

- a) describe acids in terms of the Brønsted–Lowry theory as proton donors, and bases as proton acceptors, and identify the proton donor and proton acceptor in an acid–base reaction;

**Acids are proton donors, bases are proton acceptors. In an equation, the base is the reactant which accepts the proton, and the acid is the reactant which donates it.**

- b) i. draw and interpret simple electron ‘dot-and-cross’ diagrams to show how atoms bond through ionic, covalent and dative covalent bonds and be able to describe a simple model of metallic bonding;

**In ionic bonding one ion is positively charged and the other is negatively charged. They do not ‘bond’, but rather attract each other so hold together.**

**In covalent bonding the atoms share electrons so that each atom has a full outer shell of electrons.**

**In dative covalent bonding, one atom donates two electrons to the bond, so that both atoms have a full outer shell of electrons.**

**In metallic bonding the positive ions are arranged in a regular shape. Their outer shell electrons become delocalised, and the ions are attracted to the electrons. This electro-static attraction holds the metal together. The more delocalised electrons (more electrons in the outer shell), the stronger the metal**

- ii. use the electron pair repulsion principle to predict and explain the shapes of simple molecules (such as  $CH_4$ ,  $NH_3$ ,  $H_2O$  and  $SF_6$ ) and ions (such as  $NH_4^+$ ) with up to six outer pairs of electrons (any combination of bonding pairs and lone pairs) (no treatment of hybridisation or molecular orbitals is expected);

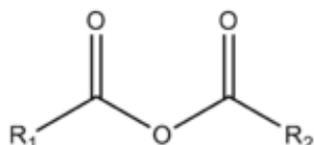
**Electron pairs repulse each other, so the number of electron pairs dictates the shape of a molecule. A molecule with 4 pairs of outer shell electrons will be tetrahedral.**

- iii. recall the typical physical properties (melting point, solubility in water, ability to conduct electricity) characteristic of giant lattice (metallic, ionic, covalent network) and simple molecular structure types (synoptic);

TYPICAL PROPERTIES					
	GIANT LATTICE			COVALENT MOLECULAR	
	Ionic	Covalent network	Metallic	Simple molecular	Macromolecular
<b>Melting and boiling points</b>	High	Very high	Generally high (except mercury)	Low	Moderate (often decompose on heating)
<b>Hardness</b>	Hard but brittle	Very hard (if 3D)	Hard but malleable	Soft	Variable; many are soft, but often flexible
<b>Electrical conductivity</b>	Conducts when molten or dissolved in water	Does not normally conduct (except graphite)	Conducts when solid or liquid	Do not conduct	Do not normally conduct
<b>Solubility in water</b>	Often soluble	Insoluble	Insoluble (but some react)	Usually insoluble, unless molecules contain groups which can hydrogen bond with water	Usually insoluble
<b>Solubility in non-polar substances</b>	Generally insoluble	Insoluble	Insoluble	Usually soluble	Sometimes soluble

c) recognise and write formulae for members of the following homologous series:

- i. diols,  
**Two –OH groups**
- ii. diamines,  
**Two –NH<sub>2</sub> groups**
- iii. dicarboxylic acids,  
**Two –COOH groups**
- iv. phenols,  
**–OH attached to a benzene ring**
- v. acyl chlorides,  
**–COCl group**
- vi. acid anhydrides,  
**RCOOCOR<sup>1</sup>**



- vii. esters  
**RCOOR<sup>1</sup>**
- viii. and other homologous series met in the AS course (synoptic);

d) use systematic nomenclature to name and interpret the names of

- i. diols,  
**Suffixed with -diol**
- ii. carboxylic acids,  
**Suffixed with -oic acid**
- iii. dicarboxylic acids,  
**Suffixed with -dioic acid**
- iv. esters,  
**Alcohol -yl, acid -oate**
- v. aldehydes  
**Suffixed with -al**
- vi. ketones,  
**Suffixed with -one**
- vii. and other organic compounds whose naming was required in the AS course (synoptic);

e) recall the reactions (as described in the modules named) of

- i. halogenoalkanes (ES),  
**(Nucleophiles)**
  - $R-Hal+H_2O \rightarrow R-OH+H^++Hal^-$       Heated under reflux
  - $R-Hal+OH^- \rightarrow R-OH + Hal^-$       Heated under reflux with NaOH(aq) with ethanol as a solvent
  - $R-Hal+NH_3 \rightarrow R-NH_2+ H^++Hal^-$       Heated with concentrated NH<sub>3</sub> in a sealed tube
- ii. alkenes (PR)
  - $CH_2CH_2+Br_2 \rightarrow CH_2BrCH_2Br$       Room temp & pressure
  - $CH_2CH_2+Br_{2(aq)} \rightarrow CH_2BrCH_2OH$       Room temp & pressure
  - $CH_2CH_2+HBr \rightarrow CH_3CH_2Br$       Room temp & pressure, aqueous solution
  - $CH_2CH_2+H_2O \rightarrow CH_3CH_2OH$       Conc H<sub>2</sub>SO<sub>4</sub>, then H<sub>2</sub>O at 1atm
  - $CH_2CH_2+H_2 \rightarrow CH_3CH_3$       Room temp & pressure, Pt catalyst
- iii. and alcohols (PR) (synoptic);
  - Primary alcohols become first an aldehyde, and then a carboxylic acid when heated under reflux with acidified potassium dichromate(VI).
  - Secondary alcohols are oxidised to ketones under the same conditions.
  - In both reactions the colour changes from orange to green.

f) describe and explain the acidic nature of carboxylic acids, and their reaction with alkalis and carbonates;

**Carboxylic acids can donate a proton to become –COO<sup>-</sup>.**

**They react with alkalis to form a salt**

**They react with carbonates to form carbon dioxide**

g) describe the reaction of alcohols with carboxylic acids in the presence of concentrated sulfuric acid or concentrated hydrochloric acid to form esters;

**The acid acts as a catalyst.**

**The reaction is in equilibrium, so is reversible.**

h) describe the following properties of phenols:

i. acidic nature,

**Can donate a proton from the –OH group**

ii. and their reaction with alkalis but not carbonates;

**Form a salt when reacting with alkalis.**

iii. **test with neutral iron(III) chloride solution, to give a purple colouration;**

iv. reaction with acyl chlorides to form esters;

**Anhydrous conditions. Will react at room temperature**

i) describe the following reactions involving carbonyl compounds (aldehydes and ketones):

i. **formation of carbonyl compounds by oxidation of alcohols using acidified dichromate with the need to distil in the case of aldehydes (synoptic);**

ii. **oxidation of aldehydes to carboxylic acids using acidified dichromate, under reflux;**

iii. reaction with hydrogen cyanide to form the cyanohydrin;

**The carbonyl group is slightly positively charged, so is attacked by the negative cyanide ion to undergo nucleophilic addition in the presence of an alkali.**

j) describe the techniques for heating and purifying volatile liquids:

i. heating under reflux and distillation (synoptic);

**Heating under reflux**

i. Put the reactants in a pear shaped flask. Add anti-bumping granules. Attach a condenser vertically.

ii. Connect the condenser to a water supply

iii. Heat so that the liquid boils gently.

**Distillation**

i. Put the impure liquid in a pear shaped flask. Add anti-bumping granules.

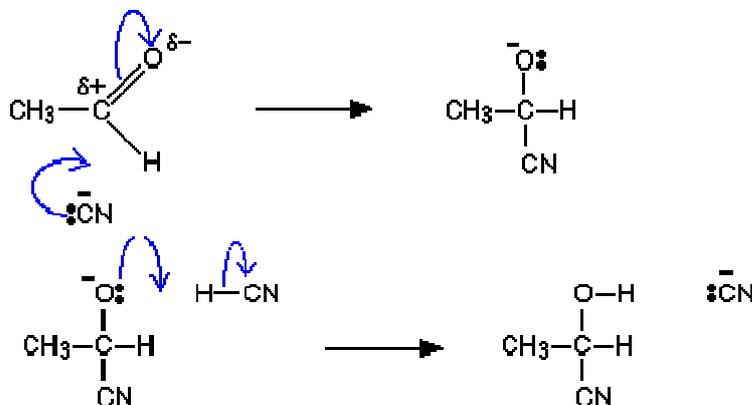
ii. The mixture is heated until the thermometer shows the vapour temperature of the desired beaker.

iii. A clean beaker is placed below the condenser to collect the condensed liquid.

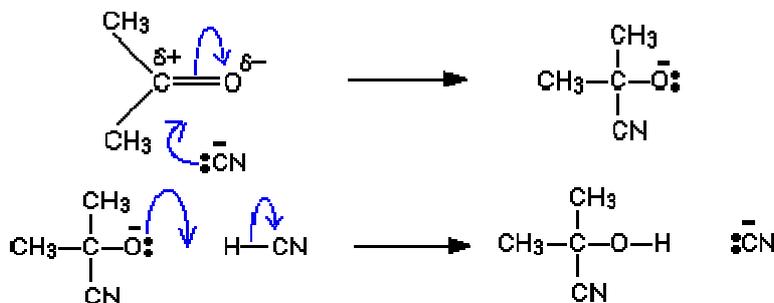
iv. When the temperature of the thermometer rises above the boiling point of the desired liquid, the process is stopped.

k) describe the mechanism of the nucleophilic addition reaction between a carbonyl compound and hydrogen cyanide, using 'curly arrows' and bond polarities;

**Aldehyde**



**Ketone**



l) understand that **more effective medicines can be obtained by modifying the structure of existing medicines;**

m) discuss given examples and understand that **combinatorial chemistry is used to make a large number of related compounds together, so that their potential effectiveness as medicines can be assessed by large-scale screening;**

- i. recall the meaning of the concept 'atom economy' (synoptic)

**The efficiency of a chemical process**

understand that **most reactions used in chemical synthesis can be classified as:**

1. **rearrangement,**
2. **addition,**
3. **substitution,**
4. **elimination;**

ii. understand that **a condensation reaction is addition followed by elimination;**

iii. classify a given reaction using these terms.

**Rearrangement**

**100% atom economy**

**The atoms in the molecule are rearranged**

**Addition**

**100% atom economy**

**Groups are added to the molecule, usually around a double bond**

**Substitution**

**Less than 100% atom economy**

**Groups are swapped**

**Elimination**

**Less than 100% atom economy**

**Groups are removed**

- ii. recall and understand that **rearrangement and addition reactions have a higher atom economy than substitution and condensation reactions, which have a higher atom economy than elimination reactions,**
- iii. discuss the importance of 'atom economy' and reaction type in working towards the development of environmentally friendly industrial processes in the production of polymers and medicines;

**Higher atom economy means that less energy can be used, and fewer reactants need to be purchased.**

**Less energy use reduced greenhouse gas emissions.**

- o) understand that **testing a medicine involves clinical trials which answer the following questions about a potential new drug:**

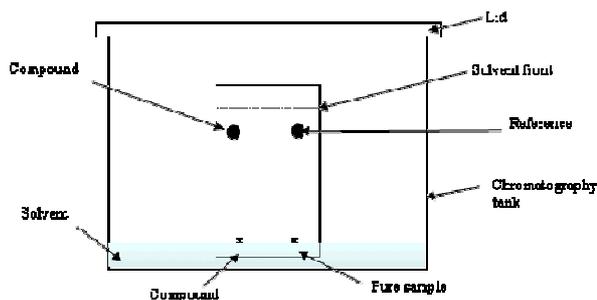
**Step I – Is it safe?**

**Step II – Does it work?**

**Step III – Is it better than the standard treatment?;**

p)

- i. describe the technique of thin-layer chromatography (TLC), including location of spots using iodine or ultraviolet radiation, and interpret results in terms of number of spots and matching heights or  $R_f$  values with known compounds;



1. Draw a pencil line approximately 1cm from the bottom of the paper. Mark a cross and produce a concentrated spot of the compounds to be used by repeated application followed by drying.
  2. Mark a reference spot (known compound).
  3. Mark a spot of unknown substance.
  4. Place in chromatography tank; ensure that the spots are above the solvent.
  5. Cover with lid.
  6. Allow time for the solvent to run up the chromatography plate, so it reaches just below the end of the paper.
  7. Use locating agent to find spots, e.g. iodine, UV light etc.
  8. Compare the unknown compound with the reference compound.
- ii. understand that **chromatography can be used for the purification of an organic substance;**

q)

i. *interpret and predict mass spectra:*

**The peak furthest to the right shows the  $M_r$ . Sometimes there are two peaks that show the  $M_r$ . These are present when there are two naturally occurring isotopes, and their heights are proportional to the relative abundance of the isotopes.**

ii. *identify the  $M^+$  peak and explain that it indicates the  $M_r$  (synoptic);*

**The  $M^+$  peak is the peak to the furthest right of the spectra**

iii. *explain how the molecular formula can be worked out from the high-resolution value of the  $M^+$  peak;*

**Aside from the line corresponding to the  $M_r$ , the other peaks on the spectrum correspond to lighter ions which are the result of fragmentation.**

**The differences between masses of the different peaks show which groups have been lost, and so the whole molecular formula can be deduced.**

iv. *recall that other peaks are due to positive ions from fragments and the mass differences between peaks;*

v. *Indicate the loss of groups of atoms, suggest the origins of peaks, eg peaks at masses of 15 and 77 are usually due to the presence of the methyl and phenyl positive ions; loss of a methyl group would be indicated by a mass difference of 15;*

r)

i. *use information given in the Data Sheet to interpret and predict infrared spectra for organic compounds, in terms of the functional group(s) present;*

**The peaks on the spectra correspond with the relevant peaks on the data sheet**

ii. *understand that specific frequencies of infrared radiation make specific bonds vibrate more.*

a)

- i. explain the term electronegativity:  
**The degree to which an atom of an element attracts electrons**
- ii. recall qualitatively the electronegativity trends in the Periodic Table;  
**More electronegative towards the top right**
- iii. use relative electronegativity values to predict bond polarity in a covalent bond;  
**The electrons in a bond will be nearer to the more electronegative atom, meaning that it will be  $\delta^-$ , and the less electronegative atom will be  $\delta^+$**
- iv. decide whether a molecule is polar or nonpolar from its shape and the polarity of its bonds;  
**In tetrachloromethane, there are four dipoles, but because the chlorine atoms are arranged symmetrically, there is no overall dipole.**
- v. explain, give examples of and recognise in given examples the following types of intermolecular bonds:
  - i. instantaneous dipole-induced dipole bonds (including dependence on branching and chain length of organic molecules),  
**Very weak. often between molecules which don't usually have a dipole. They are continuously breaking and reforming**
  - ii. permanent dipole-permanent dipole bonds,  
**In bonds between atoms with different electronegativities. The  $\delta^+$  atom from one molecule is attracted to the  $\delta^-$  atom from the other molecule and a bond forms. These are stronger than instantaneous dipole-induced dipole**
  - iii. hydrogen bonds (synoptic);  
**Occurs between a Hydrogen atom attached to either an Oxygen, Nitrogen or Fluorine molecule, and the lone pair on another Oxygen, Nitrogen or Fluorine molecule. Very strong types of permanent dipole-permanent dipole bonds**

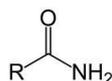
b)

- i. explain and predict the effect of temperature, crystallinity and chain length on the properties of polymers:
    - i. **temperature**
      1. **intermolecular bonds have more effect as the temperature is lowered;**
      2. **a polymer softens above its  $T_m$  and becomes brittle below its  $T_g$ ;**
    - ii. **crystallinity (regular packing of the chains, due to the regular structure of the polymer) – the chains are closer and the intermolecular bonds have more effect, leading to greater strength;**
    - iii. **chain length – there are more intermolecular bonds leading to greater strength;**
  - ii. explain that **flexibility depends on the ability of the polymer chains to slide over each other;**
- c) explain the following ways that chemists can modify the properties of a polymer to meet particular needs:
- i. cold drawing to make the structure more crystalline,  
**Cold drawing increases the strength of a polymer by making the chains more crystalline. This means that the chains can get closer together and so there are more points where intermolecular forces can act, leading to an increased tensile strength**
- d) understand that **the properties of all materials depend on their structure and bonding** and explain examples given relevant information;
- e) recognise members of the following homologous series: amines and amides;

**Amine**



**Amide**



- f) use systematic nomenclature to name and interpret the names of aliphatic primary amines and diamines (**use the prefix amino- for the  $\text{NH}_2$  group together with the parent hydrocarbon, eg 2-aminopropane, 1,6-diaminohexane**);
- g) explain the difference between addition and condensation polymerisation;
- Addition polymerisation**  
**Many identical monomers are joined together to form a polymer.**
- Condensation polymerisation**  
**Lots of monomers join together to form a polymer and a smaller molecule is released**
- h) predict the structural formula of the condensation polymer formed from given monomer(s), and vice versa;

- i) describe the hydrolysis of esters and amides by both aqueous acids and alkalis, including salt formation where appropriate;

**Amides**

**Acid**

Heating under reflux with a moderately concentrated acid produces a carboxylic acid and an ammonium ion

**Alkalis**

Heating under reflux with a moderately concentrated alkali produces a carboxylate ion and an amine

**Esters**

**Acid**

Reflux with a dilute acid. Forms a carboxylic acid and an alcohol. This reaction is reversible, so the weaker the acid, the better.

**Alkali**

Reflux with a dilute alkali. Forms carboxylate salt and an alcohol

- j) describe the following reactions of amines:

- i. neutralisation by acids,

Amines have a lone pair on the  $\text{NH}_2$ . This means that they can act as proton acceptors, and so react with acids to form salts

- ii. acylation to form an amide;

The reaction between amines and acyl chlorides to form amines and hydrochloric acid is vigorous.

- k) recall the procedure for purifying an organic solid product by recrystallisation

Dissolve the solid in a minimum volume of hot solvent

Filter and retain the filtrate

Allow the filtrate to cool until crystals form

Collect the crystals by vacuum filtration. Wash with a minimum volume of cold solvent

Dry in air, in an oven set at below the melting point of the crystals, or in a desiccator

**explain that the solvent used:**

- i. must be one in which the substance is very soluble at higher temperatures and insoluble, or nearly so, at lower temperatures;

- ii. is saturated by the substance at higher temperatures, and on cooling the substance then crystallises out, to leave the impurities in solution;

- l) explain the basic nature of the amino group, in terms of a lone pair on the nitrogen accepting a proton to give a cation; The Nitrogen in the  $\text{NH}_2$  group has a lone pair, which means that it can act as a proton acceptor, thus making it a Brønsted-Lowry base. By accepting the proton, the group becomes a positively charged  $\text{NH}_3^+$  cation.

- m) understand how the principles of 'green chemistry' are important in the manufacture, use, recycling and the eventual disposal of polymers, including:

- i. minimising any hazardous waste during production of raw materials and their resulting polymers to reduce any negative impact on the environment,

Hazardous waste can cause environmental impacts, either by animals consuming it, or chemical waste making it into the water supply.

- ii. reducing carbon emissions resulting from the 'life cycle' of a polymer,

The 'life cycle assessment' measures the emissions from the extraction of the raw materials, the manufacture of the product, the distribution to the customers and the eventual disposal.

This allows manufacturers to better evaluate the impact of producing the materials, and aid chemists to design processes which have a lower impact on the environment

- iii. recycling to produce energy and chemical feedstocks.

The energy consumed in producing a tonne of material by recycling is much lower than producing a tonne of material from new raw materials.

Polymers can be returned to their original monomers by cracking. The monomers can then be made into new plastics, or used for something entirely different.

Plastics can be burned to release energy, but a consequence of this is the release of  $\text{CO}_2$

a)

i. explain and use the terms:

i. rate of reaction,

**How fast the reactants are used up and how fast the products are formed**

ii. rate constant, including units

**k. For a given reaction it will constant at a certain temperature. It will change in the presence of a catalyst.****For a reaction which is overall order n, the rate constant has units of  $\text{mol}^{1-n} \text{dm}^{n-1} \text{s}^{-1}$** 

iii. order of reaction (both overall and with respect to a given reagent);

**The order of reaction for each reagent shows the effect of doubling the concentration of a reactant on the rate of reaction; if there is no effect, the order is zero, if the rate doubles, the reaction is first order, and if the rate quadruples when the concentration of the reactant doubles, then the reaction is second order with respect to that reaction.****The overall order of reaction is the sum of all of the orders of reaction.**ii. use empirical rate equations of the form:  $\text{rate} = k[\text{A}]^m[\text{B}]^n$  where m and n are integers;**In the reaction****A + B → Products****The rate equations would be****Rate =  $k[\text{A}]^m[\text{B}]^n$** **Where m is the order of reaction with respect to A, and n is the order of reaction with respect to B.****The order of reaction can only be obtained experimentally, and cannot be deduced theoretically or from the equation**

iii. carry out calculations based on the rate equation;

**[B] = rate/k[A]****[A] = rate/k[B]**iv. understand that **the rate constant k increases with increasing temperature;**b) understand that **these experimental methods can be used in a school laboratory for following a reaction:**i. **titration,**ii. **pH measurement,**iii. **colorimetry,**iv. **measuring volumes of gases evolved,**v. **measuring mass changes;**

c) design experiments using given information and explain how the results of such experiments can be used to calculate the rate of the reaction;

d) use given data to calculate half-lives for a reaction;

**Half lives are calculated using a concentration-time graph. One half life is the time taken for the concentration of the reactant to half.****In first order reactions the half life is constant, and in second order reactions the half life doubles every time the concentration halves.**

e) use experimental data (half-lives or initial rates when varying concentrations are used) to find the order of a reaction (zero-, first- or second-order), and hence construct a rate equation for the reaction;

**Half lives****Zero order- the line on the concentration-time graph is a straight, diagonal line.****First order- the line is curved. The time taken for the concentration of the reactant to halve stays constant****Second order- the line is curved. The time taken for the concentration of the reactant to half doubles.**

f)

i. **use the term rate-determining step to describe the slowest step in a reaction;**

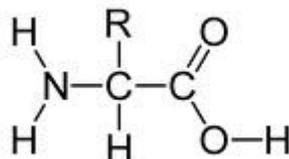
ii. explain the shape of the rate versus substrate concentration curve for an enzyme-catalysed reaction in terms of the rate-determining step:

i. **at low concentrations of substrate the order with respect to the substrate is one, at higher concentrations of substrate the order with respect to the substrate is zero,****This is because at higher concentrations of substrate, the enzyme molecules become saturated- all of the active sites of the enzymes are occupied, so adding more substrate molecules will not affect the rate of reaction**

iii. explain, given the necessary data, the useful information about the mechanism of a reaction that can be obtained from the rate-determining step;

**The rate determining step shows the slowest step of a reaction. This means that the other molecules are involved in other, faster steps of the reaction.**

- g) recognise and describe the generalised structure of amino acids and recall that **proteins are condensation polymers formed from amino acid monomers**;



h)

- i. describe the primary, secondary and tertiary structure of proteins;

**Primary structure- the order of amino acids**

**Secondary structure- when a polypeptide forms either an  $\alpha$ -helix or a  $\beta$ -pleated sheet.**

**Tertiary structure- the 'global' folding of the polypeptide chain to give it a unique shape**

- ii. explain the importance of amino acid sequence in determining the properties of proteins, and account for the diversity of proteins in living things;

The order of the amino acids has consequences on the intermolecular forces in the protein. The R-groups may be able to have hydrophilic-hydrophobic interactions, permanent dipole-permanent dipole bonds, hydrogen bonds, ionic bonds or hydrogen bonds with other side chains, and the positioning of these side chains account for the structure of the protein.

The shape of the protein determines the properties- for example with an enzyme, if the structure is changed then the shape of the active site will change and the enzyme will not catalyse the same reaction.

There is a diverse range of proteins because even the change of one amino acid in the sequence will change the overall structure.

- i) explain the role of hydrogen bonds and other intermolecular bonds in determining the secondary and tertiary structures, and hence the properties of proteins;

**Secondary structure- hydrogen bonds between the N-H and C=O groups. These determine the shape**

**Tertiary structure- interactions between the R groups produce the tertiary structure. The interactions can be:**

**Ionic bonds between charged R groups**

**Hydrogen bonds between polar R groups**

**Instantaneous dipole- induced dipole bonds between non-polar R groups**

**Covalent disulfide bonds- form between cysteine residues**

- j) describe the acid-base properties of amino acids and recall that **they usually exist as zwitterions**;

**The Carboxyl group can act as a proton donor**

**The Amine group can act as a proton acceptor**

- k) describe the formation and hydrolysis of the peptide link between amino acid residues in proteins and the use of paper chromatography to identify amino acids, including the need for a suitable locating agent, such as ninhydrin;

**Formation**

**The  $\text{-NH}_2$  group from one amino acid reacts with the  $\text{-COOH}$  group from the second amino acid, forming a peptide link, which is a secondary amide group. Water is eliminated**

**Hydrolysis**

**Acid**

**Reflux with moderately concentrated acid. The  $\text{-NH}_2$  groups are protonated to give  $\text{-NH}_3^+$  groups**

**Alkali**

**Reflux with moderately concentrated alkali. The  $\text{-COOH}$  groups are deprotonated to give  $\text{-COO}^-$  groups**

l) describe the characteristics of enzyme catalysis, including:

i. specificity,

**The active sites are shaped to fit the shape of the substrate. They also contain specific –R groups which interact chemically with the substrate**

ii. temperature sensitivity,

**At higher temperatures the intermolecular bonds in the enzyme become weaker and break. This causes denaturing of the enzyme, and the shape of the active site changes, so the enzyme can no longer catalyse reactions**

iii. pH sensitivity,

**The presence of alkali or acidic molecules will affect the secondary structure of the enzyme, as the presence, or lack of, H<sup>+</sup> ions will change the Hydrogen bonds**

iv. inhibition;

**An inhibitor is a chemical other than the substrate whose presence affects enzyme function. Molecules acting as inhibitors either bind to the active sites but do not react (competitive inhibitors), or bind to somewhere else on the enzyme and consequently change the shape of the active site (non-competitive inhibition)**

m) explain these characteristics of enzyme catalysis in terms of a three-dimensional active site (part of the tertiary structure) to which the substrate forms intermolecular bonds, recalling that **molecules acting as inhibitors bind to active sites but do not react;**

**The three dimensional structure of the enzyme gives rise to crevices of a precise geometric shape- the active sites. They contain specific –R groups which interact chemicals with the substrate**

n)

i. understand that **DNA is a condensation polymer formed from nucleotides, which are monomers having three components: phosphate, sugar and base;**

ii. explain, using the structures on the Data Sheet, how:

i. phosphate units join by condensation with deoxyribose to form the phosphate–sugar backbone in DNA;

**The phosphate unit joins to the CH<sub>2</sub>OH group of the deoxyribose, with a molecule of water being eliminated**

ii. the four bases present in DNA join by condensation with the deoxyribose in the phosphate sugar backbone;

**The –NH from the bases join to the –OH deoxyribose, with a molecule of water being eliminated**

iii. two strands of DNA form a double-helix structure through base pairing;

**Adenine joins to Thymine or Uracil by two hydrogen bonds.**

**Cytosine joins to Guanine by three hydrogen bonds**

iii. understand that **various models were devised before the currently accepted version was formulated;**

o)

i. using the structures on the Data Sheet, describe and explain the significance of hydrogen bonding in the pairing of bases in DNA, and relate to the replication of genetic information;

**The base pairs hydrogen bond to each other. Adenine can only bond to Thymine or Uracil, (and vice versa), and Cytosine can only bond to Guanine (and vice versa). This means that when the DNA is replicated it will be a complimentary copy of the original strand of DNA**

ii. use the diagram on the Data Sheet to explain how DNA encodes for an amino acid sequence in a protein;

**Three bases code for an amino acid. A tRNA molecule with the complementary anticodon brings the specific amino acid. These amino acids join together via peptide bonds.**

- i. draw and interpret structural formulae (full, shortened and skeletal);
- ii. use the concept of repulsion of areas of electron density to deduce the bond angles in organic molecules (including double bonds, no treatment of small deviation of angle due to lone pair repulsion required);

**Groups of electrons will arrange themselves to be as far away from each other as possible in the space**

**Bond angles of 109°**

**4 groups of electrons**

**Tetrahedral**

**4 bonding pairs**

**Pyramidal**

**3 bonding pairs, 1 lone pair**

**Bent**

**2 bonding pairs, two lone pairs**

**Bond angles of 120°**

**3 groups of electrons**

**Planar triangular**

**3 bonding pairs**

**2 bonding pairs, 1 double bond**

**Bond angles of 180°**

**Two groups of electrons**

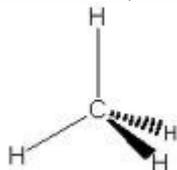
**Linear**

**Two bonding pairs**

**Triple bond, 1 bonding pair**

**2 double bonds**

- iii. relate molecular shape to structural formulae and use wedges and dotted lines to represent 3D shape;



- iv. recognise and draw structural isomers; recognise where E/Z isomerism occurs, explaining it in terms of **lack of free rotation about C=C bonds when there are two different groups on each carbon;**
- v. draw and interpret diagrams to represent E/Z isomers for alkenes which have the same groups on both sides of the double bond (**E – opposite sides of bond; Z – same side of bond**);
- vi. in such molecules, describe 'E' as 'trans' and 'Z' as 'cis' and extend this cis/trans nomenclature to other, more complicated, alkenes (synoptic) (knowledge of Cahn–Ingold–Prelog priority rules will not be required);

q)

- i. draw and interpret diagrams to represent optical stereoisomers of molecules;
- ii. explain and use the term chiral as applied to a molecule,

**A molecule that has a non-superimposable mirror image**

- iii. explain that **enantiomers are non-superimposable mirror image molecules;**

r)

- i. understand that **DNA analysis can be used for 'genetic fingerprinting';**
- ii. discuss the ethical issues of using and storing data from human DNA analysis, given examples;

**Who should have access to personal genetic information?**

**Who owns and controls genetic information?**

**Who owns genes and other pieces of DNA?**

**Should parents have the right to have their children tested?**

**Should tests be performed for genetic diseases?**

**Should an individual always be given their genetic information?**

- s) given examples, understand the industrial importance of enzymes and of their contribution to 'green chemistry' processes.

**They are specific- no need to separate a mixture of reactant**

**They work effectively at low temperatures**

**They work well in aqueous conditions- no need for harmful organic solvents**

**They often convert reactants to products in one step- increased atom economy**

(a) use the concept of amount of substance to perform calculations involving:  
molecular formulae.

**Empirical formula**

The % compositions are taken as masses.

The number of moles is calculated

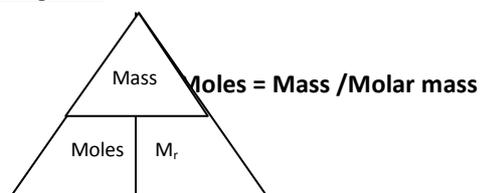
÷ by smaller to get the ratio

**Molecular Formula**

Either equal to Empirical formula or a simple multiple of it.

The relationship between the formula mass of the empirical formula, and the relative molecular mass, and the empirical formula and the molecular formula is the same

masses of reagents.

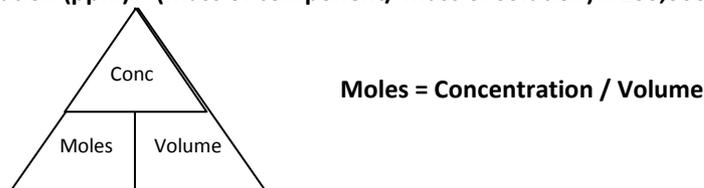


volumes of gases.

1 mole of gas under standard conditions occupies 24dm<sup>3</sup>

concentrations of solutions.

**Concentration (ppm) = (Mass of component/ Mass of solution) x 100,000**



percentage composition.

**% Composition of solids = (Molecular mass of one component/ total molecular mass) x 100**

**% by volume = (Volume of one component/ total volume) x 100**

percentage yield

**% yield = Mass of useful products/ Total mass of products**

**Atom economy (%) = Mass of atoms in desired product / Mass of atoms in reactants**

balanced chemical equations (synoptic);

**There must be the same number of each element on each side of the equation.**

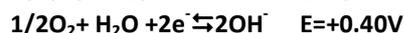
**The oxidation states and charges on each side must add up to the same value**

- b) write and interpret balanced equations, including ionic, given the necessary information (synoptic);  
c) given the necessary information, describe and explain procedures for acid-base (synoptic) and redox titrations and carry out non-structured calculations based on the results;  
d)  
a. use and explain the term coordination number:  
**The number of bonds between the central metal ions and the ligands**  
b. draw and name the shapes of complexes with coordination numbers 4 (square planar and tetrahedral) and 6 (octahedral);

- a. given the necessary information,
- describe redox reactions of d-block elements (and main group elements – (synoptic) in terms of electron transfer: assigning oxidation states (synoptic).  
**Oxygen has an oxidation state of –2, except in peroxides**  
**Hydrogen has an oxidation state of +1**  
**Group 1 elements have an oxidation state of +1**  
**Group 2 elements have an oxidation state of +2**
  - using half-equations to represent the oxidation and reduction reactions (synoptic),
  - combining half equations to give the overall equation for the reaction,  
**Put the two half equations together and then remove anything that cancels each other out**
  - recognising the oxidising and reducing agents,  
**Oxidising agents are reduced, so gain electrons**  
**Reducing agents are oxidised, so lose electrons**
  - defining oxidation and reduction in terms of loss and gain of electrons;  
**Oxidation is loss**  
**Reduction is gain**
  - use systematic nomenclature to name and interpret the names of inorganic compounds [ie copper(II) sulfide, lead(II) nitrate(V), potassium manganate(VII), not complex ions];  
**The oxidation state of the transition metal is put in roman numerals in brackets**
- f) recall and explain the procedure for carrying out a redox titration involving manganate(VII) ions;  
**Use a pipette to transfer a known volume of the test solution ( containing Fe<sup>2+</sup> ions or hydrogen peroxide) into a conical flask**  
**Acidify this solution with dilute Sulfuric acid**  
**Slowly add Potassium Manganate (VII) to the solution in the conical flask from a burette, swirling until the pink colour persists**  
**Repeat until there are two titrations within 0.1cm<sup>3</sup> of each other**
- g) describe the construction of simple electrochemical cells involving:
- metal ion/metal half-cells,  
**A metal electrode is placed in a solution of metal ions and an equilibrium is established. If the metal has a high tendency to release electrons, the electrode potential is very negative compared to the Hydrogen half cell, which has been given a Standard Electrode Potential of 0V**
  - half-cells based on different oxidation states of the same element in aqueous solution with a platinum or other inert electrode, acidified if necessary;  
**An electrode made from an inert metal, such as Platinum is placed in an aqueous solution of 1mol dm<sup>-3</sup> of two ions of the same element**
- h)
- explain and use the term standard electrode potential and understand how a standard electrode potential is measured using a hydrogen electrode (details of electrode not required);  
**The Standard Electrode Potential is a measure of the tendency for the ion to be oxidised to the element**
  - explain the action of an electrochemical cell in terms of half-equations and external electron flow;  
**In each half cell, a half equation takes place. One half is oxidised, and the other is reduced. The electrons flow through an external wire to allow these two reactions to occur.**
- i) use standard electrode potentials to:
- calculate E<sub>cell</sub>,  
**The sign of the more negative electrode potential is reversed and then it is added to the other electrode potential.**
  - predict the feasibility of redox reactions and understand that the rate of reaction may be an important factor in deciding whether the reaction actually takes place under standard conditions;  
**The reaction is feasible if the E<sub>cell</sub> value is positive**

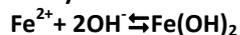
- j) describe rusting in terms of electrochemical processes involving iron, oxygen and water, and the subsequent reactions to form rust;

The half reactions in the first step are:



The first reaction occurs in the centre of the droplet, and the electrons move to the outside of the water, along with the  $\text{Fe}^{2+}$  ions.

The secondary reactions are



$\text{Fe}(\text{OH})_2$  in the presence of oxygen  $\rightleftharpoons \text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$  (rust)

- k) describe and explain approaches to corrosion prevention:
- sacrificial protection by galvanising and use of zinc blocks,
  - barrier protection using oil, grease, paint or a polymer coating;
- l) describe and explain the issues involved in the recycling of iron and steel:
- all steel packaging except aerosols can be recycled,
  - cleaning by incineration,
  - ease of sorting using magnetic properties,
  - composition of new steel easily adjusted,
  - scrap is used to adjust temperature of furnace;
- m) given the necessary information, explain the chemical processes occurring during the extraction and purification of metals from their ores;

Metal ores are mined and their elements extracted by reduction

Reactive metals (Groups 1, 2 and Al) are extracted by electrolysis

Less reactive metals (iron and zinc) are obtained from their ores by reduction with C or CO

Non-reactive metals (gold and platinum) can be found as elements in their earth's crust

- n) recall that the Periodic Table lists elements in order of atomic (proton) number and groups elements together according to their common properties; recall the classification of elements into s-, p- and d-blocks;
- recall and explain the relationship between the position of an element in the Periodic Table and the charge on its ion,

Elements on the left of the periodic table must lose electrons to have a full outer shell, so they are positively charged. Elements on the right of the periodic table must gain electrons to have a full outer shell, so they are negatively charged. Group 0 elements are uncharged and Group 4 elements can be positive or negative

- recall the names and formulae of



Nitrate ion



Sulfate ion



Carbonate ion



Hydroxide ion



Ammonium ion



Bicarbonate

write formulae for compounds formed between these ions and other given anions and cations (synoptic);

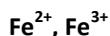
The oxidation states must add up to the same number on each side, and there must be the same number of each molecule on each side of an equation

- a. recall that **transition metals are d-block elements forming one or more stable ions which have incompletely filled d orbitals**;
- b. recall the common oxidation states of iron and copper and the colours of their aqueous ions;

**Copper**



**Iron**



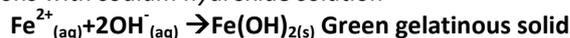
**Cu<sup>2+</sup><sub>(aq)</sub>-blue**

**Fe<sup>2+</sup><sub>(aq)</sub>-green**

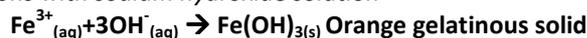
**Fe<sup>3+</sup><sub>(aq)</sub>-yellow/orange**

- p) describe the colour changes in and write ionic equations for the reactions of:

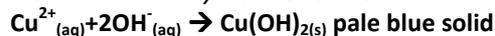
- a. Fe<sup>2+</sup><sub>(aq)</sub> ions with sodium hydroxide solution



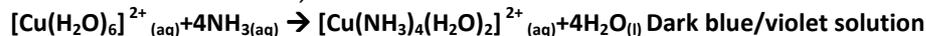
- b. Fe<sup>3+</sup><sub>(aq)</sub> ions with sodium hydroxide solution



- c. Cu<sup>2+</sup><sub>(aq)</sub> ions with sodium hydroxide solution



- d. Cu<sup>2+</sup><sub>(aq)</sub> ions with ammonia solution;



q)

- a. use conventions for representing the distribution of electrons in atomic orbitals (no treatment of the shapes of atomic orbitals is expected);

**An atom's nth electron shell can accommodate 2n<sup>2</sup> electrons**

**Each electron shell is split into subshells, with the orbital of each subshell holding up to two electrons**

**S=2 orbitals**

**P=5 orbitals**

**D= 10 orbitals**

**F= 14 orbitals**

- b. write out the electronic configuration, using sub-shells and atomic orbitals, for atoms and ions of the first row of the d-block elements (and the main group elements up to krypton – synoptic)

**1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>3s<sup>2</sup>3p<sup>6</sup>4s<sup>2</sup>3d<sup>10</sup>4p<sup>6</sup> is Krypton. Minus the number of electrons needed, starting with the 4p subshell until there is the correct number of electrons**

- c. use them to explain the existence of variable oxidation states, in terms of the stability of d orbital electron arrangements;

**The 4s subshell has a slightly lower energy than the 3d subshell, so it fills first, and are the first to be lost**

- r) explain the catalytic activity of transition metals and their compounds:

- a. homogeneous catalysis in terms of variable oxidation states,

**They can change from one oxidation state to another during the reaction, before returning to the original oxidation state**

- b. heterogeneous catalysis in terms of the ability of transition metals to use (3)d and (4)s electrons of the atoms on the catalyst surface to form weak bonds to reactants;

**They provide a surface to which gaseous reactant molecules are adsorbed. Weak interactions between the 3d and 4s subshells and the reactants hold the molecules in place while bonds are broken and formed**

- s) explain and use the terms:
- ligand,  
**Molecules or anions with one or more lone pairs of electrons**
  - complex/complex ion,  
**A central metal atom or ion surrounded by ligands. If there is an overall charge, then it is a complex ion**
  - ligand substitution,  
**When one ligand displaces another**
  - recall the formulae of the following examples of complex ions from the chemistry of:
    - iron:
      - $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ ,
      - $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ;
    - copper:
      - $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ ,
      - $[\text{Cu}(\text{NH}_3)_4]^{2+}$ ,
      - $[\text{CuCl}_4]^{2-}$ ;
- t)
- describe the formation of complexes in terms of coordinate (dative) bonding between ligand and central metal ion;  
**Ligands form dative covalent bonds with the metal atom or ion**
  - explain the terms bidentate and polydentate as applied to ligands, exemplified by ethanedioate and  $\text{EDTA}^{4-}$ ;  
**Bidentate ligands can form two bonds to the central metal, e.g. ethanedioate**  
**Polydentate ligands can form many bonds with the central metal, e.g.  $\text{EDTA}^{4-}$**
- u) recall that the **ions of transition metals in solution are often coloured and explain that this is because they absorb in specific parts of the visible spectrum and transmit the complementary frequencies** (no explanation in terms of energy levels is required in this unit);
- v) describe and explain a simple colorimeter, and use colorimetric measurements to determine the concentration of a coloured solution:
- choose suitable filter/set wavelength,
  - make up standard solutions of coloured solution,
  - zero colorimeter with tube of water/solvent,
  - measure absorbance of standard solutions,
  - plot calibration curve,
  - measure absorbance of unknown,
  - read off concentration from calibration curve.