass of one unit.
- **-neutron**: subatomic particle having no electrical charge (neutral) and mass of one unit.
- **- proton/atomic number**: number of protons (Z)
- **-nucleon/mass number**: number of protons + number of neutrons (A)
- **-mass spectrometer**: the mass of one atom can be compared with that of another using this
- **-scanning tunneling microscope**:helps to see individual atoms in structure
- **-isotopes**: atoms of the same element which have the same proton number but different mass number due to different neutron number. But they have the same properties due to same electron structure.
- **- relative atomic mass**: the average mass of naturally occurring atoms of an element on a scale where the carbon-12 atom has a mass of exactly 12 units
- **- metals**: an element that conducts electricity, is malleable, is ductile
- **-non metals**: an element that does not conduct electricity, isn't malleable and isn't ductile
- **-chemical bonding**: keeps two ions or atoms together and it involves the outer electrons of each atom also called valence electrons
- **-diatomic molecules**: molecules made up of two atoms of the same element
- **-metallic bonding**= metals + metals (metallic lattices) and they have positive metal ions surrounded by sea of electrons
- **-covalent bonding**=non metals + non metals (simple molecules/giant molecular lattices) and they share electrons from last shell forming covalent bonds
- **-ionic bonding**= metals + non metals (giant ionic lattices) and transfer of electrons from metals to nonmetals take place
- **-molten state**: when an object is reduced to liquid form by heating it
- **-formulae of ionic compounds**: the whole numbered ratio of the positive to negative ions in the structure
- **-formulae of covalent compounds**: whole number ratio of the number of atoms present in the giant lattice
- **-types of solid physical structure:**
- **. Giant metallic lattice:** a lattice of positive ions in a sea of electrons

- **. Giant ionic lattice:** a lattice of alternating positive and negative ions
- **. Giant covalent (molecular) lattice:** a giant molecule (macromolecule) making the lattice
- **. Simple molecular substance:** consisting of simple molecules in a lattice held together by weak forces
- **-malleable**: when metals can be beaten or rolled into sheets due to their flexibility in their layered structure and how metal ions can be moved over one another without breaking the structure
- **-ductile**: property of metals to be able to be drawn out into wires
- **-alloys**: are formed by mixing the molten metals together thoroughly and then allowing them to cool and form a solid
- **-bond length:** the distance between the two nuclei of the two bonded atoms
- **Structure of silicon oxide:** tetrahedral structure, each Si atom bonds with 4 oxygen atoms and each oxygen atom bonds with 2 Si atoms
- **Structure of diamond:** hard, high m.p and b.p, not good conductors of heat and electricity, colourless and transparent crystals that sparkle in light, the hardest natural substance. Used in jewellery, ornamental objects, drill bits, diamond saws and glass-cutters.
- **Graphite**: dark grey, shiny solid, soft and has a slippery feel, conducts electricity. Used in pencils, lubricants, as electrodes and for the brushes in electric motors.

C4: stoichiometry

- **Relative atomic mass: (A_r)** of an element is the average mass of an atom of the element, taking into account the different natural isotopes of that element, on a scale where carbon-12 atom has a mass of exactly 12 units (amu)
- **Relative formula mass (M_r / RFM)**: the sum of all the relative atomic masses of all the atoms of all the elements of an ionic compounds which consists of ions is taken as the basic unit
- **Relative molecular mass (M_r)**: the sum of the relative atomic masses of all the atoms of all the elements of a covalent compound consisting molecules
- **Avogadro constant (L)** = 6.02×10^{23}
- **Mole**: one mole of a substance has a mass equal to its relative formula/ molecular mass in grams and contains 6.02×10^{23} atoms, molecules or formula units, depending on the substance considered and contains as many species of atoms, molecules or ions as there are In exactly 12g of C-12 isotope

- **Molar mass**: mass of one mole of any substance
- **Number of moles** = mass (g) / molar mass (mol/g)
- **Finding the formula**: number of moles of each element and their ratios in simplest form
- **Empirical formula**: formula obtained by the ratio of moles of two substances which are reacting
- **Law of conservation of mass:** the total mass of reactants is equal to the total mass of the products
- **Reacting ratios**: molar mass of balanced equation is the ratio in which the reactants should be reacted
- **Avogadro's law**: one mole of any gas occupies a volume of 24 dm3 or 24 l at room temperature and pressure (r.t.p) and equal volumes of all gases measured at rtp must contain the same number of molecules
- **Molar gas volume(V_m)**: of any gas has value 24dm3/mol
- **1dm3 = 1litre = 1000 cm3**
- **Number of moles** = volume / molar volume (always 24)
- **Concentration** = amount of solute / volume of solution
- **Molarity/concentration** = weight/molecular weight X 1000/v (ml)
- **Molality** = weight/molecular weight X 1000/mass (kg)
- **Normality** = molarity X n_f
- **Mass concentration**: of a solution is measured in g/dm3
- **Molar concentration**: of a solution is measured in mol/dm3
- **Number of moles in solution** = molar concentration X volume of solution in dm3 (or) concentration/1000 X volume of solution in cm3
- **Standard solution**: a solution that has been carefully made so that its concentration is known precisely
- Mass of one molecule/atom has **amu** in units
- Relative atomic/molecular/formula mass has **no units**
- Molar mass has unit **g/mol**
- (All formulae in syllabus guide as well)

C5: Electricity and chemistry

- **Electrical conductor**: a substance that conducts electricity but is not chemically changed in the process
- **Electrical insulator**: a substance that does not conduct electricity

- **Electrolysis**: the breakdown of an ionic compound, molten or in aqueous solution, by the use of electricity. The three stages involved are mining the ore, purification of the ore and electrolysis of the molten ore.
- **Electrolytes**: liquids or molten state solids or substances in solution which conducts electricity by movement of ions. Ex: molten salts, solutions of salts in water, solutions of acids and solution of alkalis
- **Non-electrolytes**: liquids or molten state solids or substances in solution which do not conduct electricity as they usually can't break their bonds
- **Weak electrolyte**: liquids or molten state solids or substances in solutions which conduct electricity to a small extent
- **Metallic conductivity**: electrons flow, a property of metals and alloys, takes place in solids and liquids and no chemical change takes place
- **Electrolytic conductivity**: ions flow, a property of ionic compounds, takes place in liquids and solutions only and chemical decomposition takes place
- **Electrochemical cell**: A cell is a device which converts chemical energy into electrical energy and is composed of two metals of different reactivity connected by an external circuit and an electrolyte.Consist of a negative pole (the more reactive metal) and a positive pole (less reactive metal) and an electrolyte.The greater the difference in reactivity of the two metals, the greater the voltage will be.The electrons flow because one metal is more reactive, so it has a stronger drive to give up its electrons.The atoms give up electrons and enter the solution as ions.
- **Cations**: positive ions that move towards the cathode during electrolysis
- **Anions**: negative ions that move towards the anode during electrolysis
- **Cathode**: negatively charged electrode which attracts cations(+ve) and is connected to the negative terminal of the battery
- **Anode**: positively charged electrode which attracts anions(-ve) and is connected to the positive terminal of the battery
- **Electrolytic cell**: the apparatus in which electrolysis is carried out. It consists of the battery, electrodes and the electrolyte
- **Inert electrodes**: usually made up of unreactive metals like platinum, graphite,etc.
- **Reactive electrodes**: usually made up of metals like copper, silver and gold for electroplating and other reactive metals for purification of metal extracts
- **Extraction of aluminium/Hall héroult process: Bayer process** is used to first purify the bauxite ore. The aluminium oxide obtained is treated with sodium hydroxide. **Cryolite** (sodium aluminium fluoride) is used in molten form as it will dissolve oxide minerals and lower the melting point. The graphite anodes react

with oxygen and form carbon dioxide. The alminimum3+ goes to cathode and forms aluminium. Reactions:

- At the anode: $6O_{2-}$ —> $3O_2$ + 12e and C + O_2 —> CO_2 (electrode)
- At the cathode: $4Al^{3+}$ +12e—> 4Al
- Overall reaction: $2Al_2O_3$ —> 4Al + $3O_2$
- **Electrolysis of sulfuric acid/the Hofmann voltameter :** is used as there are no halides and thus water can split into hydrogen and oxygen gas by using the Hofmann voltameter setup.
- At the anode: 4OH- —> O2 +2H2O + 4e
- At the cathode: 2H+ + 2e—> H2
- **Electrolysis of conc.sodium chloride / brine solution / Chlor alkali process:** it is used industrially to obtain sodium hydroxide, chlorine and hydrogen. It is done in a membrane cell setup which allows only Na+ and OH- ions to enter the cathode chamber and thus sodium hydroxide can be obtained and purified. Brine solution enters the anode chamber and water enters the cathode chamber at the start. In the anode side chlorine gas bubbles are formed around the titanium anode and Na goes to the cathode chamber where the hydrogen gas is given off at the cathode and Na and OH ions combine to form a solution.
- At the cathode: 2H+ + 2e —> H2 gas
- At the anode: 2Cl- —> Cl2 + 2e gas and NaOH
- The membrane used is called ion exchange membrane/ proton exchange membrane/ polymer electrolyte membrane
- **Molten electrolysis of molten lead bromide:** the melting point of lead bromide is 373 C.
- At the anode:2Br- —> Br2 + 2e
- At the cathode: Pb2+ + 2e —> Pb
- **RED CAT**: reduction at cathode
- **AOCR**: anode..oxidation and cathode..reduction
- **Aqueous electrolysis:**
- At the anode: if a concentrated halide is present, then halogen is formed. Otherwise oxygen is formed.
- At the cathode: if the metal is less reactive than hydrogen, then the metal is formed, otherwise hydrogen is formed
- **Molten electrolysis**: at the anode, non metal is formed and at the cathode, metal is formed
- **Electroplating**: is a process used to coat a metal with another metal. The anode is the metal which is the coating and the cathode is the metal which needs to be coated. The solution consists of the salt of the metal which is being used as a coating. When current is passed through the solution, the anode ions deposit on

the cathode, making the cathode thicker and the anode eventually disappears. The concentration of the solution remains the same all the time. The anode releases ions into the solution and ions from the solution get deposited in the cathode until the anode disappears.

- **Electrolytic refining**: is the process of obtaining pure metals like gold, silver, copper etc. by the process of electrolysis.
- **Refining of copper:** the cathode is a strip of pure copper and anode is a strip of impure copper. The electrolyte is an aqueous solution of dilute copper sulphate. When electricity is passed the Cu ions from the solution go to the cathode and get deposited and the cu ions from the imputed rod enter the solution and it goes on. Since the impurities on the rod have no attractive forces to hold them together, they fall to the bottom of the container as anode mud.
- At the anode: cu —> cu2+ + 2e
- At the cathode: cu2+ + 2e —> cu

C6 andC7: energy changes in chemical reactions and chemical reactions

- **Hydrocarbons**: molecules containing only hydrogen and carbon
- **Endothermic process**: breaking chemical bonds that takes in energy from the surroundings
- **Endothermic processes**: making chemical bonds which gives out energy to the surroundings
- **Activation energy**: a certain amount of energy given to the reactants as this energy activated the reaction and is used to either break bonds or make bonds
- **Exothermic reaction**: if energy taken is less than energy released(reactants ,have more energy than products) examples: hydration, neutralisation, respiration, combustion and displacement
- **Endothermic reaction**: if energy taken is more than energy given out (reactants have less energy than products) examples: photosynthesis, dehydration and thermal decomposition
- **Enthalpy change/energy changed**: the total energy change(energy in - energy out). It is positive for endothermic reactions and negative for exothermic reactions
- **Energy level diagram/energy profile**: the overall change in energy for eco or endo reactions

- **Heat of combustion**: the energy change of a reaction when a substance is burnt. A metal calorimeter and a spirit burner can be used for liquid fuels such.
- **Heat of neutralisation**: the heat energy given out during the neutralisation reactions between acids and alkalis and can be measured by a polystyrene cup used as a simple calorimeter.
- **Catalyst**: a substance that increases the rate of a chemical reaction and it remains chemically unchanged at the end of the reaction
- **Adsorption**: the process by which a solid holds molecules of the gas or liquid or solute as a thin film
- **Chemical energy**: energy stored in the chemical bonds of substances
- **Physical forms**: different forms of the same substance due to different conditions in temperature and pressure
- **Chemiluminescence**: chemical reactions which give out energy in the form of light
- **Reactants**: substances that react
- **Products**: the new substances that are formed after the reaction takes place
- **Law of conservation of mass**: the total mass of all the products is equal to the total mass of the reactants
- **Balanced equation**: the number of each type of atom is equal on both sides of the reaction
- **Synthesis/direct combination**:occur where two or more substances react together to form just one product
- **Decomposition reactions**: one reactant which breaks down onto two or more simpler products
- **Neutralisation reactions**: a reaction between an acid and an alkali which results in the formation of salts and a gas and the solution is neutral
- **Precipitation reactions**: the sudden formation of a solid, either when two solutions are mixed or when a gas is bubbled into the solution
- **Displacement reactions**: occurs because a more reactive element will displace a less reactive one from a solution of one of its compounds
- **Combustion**: the reaction of a substance with oxygen causing the release of energy. It is exothermic and often involves a flame
- **Burning**: combustion in which a flame is produced
- **Oxidation**: the addition of oxygen/ reduction of hydrogen/ removal of electrons/ addition of positive charge
- **Reduction**: the removal of oxygen/ addition of hydrogen/ addition of electrons/ removal of positive charge
- **Reducing agent**: An element or compound that will remove oxygen from other substances. example: hydrogen, carbon, carbon monoxide

- **Oxidizing agen**t: a substance that will add oxygen to another substance. example: oxygen, hydrogen peroxide, potassium manganate 7 and potassium dichromate 6
- **Corrosion**: the effect by which a reactive metal's surface may be attacked by air, water or other substances around it
- **Rancidity**: is a process where oxidation has damaging effect on food. Example: fat and oils in butter and margarine are oxidized
- **Chemical changes**: they can be observed by change in pH, color, temperature, precipitate formation and evolution of a gas
- **Rate**: is measuring changes in a given time range
- **Rates of reaction**: is understanding the chemical reactions and the rate at which it takes place
- **Redox reactions**: reactions in which oxidation and reduction take place at the same time
- **Oxidation state**: refers to the number of electrons that can be lost, gained or shared by an atom during its compound formation

C8: acids, bases and salts

- **pH scale**: the numerical scale used to specify the acidity or basicity of an aqueous solution. It measures the hydrogen ion concentration in a given solution.
- **Indicators**: chemicals or chemicals in form of paper(aqueous) or liquids which show if a substance is an acid or an alkali by colour change.
    1. Damp litmus turns red in the presence of acid and turns blue in the presence of a base. It stays purple if the solution is neutral. It is because of H+ ions in acids and OH- ions in a base which causes colour changes in a litmus.
    2. Methyl orange is red in acid, orange in neutral solution and yellow in an alkali.
    3. Thymolphthalein is colourless in acidic and neutral solutions but blue in alkali.
- **Universal indicator / full-range indicator:** is a mixture of indicator dyes. It gives a range of colours (spectrum) depending on the strength of the acid or alkali added. Acidic is red, neutral is green and basic is violet.
- **pH meter**: is an accurate method to measure pH which uses an electrode to measure pH electrically.

- **Acids**: substances made of H^+ ions and non metal ions which taste sour and don't feel slippery. The have a pH less than 7, corrode metals and are proton donors. Solutions of acids conduct electricity very well. And acidic properties are only shown if the acid is dissolved in water.
- **Mineral acids:** are powerful acids. Eg: hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4), carbonic acid (H_2CO_3) and phosphoric acid (H_3PO_4).
- **Organic acids:** are not as powerful as mineral acids. Eg: ethanoic acid (CH_3COOH), methanoic acid (HCOOH) and citric acid ($C_6H_8O_7$).
- **Bases**: substances which are made of OH^- ions and metal ions which taste bitter and feel slippery. They have a pH greater than 7, don't corrode metals and are proton acceptors. Their alkaline nature is only shown if they are dissolved in water. Example: metal oxides, metal hydroxides, metal carbonates, metal bicarbonate, ammonium hydroxide and ammonium carbonates.
- **Alkali**: a base that is soluble in water.
- All alkalis are bases, but not all bases are alkalis
- **Oxides**: are chemical compounds with one or more oxygen atoms combined with another element (metal/non metal). They are classified into acidic, basic, amphoteric and neutral oxides based on the acid-base characteristics.
- **Basic oxides**: they are metal oxides and react with acid and form salt and water. They are solids and insoluble in water except group 1 metal oxides.
- **Amphoteric metal oxides/amphoteric hydroxide:** a metal oxide or hydroxide which reacts with an acid and base to give a salt and water (or) oxides of aluminum, zinc and lead which produce water and a salt when they react with acid. Their hydroxides are amphoteric too and act as an acid when they react with an alkali and vice-versa. Eg: ZnO and Al_2O_3
- **Acidic oxides**: non metal oxides except monoxides of nonmetals. They are all gases and react with an acid to form a salt and water.
- **Neutral oxides**: metal monoxides which don't react with acids or alkalis. Eg: H_2O, CO, NO
- **Antacids**: are compounds that are used to neutralise acidity to help get rid of acid indigestion. Eg:
    1. Magnesium oxide and magnesium hydroxide
    2. Sodium carbonate and sodium hydrogen carbonate
    3. Calcium carbonate and magnesium carbonate
- **Salts**: they are neutral ionic compounds formed by the reactions in which the H^+ ion from the acid is replaced by any other metal ion.
- **Salt preparation**: they can be prepared by the following reactions: metal+acid, excess of metal oxide+acid, soluble base+solid(titration) or precipitation method.

- **Strong acids:** have pH 0,1,2,3 and they ionize fully. When dissolved in water they give large amounts of H+ ions.
- **Weak acids:** have pH 4,5,6 and they don't ionize fully. When dissolved in water, they give a small amount of H+ ions.
- **Solubility rules:**
    1. All salts of group 1 and ammonium are soluble
    2. All salts of nitrates are soluble
    3. All salts of halides are soluble except silver, copper, lead and mercury
    4. All salts of sulfates are soluble except barium sulfate, lead sulfate and strontium sulfate
    5. All salts of carbonates, phosphates and sulfites are insoluble except for group 1 and ammonium.
    6. All hydroxides and oxides are insoluble except group1, calcium, strontium and barium
    7. All salts of sulfides are insoluble except group 1, group 2 and ammonium.
    8. All metal oxide and hydroxides will neutralise acids, if they dissolve in water or not.
- **Reaction of acids:**
    1. **With metals: acid + metal → salt + hydrogen**
       Eg: $Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$
       Eg: $Zn + HCl \rightarrow ZnCl_2 + H_2$
    2. **With bases and alkalis: acid + base → salt + water**
       Eg: $NaOH + HCl \rightarrow NaCl + H_2O$
    3. **With carbonates: acid + metal carbonate → salt + water + carbon dioxide**
       Eg: $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$
- **Soluble salt preparation method:**
    1. **Method 1 (acid plus solid metal, base or carbonate): only for MAZIT metals (magnesium, aluminium, zinc, iron and tin)**
        a. An excess of the solid is added and allowed to react with the acid so that the acid is used up.
        b. The excess solid is filtered out
        c. The filtrate is gently evaporated to concentrate the salt solution
        d. When crystals start forming (crystallisation point), heating is stopped and the solution is left to crystallise
        e. The concentrated solution is cooled to let the crystals form and then the crystals are filtered off and washed with a little distilled water, after which the crystals are dried between two filter papers.

2. **Method 2 (acid plus alkali by titration): only for metals below hydrogen in the reactivity series (copper, gold, silver, mercury and platinum, etc)**

a. The acid solution is poured into a burette and a known volume of alkali is placed in a conical flask using a pipette. Also, a few drops of an indicator are added to the flask.
b. The acid is dropped into the flask using a pipette until the indicator changes colour to show that the solution has become acidic. The end-point is reached. The volume of acid used is noted. The second step is repeated without the indicator and directly with the noted volumes of the acid and base.
c. The salt solution is evaporated and cooled to form crystals.

- **Precipitation**: is the sudden formation of a solid either when two solutions are mixed or when a gas is bubbled into a solution. This method is used to prepare insoluble salts.
- **Methods of collecting gases:**
    1. **Downward delivery:** is used to collect gases that are denser than air
    2. **Upward delivery:** is used to collect gases that are less dense than air
    3. **Collection over water:** is used to collect gases which are not very soluble in water
    4. **Collection in a gas syringe:** is useful when the volume of gas needs to be measured

C9: The periodic table

- **Periodic table:** it consists of elements in order of increasing proton number (atomic number). It is used to classify elements and to predict properties of elements.
- **Groups**: the vertical columns of elements with similar properties. elements of the same group have the same number of outer electrons.
- **Periods**: the horizontal rows of elements. The elements in the same period have the same number of electron shells.
- **Metals**: an element that conducts electricity, is malleable and ductile
- **Non-metals**: an element that doesn't conduct electricity well and neither is malleable nor ductile

- **Metalloids/semimetals**: such elements have some properties of metals and others that are more characteristic to non metals
- **Group 1: the alkali metals-** soft solids, low melting points, low densities, highly reactive, density increases down the group, melting point becomes low down the group.
  Metal + water → metal hydroxide + hydrogen
- **Group 7: the halogens-** most reactive nonmetals, reactivity increases down the group, increase in melting and boiling points down the group, change in elements from gases to solids down the group, all are poisonous and have a similar strong smell, diatomic, intensity of color increases down the group, decreasing oxidizing ability down the group
- **Chlorine water:** when chlorine dissolves in water to give two acids; hydrochloric acid and hypochlorous acid. Chlorine water is an oxidizing agent and bleach.
- Halide: a halogen joined to a metal
- **Group 8: the noble gases-** inert, low melting and boiling points
- **Trends across a period**: from left to right, metallic to non metallic, atomic size decreases
- **Transition elements**: hard and strong, high density, high melting and boiling point, many of their compounds are colored, act as catalysts, have more than one valency, few of them are magnetic, good conductors of heat and electricity.

C10: Metals

- **Metal**: an element that conducts electricity and heat. It is malleable, ductile and sonorous. They have high melting and boiling points. They are dense in nature and can be polished. Metals become positive ions as they lose electrons more easily and form basic oxides.
- **Non-metals**: are elements which don't conduct electricity or heat, aren't malleable or ductile, have low melting and boiling points, brittle when solid, aren't sonorous and have a dull surface. They form acidic oxides.
- **Metallic bonding:** happens between atoms and it is caused by the sea of electrons which have delocalized from their atoms, holding the metallic structure together. Due to the mobile electrons, metals conduct electricity and are malleable (or) metallic bonding is a type of bonding that arises from the strong electrostatic forces of attraction between the positive metal cations and the negative delocalised ions.

- Alloys: are combination of two or more metals or metal and non-metal, which have been made molten and then mixed together.
- **Aluminium** is a light, strong metal with good electrical conductivity. It is extracted by electrolysis of alumina, which is extracted from purifying the bauxite ore in a bauxite plant. It is used in:
    1. Building modern car bodies
    2. Construction of aeroplanes
    3. Overhead power lines
    4. Food packaging in the form of aluminium foil
    5. External structures like window frames
- **Information about reactivity of metals can be obtained by:**
    1. Ease of their extraction
    2. Reactions with air or oxygen
    3. Reactions with water
    4. Reactions with dilute acid
    5. Metal displacement reactions
    6. Heat stability of metal compounds
- **Thermal decomposition of:**
    1. **Carbonates**: decompose to oxides and carbon dioxide on heating. Reversible. Carbonates of potassium and sodium don't decompose.
    2. **Hydroxides**: thermally decompose to metal oxides and water. Unless electrolysis is done, hydroxides of potassium and sodium don't decompose.
    3. **Nitrates**: nitrates of sodium and potassium, break down to give nitrites and oxygen. Lithium, group 2 and transition elements decompose to give metal oxide, nitrogen dioxide and oxygen.
- **Electrolysis of molten ores: K, Na, Ca, Mg, Al**
- **Reduction of oxides with carbon: Zn, Fe, Sn, Pb**
- **Occur native / uncombined: Cu, Ag, Au**
- **Production of iron in the blast furnace:**
    1. Charge (iron ore, coke and limestone) is added into the furnace.
    2. The coke burns, giving off heat ($C + O_2 \rightarrow CO_2$)
    3. Carbon monoxide is made ($C + CO_2 \rightarrow 2CO$)
    4. Iron oxide is reduced to give iron ($Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$)
    5. Other reactions: $CaCO_3 + CaO \rightarrow CO_2$ and $CaO + SiO_2 \rightarrow CaSiO_3$
    6. Waste gases like nitrogen and carbon dioxide are released from the top of the furnace but are reused and sent back inside
    7. The furnace has walls of heat resistant magnesium bricks, which are always cooled by water.

- **Steelmaking (basic oxygen process):**
    1. Once the pig iron is collected from the blast furnace, it is put into another furnace along with lime and scrap steel.
    2. A water cooled oxygen lance is put into the furnace and fumes come out
    3. Then the furnace is tilted to pour out the molten steel
    4. Then the furnace is tilted again to pour out the slag
- **Extracting zinc from zinc blende:**
    1. Roasting: zinc sulfide is turned into zinc oxide by roasting.
    2. Smelting: zinc oxide is either reduced by carbon monoxide or it is dissolved in sulfuric acid and then electrolyzed.
- **Recycling metals** is important as metal resources are finite, recycling needs less energy compared to energy needed to extract metals, saves money and helps the environment.
- **Uses of metals:**
    1. **Aluminium**: aircrafts and food containers / packaging.
    2. **Copper**: in electrical wiring and cooking utensils
    3. **Zinc**: making brass and galvanizing
    4. **Stainless steel**: in chemical plant and cutlery

C 11, 12 and 13: air and water

- **Water can be tested** using either cobalt (II) chloride paper (blue to pink) or copper (II) sulfate (white to blue).
- **Water treatment procedure:** Water from river → screens for floating rubbish → river water pumping station → treated with ozone in storage reservoir → precipitators to clear solid particles → rapid gravity sand filters → main ozone pumps to break down pesticides and other material → activated carbon granules to absorb some of the chemicals → microstrainers → chlorine to disinfect → service reservoir → domestic use
- **Clean air composition:**
    1. **Nitrogen 78%**: used in haber process, fertilisers, ammonia manufacture, cryogenics, sealing food and substances
    2. **Oxygen 21%:** used to make steel from cast iron, oxyacetylene torches and oxygen cylinders in hospitals.
    3. **Argon 0.9%:** is used to fill light bulbs as it is unreactive
    4. **Carbon dioxide 0.04% and noble gases 0.06%:** used in advertising signs
- **Pollutants** (how they are emitted and how they are damaging):

1. **Oxides of nitrogen:** cause photochemical smog, acid rain and global warming. It is emitted by car engines, due to the high temperatures, which causes it to combine with oxygen. $N_2 + 2O_2 \rightarrow 2NO_2$
2. **Unburnt hydrocarbons and carbon monoxide:** cause photochemical smog. They are emitted by car engines due to incomplete combustion that takes place and from burning of carbon containing substances.
3. **Sulfur dioxide:** causes acid rain. It is also released from vehicles which use high sulfur fuels and from fossil fuels. It can be reduced by the method of flue gas desulfurization. (scrubbers containing CaO which neutralise the effects of the SO_2 being released)
4. **Carbon dioxide:** causes global warming. It enters the air through respiration, burning of fuels, complete combustion of carbon containing fuels, a product of the reaction between an acid and a carbonate and as a product of thermal decomposition of calcium carbonate.
5. **Methane**: causes global warming. It is a product of anaerobic decay of organic matter and is produced in huge amounts in rice paddy fields and landfill rubbish sites.

- **Reactions that take place in catalytic converters:**
    1. $2CO + O_2 \rightarrow 2CO_2$
    2. $2NO + 2CO \rightarrow N_2 + 2CO_2$
    3. $2NO \rightarrow N_2 + O_2$
- **Rust**: is a red-brown powder containing mainly of hydrated iron(III)oxide. It occurs when iron or steel get corroded. The conditions needed for rusting are water (moisture) and oxygen ($4Fe + 3O_2 + 2H_2O \rightarrow 2FeO_3.2H_2O$). It can be prevented by:
    1. Painting
    2. Oiling and greasing
    3. Plastic coating
    4. Electroplating
    5. Galvanising
    6. Sacrificial protection
- **Corrosion**: occurs when a metal is attacked by air, water or other surrounding substances.
- **Fertilizers**: are the chemical substances which provide mineral ions needed for healthy plant growth.
- **Straight N fertilisers**: are those fertilisers which consist of solid nitrogen, sold in pellet form. Eg: ammonium nitrate (NH_4NO_3), ammonium sulfate ($(NH_4)_2SO_4$) and urea ($CO(NH_2)_2$).

- **NPK compound fertilisers:** are mixtures that supply the three most essential elements lost from the soil by extensive use; nitrogen, phosphorous and potassium. Majority of the ammonia in the fertilisers are obtained from the haber process.
- **Haber process:** is used to obtain ammonia. The nitrogen is obtained from the fractional distillation of air and hydrogen is obtained from the cracking of hydrocarbons.($CH_4 + H_2O \rightarrow CO_2 + H_2O$) The catalyst is iron, the temperature is 400-450 celsius and the pressure 200 atm. The reactions involved: $N_2 + 3H_2 \rightarrow 2NH_3$
  First, the gases are passed through compressors containing a pressure of 200 atm where they get heated to 450 celsius. Then they go through the iron catalyst beds, which causes the formation of ammonia. The ammonia vapours go to the cooling tank, where they get liquified and are filtered out. The N_2 and H_2 gases go back to the compressor and the process repeats.
- **Contact process:** is used to manufacture sulfuric acid. The conditions required are; temperature of 450 celsius, 2-3 atm pressure and vanadium(V)oxide catalyst
  1. Combustion of sulphur: $S + O_2 \rightarrow SO_2$ (or) $2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$ (or) $2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$
  2. Formation of sulphur trioxide: $2SO_2 + O_2 \rightarrow 2SO_3$ (CONDITIONS)
  3. Formation of oleum: $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$
  4. Formation of sulphuric acid: $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$
- **Carbonates**:
  1. Limestone is a sedimentary rock and is composed of $CaCO_3$ in the form of the mineral calcite. When limestone, is thermally decomposed, it produces calcium oxide and carbon dioxide. ($CaCO_3 \rightarrow CaO + CO_2$)
  2. Uses of limestone: steel, concrete, cement, mortar, paper, glass, building, roads and neutralising acidic soil and lakes.
  3. On heating $CaCO_3$, lime is obtained. Also called calcium oxide and quick lime. A little bit of water makes it slaked lime and more water makes it limewater.

C 14: Organic chemistry

- **Organic chemistry** is the study of carbon-containing compounds and it deals with their structure, properties and reactions.
- **Special features involving covalent bonding involving carbon:**
  1. **Catenation**: they can form very long chains and atoms of other elements can also join that chain

2. The carbon atoms can be linked by single, double or triple bonds
3. Carbon atoms can also arrange themselves in rings

- **Hydrocarbon**: a compound that consists only of carbon and hydrogen
- **Reason for large number of organic compounds:**
    1. **Catenation**: property of carbon which allows its atoms to form long chains
    2. **Tetravalency**: carbon atom having a valency of 4, allows it to form multiple bonds with atoms.
- **Alkanes**:
    1. are saturated hydrocarbons.
    2. Their molecules contain only single bonds between carbon atoms in the chain
    3. their general formula is C_nH_{2n+2}. Each molecule is increased by a CH_2 group as the chain gets longer.
    4. As the chain gets longer,the strength of the weak forces between the molecules (the intermolecular / van der Waal's) increases. Due to this, their melting and boiling points increases gradually.
    5. C1 to C4 alkanes are gases. C5 to C16 are liquids. C17 onwards are waxy solids.
    6. Eg: methane, ethane, propane, butane, pentane, hexane, heptane, octane, nonane, decane.
    7. Alkane + oxygen → water + carbon dioxide
    8. They are very good fuels and burn exothermically.
    9. Methane forms a major part of natural gas
    10. Propane and butane burn with very hot flames and are sold as LPG. propane tanks are used to supply the fuel for heating systems. Cylinders of butane gas are used in portable fires around the home, portable camping stoves, blowtorches and gas lighters.
    11. When tested with bromine water, by shaking the alkane with it, the colour of the water remains orange brown as no bonds are broken.
- **Structural formula:** shows how the molecules are bonded.
- **Molecular formula:** represents the actual number of atoms present in the molecule.
- **Functional group:** is the group of atoms in a structure that determines the characteristic reactions of a compound.
- **Homologous series:** is a family of organic compounds that:
    1. Have the same general formula
    2. Have similar chemical properties
    3. Show a gradual increase in physical properties (melting and boiling points)
- **Alkenes**:

1. Unsaturated hydrocarbons.
2. Molecules of these compounds contain a carbon double bond (functional group is c and c double bond)
3. General formula is CnH2n
4. Boiling point and melting point increase gradually
5. The double bonds are easy to break and add extra atoms to this molecule
6. more reactive than alkanes as the double bonds can easily break
7. When added to bromine water, the orange-brown colour of the solution goes colourless as the bromine reacts with the alkene. This is also called addition reaction.
8. The chemical reactions of the alkenes are: bromination. Hydrogenation and hydration
9. Bromination (chemical test): ethene + bromine → 1,2-dibromoethane
10. Hydrogenation (manufacture of margarine form veg oils/alkene to alkane): ethene + hydrogen → ethane (150-300 celsius, nickel as a catalyst)
11. Hydration (high purity ethanol/addition reaction): ethene + steam → ethanol (300 celsius, 60 atmospheres and phosphoric acid as catalyst)
12. Eg: ethene, propene, butene, pentene, hexene, heptene, octene, nonene, decene

- **Alcohols**:
    1. A series of organic compounds containing the functional group -OH and
    2. general formula CnH2n+1OH
    3. The early alcohols are neutral, colourless liquids that don't conduct electricity
    4. Boiling point increases gradually
    5. Eg: methanol, ethanol, propan-1-ol, butan-1-ol, pentan-1-ol
    6. Ethanol can be made either by fermentation or hydration of ethene
    7. Hydration of ethene: ethene + steam → ethanol (300 celsius, 60 pressure and phosphoric acid as a catalyst). The ethanol in this process from the non-renewable resource;petroleum. It is a continuous process where the rate of reaction is fast and small-scale equipment can withstand pressure. But it is a sophisticated and complex method which yields high purity ethanol.
    8. Fermentation: glucose → ethanol + carbon dioxide (catalysts-enzymes in yeast). It is made in a fermentation vessel where glucose solution with yeast is confounded in copper/steel vats. The air-lock containing water connected to the bung, allows CO2 produced to escape but not allow air-borne bacteria to enter. Ethanol in this process is made from readily available renewable resources. It is a batch process (need to start

processing each time) and is also slow. It is relatively simple and straightforward but uses large vessels. The fermented product can be used for a few purposes, but it needs to be purified by distillation.

9. Uses of ethanol: important solvent, raw material for making other organic chemicals, paints, glues, perfumes, aftershaves, etc.
10. Ethanol burns exothermically giving out a clear flame. It can be used as methylated spirit (ethanol mixed with methanol, etc) on a small scale in spirit lamps and stoves. It can also be used industrially as a biofuel.
Ethanol + oxygen → water + carbon dioxide

- **Fossil fuels:** were formed in the earth's crust from the material that was once living. The three major fossil fuels are coal (fossil plant material), petroleum/crude oil (bodies of marine microorganisms) and natural gas (bodies of marine microorganisms). The formation of these fossil fuels took place over geological periods of time. Thus, these fuels are non-renewable and finite.
- **Petroleum** was formed millions of years ago when dead marine microorganisms sunk to the sea bed and got covered with layers of mud. The matter then changed into hydrocarbons but compression of the mud from above changed it into shale. Then the geological movements and pressure, changed the shale into harder rocks, squeezing out the oil and gas from them which moved upwards, from high to low pressure areas where they got trapped by non-porous rocks. From here, they are extracted as petroleum.
- **petroleum/crude oil** is preheated to 350-400 celsius and passed through a fractionating column for fractional distillation to take place. The products obtained are bitumen, lubricating wax, fuel oil, diesel oil, kerosene/paraffin, naphtha, gasoline and refinery gas.
- **Catalytic cracking:** larger molecules from heavier fractions can be broken into smaller, more valuable molecules by the process of catalytic cracking. It is done in a reactor. Particles of catalysts made of powdered minerals such as silica, alumina and zeolites, are mixed with the hydrocarbon fraction at a temperature around 500 celsius. The cracked vapous containing smaller molecules are separated by distillation.
Eg: decane → octane + ethane (heat and catalyst)
- **All cracking reactions give:**
  1. An alkane with a shorter chain than the original, and a short chain alkene
  2. Or two or more alkenes and hydrogen
- **Quality of the petrol can be increased by** adding some of the products from cracking to the gasoline fraction.

- **Re-forming**: many branched-chain hydrocarbons (made in the process of reforming) are added to high-quality petrol, so that the engine doesn't ignite too soon.
- **Compression ignition engines**: are those engines in which the fuel ignites spontaneously without a spark. Eg: diesel engines. Diesel engines are more efficient than petrol engines as they produce much less CO, but due to their high working temperatures, many oxides of nitrogen are produced.
- **Polymerisation**: is the reaction in which monomers covalently join to form one large molecule.
- **Carboxylic acid:** is an organic compound that contains a carboxyl group.
  The general formula is R-COOH with R referring to an alkyl group.
  Eg: methanoic acid (HCOOH),
  ethanoic acid (CH_3COOH),
  propanoic acid (C_2H_5COOH)
  butanoic acid (C_3H_7COOH).
- The first four are formed by alkanes as shown above
- **Addition polymerisation:**
  1. **Polymers**: are large organic macromolecules. They are made up of small repeating units called monomers, joined together by polymerisation.
  2. **Synthetic polymers:** are man made polymers, which are often called plastics. Their properties can be changed to match a variety of needs.
  3. **Addition reactions:** in those reactions, where the double bonds between the carbon atoms are broken, and other atoms join with carbon.
  4. In addition polymerisation, many molecules of a single monomer are used. The monomer is usually unsaturated (C=C). In an addition reaction, monomers join together by opening the C=C double bond. The products formed are the polymer which are non-biodegradable and resistant to acids.
  5. Eg: ethene → poly(ethane) / PE (high pressure, heat and a catalyst). Polythene was very tough and durable, and a very good electrical insulator. Used in plastic bags, bowls, bottles and packaging. Monomer was ethene $CH_2=CH_2$.
  6. Propene → poly(propene) / PP. It's common trade name is polypropylene. It's structure is similar to poly(ethen) but it has a CH_3 (methyl group) attached. It is used to make crates, boxes and plastic ropes as it is easy to melt, mould, tough and durable. Monomer is propene $CH_3CH=CH_2$
  7. chloroethene/vinyl chloride → poly(chloroethene)/PVC. It is used for making pipes, insulation, guttering and plumbings because it was harder

and stronger than polyethene but not as flexible. Its monomer unit is chloroethene $CH_2=CHCl$

8. Tetrafluoroethene → PTFE / teflon / poly(tetrafluoroethene). It is very stable at high temperatures and formed a slippery surface which makes its surface non-sticky. Thus, it is used in non-stick frying pans, non-stick taps and joints. Its monomer unit is tetrafluoroethene $CF_2=CF_2$.
9. Phenylethene (styrene) → poly(phenylethene) / polystyrene / PS. Its light and a poor conductor of heat which is why it is used in insulation and packaging (foam). Its monomer unit is phenylethene (styrene) $C_6H_5CH=CH_2$
10. **Properties of addition polymers:**
    - All polymers are long chain molecules made by joining together a large number of monomer molecules.
    - Addition polymerisation involves monomer molecules that contain a C=C double bond.
    - All the addition polymers are made from a single monomer
    - During addition, the double bonds open up and the molecules join themselves to make a molecule with a very long chain.

- **Condensation polymerisation:**
    1. Molecules of two monomers are used. Monomers contain reactive functional groups at both ends of the molecule. In condensation reaction, a water molecule is formed every time a monomer joins the chain. The products formed are, the polymer and water. The polymer is biodegradable and can be hydrolysed by acids.
    2. Nylon is a **synthetic fibre** which is used to make fabrics for shirts, ties, sheets, etc, racquet strings, ropes and gear wheels.
    3. The monomers used to make nylon have one functional group as NH_2 (diamide) and COOH (dicarboxylic acid).
    4. Nylon is also known as a polyamide because an amide link/peptide link is formed during polymerisation.