The term ligand refers to a molecule or ion that donates a pair of electrons to a metal ion through coordinate (dative covalent) bonding. This type of bonding involves the sharing of a pair of electrons, where one atom provides both electrons. Ligands can be monodentate (single-dentate), meaning they donate only one pair of electrons, or bidentate (double-dentate), indicating they can form two dative bonds. Monodentate ligands include water (H_2O), chloride ions (Cl^-), and ammonia (NH_3). Bidentate ligands, on the other hand, have pairs of electrons that are usually separated by two carbon atoms. Ethane-1,2-diamine is an example of a bidentate ligand. A complex ion forms when a metal ion surrounds itself with 2, 4, or 6 ligands through dative covalent bonds. The coordination number of the complex ion refers to the number of these dative bonds, which may not always match the number of ligands if some can form multiple bonds. Transition metals can accept electron pairs from other ions or compounds, allowing them to form coordinate bonds with ligands. These metal ions will often have an octahedral shape when surrounded by six ligands, resulting in a hexaqua complex. This is common for many transition metal ions, such as copper(II) and iron(III), which can form $[Cu(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{3+}$, respectively. In contrast, some complexes have a tetrahedral shape, with four ligands arranged around the central metal ion. Examples include tetrachloro complexes like $CuCl_4^{2-}$ and $CoCl_4^{2-}$. Transition metals can also form square planar complexes, as seen in platinum compounds such as $Pt(NH_3)_2Cl_2$. The size of the ligand plays a significant role in determining the coordination number of the complex ion. Ligands with multiple pairs of electrons available can donate more than one pair to the metal ion, contributing to its coordination number. The water molecules forming ligands around a metal ion are neutral, resulting in an overall charge of 2+. The bond angles are all 90 degrees, indicating a tetrahedral shape for the complex. Alternatively, with four coordination bonds, the geometry can be square planar. Copper and Cobalt tend to form tetrahedral complexes due to their lower prices, whereas Platinum and Rhodium tend to form square planar complexes because they are more expensive. It's worth noting that Chloride ions have a tendency to form tetrachloro-cobalt and tetrachloro-copper ions. The only square planar complex we need to focus on is Cis-Platin, which will be discussed further in part (f) and (g). A ligand is an atom or group of atoms that can donate a lone pair of electrons to form a coordinate bond with a transition metal ion. Ligands can be monodentate, having one pair of electrons, such as water, ammonia, chloride ions, and cyanide ions, or bidentate, having two pairs of electrons, like 1,2-diaminoethane or the ethanedioate ion. Some examples of multidentate ligands include EDTA (ethylene diamine tetraacetic acid), which has six pairs of electrons. The coordination number is the number of coordinate bonds formed between the central transition metal atom and the surrounding ligands. Small ligands like water and ammonia have a coordination number of six, while larger ligands like chloride ions have a coordination number of four. Ligands play a key role in forming coordination compounds with transition metals. They can be neutral molecules or ions that bond to the metal through covalent bonds, known as coordination bonds. The type and number of ligands present determine the oxidation state and coordination number of the metal, which in turn affect the physical and chemical properties of the resulting compound. There are several types of ligands, including monodentate ligands, which bond to the metal through a single coordination bond, and polydentate ligands, which form multiple bonds. Chelating ligands, on the other hand, form cyclic structures around the metal, while anionic ligands carry a negative charge. Ligands can also influence the color of transition metal compounds by altering the energy levels of the orbitals involved in bonding. The coordination number and oxidation state of a transition metal are distinct concepts, with the former referring to the number of bonds between the metal and its ligands, and the latter referring to the charge on the metal ion. The study of transition metals and ligands is crucial in A-Level Chemistry as it provides a fundamental understanding of their properties and behavior. This knowledge has applications in various industrial and biological processes, including catalysis, coordination chemistry, and synthesis. Common techniques used to study transition metals and ligands include spectroscopy and crystallography. Spectroscopic methods, such as ultraviolet-visible spectroscopy and infrared spectroscopy, allow for the determination of oxidation states and coordination numbers, while crystallography provides information on the structure and properties of crystals containing transition metals. Monodentate ligands, which have a single lone pair of electrons, can form only one dative bond with the metal ion. Examples include water molecules, ammonia molecules, chloride ions, and cyanide ions. Bidentate ligands, on the other hand, contain two atoms with lone pairs and can form two bonds with the metal ion, as seen in complexes such as ethanedioate and 1,2-diaminoethane. Multidentate ligands have more than two atoms with lone pairs and can form multiple bonds with the metal ion. Ligands that form more than two dative bonds are referred to as multidentate ligands. $EDTA^{4-}$ is an example of such a ligand, classified as hexadentate due to its formation of six dative covalent bonds with the central metal ion, illustrating a polydentate ligand complex.