IB CHEMISTRY
SUMMARY –M Waters
I take no responsibility for the accuracy of these notes! Actually I take no responsibility for anything whatsoever. In case you were wondering, ive gone through the whole syllabus, including my options, and written out definitions and notes under headings. Places where I needed more revision (ie the options) are covered in greater detail.

SL

Mole: 6.02×10^{23} of something also n= m/M (n = number of moles, m = mass, M = Molar mass)

Avogadros number: 6.02×10^{23}

Molar Mass: The mass (in grams) per mole of a substance where C_{12} is exactly 12g.

Molecular Mass: The mass per mole of a substance where C_{12} is exactly 12g.

Empirical formula: The simplest ratio of the atoms in a chemical compound.

Molecular formula: The actual ratio of the atoms in a chemical compound.

Limiting reagent: The reagent that limits or determines the amount of product that can be formed in a reaction. The reaction occurs only until the limiting reagent is used up.

Solvent: In a solution, the dissolving medium

Solute: In a solution, the dissolved particles.

Concentration: The number of moles per unit volume of a substance.

Mass Number: ^{A}X : the A, represents the total number of protons and neutrons in the nucleus of an atom.

Atomic number: $_{Z}X$: The Z, represents the total number of protons in the nucleus of an atom.

Isotope: Atoms with the same number of protons but different numbers of neutrons.

Continuous spectrum: A spectrum representing all the colours of the rainbow: ROYGBV, with no distinction between colors.

Line Spectrum: Also known as absorption spectrum, all wavelengths have been absorbed by an atom (or whatever) as the light has passed through, except a few and these are shown as lines on the spectrum.

Emission spectrum: Shows the wavelenths of the lines that have been emitted, will consist of a continuous spectrum with a few lines blacked out. (that have been absorbed)

Atomic Radius: Half the distance between the centres of two atoms in a compound.

Ionic radius: Same as atomic radius except for ions. (?)

Electronegativity: The tendency for the atoms of the element to attract electrons when they are chemically combined with another element.

Polarity: In a polar molecule one end of the molecule is slightly negative and one end is slightly positive. The polarity is a measure of this.

Intermolecular bond: The force of attraction between atoms in a molecule.

Intramolecular bond: The force of attraction between molecules.

Alkali metals: A group 1 metal.

Halogen: A group 7 atom
Halide: A group 7 ion.

Metal: An atom from the left of the periodic table displaying metal- like properties.

Non Metal: An atom from the right of the periodic table displaying non metal like properties.

Acidic oxide: A non-metal oxide

Basic oxide: A metal oxide.

Bonding: A term used to refer to the forces between particles.

Structure: A term used to refer to the structure of a substance, generally on a microscopic level.

Ionic Bond: Electrostatic force of attraction between two oppositely charged ions.

Covalent bond: Electrostatic force of attraction when 1 or more pairs of electrons are shared between atoms.

Dative bond: A covalent bond in which the pairs of electrons involved in the bond are donated entirely from one of the atoms.

Metallic bond: The attraction of free floating valence electrons for the positively charged metal ions.

Volatility: A measure of the willingness of a substance to change phase in the direction of the gas phase.

Conductivity: A measure of the willingness of a substance to allow electrons to freely flow through it.

Solubility: A measure of the amount of substance that dissolves in a given quantity of solvent at a given temperature to produce a saturated solution.

Hydrogen bonding: Attractive forces in which hydrogen that is covalently bonded to a very electronegative atom is also weakly bonded to an unshared electron pair of an electronegative atom in the same molecule or in a nearby molecule. The hydrogen bonding in water has about 5% of the strength of an average covalent bond.

Van Der Waals forces: The weakest of all attractions. Also known as Dispersion forces: generally thought to be caused by the motion of electrons, the strength of dispersion forces increases as the number of electrons in a molecule increases. As the electrons move about the molecule, temporary dipoles will be created that attracts the molecules to each other. Generally larger molecules exhibit larger van der waals forces.

VSEPRT: Valence **S**hell **E**lectron **P**air **R**epulsion **T**heory, States that because electron pairs repel, molecules adjust their shapes so that the valence electron pairs are as far apart from possible.

Binary compound: A compound that consists of two elements.

Lewis structure: A diagram showing the location of electrons in pairs around the atoms in a compound.

Bond length: A measure of the distance between the centers of two bonded atoms (?)

Kinetic theory: A theory stating that the tiny particles in all forms of matter are in constant motion.

Absolute temperature: A temperature scale measured in Kelvin, 0 K is defined as the point at which there is absolutely no heat and, therefore, absolutely no kinetic energy in particles. From pV=nRt, there would also have to be no mass.

Evaporation: The conversion of a liquid to a gas or vapour at a temperature below its boiling point.

Boiling point: The temperature at which the vapor pressure of the liquid is just equal to the external pressure.

Boiling: The process of a change of state from liquid to gas.

Condensing: The process of a change of state from gas to liquid.

Melting: The process of a change of state from solid to liquid.

Freezing: The process of a change of state from liquid to solid.

Ideal gas: A gas that follows the gas laws at all conditions of pressure and temperature. An ideal gas has no volume, no mass and there are no intramolecular forces at all.

Diffusion: The tendency of molecules and ions to move toward areas of lower concentration until the concentration is uniform throughout the system.

Exothermic: A process that looses heat to the surroundings.

Endothermic: A process that absorbs heat from the surroundings.

Enthalpy of reaction: The amount of heat taken in or given out when one mol of substance is reacted in standard conditions.

Hess law: If you add two or more thermochemical equations to give a final equation, then you can also add the heat changes to give the final heat change. The enthalpy of reaction will be the same independent of path.

Bond enthalpy: The energy required to break a bond in standard conditions.

Standard state: The state of a substance at 25^oC and 1 atm pressure.

Rate of reaction: The rate at which products are formed, which is equal to the rate at which the reactants are consumed. It has units of $moldm^{-3}s^{-1}$.

Rate determining step: The slowest step in the sequence of steps leading to the formation of products.

Dynamic equilibrium: The condition in which the rate of a forward process is exactly balanced by the rate of a reverse process.

Phase equilibrium: An equilibrium in which only physical properties change. In IB, usually refers to the physical equilibrium between a liquid and its vapor.

Equilibrium constant: A number equal to the ratio of the equilibrium concentrations of the products to the equilibrium concentrations of the reactants, each raised to the power of its stoichiometric co-efficient.

Eg in the reaction $H_{2(g)} + I_{2(g)} \longleftrightarrow 2HI_{2(g)}$ the equilibrium constant is $K_c = \dfrac{[HI]^2}{[H_2][I_2]}$

Le Chatelier's principle: If an external stress is applied to a system at equilibrium, the system will adjust itself in such a way as to partially offset the stress.

Haber process: The process in which ammonia is synthesised. This is often used to demonstrate equilibrium principles, and that often the conditions that take place are a compromise between different factors determining the rate and size of product in a reaction.

$$N_2 + H_2 \longleftrightarrow 2NH_3 \ , \Delta H = -92 kJMol^{-1}$$

Bronsted-lowry acid: A substance capable of donating a proton.

Bronsted-lowry base: A substance capable of accepting a proton.

Alkali: A base dissolved in water.

pH: -log[H^+], minus the log of the concentration of hydrogen ions.

Oxidation reaction: The half reaction that involves loss of electrons.

Reduction: The half equation that involves a gain of electrons.

Oxidation number: The number of charges an atom would have in a molecule if electrons were transferred completely in the direction indicated by the difference in electronegativity.

Oxidising agent: An oxidising agent is itself reduced, that is it is a substance that can accept electrons from another substance or increase the oxidation numbers in another substance.

Reducing agent: A reducing agent is itself oxidised, that is it is a substance that can donate electrons to another substance or decrease the oxidation numbers in another substance.

Electrolysis: A process in which electrical energy is used to cause a non-spontaneous chemical reaction to occur.

Electrolytic cell: The cell in which electrolysis occurs. The cell contains the anode (positive), cathode (negative) and the electrolyte.

Reactivity series: A simplified form of a table of standard electrode potentials, this shows the relative reactivities (and spontaneities) of a set of chemicals.

Homologous series: A series of compounds (usually hydrocarbons) that display similar chemical properties and functional groups but different physical properties (generally boiling point), often differing by one repeating unit, usually a CH_2/CH_3 molecule. They can be given a general formula, eg C_nH_{2n+2}

Alkane: Hydrocarbons having the general formula C_nH_{2n+2}

Isomer: Two molecules with the same general formula but different structural formula (ie containing the same amounts of each atom but bonded differently) are said to be isomers of each other.

Alkene: Hydrocarbons that contain one or more carbon-carbon double bonds, and have the general formula C_nH_{2n}

Complete combustion:
In terms of hydrocarbons, this is the reaction of the substance with oxygen to produce carbon dioxide and water.

Incomplete combustion:
In terms of hydrocarbons, the reaction of the substance with hydrogen to produce (among other things) Carbon monoxide.

Alkanal: An organic compound containing the functional group C=O at the end of a chain.

Alkanoic acid: An organic compound containing the functional group C=O

$$\overset{\textstyle |}{\text{OH}}$$

Alkanol: Also known as an alcohol, this is an organic compound containing the hydroxyl group OH

$$\overset{\textstyle O}{\overset{\textstyle \|}{}}$$

Amide: An organic compound containing the functional group R-C-NH$_2$

Amine: An organic compound containing the functional group R - NH$_2$

Ester: Compounds that have the general formula R'COOR.

Halogenalkane: An alkane that has one or more group 7 elements bonded to its carbon stem in the place of a hydrogen atom.

Functional group: The part of a molecule characterized by a special arrangement of atoms that is largely responsible for the chemical behaviour of the parent molecule.

Optical isomer: Compounds that are non superimposable mirror images, and can be detected by their different effects on plane polarized light.

Polymerisation: The process of changing between a chemical of small to medium molar mass to a very high one, perhaps ranging into thousands and millions of grams.

Condensation polymer: A polymerisation reaction in which the monomers react to form a polymer with the loss of a small molecule, usually water.

Amino acid: A compound that contains amino (NH$_2$) and carboxylic acid (alkanoic acid – COOH) groups in the same molecule.

Peptide: The bond between the carbonyl group of one amino acid and the nitrogen of the next amino acid in the peptide chain.

AHL

Ionisation energy: The energy that is required (or given out) to overcome the attraction of the nuclear charge and remove an electron from a gaseous atom. Removing 1 electron results in a +1 charge.

Electron affinity: The energy that is required (or given out) to overcome the attraction of the nuclear charge and add an electron to a gaseous atom. Adding 1 electron results in a –1 charge.

Orbital: The cloud shapes that electron pairs travel around the nucleus in the quantum mechanical model.

Aufbau principle: Electrons enter orbitals of lowest energy first.

Pauli exclusion principle: An atomic orbital may describe at most two electrons.

Hunds rule: When electrons occupy orbitals of equal energy, one electron enters each orbital until all the orbitals contain one electron with spins parallel.

D block elements: Elements that occupy the d block of the periodic table and contain a d subshell.

Ligand: The ions of d-block elements have low energy unfilled orbitals. These orbitals can a pair of electrons from some species, known as ligands. Also can be defined as a molecule or ion which has a spare pair of electrons which it can donate to a transition element via a dative bond.

Dative bond: A bond in which both electrons come from a single donator atom.

Complex ion: A species containing ligands, usually large.

Synthesis: The coming together of two molecules.

Decompose: A reaction in which a single compound is broken down into two or more products.

Pi bond: In a pi bond, the bonding electrons are most likely to be found in sausage-shaped regions above and below the bond axis of the bonded atoms.

Sigma bond: A bond formed when two atomic orbitals combine to form a molecular orbital that is symmetrical along the axis connecting two atomic nuclei.

Hybridisation: process in which several atomic orbitals mix to form the same number of equivalent hybrid orbitals. The precise type of hybridisation that occurs depends on the number of sigma bonds and non bonding electron pairs that have to be accommodated about the atom.

Delocalisation: On some occasions the interaction between the atoms involved in a pi bond can involve more than those two atoms. The result is known as a delocalised pi bond, The classic examples are benzene and CO_3.

Ideal gas equation: $PV = nRT$. R is 8.31 $dm^3 kPa K^{-1} mol^{-1}$

Partial pressure: The contribution each gas makes to the total pressure.

Daltons law of partial pressures: At constant volume and temperature, the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of the component gases.

Lattice energy: The energy required to convert one mole of the solid compound into gaseous ions.

Born-Haber cycle: The formation of an ionic compound can be considered as the sum of a number of individual process – converting the elements from their standard states into gaseous atoms, losing and gaining electrons to form the cations and anions and finally the coming together of these ions into the solid compound. The diagrammatic representation of this is known as the Haber cycle.

Gaseous anions and cations

Ionisation energy(ies)

Gaseous anions and metal atoms.

Lattice enthalpy

Electron affinity(ies)

Elements as gaseous atoms

Energies of atomisation

Elements in standard state ──────────────▶ Solid compound.

Enthalpy of formation
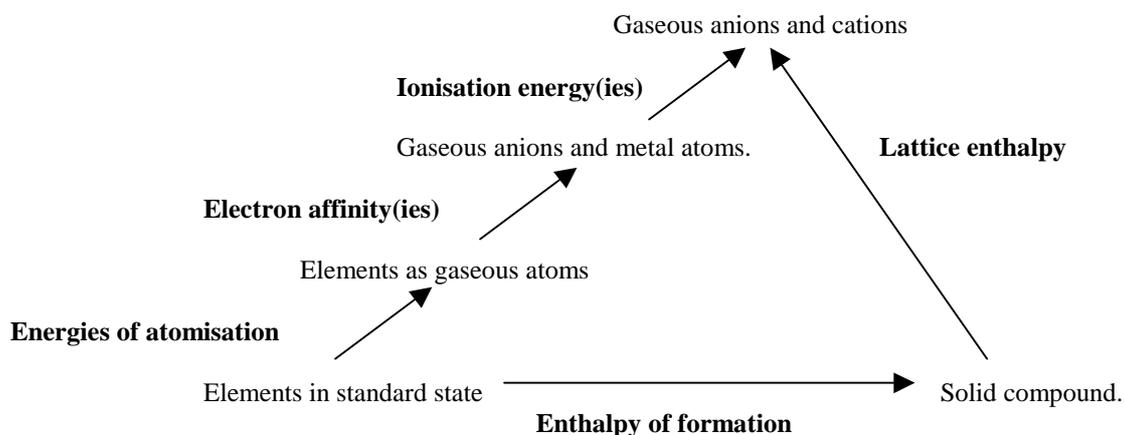
Entropy: The disorder of a system is measured as its entropy. Scattered marbles have a higher entropy than gathered marbles.

Entropy change: The change in disorder of a system. When going from more moles of gas to less moles there is a decrease in entropy, and vice versa.

Gibb's free energy: Given by the formula $\Delta G = \Delta H - T\Delta S$. A measure of the spontaneouty of the reaction. If ΔG is negative, the reaction is spontaneous.

Rate expression: The concentrations of the reactants to the power of the order of each product multiplied by the rate constant: Rate=k[A]^m[B]^n[C]^o

Order of reaction: The order of reaction is said to be *m* for substance A, *n* for substance B, etc. The total order of reaction is the sum of these powers, ie *m* + *n* etc.

Rate constant: The constant in the above equation represents the proportionality between the reaction rate and the concentrations of the reactants. Its units depend on the number of reactants and their orders.

Half life: The time required for the concentration of a reactant to decrease to half of its initial concentration.

Rate determining step: The slowest step in the sequence of steps leading to the formation of products.

Molecularity: The number of molecules reacting in an elementary step.

Activated complex: The series temporarily formed by the reactant molecules as a result of the collision before they form the product.

Maxwell – boltzman energy distribution curve: A curve of probability of energy as a function of the energy of each collision. It is shown that at lower temperatures, the graph peaks at a lower energy and at a higher probability of energy than at higher temperatures, when the graph peaks at a lower probability of molecules but colliding with a higher energy, but the area under both curves are the same. From this graph it can be seen that at a higher temperature a greater number of molecules will have any energy at a higher temperature, such as the activation energy.

Arhenius equation: $k = Ae^{\frac{-E_a}{RT}}$, where E_a is the activation energy of the reaction (in kJmol^{-1}), R the gas constant (in data book), T the <u>absolute temperature</u>, and *k* the rate constant.

Enthalpy level diagram: A diagram showing the energy that each molecule contains…. This reaction below is exothermic. Energy is put in until the particles have an energy equal to the activation energy, then it is released.
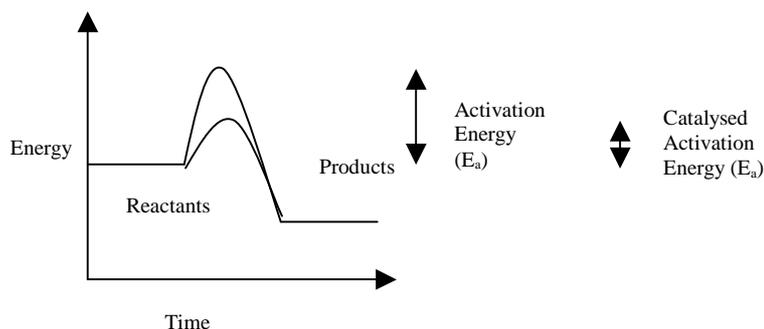
Activation energy: The minimum amount of energy required to initiate a chemical reaction.

Homogeneous catalyst: A catalyst that is in the same state as the reactants and products, usually a liquid.

Heterogeneous catalyst: A catalyst that is in a different state to the reactants and products.

Equilibrium vapour pressure: The vapor pressure measured under dynamic equilibrium of condensation and evaporation.

Enthalpy of vaporisation: The energy required to vaporize 1 mol of liquid.

Fractional distillation: A procedure for separating liquid components of a solution that is based on their different boiling points.

Lewis acid: A substance that can accept a pair of electrons.

Lewis base: A substance that can donate a pair of electrons.

Ionic product constant of water: The product of the molar concentrations of H^+ and OH^- ions at a particular temperature. $K_w = [H^+][OH^-]$

POH: defined as $-\log[OH^-]$

pK$_w$: defined as $-\log(K_w)$

K$_a$: This is the acid ionisation constant, given by $K_a = \dfrac{[H^+][A^-]}{[HA]}$ when HA $\rightarrow$ H^+ + A^-

K$_b$: This is the base ionisation constant, given by $K_b = \dfrac{[BH^+][OH^-]}{[B]}$ when B + H_2O $\rightarrow$ BH^+ + OH^-

pK$_a$: Defined by $-\log(K_a)$

pK$_b$: Defined by $-\log(K_b)$

Buffer solution: A solution of a) a weak acid and its base and b) its salt; both components must be present. The solution has the ability to resist changes in pH upon the addition of small amounts of either acid or base.

Standard electrode potential (E^{ϕ}): The potential difference between a given half-cell and the standard hydrogen electrode.

Standard hydrogen electrode: The half cell containing hydrogen gas at 1atm being bubbled through a H^+ (ie HCl) solution. – note all at standard conditions.

Cell potential: The difference between the reduction and oxidation potentials of the two half-cells.

Faraday constant: The number of coulombs in 1 mol of electrons.

Infared spectrum: The Infra red absorbtion spectra of a particular substance. Certain bonds in a molecule absorb infra-red radiation of a characteristic frequency.

Mass spectrum: The output of a mass spectrometer, showing the relative amounts of each fragment (by molar mass) that is passed through the mass spectrometer.

^{1}H NMR spectrum: A radio absorption spectrum (when substance is paced in a strong magnetic field). Generally it is used to determine the number of hydrogen atoms and the type of bonding in each carbon environment. There is a table in the data book. Thus, there may be peaks in the spectra for OH groups, CH_2 groups, CH_4 groups, etc.

Octane Rating: A measure of gasolines tendency to cause knocking, from 1 (worst) to 100 (best)

Nucleophilic substitution: A reaction in which a halogen alkane is replaced by a nucleophile.

S_n1: A nucleophilic substitution in which there is a slow, unimolecular, rate determining, heterolytic fission of the carbon-halogen bond to yield an intermediate carbocation. This then reacts rapidly with any nucleophile present to yield the final product.

S_n2: A nucleophilic substitution in which the attack of the nucleophile is rate determining. The reaction passes through an activated complex in which the bond to the nucleophile is starting to form at the same time as the bond to the halogen breaks, ie the substitution occurs in one concerted step.

Soap: The sodium salt of a long chained carboxylic acid.

OPTION E

Blast furnace: A furnace in which iron is obtained from iron ore by reduction with carbon. Iron ore, limestone and coke are pored into the top, while hot air is pumped in at the bottom. The oxygen reacts with the carbon in the coke to form mostly carbon monoxide and some carbon dioxide. These reactions are highly exothermic:

$$C_{(s)} + O_{2(g)} \longleftrightarrow CO_{2(g)} + heat$$
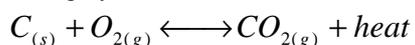
This takes place in the lower region of the furnace, at about 1900^oC. Higher up the furnace, CO_2 reacts with coke to form carbon monoxide. This reaction is endothermic, with the furnace in this region at 1100^oC.

$$CO_{2(g)} + C_{(s)} + heat \longrightarrow 2CO_{(g)}$$
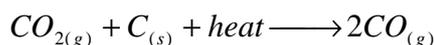
It is the CO that plays the largest part in the reduction of the ore towards the top of the furnace. Iron oxides are reduced exothermically:

$$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow Fe_{(s)} + 3CO_2 + heat$$
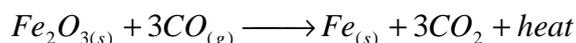
The iron produced forms a molten layer at the bottom of the furnace, (under the slag), which can be tapped off.
At the same time, the limestone dissociates exothermically to form calcium oxide and carbon dioxide.

$$heat + CaCO_{3(s)} \longleftrightarrow CaO_{(s)} + CO_{2(g)}$$
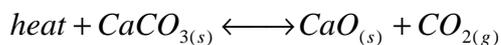
The highly basic calcium oxide combines with the acidic silicon dioxide impurity and the amphoteric aluminium oxide impurity. These impurities in the ore form molten slag.

$$CaO_{(s)} + SiO_{2(s)} \longrightarrow CaSiO_{3(l)}$$

$$CaO_{(s)} + Al_2O_{3(s)} \longrightarrow CaAl_2O_{4(l)}$$
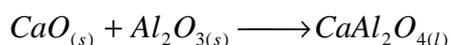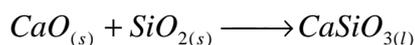
Basic oxygen converter: This is the most common way to make steel. O_2 is blasted through the impure molten iron. No external heating is required because reaction is very exothermic. This quickly oxidises any impurities.

Cast iron: This is solidified blast furnace products, containing roughly 4 % Carbon, with a lower ductility lower melting point and greater hardness than steel

Wrought iron: This is the substance after most of the carbon has been removed. It is Malleable and readily worked.

Steel: This contains less than 1.5 % Carbon content, and includes added metals. Both of these factors determine the nature of the steels. Low Carbon content (less than 0.3 %) is used for boilerplates. Medium carbon content (0.3 – 0.7 %) is used in cars. High carbon content (0.7 – 1.5 %) is used in cutting toils. When chromium is added, stainless is steel is made, with a layer of Cr_2O_3 preventing the iron from rusting.

IRON ALLOY	IMPORTANT PROPERTIES	SOME USES
Titanum steel	Withstands high temperatures	Gas turbines, spacecraft.
Cobalt steel	High magnetic permeability	Magnets
Chromium steel:	Hard	Ball bearings

| Manganese steel: | Tough tool steel | Earth moving machinery |
| Stainless steel: | Non-rusting | Cutlery sinks, car accessories etc |

Production of Aluminium: Aluminium is obtained industrially by the electrolysis of molten aluminium oxide, Al_2O_3. This is obtained from bauxite, impure aluminium oxide, Al_2O_3 x XH_2O

1) The first step is to obtain pure aluminium oxide is obtained from the bauxite.
    a. D The amphoteric nature of Al_2O_3 is an essential feature on which its purification is based. When the impure bauxite is treated with concentrated sodium hydroxide, Al_2O_3 and SiO_2 dissolve:

    $Al_2O_3 + OH^- + H_2O \rightarrow 2Al(OH)_4^-$
    $SiO_2 + NaOH \rightarrow NaSiO_3$
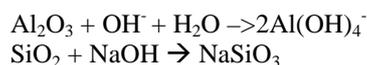
    Fe_2O_3 and other basic materials remain solid and are removed by filtration.

    b. The remaining solution is then treated with the acidic non-metal oxide CO_2 to precipitate aluminium hydroxide:

    $CO_{2(g)} + Al(OH)_4^- \rightarrow Al(OH)_{3(s)} + HCO_3^-$
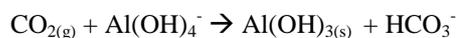
    Thus the sodium silicate stays in the solution, while the aluminium hydroxide precipitates out.

    c. Finally, pure Al_2O_3 is obtained by heating the aluminium hydroxide:
    $2Al(OH)_{3(s)} + heat \rightarrow Al_2O_3 + H_2O$
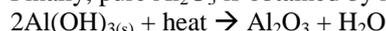
2) The second step is the electrolysis of the Al_2O_3.
    a. The melting point of Al_2O_3 is too high (2000^oC) so molten cryolite, Na_3AlF_6 is used as a solvent to lower the melting point to about 850^oC. The current passing through the electrolyte maintains this temperature.

    b. The electrolysis takes place in a cell with carbon anodes and a carbon lining that serve as the anode and the cathode, respectively (remember the cathode where reduction wants to take place – I always remember as "you want to reduce cats" (thanks to kylie):

    Overall reaction:
    $4Al^{3+}_{(l)} + 6O^{2-} \rightarrow 4Al_{(l)} + 3O_{2(g)}$

    c. This is complicated by the fact that the oxygen produced reacts with the carbon anode and cathode to produce oxides of carbon, so every ton of Al requires half a ton of carbon

Extraction of nitrogen and oxygen from air:
There are also several steps involved here:
1) Water vapor and carbon dioxide are removed by pre-cooling air using refrigeration or using silica gel to absorb H_2O as well basic $Ca(OH)_2$ to absorb acidic oxide CO_2.
2) The air is then compressed to a pressure exceeding 100 atmospheres, cooled to room temperature and allowed to expand in a chamber. This produces a cooling effect, known as the Joule-thompson effect (and also u can figure it from the ideal gas law). This is repeated until the expanding air cools to liquifecation.
3) The two main components: liquid nitrogen and air, are removed using fractional distillation.

The Oxygen is used in things like hospital oxygen cylinders and rocket fuel but most of the Oxygen obtained from this method is used in steel making.

The Nitrogen is extremely inert because it is a cryogen, it can be used as a coolant instead of air because it does not support combustion, in food packaging and in welding.

Uses of ammonia: Ammonia is used in the manufacture of fertilisers (75%), nitric acid (TNT, dynamite, dyes – 15 %) and in the manufacture of polymers such as nylon (25%).

Contact process: This is the process by which concentrated sulfuric acid is obtained.
1) Firstly, sulfur is burnt to make sulfur dioxide. This process is very exothermic, and supplies heat to the rest of the process.

$$S_{(l)} + 2O_{2(g)} \rightarrow SO_{2(g)} + heat$$
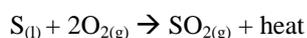
2) The second step is the catalytic conversion of sulfur dioxide and oxygen gas into sulfur trioxide gas:
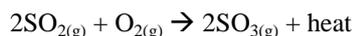
$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)} + heat$$
catalyst: vanadium pentoxide

3) The third step is to dissolve sulfur trioxide in concentrated sulfuric acid to form a solution of highly concentrated sulfuric acid, as well as dissulfuric acid, $H_2S_2O_7$
$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)} + heat$$
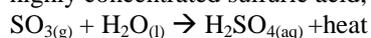
4) After cooling, the oleum is mixed with dilute H_2SO_4 to give H_2SO_4 of the required concentration.

According to le chatelier, production is favored by low temperature and high pressure. However, at too low a temperature the reaction is too slow, also there is a large cost associated with a high pressure plant, so once again optimal conditions are a compromise between the two.

Uses of sulfuric acid: Although corrosive, H_2SO_4 is cheap and easily transported. This makes it one of the most important industrial acids.
- It plays an important role in the manufacture of organic dyes, plastic, drugs and other products
- It is used in the manufacture of fertilisers, in the petroleum industry and in the production of steel.
- It is used in detergents, paints, pigments, paper, rayon and other polymers
- It is used as a dehydrating agent in the synthesis of organic chemicals and in the processing of petrochemicals.
- It is used to pickle and descale steel and to leach copper, uranium and vanadium from their ores
- A direct use is the lead-acid storage battery.

Catalytic cracking: The process of conversion of alkanes to alkenes through the use of a catalyst.

Thermal cracking: This is used to covert alkanes to alkenes by heating to 800°C and rapidly cooling. Ethene is the most favoured product.

Hyrdocracking: Refining process in which middle and heavy distillate fractions are cracked (broken into smaller molecules) in the presence of hydrogen at high pressure and moderate temperature to produce saturated hydrocarbons (ie no alkenes). The catalyst is Aluminate silicate.

Reforming: Thermal or catalytic refining process in which the hydrocarbon molecules of a naphtha are rearranged to improve its octane number; the resulting product is used in blending high-octane gasoline.

Alkylation: Smaller alkenes, when obtained by thermal cracking, react with alkanes in the presence of concentrated H_2SO_4 to form larger alkanes.

Cyclisation: This is the process by which a hydrocarbon is converted to a cyclic "ring" hydrocarbon, often with the loss of hyrdocgen.

Aromatisation: Similar to cyclisation, except a benzene based structure is produced.

The removal of sulfur from crude oil: For environmental reasons, sulfur impurities in natural gas and petroleum must be removed.
1) H$_2$S and other impurities can be extracted into basic potassium carbonate: H$_2$S + CO$_3^{2-}$ → H$_2$S- + HCO$_3^-$
2) After removal from this solution, the H$_2$S is burned in air at high temperature using aluminium oxide as a catalyst to yield sulfur dioxide: H$_2$S$_{(g)}$ + 3/2O$_{2(g)}$ → SO$_{2(g)}$ + H$_2$O$_{(g)}$
3) The SO$_2$ is then reacted with additional H$_2$S:
   SO$_{2(g)}$ + 2H$_2$S$_{(g)}$ → 2S + 2H$_2$O$_3$

Factors in determining the properties of polymers:
1) Chain length: the greater the chain length, the higher the strength and the higher the melting point
2) Intermolecular forces: The stronger the intermolecular forces, the higher the melting point
3) Branching: straight chains can pack closer together, the presence of branches limits how close polymer chains can come to each other, lowering the intermolecular forces, and leading to a lower melting point.
4) Cross linking: the greater the cross linking, the more rigid the polymer.

Examples:
- Thermosetting polymers are designed to produce crosslinks when hot
- Dunlop discovered that when sulfur is added to rubber, a better (ie retains shape, spring etc) rubber is formed. The sulfur allows polymers to cross link.
- Polyethene has low van der waals forces, and becomes soft on melting. It is used in rods, tubes, plastic bags, wrappers, squeeze bottles etc.
- High density polyethene is used for buckets, milk crates, syringes etc.

Production of chlorine by the electrolysis of sodium chloride:
- Water is pumped through salt rock and removed as brine (salt water: NaCl * xH$_2$O)
- There are two processes: the mecury cell process and the diaphragm cell, syllabus sais diaphragm cell is preferred:
    o Anode and cathode are in two compartments separated by a diaphragm made of asbestos. The anode is titanium, and the cathode is steel.
    o Anode half reaction: 2Cl$^-_{(aq)}$ → Cl$_2$ +2e$^-$
    o Cathode half reaction 2H$_2$O$_{(l)}$ + 2e$^-$ → 2OH$^-$ + H$_{2(g)}$
    o The sodium ions can migrate through the diaghragm to the cathode, where they combine with hydroxide ions. Thus the solution becomes increasingly alkaline with the effect being that the brine looses its chloride ions and becomes richer in hyroxide ions as a result of the electrolysis.
    o This is a very elegant process because it produces sodium hydroxide with chlorine and hyrdorgen as by-products.

Ellingham diagram: This is a diagram used to predict the feasibility of reducing metal ores. A graph of ΔG is plotted against temperature. From $\Delta G = \Delta H - T\Delta S$, if one were to plot a graph of ΔG against temperature, the result would be equal to $-\Delta S$, provided that both ΔH and ΔS are not very dependant on temperature, which can be assumed for an IB reaction. So basically take a line, and its slope is $-\Delta S$, with any sudden change in slope due to a phase change.

For a metal oxide to decompose to a metal, delta G must be negative. So, for example on the Ag/Ag$_2$O line delta G is positive above standard conditions and thus silver is found in nature rather than its oxide. Another example is the fact that by heating HgO to above 750K, mercury can be obtained because above this temperature delta G is positive. Basically, remember that a less stable metal will displace a more stable metal, and the lines on the graph cross at different temperatures.

OPTION F

Fossil fuel: Carbon/hydrocarbon compounds that generally release a great deal of heat upon combustion.

Nuclear fission: The splitting of large nuclei into smaller ones, caused by the bombardment of neutrons and in the process releasing large amounts of energy that has been converted from mass.

Nuclear fusion: The joining of two smaller nuclei to form larger ones, releasing energy in the process. This is yet to become an energy source. Problems include the containment of plasma and the high temperature required.

Electrochemical cell: A cell in which energy is converted from stored chemical energy to electrical energy.

Solar energy: Through the use of doped semiconductors, solar energy can be converted to electrical energy.

Wind energy: Energy is obtained from wind energy by the use of two or three blades on a horizontal which turn a turbine, generating electricity.

Tidal energy: This is the generation of electricity from tidal movement, its disadvantage is that it only applies when the tide is going in or out.

Geothermal: This is the use of heat obtained from the interior of the earth (from gravitational forces and natural radioactivity) to generate electricity.

Coal: Solidfied plant material that has been deposited in rock layers, has undergone partial decay and has been subjected to geological heat and pressure from the overlaying rocks over millions of years. It is readily combustible, containing between 40 and 98 % carbon, variable amounts of volatile mixtures and some moisture. Impurities include sand, and molecules made up of elements H, O N and S. Coal with higher percentages of iron sulfide are considered dirty because this is a major cause of acid rain. Most of the worlds estimated 300 to 350 years of remaining coal reserves are in the northern hemisphere.

Coal gasification: This is the most economical way of converting dirty coal into clean burning methane gas. There are four steps:
1) Hydrogasification: $Coal_{(s)} + H_2O + heat \rightarrow CO_{(g)} + H_{2(g)} +$ impurities.
2) Catalytic increase of hydrogen gas: $CO_{(g)} + H_2O \rightarrow CO_{2(g)} + H_{2(g)}$
3) The removal of impurities/desulfurization .
4) Catalytic methanation: $3H_2 + CO_{(g)} \rightarrow CH_{4(g)} + 4H_2O_{(g)}$

The water is removed, leaning behind cleain burning, high heating value methane fuel, called synthetic natural gas (SNG)

Coal liquefaction: This is the process by which coal is turned into synthetic liquid fuels such as methanol and gasoline. The starting points are the gasification products when coal is heated with superheated steam between 500 and 1000°C to produce CO and H$_2$:
$Coal_{(S)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)}$
When the mixture is passed over an iron catalyst a variety of liquid fuels are produced. It is the amount of hydrogen introduced that determines wether the product is an alkanol or an alkanal. By varying the conditions of the reaction, higher moalr mass alkanols and hydrocarbons can be formed.
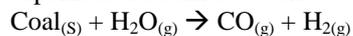
Crude oil: A dark, foul smelling liquid that was created from the remains of marine living organisms between 50 and 500 million years ago. Under high pressures and with the presence of little air these animal remains changed into over 500 usefull hydrocarbons. It is easy to transport but is a dirtier fuel than natural gas.

FRACTION	Carbon chain composition	Major uses	B.P range (^{o}C)
Gaseous hydrocarbons	C1-C4	Gaseous fuels for industrial heating, automobiles, cooking.	0-20
Petroleum	C5-C7	Solvents for varnishes, dry cleaning, as a cracking	20-100

ether/naptha		stock for methane.	
Gasoline	C5-C12	Fuels for internal combustion engines	40-175
Kerosine oil	C12-C18	Diesel fuel and jet engine fuel	175-300
Gas oil/diesel oil	C18-C24	Diesel fuel, cracking stock to produce gasoline	300-400
Lubricating oil, wax oil, greases	C20-C30	Lubricants, cracking stock.	Non-volatile fraction
Parrafin wax	C25-C40	Water proofing, candles, polishing wax, packaging, petroleum jelly.	Solids
Residue, bitumen	>C30	Water proofing, asphalt, roofing.	Soilds

Natural gas: A gas formed from the decombustion of crude oil and coal deposits. It is the cleanest of the fossil fuels, producing CO_2, H_2O and no solid residues. Impurities can be easily removed.

Catalytic cracking: The breaking down of heavier long-chain hydrocarbons into gasoline molecule by passing them over catalysts at high temperature and pressure, resulting in breaking of some c-c bonds.

Thermal cracking: This is similar to catalytic cracking, but without a catalyst so more energy is required.

Reforming: A process used to reform smaller hydrocarbons into larger (more useful) ones.

Isomerisation: This is when straight chain hydrocarbons are converted to branched chain isomers, with a higher octane rating.

Alkylation: Smaller alkenes react with alkanes (in the presence of H_2SO_4) to form larger alkanes.

Cyclisation: Straight chain hydrocarbons are converted to cyclic compounds, often producing hydrogen which can be used in the haber process.

Aromatisation: Straight chain hydrocarbons are converted to aromatic compounds based on benzene. This also often releases hyrdrogen which can be used in the haber process.

Alpha particle: An alpha particle is a double positively charged helium nucleus.

Beta particle: There are two types of beta particle Firstly, beta - ($_{-1}^{0}\beta^{-}$, actually an electron) is emitted when a neutron decays to a proton and an electron, as well as an anitneutrino ($\bar{v}$). The second is the beta + ($_{1}^{0}\beta^{+}$, actually a positron) formed when a proton decays to a neutron and a positron, as well as a neutrino (v).

Nuclear power plant: The nuclear power plant has several main components.
1) Fuel: This is carefully diluted material enriched in U-235 (about 3 %), the rest of the elements are non-fissile.
2) Moderators: These control the fission reaction inside the core, slowing the neutrons so that they are more easily absorbed by nuclei.
3) Control rods: The chain reaction is controlled by restricting the number of neutrons available for subsequent fission. Lowered into the core, they often consist of graphite or cadmium.
4) Coolant: This is the substance that controls and extracts the heat produced. Heat from the core heats the primary lop, which is sounded by a lower pressure secondary loop where the steam is used to turn the turbine.

Gamma radiation: Gamma rays are photons having very high energy. Like an atom, a nucleus can be in an excited state. When it jumps down to a lower energy state, it emits a photon, except the energy levels within an atom are much higher than those within electrons, and thus the photon emitted has a much higher energy.

Half life: The time taken for the mass of a sample of material to be equal to half its original amount.

Solar energy: This is nuclear fission energy from the sun that has been transmitted to the earth. It is infinite, requires to purification, safe, clean, non resource depleting and can be used to produce H_2 by the electrolysis of water (H_2 is a very clean fuel). However other sources of energy are cheaper, and problems include lack or reliability (cloud cover) and the large dispersion range (ie needs to be concentrated).

Photosynthesis: This is the process in which, in the presence of sunlight and chlorophyll, carbon dioxide reacts with water to produce energy rich carbohydrates. $6CO_{2(g)} + 6H_2O_{(l)}\_ \xrightarrow{\text{sunlight / chlorophyll}} C_6H_{12}O_6 + 6O_{2(g)}$

Biofuel: A renewable energy source derived from living things, originally from solar radiation via photosynthesis. This includes vegetation, animal dung, domestic/industrial organic waste. Advantages include the fact that they are renewable, available, relatively non-polluting. Disadvantages include the replacement of food crops, depletement of soil nutrients, polluting nature of fermentation waste and the wide dispersion of biomass. It can be converted to energy in a number of ways:
1) Direct: Combustion of wood etc to produce heat, steam and electricity
2) Indirect
    a. Thermal
        i. Gasification: heat in limited air to produce biogas, SNG, methanol
        ii. Pyrolysis: heat in the absence of oxygen to produce oil (SNL) and SNG
        iii. Hyrdogenation: Biomass reacted with CO and steam to produce heavy oil.
    b. Biological
        i. Anaerobic bacterial decay of organic matter to produce biogas: a mixture of 70 % CH_4 and CO_2.
        ii. Fermentation of carbohydrates to produce ethanol: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + CO_2$. This is obtained from sugar, root crops and cereals: used for heating and for combustion within automobiles when combined with gasoline. The trees are grown on non cropland, the technology is available but disadvantages include the expense, low kilometres per litre and large amounts of H_2O required in manufacture.

Space heating: There are two types of space heating
1) Space heating from direction sunlight: the house has windows facing the sun, maximum heat is collected and absorbed by the structure.
2) Active space heating system:
    - heat is stored and distributed by pumps and fans.
    - The energy is collected using flat or inclined black collectors.
    - The storage of heat is by water or air pumped into rock.

Photovoltaic cell: This is a method used to convert solar energy into electrical energy, and is about 13 to 14 percent efficient. It consists of two layers of almost pure silicon, with As added to one and B to the other, in effect creating an extra mobile electrons in the former (n-type), and a positive electron 'hole' in the later (p-type). When an extra electron goes from the n type to the p, it pairs up. When sunlight strikes it, the suns energy is used to unpair electrons in the p and the electron goes back to the n layer. This pulls an electron in from the external source, and thus we have a source of emf!

Lead acid storage battery: This is the battery commononly used in automobiles. The electrolyte is lead acid, H_2SO_4, with a lead anode ($Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$) and a PbO_2 cathode ($PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + H_2O$).

Dry Cell battery: A common example is that with a carbon cathode, zinc anode and a moist paste of $NHCl$ and MnO_4 as electrolyte.

Another example: mercury battery: Anode: $Zn_{(s)}$, cathode: HgO

Alkaline battery: $Zn_{(s)} + 2OH^- \rightarrow ZnO_{(s)} + H_2O + 2e^- / MnO_2 + H_2O + 2e^- \rightarrow Hg + 2OH^-$

Pumped storage scheme: Used for the large scale storage of energy, excess power is used to pump water uphill where it is sotred as gravitational potential energy. Problems include huge cost, low efficiency, lack of suitable locations, environmental impacts. For small scale consumption, H_2 can be used to store energy either through a serious of reactions or electrolysis.

Third law of thermodynamics: Basically, this states that energy is always lost when transferring from one form to another.

Neutron to proton ratio: This is used to predict nuclear stability and mode of decay. If a nuclei has an n to p ratio that is too large or too small, ie outside the stability belt, then the radio nucleide undergoes radioactive decay. If there are too many neutrons, one (or more) neutron(s) decay to a proton, an electron and an anitineutrino (neutrinos are not required in chem., only physics). If there are too many protons one or more protons can decay to a positron and a neutrino.

$$^1_0 n \rightarrow ^1_1 p + ^0_{-1}e^- + \bar{v}$$ (neutron decays to a proton and an electron)

OR

$$^1_1 p \rightarrow ^1_0 n + ^0_{-1}e^+ + v$$ (proton decays to a neutron and a positron)
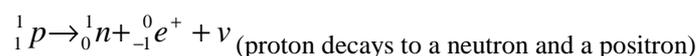
Einstein's energy mass equivalence: This is namely $E = mc^2$, where E is the energy (measured in joules), m is the mass in kilograms, and c is the speed of light in a vacuum. Using this equation, the energy equivalent of a mass change can be calculated.

Binding energy (E_b) : The energy required to break a nuclear bond – how much energy must be put into the system to separate the two atoms to infinity. This can also be defined as the energy equivalent of the difference in mass between the nucleus of an atom and the masses of the individual protons and neutrons that make it up. A new value can be derived per this, the binding energy per nucleon, meaning the binding energy divided by the number of nucleons (nucleons: protons or neutrons.)

Graph of nuclear binding energy per nucleon: I cant be bothered drawing it, but basically it shows that for small atoms, when going to a larger mass number there is an increase in binding energy per nucleon, meaning that this state will be more stable, and because energy is released when going to a more stable state, from E=mc^2 this energy comes from a loss of mass. Also for larger atoms, when going from a larger mass number to a smaller one there is an increase in binding energy, with the same effect.

Integrated form of the rate equation: In the data book, this is $\ln \dfrac{x_0}{x} = kt$ or $x = x_0 e^{-kt}$. Where x_o is the original amount, x is the final amount, t is the time and k is a constant that can be found using the formula ☺ (or I guess you are told it). The main thing is that t can be substituted in for a certain amount of half lives.

Semiconductor: Silicon and Germainium are semiconductors, that is they have a conductivity somewhere between a metal and a non-metal (because they are metalloids). This can be related to ionisation energies in the sense that metals have low ionisation energies, and therefore free electrons, while non metals have high ionisation energies, and metalloids somewhere in between.

Doping: This is explained under photovoltaic cells, but basically (from syllabus) it is the introduction of holes in crystal by introducing a small percentage of elements (eg Ga, In) and extra electrons by using other elements (eg As).