Organic Chemistry

1. Name the fossil fuels, natural gas, coal and petroleum as fossil fuels and sources of energy

- Obtain energy from petroleum, coal and gas to operate machines, power motor vehicles, cook food and light our homes by burning fuels
- Petroleum and natural gas are found in layers of non-porous rocks in the ground (hydrocarbons)
- Natural gas is mainly made up of methane (CH4)
- Petroleum is a mixture of hydrocarbon that must be refined to make useful fuels

2. Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation

- Petroleum is heated in a furnace so it vaporizes and the vapours are passed up the fractionating column (fractions come out of the column at different heights dependent on boiling points)
- Substances that are smaller have lower bp and come out at the top, larger fractions at the bottom

3. Name the following fractions and state their uses:

Fraction	Number of carbon atoms	Boiling point/Celsius	Uses
Petroleum Gases	1-4	Below RTP	Bottled gas for gas cookers
Petrol/Gasoline	5-10	35-75	Fuel for motor vehicles
Naphtha	8-12	70-170	Petrochemicals
Kerosone/Paraffin	10-14	170-250	Jet fuel; oil stoves
Diesel	15-25	250-340	Fuel for diesel engines
Lubricating Oil	19-35	340-500	Lubricant in engines; waxes and polishes
Bitumen	>35	Over 500	Surface roads

- Trend: increase in boiling point due to the increase in molecular size (harder to break intermolecular bonds that hold the molecules together)
    - Range of boiling point temperatures since each fraction has varying number of carbon atoms
- Petrol/gasoline is the fraction that is most in demand, cracking occurs to break down larger fragments into petrol for commercial use

4. *Understand the limited supply of fossil fuels and pollution problems*
5. *Describe issues relating to competing uses of oil as energy source and as a chemical feedstock*

- Nuclear energy as an alternative source of energy

6. *Interpret and use nomenclature, general formulae, molecular formula and displayed formula of:*
    a. *Alkanes*
    b. *Alkenes*
    c. *Alcohols*
    d. *Carboxylic acids*

Information on Organic Chemistry:

- Chemistry of **carbon compounds**, made up of few elements (but carbon is always present)
- Hydrogen and oxygen usually found, only nitrogen, halogens, phosphorus, sulfur and some metals
- Each carbon atom can bond with other carbon atoms to form long chains (and have 4 bonds)
- Most organic compounds are **covalent (non-polar)** and do not ionize in solution
    - Generally insoluble in water (but some organic molecules contain polar groups and dissolve)
    - Mix well with non-polar solvents like hexane, tetrachloromethane
- Have **lower boiling and melting points** than inorganic compounds
- Most are inflammable and burn exothermically to yield carbon dioxide and water

- Reactions tend to take place at slower rate compared to ionic reactions of inorganic chemistry
    - Usually require heating, thorough mixing and use of catalyst
- **Empirical formula**: simplest formula of a compounds and indicates the relative numbers of each kind of atom in a molecule of a substance
- **Molecular formula**: actual numbers of each kind of atom in a molecule of a substance
- **Full structural formula**: how the atoms are arranged within the molecule of a substance (shows the bonds in a pictorial manner)

7. Describe a homologous series
    a. Group of compounds with a general formula and with a **regular structural pattern**, **similar chemical and physical properties** and showing a gradation in physical properties as a result of increase in the size and mass of the molecules (melting and boiling points, viscosity and flammability, understand how molecular structure affects physical properties)
    b. Functional Group: atom, radical group or a bond common to a homologous series which determines the main chemical properties of the series (hydroxyl group, carboxyl group)

8. Describe alkanes as a homologous series of saturated hydrocarbons with the general formula C(n)H(2n+2)
- **Saturated** organic compound: atoms are joined by only one covalent bond
- **Unsaturated** organic compounds: contains carbon atoms with two or three covalent bonds
- Alkanes are saturated hydrocarbons and the main constituents of petroleum
    - First four members: methane, ethane, propane, butane

9. Describe the properties of alkanes as being generally unreactive except in terms of burning (difference between complete and incomplete combustion) and substitution by chlorine
- Inert and undergo few reactions, only combustion and substitution reactions
- Complete combustion: in a good supply of oxygen, methane burns to produce carbon dioxide and water ($CH_4 + 2O_2 \rightarrow CO_2 + H_2O$)
- Incomplete combustion: insufficient oxygen, carbon (soot) and carbon monoxide are produced
    - For a Bunsen burner, complete combustion occurs when the air hole is opened (non-luminous flame indicates a clean flame)
    - When air hole is closed, the flame becomes orange and soot is produced
- NOTE: ethene has a smaller concentration of carbon than ethane (and will burn will sootier flame)
- Substitution with chlorine:
    - Methane reacts with chlorine in sunlight (UV rays act as the catalyst) to give a mixture of products (each hydrogen atom in methane can be substituted for a chlorine atom)
    - One atom replaced (chloromethane), two atoms replaced (dichloromethane) …

10. Describe the manufacture of alkenes and hydrogen by cracking hydrocarbons + recognize that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process

- Cracking: process of breaking large hydrocarbon molecules into smaller molecules
- Chemical conversion: changing the hydrocarbons in petroleum into other useful chemicals
- Importance: heavy fractions obtained after fractional distillation of petroleum are less in demand than the lighter fractions and cracking converts heavy fractions into lighter fractions
- Products: depends on actual conditions but always contain an alkene
    - May contain hydrogen, carbon and other alkane molecules
    - $C_{10}H_{22} \rightarrow C_7H_{16} + C_3H_6$ (alkene and alkene)
    - $C_{10}H_{22} \rightarrow C_{10}H_{20} + H_2$ (alkene and hydrogen)
    - $C_{10}H_{22} \rightarrow C_4H_{10} + C_3H_8 + C_2H_4 + C$ (alkene, alkane, carbon)

- Types of Cracking:
    - Thermal Cracking: heated to temperatures of about 800-850 Celsius under high pressure
    - Catalytic Cracking: alkane molecules passed over catalyst at about 300 Celsius, with aluminium oxide and silicon dioxide as catalysts
- Applications of Cracking:
    - Change heavy fractions into light fractions which are of high demand
    - Change naphtha into alkenes (ethene is the most useful)
    - Production of hydrogen gas

11. Describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine
12. Describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product

- Alkenes are much more reactive than alkanes (due to the presence of C=C double bond)
    - Alkenes can undergo addition reactions: in which two or mole molecules react to give one single molecule (by bond breaking and bond formation)
- **Addition of hydrogen (hydrogenation)**
    - Example: C2H4 + H2 -> C2H6
    - **Nickel** is used as a catalyst and an alkane is produced
    - Important in making margarine since vegetable oil is polyunsaturated and is thus liquid (addition of hydrogen to oil creates a more solid substance)
    - H-H bond in hydrogen is cleaved and C=C double bond is cleaved
- **Addition of water (hydration)**
    - Reaction takes place under high temperature (300 Celsius) and pressure (60atm)
    - **Water in the form of steam and phosphoric acid as the catalyst** are used
    - Example: C2H4 + H2O -> C2H5OH (product will be an alcohol)
    - H-OH bond is cleaved and C=C double bond
- **Addition of bromine (bromine test)**
    - Useful way to test for unsaturation, since when liquid or aqueous bromine is shaken with an alkene, the brown colour of bromine disappears quickly
    - Example: C2H4 + Br2 -> C2H4Br2 (1,2-dibromoethane is produced)
    - C=C double bond and Br-Br single bond are cleaved
- **Polymerization**
    - Many small alkene molecules can link together to form a long chain (polyethene) (common plastic used to make plastic bags and cling film)
- Note: shows the importance of ethene (present in all reactions)

13. Describe the properties of alkenes (combustion, polymerization and addition reactions with bromine, steam and hydrogen)

- General Formula: CnH(2n) (where n cannot be 0 or 1)
- Alkenes are unsaturated hydrocarbons with a carbon-carbon double bond
    - First three members: ethene (C2H4), propene (C3H6) and butane (C4H8)
    - Most alkenes are also gases of liquids in room temperature
- Can undergo combustion (complete and incomplete) producing identical products
- Can also undergo substitution reactions (similar to alkane)

14. Describe the alcohols as a homologous series containing the OH (hydroxyl) group, and with the general formula C(n)H(2n+1)OH
15. Describe the formation of ethanol by the catalyzed addition of steam to ethane and by fermentation of glucose

- Alcohols are organic compounds that contain the hydroxyl OH group

    - First four members are methanol (CH3OH), ethanol (C2H5OH), propanol and butanol
    - Colourless liquids at room temperatures
    - Polar molecules that are soluble in water
    - Molecules have a neutral pH of 7
- Uses of Ethanol:
    - As a solvent, alcoholic drinks or as a fuel for motor vehicles (biofuel)
    - Can also be a disinfectant
- **Preparation from ethene:**
    - Mixture of ethene and steam is passed over phosphoric acid at 300 Celsius and 60atm
- **Preparation by fermentation: C6H12O6 -> 2C2H5OH + 2CO2**
    - Fermentation is the slow decomposition of organic compounds induced by micro-organisms
    - Active factors responsible for the chemical reaction are the enzymes present
    - Catalytic conversion of the sugar, glucose into ethanol in an oxygen-free environment (anaerobic reaction)
    - Essential conditions: suitable temperature, presence of yeast, water and no oxygen

16. Describe the properties of alcohols in terms of combustion, oxidation to carboxylic acids, and dehydration to alkene

- **Combustion**: example (C2H5OH + 3O2 -> 3H2O + 2CO2)
    - Acts in the same manner as alkanes and alkenes
- **Dehydration**: C2H5OH-> C2H4 + H2O
    - Ethene is formed by heating ethanol with **concentrated sulfuric acid** H2SO4
- **Oxidation**: C2H5OH + 2[O] -> CH3COOH + H2O (dehydration reaction)
    - Carboxylic acid is formed, and O represents oxygen that comes from an oxidizing agent
    - Beer or wine left exposed to air becomes sour due to formation of ethanoic acid
    - Acidified potassium dichromate (VI) is a good oxidizing agent
- **Esterification:**
    - Alcohols react with carboxylic acids to produce salt and water

17. Describe the carboxylic acids as a homologous series containing the COOH (carboxyl) group, and with the general formula CnH(2n+1)COOH

- All carboxylic acids contain carboxyl group (COOH) as their functional group
    - All their names end with –oic (methanoic acid, ethanoic acid)
    - Ethanoic acid is known as acetic acid (vinegar is a solution of ethanoic acid in water)
    - Carboxylic acids are liquids at room conditions, and do not completely dissociate in aqueous solution and are therefore, weak acids
- Uses: Manufacture esters, manufacture insecticides and manufacture of drugs

18. Describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals

- Reacts with a base to form salt and water (CH3COOH + NaOH -> CH3COONa + H2O)
    - Ethanoic acid + Sodium hydroxide -> Sodium ethanoate and water
    - O-H bond in COOH cleaves and Na-OH bond cleaves
- Reacts with some metals to liberate hydrogen gas (2CH3COOH + Mg-> (CH3COO)2Mg + H2)
    - Ethanoic acid + Magnesium -> Magnesium ethanoate + Hydrogen
- Reacts with a carbonate to liberate CO2 gas (2CH3COOH + CaCO3-> (CH3COO)2Ca + CO2 + H2O)
    - Ethanoic acid + calcium carbonate -> Calcium ethanoate + Carbon dioxide + Water
- The corresponding salt of the carboxylic acid is always formed (calcium, magnesium, sodium)

19. Describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or by acidified potassium dichromate (VI)

- **From ethanol**: C2H5OH + 2[O] -> CH3COOH + H2O (dehydration reaction)

- Ethanol is oxidized by air (oxygen) or acidified potassium dichromate to form ethanoic acid
- **From methane**: methane is used to manufacture methanol and carbon monoxide, and these products are reacted in the presence of a catalyst to form ethanoic acid

20. Describe the reaction of ethanoic acid with ethanol to form the ester, ethyl methanoate

- Ester formation: ethanoic acid reacts with an alcohol to form an ester and water
- **Concentrated sulfuric acid** is used as a catalyst and heating is required
- This reaction is reversible and the forward reaction is esterification while backward is hydrolysis
  - Example: ethanoic acid + ethanol – ethyl ethanoate + water
- O-H bond in alcohol while C-OH bond in acid is cleaved
- Note: the acid forms the –oate while the alcohol forms the –yl
  - Draw the acid first (with C=O) before the alcohol

21. State some common uses of ester, as solvents, for flavoring

- Used as perfumes and flavouring (due to the colourless liquid with a sweet smell)
  - Perfumes work by adding organic acids, which react with sweat to produce fragrant esters

22. Identify structural isomers

- Isomers: molecules with the same molecular formula but different arrangement of atoms
- **Chain isomerism**: arise due to possibility of branching in carbon chains
  - Isomers of pentane: straight chain, 2-methylbutane and 2,2-dimethylpropane)
- **Position isomerism**: basic carbon skeleton unchanged, but important groups moved around
  - Two structural formulas of C3H7Br (1-bromopropane or 2-bromopropane)
- **Functional Group Isomerism**: molecules belong to two different homologous families
  - C3H6O2 (can be propanoic acid or methyl ethanoate)

Extra Notes:

- Important molecules from petroleum
  - Ethene: making plastics like polyethene
  - Chloroethene: for making PVC
  - 1,2-ethanediol: used as an antifreeze, a hydraulic fluid and in production of polyesters
  - Phenylethene: making the plastic poly(phenylethene)
  - Ethanol: important solvent
  - Propene: make the plastic poly(propene) and solvent 2-propanol
- Alkynes
  - Unsaturated hydrocarbons with a carbon-carbon triple bond
  - General formula: CnH(2n-2)
  - First three members: ethyne, propyne, butyne
- Free Radical Substitution
  - Free radical: particle in which one atom has an unpaired electron
  - Radicals are produced when covalent bond in a molecule is broken so that each atom receives one electron
  - Substitution reaction: organic reaction where one or more atoms of an organic molecule are replaced with one or more other atoms
    - Initiation, propagation and termination
  - Free radicals are highly reactive and reacts with almost any molecule
    - It might even be relevant in the aging process
- Nomenclature:
  - The root is based on the number of carbon atoms present
  - The suffix is added to indicate the presence of a functional group

- If more than one prefix is need (bromo, chloro), they are placed in alphabetical order
- The position of the substituent group of a compound is indicated by the number of carbon atom to which it is attached (numbered from the longest chain, regardless of direction)