

Edexcel IAL Chemistry A-level

Unit 5: Transition Metals and Organic Nitrogen Chemistry Definitions

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Definitions and Concepts for Edexcel IAL Chemistry A-level

Transition Metals and Organic Nitrogen Chemistry

Topic 16: Redox Equilibria

Anode: Positive electrode where oxidation takes place.

Cathode: Negative electrode where reduction takes place.

Cell potential: A measure of the potential difference between two half cells, calculated by combining two standard electrode potentials. The calculated cell potential can be used to predict the feasibility of a reaction, although this doesn't consider concentration or kinetics.

d-block: The block of elements in the middle of the periodic table. Most d-block elements are transition metals. Elements in the d block have their outer electron in the d orbital.

Disproportionation: A reaction in which a substance is simultaneously reduced and oxidised. Chlorine undergoes disproportionation in the reaction with cold, dilute, aqueous sodium hydroxide.

E.M.F: Electromotive force, measured in volts. The difference between the potential differences of the cathode and anode in an electrochemical cell.

Electrochemical cell: Combination of two half cells, consists of two electron conductors (electrodes) separated by an ionic conductor (electrolyte). Cells are used to measure electrode potentials by reference to the standard hydrogen electrode.

Electrochemical series: A series of elements arranged in order of their standard electrode potentials.

Electrode: A conductor through which electricity enters or leaves the electrolyte in an electrochemical cell.

Electrode potential: The potential difference of a cell consisting of a specific electrode as the cathode and the standard hydrogen electrode as the anode. Reduction always takes place at the cathode, and oxidation at the anode.

Entropy: A measure of the disorder of a system. The units of entropy are $\text{JK}^{-1}\text{mol}^{-1}$. On a molecular level, gases are more disordered than liquids, which are more disordered than solids. A reaction that produces a greater number of molecules than the number of reactants molecules will have a positive entropy change, as more random arrangements of these molecules will exist, in other words, the system will become more disordered.





Entropy change: This can be calculated by finding the difference between the standard entropies of the products and the reactants:

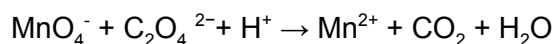
$$\Delta S_{\text{total}} = \sum \Delta S_{\text{products}} - \sum \Delta S_{\text{reactants}}$$

If the entropy change for a reaction is positive, the products are more disordered than the reactants. If the entropy change for a reaction is negative, the products are less disordered than the reactants.

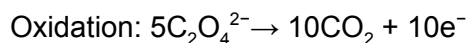
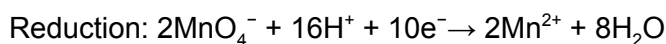
Error: The difference between a measured/experimental value and a known value. Error contributes to the accuracy of results, it can be human error or a technical error.

Fuel cell: An electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidising agent (often oxygen) into electricity through redox reactions. They do not need to be recharged but require a constant supply of fuel to maintain the potential difference.

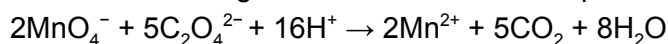
Half equation: A full redox equation can be split into two half-equations, one involving oxidation and the other involving reduction. This is useful for balancing complex redox reactions, such as:



Can be split into:



And combined to give the balanced redox equation:



Non-rechargeable cell: A cell that is designed to be used only once since the reactions involved are irreversible.

Oxidation: Process involving the loss of electrons. Results in an increase in oxidation number.

Oxidation state: The charge of an ion or a theoretical charge of an atom in a covalently bonded compound assuming the bond becomes ionic.

Oxidising agent: Electron acceptors. A species which brings about oxidation by gaining electrons. The oxidising agent is itself reduced.



p-block: The section of the periodic table in which the elements have their highest energy electron in a p-orbital.

Rechargeable cell: A cell in which reversible reactions occur, allowing them to be recharged to regain their cell potential.

Redox reaction: A reaction in which reduction and oxidation occur simultaneously.

Reducing agent: Electron donors. A species which brings about reduction by losing electrons. The reducing agent is itself oxidised.

Reduction: Process involving the gain of electrons. Results in a decrease in oxidation number.

s-block: The section of the periodic table in which the elements have their highest energy electron in an s-orbital.

Salt bridge: A porous substance soaked with a solution of an inert, strong electrolyte, e.g. a filter paper soaked in $\text{KNO}_3(\text{aq})$. The salt ions flow through the bridge to complete the circuit and balance charges in solutions.

Standard conditions: These conditions are solutions of 1.0 mol dm^{-3} concentration, a temperature of 298K and 100 kPa pressure.

Standard electrode (redox) potential (E^\ominus): The EMF of a half cell compared with a standard hydrogen half cell. This is measured under standard conditions (1 mol dm^{-3} concentrations, 298K temperature and 1 atm pressure).

Standard hydrogen electrode (SHE): The measuring standard for half-cell potentials. It has a cell potential of 0.00V, measured under standard conditions.

Uncertainty: The degree of error in taking a measurement is called the uncertainty, this is estimated to be + or - half the smallest scale division of the apparatus.

Topic 17: Transition Metals and their Chemistry

Activation energy: The minimum energy required for a reaction to take place.

Adsorption: The process by which reactants form bonds to the surface of a solid catalyst. This weakens the covalent bonds in the reactants and brings them closer together, allowing the reaction to occur more easily.





Amphoteric: A substance that is able to react as both an acid and a base.

Autocatalysis: A reaction where the product of a reaction acts as a catalyst for the reaction.

Bidentate ligand: Ligands that can form two dative covalent (coordinate) bonds with a central metal ion/atom. E.g. $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$.

Catalyst: A substance which speeds up the rate of a reaction by providing an alternative reaction pathway with a lower activation energy. It is not used up.

Catalyst poisoning: Impurities in a reaction mixture may bind to a heterogeneous catalyst's surface and block reactants from being adsorbed.

Chelate effect: When a monodentate ligand is substituted with bidentate or polydentate ligands, the entropy change is positive. This is due to there being more moles of product compared to the reactants, which is favourable. The greater this entropy change, the more negative the Gibbs free energy change (ΔG) will be, meaning the reaction is more favourable.

Colours in transition metal complexes: Colour arises when some of the wavelengths of visible light are absorbed and the remaining wavelengths of light are transmitted or reflected. The d electrons move from the ground state to an excited state when light is absorbed.

Complex ion: An ion which has a central metal atom (typically a transition element) surrounded by ligands. The ligands are bound to the transition metal centre by dative coordinate bonds.

Coordination number: The number of dative covalent bonds formed with the central metal ion.

d-block: The section of the periodic table in which the elements have their highest energy electron in a d-orbital.

Dative covalent (coordinate) bond: A type of covalent bond in which one bonding atom provides both electrons in the bonding pair.

Electron configuration: The arrangement of electrons into orbitals and energy levels around the nucleus of an atom/ion.

Entropy: A measure of the disorder of a system. The units of entropy are $\text{J K}^{-1}\text{mol}^{-1}$. On a molecular level, gases are more disordered than liquids, which are more disordered than solids. A reaction that produces a greater number of molecules than the number of reactant molecules will have a positive entropy change, as more random arrangements of these molecules will exist, in other words, the system will become more disordered.





Entropy change: This can be calculated by finding the difference between the standard entropies of the products and the reactants:

$$\Delta S_{\text{total}} = \sum \Delta S_{\text{products}} - \sum \Delta S_{\text{reactants}}$$

If the entropy change for a reaction is positive, the products are more disordered than the reactants. If the entropy change for a reaction is negative, the products are less disordered than the reactants.

Gibbs free-energy change: A measure of the feasibility of a chemical reaction. This equation relates Gibbs free energy to enthalpy change, entropy change and temperature. A negative Gibbs free energy change means the reaction is feasible and a positive Gibbs free energy change means it is not feasible.

$$\Delta G = \Delta H - T\Delta S_{\text{system}}$$

Haemoglobin: A protein which is important for oxygen transport in the blood. A ligand substitution reaction can occur between oxygen and carbon monoxide in haemoglobin, which is why carbon monoxide is toxic.

Heterogeneous catalysts: Catalysts that are in a different phase or state to the species in the reaction.

Homogeneous catalysts: Catalysts that are in the same phase or state as the species in the reaction.

Ligand: An atom, ion or molecule that forms a coordinate bond with a central transition metal ion by donating a pair of electrons.

Ligand substitution: A reaction in which one ligand in a transition metal complex is replaced by another. Typically, these reactions are associated with a colour change.

Monodentate ligand: Ligands that can form one dative covalent (coordinate) bond with a metal ion/atom. E.g. H_2O , Cl^- and NH_3 .

Octahedral: The shape of a transition metal complex with a coordination number of 6 and a bond angle of 90° . E.g. $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$.

Polydentate/Multidentate ligand: Ligands that can form two or more dative covalent (coordinate) bonds with a metal ion/metal.



Square planar: One of the possible shapes of a transition metal complex with a coordination number of 4 and a bond angle of 90° . Platinum and nickel complexes form square planar complexes. E.g, $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$.

Tetrahedral: One of the possible shapes of a transition metal complex with a coordination number of 4 and a bond angle of 109.5° . E.g. CuCl_4^{2-} .

Transition metal elements: d-block elements that can form one or more stable ions with an incomplete d-subshell. Transition elements have more than one oxidation state, form coloured ions and can often act as catalysts.

Topic 18: Organic Chemistry: Arenes

Aromatic compound/Arene: A compound containing at least one benzene ring.

Benzene: A 6 membered carbon ring (C_6H_6) containing a delocalised π system. Benzene has a planar structure and an intermediate bond length between a single and double bond. Delocalisation of the p electrons into the π system makes benzene more stable than expected.

Combustion: A rapid exothermic reaction of a substance with oxygen. Complete combustion produces water and carbon dioxide only.

Delocalisation of p electrons: In benzene, the empty p orbital on each carbon atom overlaps with the others to form a delocalised π system which contains 6 electrons.

Electrophile: An electron pair acceptor.

Electrophilic addition: A reaction where a π bond is broken and two new σ bonds form due to the addition of an electrophile.

Electrophilic substitution: A reaction in which an electrophile replaces an atom/group of atoms in a compound.

Enthalpy of hydrogenation: The enthalpy change that takes place when one mole of an unsaturated compound reacts completely with hydrogen to form a saturated compound. Comparing the enthalpy of hydrogenation of benzene with that of the theoretical molecule cyclohexa-1,3,5-triene shows that benzene is more thermodynamically stable as more energy is needed to hydrogenate benzene.



Friedel-Crafts acylation: An important synthetic reaction involving an electrophilic aromatic substitution reaction between benzene and acyl chlorides or anhydrides used to form monoacylated benzene rings. AlCl_3 is used as a catalyst.

Infrared spectroscopy: An analytical technique used to identify particular bonds and functional groups within a molecule.

Kekulé's structure of benzene: A model of benzene which contains alternating C=C double and C-C single bonds in a hexagonal ring, with each carbon atom bound to one hydrogen atom. This is the structure of cyclohexa-1,3,5-triene. **Monosubstituted benzene ring:** A benzene ring with one hydrogen replaced by another atom/group of atoms. E.g. Nitrobenzene, $\text{C}_6\text{H}_5\text{NO}_2$.

p orbital: A dumbbell-shaped region in which up to two electrons can be found. There are three p orbitals at right angles to each other, so in total, the p subshell can hold up to 6 electrons.

π -bond: A type of covalent bond formed when adjacent p orbitals overlap above and below the σ single carbon bond. Pi (π) bonds can't be rotated. As π -bonds have low bond enthalpy, alkenes are more reactive than alkanes.

Substitution reaction: A reaction in which one atom or a group of atoms is replaced by another atom or group of atoms.

X-ray Diffraction: An analytical technique used to work out the atomic and molecular structure of a crystal.

Topic 19: Organic Nitrogen Compounds: Amines, Amides, Amino Acids and Proteins

α -Amino acid: A compound with the general formula $\text{RCH}(\text{NH}_2)\text{COOH}$, where an amino group and a carboxylic acid group are bonded to the same carbon atom. The carboxylic acid group of an amino acid can react with alkalis or can be used to form esters. The amine group of an amino acid can react with acids.

Addition polymerisation: The formation of a long chain molecule when many monomers join together (the polymer is the only product).

Aliphatic amine: An amine which only contains straight or branched alkyl chains. Aliphatic amines can be formed via a substitution reaction of haloalkanes with either ammonia or amines in ethanol solvent.



Amines: Compounds that contain the NR_3 functional group (where R could be hydrogen atoms or alkyl chains). Amines are basic as the nitrogen atom has a lone pair of electrons that can accept a proton. In a reaction between amines and dilute acids, salts are formed.

Amino acid: An organic compound containing both a carboxyl group ($-\text{COOH}$) and an amino group ($-\text{NH}_2$).

Aromatic amine: An amine which contains a benzene ring directly attached to the nitrogen atom. Aromatic amines can be formed by reducing nitroarenes with tin and concentrated HCl.

Chiral centre: A carbon atom that is bonded to 4 different groups.

Condensation polymerisation: A long chain molecule formed when monomers react together with the release of small molecules such as water. Types of condensation polymers are polyamides (formed from carboxylic acids/acetyl chlorides and amines) and polyesters (formed from carboxylic acids/acetyl chlorides and alcohols).

Coupling reactions: Organic reactions that involve the joining together of two chemical species in an alkaline solution.

Hydrogen bonding: An interaction between a hydrogen atom and an electronegative atom, commonly nitrogen, fluorine or oxygen. The slightly positive hydrogen is attracted to the lone pair on the electronegative atom. Hydrogen bonds are stronger than van der Waals and dipole-dipole forces but weaker than ionic and covalent bonds.

Hydrogenation: A reaction between H_2 and another substance, which often reduces or saturates a compound. These reactions usually require a catalyst like nickel.

Inductive effect: The result of having electron-withdrawing or electron-donating groups, resulting in the polarisation of a bond.

Isoelectric point: Is the pH where a molecule is neutral or does not have a charge. For an amino acid, this is when it is in a zwitterion form.

Monomer: A small molecule that is used to form polymers.

Nucleophilic addition-elimination: A reaction in which a nucleophile is added to a molecule by breaking a π bond, and then a leaving group is removed to reform the π bond.

Nucleophilic substitution: A reaction in which an electron pair donor attacks an electrophilic atom (an atom with a partial or full positive charge) to replace an atom/group of atoms.



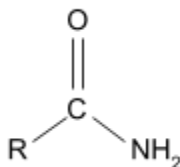


Octahedral: The shape of a transition metal complex with a coordination number of 6. E.g. $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$.

Polymer: A large molecule made from many small monomers that have been bonded together.

Polymerisation: The process of making a polymer from its monomers. There are two types: addition polymerisation and condensation polymerisation.

Primary amide: A molecule containing the functional group $-\text{CONH}_2$, as shown below.



Primary amine: An organic compound that contains the functional group RNH_2 (where R is an alkyl chain).

Protein: A molecule made up of amino acids joined by peptide bonds.

Quaternary ammonium salts: An organic compound formed when a halogenoalkane reacts with a tertiary amine. These salts have the general formula $\text{R}_4\text{N}^+\text{X}^-$ (where R is an alkyl group and X^- is a halide ion).

Repeat unit: A structure within a polymer that appears over and over again. Joining many repeat units together would form the polymer.

Secondary amine: An organic compound that contains the functional group R_2NH (where each R is an alkyl chain).

Tertiary amine: An organic compound that contains the functional group R_3N (where each R is an alkyl chain).

Thin Layer Chromatography (TLC): A type of chromatography used to separate mixtures. The stationary phase is a thin layer of alumina or silica fixed to a metal or glass plate. The plate is dotted with the mixture and placed in a beaker of solvent which is allowed to travel up the plate. The mixture separates due to the components having different solubilities in the mobile phase.

Weak base: A base that only slightly ionises in water. E.g. NH_3 .



Zwitterion: A dipolar ion with a positive charge in one part of the molecule and a negative charge in another part of the molecule. The zwitterionic form of an amino acid is the state in which the amine group has a positive charge ($^+\text{NH}_3$) and the carboxyl group has a negative charge (COO^-).

Topic 20: Organic Synthesis

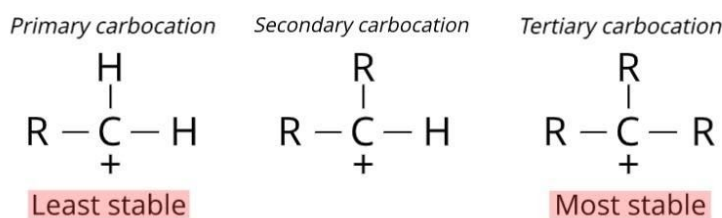
Atom economy: A measure of the amount of starting materials that end up as useful products.

$$\text{Percentage atom economy} = \frac{\text{Molecular mass of desired product}}{\text{Sum of molecular masses of all reactants}} \times 100$$

Functional group: An atom/group of atoms responsible for the characteristic reactions of a compound.

Grignard reagents: Molecules with the general formula RMgX , where X is a halogen and R is an alkyl or aryl group.

Major/minor products: Major and minor products are formed from electrophilic addition due to the relative stabilities of the primary/secondary/tertiary carbocation intermediates. The major product is formed from the most stable intermediate and the minor product is formed from the least stable intermediate.



Organic compound: A carbon-containing compound.

Percentage yield: The percentage ratio of the actual yield of product from a reaction compared with the theoretical yield.

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoretical Yield}} \times 100$$





Solvent: A liquid that can dissolve other substances.

Synthesis: The process of combining different elements and compounds to build new molecules.

Synthesis maps: Provide a good summary of reactions in organic chemistry and show how multistep reactions can be used to get from one compound to another.

