

Chemistry Worksheet on Chapter 9 Coordination Compounds with Answers -Set 1

Q-1: In the complex $[M(\text{acac})(\text{en})_2]\text{Cl}$, the coordination number and oxidation state of the element 'M' are respectively

- a) 6 and 2
- b) 4 and 2
- c) 4 and 3
- d) 6 and 3

Answer: d) 6 and 3

Explanation:

A metal ion's coordination number (CN) in a complex is defined as the number of ligand donor atoms to which the metal is directly bonded.

Acetylacetonate (acac) and ethylenediamine (en) are bidentate ligands. A bidentate ligand is one that has two donor sites or is linked to metal ions via its two donor sites.

We have one "acac" ligand and two "en" ligands, with two donor sites per ligand, resulting in a coordination number of six for the metal ion M.

To calculate the oxidation number, we need to know that the ligand "en" is neutral and the ligand "acac" has a charge of -2. Chlorine is a -1 charge negative ligand.

Let M's oxidation number be x.

$$x + (\text{acac}) + (\text{en})_2 + \text{Cl} = 0$$

$$x + (-2) + 2(0) + (-1) = 0$$

$$x = +3$$

Hence coordination number and oxidation state for metal atom M are respectively 6 and +3.

Q-2: An example of double salt is

- a) Carnallite
- b) Potassium Ferricyanide
- c) Cuprammonium nitrate
- d) triglycinatocobalt(III)

Answer: a) Carnallite

Explanation: When dissolved in water, a double salt completely dissociates into ions. The chemical formula for carnallite is $KCl \cdot MgCl_2 \cdot 6H_2O$. It dissociates into its constituent ions (K^+ , Mg^{2+} , Cl^-) after being made into an aqueous solution.

However, other salts do not dissociate completely in water.

In Potassium Ferricyanide ($K_3[Fe(CN)_6]$), complex ion $[Fe(CN)_6]^{3-}$ do not ionise into Fe^{3+} and CN^- ions. Similar is the case with other salts i.e Cuprammonium nitrate and triglycinatocobalt(III).

Q-3: The characteristics shared by the species CN^- , CO , and NO^+ are

- a) Isoelectronic
- b) Bond order three
- c) All are sigma donor and pi acceptor
- d) All of these

Answer: d) All of these

Explanation:

a) Number of electrons in $CN^- = 6+7+1 = 14$

Number of electrons in $CO = 6+8 = 14$

Number of electrons in $NO^+ = 7+8-1 = 14$

Because the number of electrons in all species is the same, they are isoelectronic.

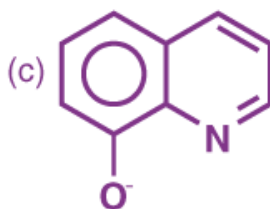
b) Because all of the species have triple bonds between their atoms, the bond order is 3.

c) Any ligand acts as a sigma donor first. The given species are classified as a pi acceptor and sigma donor ligands.

Q-4: Which of the following is a didentate ligand?

(a) $P(OPh)_3$

(b) NH_2NH_2



(d) None of these

Answer: c)

Explanation: A ligand is said to be didentate if it can bind through two donor atoms. Because the ligand in c) has two donor sites (O and N), it will act as a didentate ligand.

Despite the fact that ligand b) has two donor sites (two N-atoms), it cannot act as a didentate because if it donates from two N-atoms, a three-membered ring is formed, which is highly unstable due to strain. As a result, will only donate from one N-atom.

Ligand (a) has a single donor site, P. As a result, it cannot function as a didentate ligand.

Q-5: Which of the following cannot act as a chelating agent?

- a) $\text{HC}(\text{CH}_2\text{CH}_2\text{NH}_2)_3$
- b) $\text{CH}_3\text{NHCH}_2\text{CH}_2\text{CH}_3$
- c) $\text{N}(\text{CH}_2\text{CH}_2\text{NH}_2)_3$
- d) $\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

Answer: b) $\text{CH}_3\text{NHCH}_2\text{CH}_2\text{CH}_3$

Explanation: A chelating agent is one that has more than one donor site from which it can donate electrons to the metal atom.

With the exception of the ligand in b), all other ligands have more than one N atom for the lone pair donation to metal atom. As a result, all other ligands are chelating, but ligand $\text{CH}_3\text{NHCH}_2\text{CH}_2\text{CH}_3$ is not because it contains only one N-atom.

Q-6: Which one of the following compounds will exhibit linkage isomerism?

- a) $[\text{Pt}(\text{NH}_3)_2\text{Cl NO}_2]$
- b) $[\text{Co}(\text{NH}_3)_2\text{NO}_2]\text{Cl}_2$
- c) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
- d) $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$

Answer: b) $[\text{Co}(\text{NH}_3)_2\text{NO}_2]\text{Cl}_2$

Explanation: Linkage isomerism arises in a coordination compound containing ambidentate ligand. Ambidentate ligands have two different donor atoms and can be either of the two ligetes in the complex. NO_2^- is an example of such a ligand. NO_2^- ion can coordinate with a central metal atom/ion via either nitrogen or oxygen.

Apart from b), no other complex has an ambidentate ligand, therefore only coordination compound $[\text{Co}(\text{NH}_3)_2 \text{NO}_2] \text{Cl}_2$ will exhibit linkage isomerism.

Q-7: Give the IUPAC name of the complex compound $[\text{Co}(\text{NH}_3)_4 (\text{H}_2\text{O})\text{Br}](\text{NO}_3)_2$

Answer: tetraammineaquabromocobalt(III) nitrate

Explanation: The complex ion is inside the square bracket, which is a cation. The amine ligands are named before the aqua ligands according to alphabetical order. Since there are two nitrate ions in the compound, the charge on the complex ion must be +2 (since the compound is electrically neutral). From the charge on the complex ion and the charge on the ligands, we can calculate the oxidation number of the metal. In this example, all the ligands are neutral molecules except the bromo ligand which has charge of -1. Therefore, the oxidation number of cobalt must be +3.

Note: For IUPAC naming, ligands are always named alphabetically first, followed by the metal name and oxidation state in roman numerals in parentheses.

Q-8: The primary valency of Ag in $\text{Na}_3[\text{Ag}(\text{S}_2\text{O}_3)_2]$ is

- a) +2
- b) -2
- c) 0
- d) +1

Answer: d) +1

Explanation: According to Werner's, primary valency relates to the oxidation number of the metal atom in the compound.

The complex ion is anion, which is enclosed by a square bracket. Because the compound contains three sodium ions, the complex ion's charge must be -3. (since the compound is electrically neutral). We can calculate the metal's oxidation number using the charge on the complex ion and the charge on the ligands. In this case, the thiosulphate ligand is an anionic ligand with a charge of -2. As a result, the oxidation number of Ag must be +1.

Therefore, the primary valency of Ag is +1 in the given complex.

Q-9: Transition metal complexes' CFSE can be calculated using

- a) Spectroscopy of UV-visible light
- b) Spectroscopy in the infrared

- c) Spectroscopy by NMR
- d) Spectroscopy of microwaves

Answer: a) Spectroscopy of UV-visible light

Q-10: What is the order of magnitude of Δ_o values for Cr(III) octahedral complexes with sigma donor, pi donor, and pi acceptor ligands?

Answer: The higher the ligand strength, the higher the Δ_o values for the octahedral complex.

Ligand strength: pi acceptor > sigma donor > pi donor

As a result, the magnitude of Δ_o value will follow the same order.

Q-11: Calculate the spin only magnetic moment of the compound $\text{Hg}[\text{Co}(\text{SCN})_4]$.

Answer: Cobalt is in a +2 oxidation state with a d-electronic configuration of $3d^7$ in the complex $\text{Hg}[\text{Co}(\text{SCN})_4]$. Because SCN^- is a weak field ligand, electrons will fill in the d-orbital according to Hund's rule, leaving three unpaired electrons.

A complex's spin only magnetic moment can be calculated using the formula:

$$\mu = \sqrt{n(n+2)}$$

Where, n = number of unpaired electrons.

Substituting n=3 in the formula, we will get a magnetic moment value as 3.87 BM.

Q-12: How many electrons are present in the e_g set of d-orbital of sodium nitroprusside complex?

Answer: zero

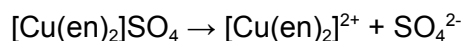
Explanation: The formula for sodium nitroprusside is $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]$. In the complex, Fe is in +2 oxidation state with d-electronic configuration of $3d^6$. Cyanide (CN^-) and nitrosyl ligands (NO) are strong field ligands. As a result, when d-orbitals are split into two sets of orbitals, t_{2g} and e_g , all six electrons are paired in t_{2g} , leaving zero electrons in e_g .

Note: t_{2g} has less energy than e_g , thus, filling occurs first in t_{2g} and then in e_g .

Q-13: When bis(ethane-1,2-diamine) copper (II) sulphate is dissolved in water, calculate the number of ions formed.

Answer: bis(ethane-1,2-diamine) copper (II) sulphate has a complex formula of $[\text{Cu}(\text{en})_2]\text{SO}_4$.

The following dissociation takes place:



Thus, two ions can clearly be seen forming.

Q-14: a) Identify the dark blue complex formed when $[\text{Fe}(\text{CN})_6]^{3-}$ is treated with ferrous sulphate and account for the origin of its colour.

b) What is the common name for the formed complex?

Answer:



The origin of the colour is due to intravalence charge transfer.

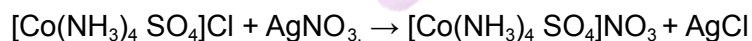
b) Turnbull's blue

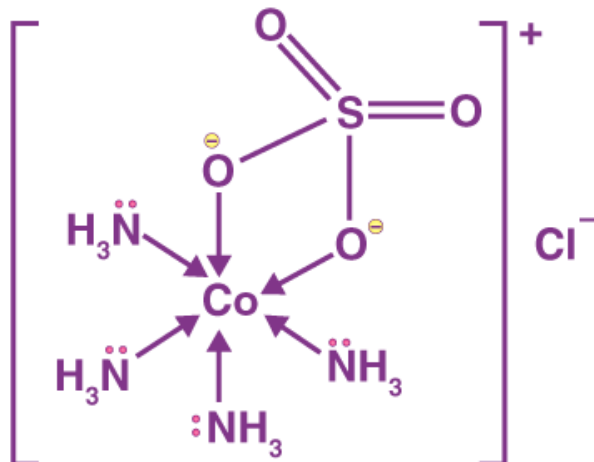
Q-15: A coordination compound is made up of one Co(III), one chloride, one sulphate, and four ammonia molecules. When combined with aqueous BaCl_2 , the compound's aqueous solution yields no precipitate, whereas a precipitate is formed when combined with aqueous AgNO_3 solution. Draw its structure and use chemical equations to explain the observations.

Answer: The coordination compound complex is $[\text{Co}(\text{NH}_3)_4 \text{SO}_4]\text{Cl}$. Because SO_4^{2-} is present inside the coordination sphere, this complex does not react with BaCl_2 , and thus no precipitate yields.

However, it readily reacts with AgNO_3 to form a white precipitate of AgCl .

The following reaction occurs:





Q-16: Define the following:

- Heteroleptic complex:
- Coordination Isomerism

Answer:

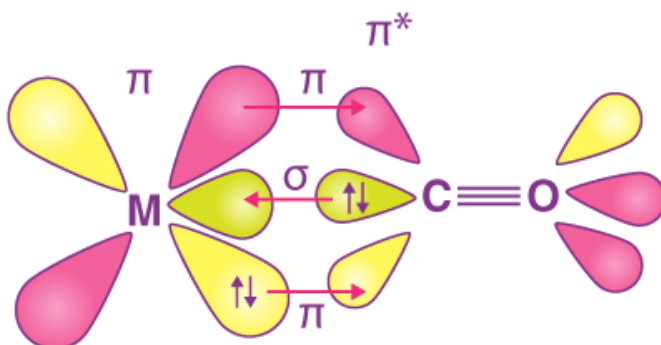
- Heteroleptic complex:** Complexes in which a metal is bound to more than one kind of donor groups, e.g., $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$, are known as heteroleptic.
- Coordination Isomerism:** The interchange of ligands between cationic and anionic entities of different metal ions present in a complex causes coordination isomerism. $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$ is one example, in which the NH_3 ligands are bound to Co^{3+} and the CN^- ligands to Cr^{3+} . The NH_3 ligands are bound to Cr^{3+} and the CN^- ligands to Co in its coordination isomer $[\text{Cr}(\text{NH}_3)_6][\text{Co}(\text{CN})_6]$.

Q-17: List two limitations of CFT.

Answer: Based on the assumption that the ligands are point charges, anionic ligands should have the greatest splitting effect. Anionic ligands are found at the bottom of the spectrochemical series. Furthermore, it ignores the covalent nature of the bonding between the ligand and the central atom. These are two of the CFT's flaws, which are explained by ligand field theory (LFT) and molecular orbital theory (MOT) later.

Q-18: What is the synergic effect? How does it improve the bond between CO and metal?

Answer: Metal-carbon bonds in metal carbonyls have both sigma and pi character. The M–C sigma bond is formed by the donation of a lone pair of electrons from the carbonyl carbon into a metal's vacant orbital. The M–C pi bond is formed by the donation of a pair of electrons from a metal's filled d orbital into carbon monoxide's vacant antibonding pi* orbital. This metal-ligand bonding produces a synergic effect that strengthens the bond between CO and the metal.



Q-19: How will you account for ruby's red colour?

Answer: Ruby is an aluminium oxide (Al_2O_3) with 0.5-1 percent Cr^{3+} ions (d^3) randomly distributed in positions normally occupied by Al^{3+} . These chromium(III) species can be thought of as octahedral chromium(III) complexes incorporated into the alumina lattice; d–d transitions at these centres produce the red colour.

Q-20: When potassium oxalate solution is added to a hot solution of potassium dichromate containing dilute sulfuric acid, effervescence occurs and potassium trisoxalatochromate(III) is formed.

- Write the chemical formula of the formed chromium complex.
- Determine the complex's room temperature spin only magnetic moment in B.M.

Answer:

- The chemical formula of potassium trisoxalatochromate(III) is $\text{K}_3[\text{Cr}(\text{C}_2\text{O}_4)_3]$.
- Chromium has a +3 oxidation state and an electronic configuration of d^3 in complex $\text{K}_3[\text{Cr}(\text{C}_2\text{O}_4)_3]$. Three electrons will remain unpaired after filling the 3d orbital with electrons. The spin only magnetic moment of a complex can be calculated using the formula:

$$\mu = \sqrt{n(n+2)}$$

Where, n= number of unpaired electrons.

Substituting n=3 in the formula, we will get a magnetic moment value as 3.87 BM.

