

MAGNETIC PROPERTIES OF TRANSITION METAL COMPLEX

Abstract

In this abstract, the magnetic characteristics of transition metal complexes are briefly reviewed, along with the Spin-Only formula, Louis Georges Gouy's technique, and orbital contributions to the magnetic moment. It also covers kinetic and thermodynamic features, including formation constants, stability-affecting variables, and thermodynamic and kinetic stability. It also refers to Job's approach to figuring out the difficult composition.

The Gouy balance, invented by Louis Georges Gouy, is a device used to determine the magnetic susceptibility of a sample. It enables researchers to precisely determine this feature without resorting to plagiarism (1).

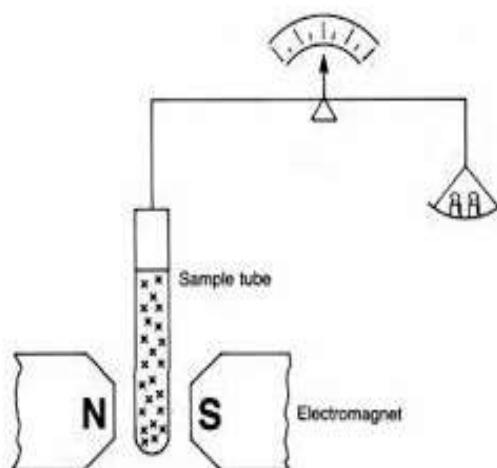
Keywords: Magnetic properties, paramagnetic, momentum, coupling, Stability

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I. PROCEDURE

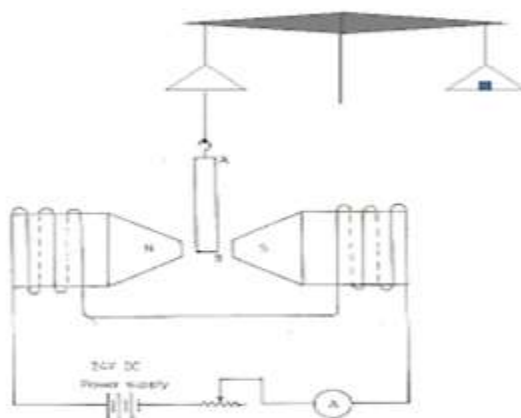
A strong magnetic field can cause a sample to attract or repel, and the Gouy balance is used to determine the apparent change in mass (2). Specific commercially existing balances comprise a part at their base to authorize this measurement. The Gouy balance is made up of a working balance and a long cylindrical test sample suspended from it. Typically, a cylindrical container such as a test tube is commonly used to hold the sample. To achieve homogeneity across the sample, solid substances are frequently crushed into fine powder. A thread or string is used to hang the sample between the magnetic poles (3).



II. CONCEPT

The magnetic force acting on the sample is what causes the mass difference that was noticed between the two balance readings. A gradient between a strong and weak magnetic field produces this force. The apparent mass difference ($m_b - m_a$) is positive when a sample contains a paramagnetic chemical because it is drawn to the magnetic field.

In situations where the sample exhibits a slight repulsion to the applied magnetic field, the observed effects can vary. There might either be no noticeable change in weight or, in the case of diamagnetic substances, a negative change. This occurrence can be attributed to the characteristic behaviour of diamagnetic materials, which tend to exhibit a weak repulsive response when subjected to a magnetic field. For paramagnetic samples, a positive magnetic susceptibility is produced when the magnetic induction's strength is greater than the applied field's. A diamagnetic material has a significantly weaker magnetic induction and a correspondingly negative magnetic susceptibility as compared to the applied field (4). The apparent change in mass is related to the sample's volume susceptibility using this mathematical equation:



$$\text{Force} = (m_b - m_a)g = (K_2 - K_1)AH^2$$

- $m_b - m_a$ = apparent difference in mass
- g = gravitational acceleration
- K_1 = volume susceptibility of the sample
- K_2 = volume susceptibility of the medium, usually air and of negligible value
- H = applied magnetic field
- A = area of the sample tube

1. Instrument: The complete balance-magnet assembly is often housed in a glass box in practical devices to prevent the impact of air currents on weight measurements. Additionally, the sample can be put within a thermostat to allow for readings at various temperatures. The Gouy balance is a stationary device that is consistently set up on a bench since it requires a substantial and potent electromagnet (5). In a controlled setting with little vibrations and disturbances, it is frequently placed on a marble balancing table. Because measurements with and without the applied magnetic field are required during the operation, an electromagnet connected to a power source is typically used as the stationary magnet in a Gouy balance.

2. Complexes of Transition Metal Ions: The magnetic moment of a combination consisting of a transition metal ion and one or more unpaired electrons is controlled by the unpaired electrons' combined orbital and spin angular momentum. These angular moments are indicated by the letters L (orbital angular momentum) and S (spin angular momentum). The term "total" in this case refers to the vector sum of these angular momenta. The magnetic moment can be stated using the following formulation when examining the electronic states of metal ions under the assumption of Russell-Saunders coupling and ignoring spin-orbit coupling: (6)

$$\mu_{\text{eff}} = \sqrt{\vec{L}(\vec{L} + 1) + 4\vec{S}(\vec{S} + 1)}\mu_B$$

III. SPIN-ONLY FORMULA AND ORBITAL CONTRIBUTION TO MAGNETIC MOMENT:

An electron in a degenerate set of orbitals receives orbital angular momentum when it rotates into another orbital. Some rotations, however, may be impossible in complexes with

great symmetry. In such cases, when the orbital angular momentum is "quenched," it results in a magnetic moment that is either lower than the anticipated value (partial quenching) or becomes zero (complete quenching). This phenomenon occurs due to interactions within the system that effectively reduce or eliminate the contribution of the orbital angular momentum to the overall magnetic moment. The concept of quenching provides an explanation for the deviations from the expected magnetic behaviour in systems with transition metal ions and unpaired electrons, highlighting the impact of internal interactions on the magnetic properties of the system. Certain circumstances reason for total quenching. Since of symmetry, an electron inside a degenerate pair of $d_{x^2-y^2}$ or d_{z^2} orbitals cannot replace the other orbital. The reason for the absence of rotational mobility in these cases, the orbital angular momentum is completely quenched (7).

Quenched orbital angular momentum

d^n	Octahedral		Tetrahedral
	High spin	Low spin	
d^1			e^1
d^2			e^2
d^3	t_{2g}^3		
d^4	$t_{2g}^3 e_g^1$		
d^5	$t_{2g}^3 e_g^2$		
d^6		t_{2g}^6	$e^3 t_2^3$
d^7		$t_{2g}^6 e_g^1$	$e^4 t_2^3$
d^8	$t_{2g}^6 e_g^2$		
d^9	$t_{2g}^6 e_g^3$		

$$t_{2g}, t_2 = (d_{xy}, d_{xz}, d_{yz}).$$

$$e_g, e = (d_{x^2-y^2}, d_{z^2}).$$

Paramagnetic behaviour is dictated solely by the electron spin. The spin-only formula is used in such instances, which assumes that the total spin angular momentum is equal to half the number of unpaired electrons. This formula is used to calculate the magnetic moment of a compound and is expressed as follows:

$$\mu_{\text{eff}} = \sqrt{n(n+2)}\mu_B$$

The number n here signifies the number of unpaired electrons. The spin-only formula, which gives a realistic estimate of their magnetic properties, is especially useful for high-spin complexes of first-row transition metals.

Ion	Ti ³⁺	V ⁴⁺	Cu ²⁺	V ³⁺	Ni ²⁺	V ²⁺	Cr ²⁺	Co ²⁺	Mn ⁴⁺	Cr ²⁺	Fe ²⁺	Mn ²⁺	Fe ³⁺
No. of unpaired electrons	1	1	1	2	2	3	3	3	3	4	4	5	5
Spin only/ μ_B	1.73			2.83		3.87				4.90			5.97
observed	1.73	1.68-1.78	1.70-2.20	2.75-2.85	2.8-3.5	3.80-3.90	3.70-3.90	5.3-5.0	3.80-4.0	4.75-4.90	5.1-5.7	5.65-6.1	5.7-6.0

The orbital angular momentum or spin-orbit coupling was ignored, which is why the deviations from the spin-only formula were so minor. Departures from the spin-only formula can differ from octahedral complexes of the same metal ion in some cases, such as tetrahedral complexes with d^3 , d^4 , d^8 and electron configurations. This is owing to the less effective "quenching" of the orbital contribution in tetrahedral complexes, which results in a greater impact of orbital angular momentum on magnetic properties. The changes from the spin-only formula can also be attributed to spin-orbit coupling, which accounts for the interaction between electron spin and orbital motion.

Example;

At 80 K and 300 K, μ of $(Et_4N)_2[NiCl_4]$ are 3.25 B.M. and 3.89 B.M. respectively.

A Ni^{2+} ion with a d^8 electron configuration is present in the combination. The formulation recommends a 4-coordinate complex, which we, suppose is tetrahedral with a d electron configuration of $e_4 t_2g$. The spin-only magnetic moment is equal to 2.83 B.M.

Because the formula predicts a tetrahedral coordination geometry, the idea of the complex being square-planar was neglected. The possibility of the complex being square-planar was ignored because the formula suggests a tetrahedral coordination geometry. Considering the free ion Russell-Saunders ground term, which is $3F$ with $L=3$ and $S=1$, the lowest energy T term is expected to be present in a tetrahedral field. Hence, the consequential magnetic moment is predictable to be temperature-dependent and has a straight orbital contribution.

The observed magnetic moments may differ significantly from the calculated spin-only magnetic moment. The value of μ_{S+L} can be calculated as: $\mu_{S+L} = \sqrt{[4S(S+1)+L(L+1)]} = \sqrt{[8+12]} = \sqrt{20} = 4.47$ B.M.

Using the spin-only formula, $\mu_s = \sqrt{[n(n+2)]} = \sqrt{8} = 2.8$ B.M. (8)

Given that the spin-only magnetic moment for the complex $[Cr(en)_3]Cl_3$

The spin-only magnetic moment is given by quantum mechanics as $\mu = \sqrt{[n(n+2)]}$ BM =
 $\mu = \sqrt{15} = 3.87$ BM

The Observed Magnetic Moment of $[Mn(NCS)_6]^{4-}$ Is 6.06 B.M. Predict The Electronic Configurations.

Mn in this complex is $Mn(II)$ d^5 . There are two possibilities of an electronic configuration for this octahedral species, namely low-spin t_2g^5 with one unpaired electron & $t_2g^3 e_g^2$ with five unpaired electrons. The observed magnetic moment is close to the spin-only value $\sqrt{5(5+2)} = 5.92$ B.M.

Therefore, the configuration should be $t_2g^3 e_g^2$ (high spin)

IV. METAL COMPLEXES: THERMODYNAMIC AND KINETIC ASPECT

A metal complex is referred to as a stable complex, indicating its presence and the ability to be stored for an extended period under appropriate conditions. It is important to

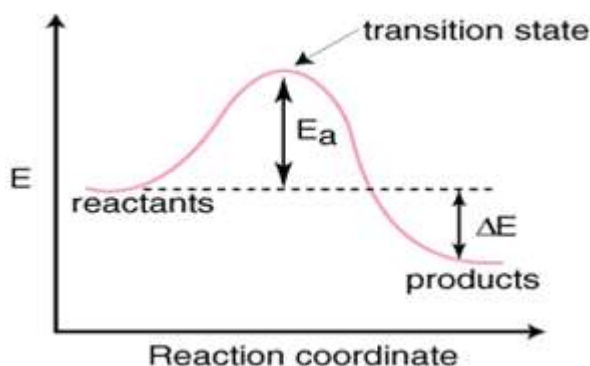
note that the stability of a complex can vary depending on the reagents involved. While a complex may exhibit stability towards one reagent, it may readily decompose in the presence of another reagent. Furthermore, external factors such as heat or light exposure could influence a complex's stability.

- Thermodynamic Stability
- Kinetic Stability

When studying the formation of complexes in a solution, two types of stability can be observed: (9)

- 1. Thermodynamic Stability:** This refers to the equilibrium between the complex and its constituent species. A thermodynamically stable complex possesses a favorable formation constant or equilibrium constant, indicating that the complex formation is preferred over the dissociation of the complex into its individual components.
- 2. Kinetic Stability:** This pertains to the rate of formation and decomposition of the complex. A kinetically stable complex exhibits slow rates of decomposition, suggesting that the complex remains intact for an extended period of time.

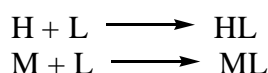
Both thermodynamic and kinetic stability play significant roles in determining the overall stability of a complex in solution.



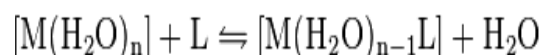
V. BOTH THE OVERALL FORMATION CONSTANT AND STEPWISE FORMATION CONSTANT

Jannik Bjerrum presented a generic approach for computing stability constants of metal-ammine complexes in 1941, about 50 years after Alfred Werner established suitable structures for coordination complexes. Beck and Nagypál listed the reasons for this delay. The concentrations of hydrogen ions in solution were determined using Bjerrum's approach with a freshly made glass electrode and pH metre.

Bjerrum understood that an acid-base balance was required to create a metal-ligand combination. The ligand, L, was being competed for by the metal ion Mn^{+} and the hydrogen ion H^{+} . As a result, two simultaneous equilibria were taken into account. For the sake of brevity, the following discussion excludes electrical charges. the two following equilibriums:



The majority of the time, a substitution process takes place when a metal ion, M, and a ligand, L, come together to create a complex. For instance, metal ions are frequently found as aqua-ions in aqueous solutions. As a result, the following reaction can be used to depict the production of the first complex:



$$\beta' = \frac{[\text{M}(\text{H}_2\text{O})_{n-1}\text{L}][\text{H}_2\text{O}]}{[\text{M}(\text{H}_2\text{O})_n][\text{L}]}$$

The concentration of the ligand L is denoted by the notation [L], and similarly, the sentences contained in square brackets denote concentrations. To simplify the formula, constant terms can be removed. In the case of metal complexes, the number of water molecules bound to each metal ion remains constant. Furthermore, the concentration of water in diluted solutions can be thought of as effectively constant. As a result, the phrase can be summarised as follows:

$$\beta = \frac{[\text{ML}]}{[\text{M}][\text{L}]}$$

Following this simplification, a general definition can be developed. The equilibrium for the production of a metal-ligand complex is as follows:

It is emphasised in laboratory courses that The term "stability of a complex in solution" mentions the degree of a link between the two species in the equilibrium state. A higher degree of connection indicates that the chemical is more stable. The value of the equilibrium constant for the association, known as the stability or formation constant, expresses the stability quantitatively. As a result, if we have a reaction of the following type:



In this situation, as the stability constant climbs, so does the proportion of ML₄ in the solution. Free metal ions are uncommon in solution because the metal ion M is generally surrounded by solvent molecules that compete with and gradually replace ligand molecules L. To make the study easier, we commonly omit the influence of solvent molecules and represent the four stability constants as follows:

1. $\text{M} + \text{L} \rightleftharpoons \text{ML} \quad K_1 = [\text{ML}][\text{L}] / [\text{M}]$
2. $\text{ML} + \text{L} \rightleftharpoons \text{ML}_2 \quad K_2 = [\text{ML}_2] / [\text{ML}][\text{L}]$
3. $\text{ML}_2 + \text{L} \rightleftharpoons \text{ML}_3 \quad K_3 = [\text{ML}_3] / [\text{ML}_2][\text{L}]$
4. $\text{ML}_3 + \text{L} \rightleftharpoons \text{ML}_4 \quad K_4 = [\text{ML}_4] / [\text{ML}_3][\text{L}]$

Where the "stepwise stability constants" K₁, K₂, etc. A different way to express the "Overall Stability Constant," represented by β_n is as follows: (10)



VI. THE RELATIONSHIP BETWEEN THE STEPWISE AND OVERALL STABILITY CONSTANTS IS AS FOLLOWS:

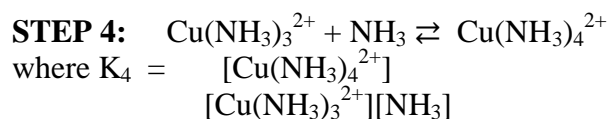
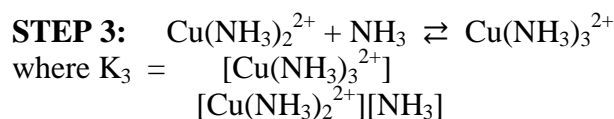
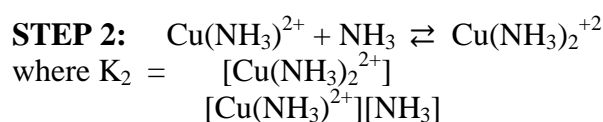
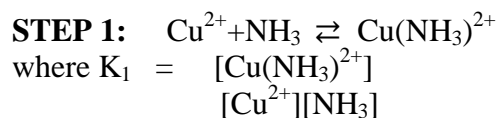
$$\beta_4 = K_1 \cdot K_2 \cdot K_3 \cdot K_4 \text{ or more generally,}$$

$$\beta_n = K_1 \cdot K_2 \cdot K_3 \cdot K_4 \dots K_n$$

$$\text{Or } \beta_n = \sum_{n=1}^n K_n$$

This equation evident that overall stability constants β_n are equal to stepwise stability constants.

Consider the four steps involved in the formation of the cuprammonium ion $Cu(NH_3)_4^{2+}$:



where the {K} constants are the stepwise stability constants.

In terms of overall stability constant:

$$\beta_4 = \frac{[Cu(NH_3)_4^{2+}]}{[Cu^{2+}][NH_3]^4}$$

Hence ,

$$\beta_4 = K_1 \cdot K_2 \cdot K_3 \cdot K_4$$

The four ammine groups added to copper show the same trend as the bulk of formation constants, in that the subsequent stability constants decrease. In this case, the four variables are:

$$\log K_1 = 4.0, \log K_2 = 3.2, \log K_3 = 2.7, \log K_4 = 2.0 \text{ or } \log \beta_4 = 11.9$$

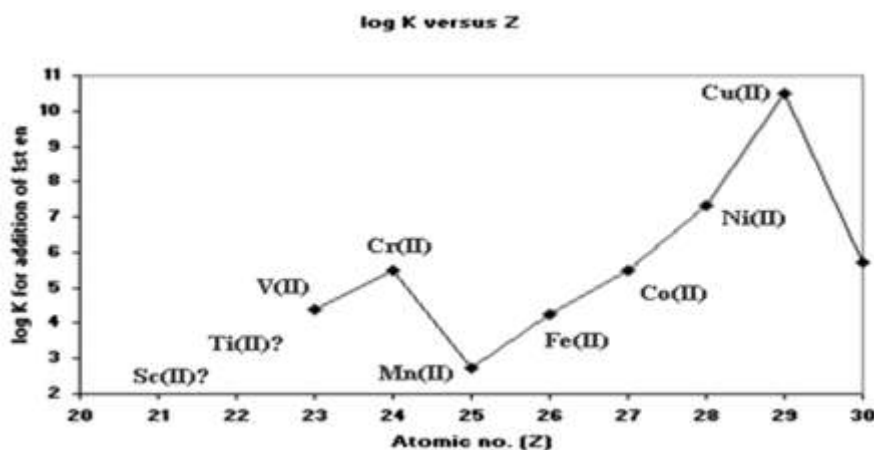
The stability of complexes is impacted by a variety of elements, all of which play an important part in determining their overall stability. The key elements influencing complex stability can be summarised as follows:

- The charge carried by the metal ion: The charge carried by the metal ion has a substantial impact on complex stability. Complexes having larger charges on the metal ion are more stable in general.
- Complex stability is also affected by the primary quantum number of the metal ion's outermost electron shell. Complexes with larger primary quantum numbers are frequently more stable.
- The type of ligands involved in complex formation is an important element. Different ligands have unique qualities such as size, shape, and electrical properties, which affect the stability of the resultant complexes.
- Chelation: Chelation is the creation of a cyclic structure when a ligand forms numerous bonds with a metal ion. Complexes containing chelating ligands have higher stability due to increased coordination number and structural integrity.
- Macrocyclic ligands are compounds with enormous ring configurations that can enclose metal ions. These ligands' distinct size and shape lead to the development of highly stable complexes.
- Hardness and softness are terms that refer to the electrical characteristics of both the metal ion and the ligands. It is critical to match the hardness or softness of the metal ion and ligands in order to achieve maximum complex stability.
- Environmental factors: Environmental circumstances such as pH, temperature, and solvent can affect the stability of complexes. Changes in these conditions can have an effect on the equilibrium between free metal ions and complexes, affecting their stability.
- Researchers can obtain a better knowledge of complex stability and make more informed decisions about the design and application of coordination molecules by taking these considerations into account

1. Charge on the Metal Ion: It is possible to understand how this affects the stability of complexes by taking into account crystal field theory. The overall stability of the complex is impacted by the degree of crystal field splitting in the context of a particular ligand, which is directly proportional to the size of the metal ion's charge.,

Ions	Ligands	CFSE (Δ_0 in cm^{-1})
V^{2+}	$6\text{H}_2\text{O}$	12601
V^{3+}	$6\text{H}_2\text{O}$	17702

Irving–Williams series (11): The Irving-Williams Series, developed in 1953 by Harry Irving and Robert Williams, illustrates a sequence in the relative stabilities of complexes caused by divalent transition metal ions in the periodic table's first row. The team's study found a tendency that indicates the stability of these complexes generally goes up as you move up the series, peaking at copper. This pattern is outlined below.: $\text{Mn(II)} < \text{Fe(II)} < \text{Co(II)} < \text{Ni(II)} < \text{Cu(II)} > \text{Zn(II)}$



Explanation: The Irving-Williams Series is often justified by three explanations:

The Irving-Williams Series, discovered by Harry Irving and Robert Williams in 1953, provides insights into the relative stabilities of complexes formed by divalent first-row transition metal ions. The trend observed in the series can be partially attributed to the decreasing ionic radius from Mn(II) to Zn(II) following the periodic pattern. This reduction in size typically leads to increased stability of the complexes.

The Crystal Field Stabilization Energy (CFSE) shows an increasing trend from Mn(II) to Ni(II), reaching its peak at Ni(II). The rise in CFSE contributes to the enhanced stability of the complexes. However, Zn(II) has a CFSE value of zero.

Despite Ni(II) having a higher CFSE than Cu(II), the stability of octahedral Cu(II) complexes is enhanced by the Jahn-Teller effect. This effect provides additional stability to these complexes.

It is important to note that none of these hypotheses fully explain the predictive effectiveness of the Irving-Williams Series in determining the relative stabilities of transition metal complexes. Recent research on metal-thiolate complexes suggests that the observed series may be influenced by a combination of covalent and electrostatic interactions in metal-ligand binding energies.

Significantly, the CFSE values for octahedral complexes of first-row transition metals such as iron, cobalt, and nickel are 0.4 (4 Dq) for iron, 0.8 (8 Dq) for cobalt, and 1.2 (12 Dq) for nickel. When stability constants are adjusted quantitatively to account for these CFSE values in the absence of crystal field effects, they align with the predicted trend between manganese and zinc. The acceptance of crystal field theory, which explains the thermodynamic, spectroscopic, and magnetic properties of transition metal complexes and forms the basis of ligand field theory, was greatly influenced by this alignment.

- Principal Quantum Number:** The Crystal Field Stabilisation Energy (CFSE) of metal ions can vary in magnitude even when they have the same charge due to changes in their primary quantum numbers, which in turn impacts the stability of complexes. This can be demonstrated by thinking about the following illustration,

Principal Q.No.	Ions	Ligands	CFSE(Δ_0 in cm^{-1})
d^6	$d^6\text{-Co}^{3+}$	$6\text{H}_2\text{O}$	18601
d^6	$d^6\text{-Rh}^3$	$6\text{H}_2\text{O}$	20610

- 3. Nature of Ligands:** Complexes' CFSE and stability can be affected by a variety of ligand characteristics, such as size, charge, dipole moment, polarizability, and π -bonding capability. These characteristics' effects can be summed up as follows:

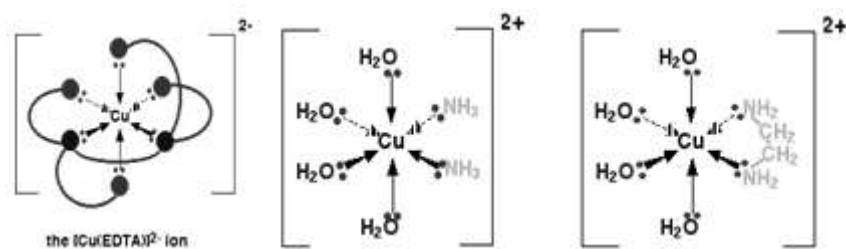
Smaller ligands are found to be closer to the metal ion, which causes more crystal field splitting and stronger interactions.

The overall stability of the complex is impacted by the increased magnitude of crystal field splitting that results from an increase in the charge of anionic ligands.

To sum up, ligand size and charge are key factors in CFSE and complex stability, with smaller ligands and higher charge on anionic ligands contributing to increased crystal field splitting..

- **Chelation:** The larger the number of the chelate ring in complex, greater is its stability. The stability of complex is also depends on number of atom present in a ring.

It has been proved that the most stable chelate are 5 and 6 – member one. It is found that 5-membered chelate is frequently more stable than 6-membered ring. On the other hand 6-membered chelates are more stable than 5-membered chelates of heterocyclic ligand. For example acetyl acetone complexes of the metal ions are more stable than the corresponding ethylene diamine complexes which contain only 5-membered chelate complex ring.



Chelation upsurges stability. This is since the entropy aspect is promising in the case of chelate complexes

For example $[\text{Cd}(\text{en})_2]^{2+}$ is extra steady than $[\text{Cd}(\text{MeNH}_2)_4]^{2+}$ since in the former there is chelation.

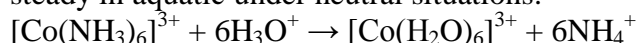
- 4. Macrocyclic Ligands:** The "macrocyclic effect" is the name given to the increased stability seen in complexes comprising macrocyclic ligands. Entropy and enthalpy considerations both contribute to this effect. Macrocyclic ligands have distinct cavities with predetermined diameters, which enables them to form strong complexes with metal ions of the right size.

A good illustration is the fact that the ligand 18-crown-6 forms more complexes with potassium ions than sodium ions. This is due to the potassium ion's good fit inside the cavity of the 18-crown-6 ligand, which increases the stability of the complex.

5. Hardness and Softness: The stability of metal complexes is influenced by the hardness and softness of both the metal and ligands involved. The HSAB (Hard and Soft Acids and Bases) principle provides a framework for understanding this phenomenon. According to this principle, soft acids tend to prefer soft bases, while hard acids have a preference for hard bases. For instance, in the case of Ni^{2+} , which is considered a hard acid, it forms a stable complex with the soft base NH_2 but not with the soft ligand PH_3 . This is because the soft base NH_2 is better suited to interact with the hard acid Ni^{2+} due to their similar electronic properties. On the other hand, Pd^{2+} , being a soft acid, forms a stable complex with the soft ligand PH_3 rather than with the hard base NH_2 . The soft acid Pd^{2+} and soft ligand PH_3 exhibit compatible electronic characteristics, making them more favourable for complex formation.

- **Surrounding Conditions:** Even though the preceding parameters outline complex stability, certain complexes that are considered stable under particular circumstances might not be stable under alternatives.

For example $[\text{Co}(\text{NH}_3)_6]^{3+}$ is unsteady in an acidic solution but then again is steady in aquatic under neutral situations.



The question "Under what situations?" must therefore always be asked when someone claims that a complex is stable. Heat, light, acidity, or basicity could be present.

VII. DETERMINATION OF COMPOSITION OF COMPLEXES USING JOB'S METHOD

The mole-ratio method is an alternate way of figuring out the stoichiometry of metal-ligand complexes. This method includes altering the amount of one reactant, typically the metal, while controlling the amount of the other, typically the ligand. The absorbance of the solution is then calculated at the wavelength in which the metal-ligand complex absorbs. The mole-ratio technique yielded the following results: The absorbance has been determined at a wavelength where only the complex absorbs, as illustrated in.

- the mole-ratio plot for the creation of a 1:1 complex.
- The mole-ratio plot of a 1:2 complex, which absorbs at the chosen wavelength for all 3 ligand—metal, the ligand, and the complex.
- A mole-ratio graph showing the production of ML and ML_2 .

VIII. OVERVIEW

By mixing solutions of iron(III) and 5-sulfosalicylic acid (SSA), different combinations were generated. The composition of these mixes was purposefully and

methodically adjusted. Some mixes had a low iron concentration and a high SSA concentration, while others had a high iron concentration and a low SSA concentration.

The % transmittance of each solution was measured using a Spectronic 20 spectrophotometer to examine the optical characteristics of these mixes. This metric indicates the amount of light that goes through the solution without being absorbed. The absorbance of each solution was then computed based on the measured percentage transmittance. Absorbance is a measurement of the amount of light absorbed by a substance at a specific wavelength.

In chemical reactions, substances react with each other in a fixed and definite mole ratio, which is referred to as the stoichiometry of the reaction. Among the systematically-varied mixtures, only one mixture reproduces the precise mole ratio at which the materials react to the supreme extent probable. This can be observed visually by the intensity of the colour of the product formed, with the mixture displaying the cordial purple colour indicating the uppermost quantity of product formed due to the extreme amount of the reaction.

IX. CALCULATIONS

Test tube	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
%T	61.0%	39.4%	27.7%	22.1%	19.9%	22.0%	27.9%	40.1%	60.5%

Assume the experiment's data was logged at 19.9% Solution Transmittance. (12)

- 1. Solution Absorbance Calculation in Test Tube #3:** The absorbance of a coloured solution is proportional to the concentration of the coloured species present. The absorbance can be computed using the measured % Transmittance using the formula below.:

$$\text{Absorbance} = -\log (\%T/100) = \log (100/\%T) = \log (100) - \log (\%T) = 2 - \log(\%T).$$

In the case of solution #3, the % Transmittance was determined to be 27.7%. To calculate the corresponding absorbance, we substitute this value into the equation:

$$\text{Absorbance} = 2 - \log(\%T) = 2 - \log(27.7\%) = 2 - 1.442 = 0.558.$$

It is important to note that when performing this calculation, one should be cautious with the use of calculators. Different calculators may require different keystrokes for computing logarithmic functions. Additionally, the resulting absorbance values should fall within the range of 0 to 2. If an absorbance value outside of this range is obtained, it indicates an error in calculator usage.

- 2. Fe³⁺ mole calculations in Test Tube #3:** To analyze the amount of moles of iron(III) present in Test Tube #3, we need the volume of the stock Fe(III) solution used and the concentration of the Fe(III) stock solution.

According to the information provided, the volume of iron(III) stock solution used in Test Tube #3 is 3.00 mL. The concentration of the iron(III) stock solution is given as 1.65×10^{-3} M (moles of Fe³⁺ per litre).

To estimate the quantity of moles of Fe(III) in Test Tube 3, we can use the formula:

Number of moles = Concentration \times Volume

Converting the volume from millilitres to litres:

Volume = 3.00 mL = 3.00×10^{-3} L

Plugging in the values into the formula:

Number of moles = $(1.65 \times 10^{-3} \text{ M}) \times (3.00 \times 10^{-3} \text{ L}) = 4.95 \times 10^{-6}$
moles of Fe(III)

Therefore, the number of moles of Fe(III) in Test Tube #3 is 4.95×10^{-6} moles.

- 3. SSA molecular weight calculation in Test Tube #3:** To analyze the amount of moles of SSA (5-sulfosalicylic acid) in Test Tube #3, we need the volume of the SSA solution used and the concentration of the stock SSA solution.

According to the information provided, the volume of SSA solution used in Test Tube #3 is 7.00 mL. The concentration of the stock SSA solution is given as 1.71×10^{-3} M (moles of SSA per litre).

To calculate the number of moles of SSA in Test Tube #3, we can use the formula:

Number of moles = Concentration \times Volume

Converting the volume from millilitres to litres:

Volume = 7.00 mL = 7.00×10^{-3} L

Plugging in the values into the formula:

Number of moles = $(1.71 \times 10^{-3} \text{ M}) \times (7.00 \times 10^{-3} \text{ L}) = 1.197 \times 10^{-5}$ moles of SSA

Therefore, the number of moles of SSA in Test Tube #3 is 1.197×10^{-5} moles.

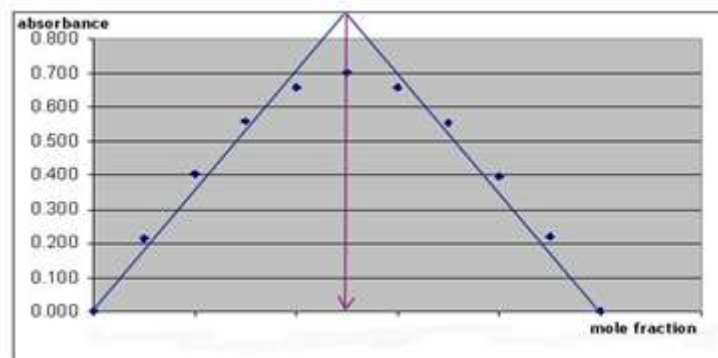
- 4. SSA mole fraction calculation in Test Tube #3:** The amount of moles existing in the constituent of notice alienated by the sum of all the additional components' moles in a mixture is identified as the mole fraction. 4.95×10^{-6} moles of Fe³⁺ and 1.20×10^{-5} moles of SSA are present in the combination.
- 5. Calculation of mole fraction Fe(III) in Test Tube #3:** This calculation is based on the same data as in Part D above, only in terms of Fe(III) rather than SSA: (13)

$$X_{\text{Fe}} = (1 - X_{\text{SSA}}) = (1 - 0.708) = 0.292.$$

Summary of Results: The table only lists your totals for Mole Fraction and Absorbance for each of your solutions. The computations are carried out exactly as shown before, with the exception that the appropriate volumes of Fe and SSA are used in place of the individual answers.

Results from Graph: When the nine data points are plotted on a graph, it is clear that there are two separate groups of data points: one set exhibiting an ascending trend and the

other exhibiting a downward trend. To show these patterns visually, two lines should be drawn on the graph: one for growing data points and one for declining data points. A smooth curve should also be drawn through the data points to depict the overall pattern.



The point at which these two lines connect on the graph represents the highest point, which corresponds to the maximum value on the graph based on the mole fraction (horizontal scale). This is the composition at which the measured property, such as absorbance or transmittance, reaches its highest value within the given composition range. Here's a basic representation of the form. (14)

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