Answer all the questions below as fully as you can then check your answers

1: Which of the following factors affects the colour of a transition metal complex?

a) The type of metal ion

b) The oxidation state of the metal ion

c) The ligands attached to the metal ion

d) All of the above

2: In a transition metal complex, the ligands approach the central metal ion along:

a) Diagonal axes

b) Axes between orbitals

c) The x, y, and z axes

d) Random directions

3: The absorption spectrum of $[Ti(H_2O)_6]^{3+}$ shows strong absorption at 495 nm. Calculate the crystal field splitting energy (Δ) in kJ mol^{-1}.

(Planck's constant = 6.63×10^{-34} Js, speed of light = 3.00×10^{8} m/s, Avogadro's constant = 6.02×10^{23} mol^{-1}).

4: True or false? The colour of a transition metal complex depends on the frequency of light absorbed due to electron transitions within the d-orbitals.

5: The spectrochemical series ranks metal ions based on their ability to split the d-orbitals.

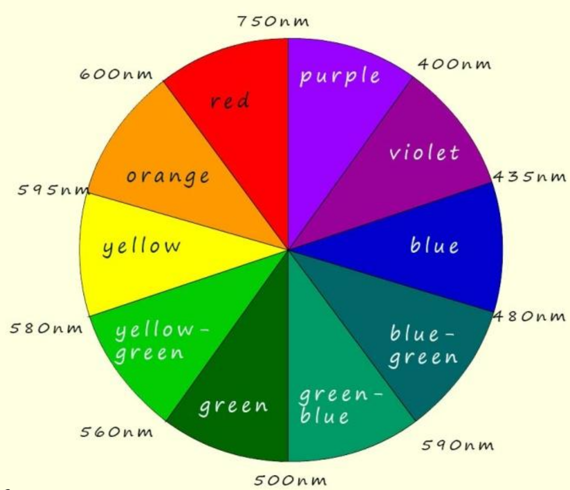
6: Explain why the hexaaquacopper(II) complex, $[Cu(H_2O)_6]^{2+}$, appears blue.

7: How does the geometry of a complex affect the colour of the compound?

8: The complex ion $[Cr(H_2O)_6]^{3+}$ is purple. Explain why its colour change when it is converted to $[Cr(H_2O)_6]^{2+}$.

9: Why do tetrahedral complexes generally have smaller crystal field splitting energies (Δ) compared to octahedral complexes?

10: A solution absorbs light strongly in the green region of the visible spectrum. What is the observed colour of the solution?



11: If a complex absorbs blue light, what colour will the solution appear?

12: The absorption spectrum of $[Ni(H_2O)_6]^{2+}$ shows strong absorption in the red region of the spectrum. Predict the observed colour of the solution.

13: Explain why a solution of $[Ti(H_2O)_6]^{3+}$, which absorbs yellow/green light, appears violet/red.

14: A complex absorbs wavelengths in the orange region of the spectrum. What region of the visible spectrum is transmitted, and what colour does the solution appear?

15: Explain why transition metal complexes are often coloured.

16: Why are transition metals like zinc and scandium typically not coloured in their common oxidation states?

17: Why does changing the ligand in a transition metal complex alter its colour?

18: Why does a change in the oxidation state of a transition metal ion lead to a colour change?

19: Explain why the spectrochemical series helps predict the colour of transition metal complexes.

Answers

1: Which of the following factors affects the colour of a transition metal complex?

a) The type of metal ion

b) The oxidation state of the metal ion

c) The ligands attached to the metal ion

d) All of the above

Answer: d) All of the above

2: In a transition metal complex, the ligands approach the central metal ion along:

a) Diagonal axes

b) Axes between orbitals

c) The x, y, and z axes

d) Random directions

Answer: c) The x, y, and z axes

3: The absorption spectrum of $[Ti(H_2O)_6]^{3+}$ shows strong absorption at 495 nm. Calculate the crystal field splitting energy (Δ) in kJ mol^{-1}.

(Planck's constant = 6.63×10^{-34} Js, speed of light = 3.00×10^{8} m/s, Avogadro's constant = 6.02×10^{23} mol^{-1}).

Answer:

$$\text{Energy of one photon (E)} = \frac{h \cdot c}{\lambda} = \frac{6.63 \times 10^{-34} \cdot 3.00 \times 10^{8}}{495 \times 10^{-9}} = 4.02 \times 10^{-19}\ \text{J}$$

$$\Delta = 4.02 \times 10^{-19} \cdot 6.02 \times 10^{23} = 242\ \text{kJ mol}^{-1}$$

True/False Questions:

4: The colour of a transition metal complex depends on the frequency of light absorbed due to electron transitions within the d-orbitals.

Answer: True

5: The spectrochemical series ranks metal ions based on their ability to split the d-orbitals.

Answer: False (It ranks ligands based on their ability to split the d-orbitals.)

6: Explain why the hexaaquacopper(II) complex, $[Cu(H_2O)_6]^{2+}$, appears blue.

Answer:

$[Cu(H_2O)_6]^{2+}$ absorbs orange light in the visible spectrum. The complementary colour of orange is blue, so the solution appears blue.

7: How does the geometry of a complex affect the colour of the compound?

Answer:

The geometry (e.g., octahedral, tetrahedral, square planar) determines how the d-orbitals split into energy levels. The magnitude of the crystal field splitting energy (Δ) varies with geometry, affecting the wavelength of light absorbed and thus the observed colour.

8: The complex ion $[Cr(H_2O)_6]^{3+}$ is purple. Explain why its colour change when it is converted to $[Cr(H_2O)_6]^{2+}$.

Answer:

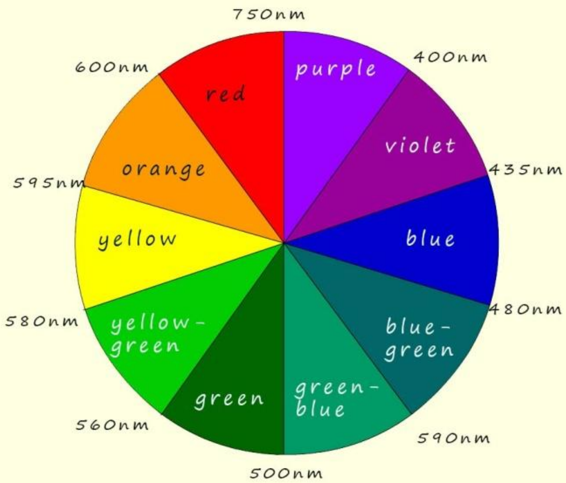
The colour changes to blue because the oxidation state of chromium changes from +3 to +2, altering the crystal field splitting energy and the wavelengths of light absorbed.

9: Why do tetrahedral complexes generally have smaller crystal field splitting energies (Δ) compared to octahedral complexes?

Answer:

In tetrahedral complexes, none of the ligands point directly at the d-orbitals, resulting in less repulsion and smaller splitting of the d-orbital energy levels compared to octahedral complexes where ligands approach along the axes.

10: A solution absorbs light strongly in the green region of the visible spectrum. What is the observed colour of the solution?



Answer:

The observed colour is red because red/violet is complementary to green on the colour wheel.

11: If a complex absorbs blue light, what colour will the solution appear?

Answer:

The solution will appear orange/yellow, as orange/yellow is the complementary colour of blue.

12: The absorption spectrum of $[Ni(H_2O)_6]^{2+}$ shows strong absorption in the red region of the spectrum. Predict the observed colour of the solution.

Answer:

The observed colour is blue/green, as blue/green is complementary to red on the colour wheel.

13: Explain why a solution of $[Ti(H_2O)_6]^{3+}$, which absorbs yellow/green light, appears violet/red.

Answer:

The observed colour is the complementary colour of the light absorbed. Since $[Ti(H_2O)_6]^{3+}$ absorbs yellow/green light, the complementary colours violet and red are transmitted, making the solution appear violet/red.

14: A complex absorbs wavelengths in the orange region of the spectrum. What region of the visible spectrum is transmitted, and what colour does the solution appear?

Answer:

The blue region of the visible spectrum is transmitted, so the solution appears blue.

15: Explain why transition metal complexes are often coloured.

Answer:

Transition metal complexes are coloured because of the splitting of the d-orbitals in the metal ion when ligands approach. When visible light passes through the complex, specific wavelengths are absorbed to promote electrons from lower-energy to higher-energy d-orbitals. The remaining light is transmitted, and the colour observed corresponds to the complementary colour of the absorbed light.

16: Why are transition metals like zinc and scandium typically not coloured in their common oxidation states?

Answer:

Zinc and scandium ions in their common oxidation states (Zn^{2+} and Sc^{3+}) have either completely filled or empty d-orbitals. Without partially filled d-orbitals, d-d electronic transitions cannot occur, so no visible light is absorbed, and the compounds are colourless.

17: Why does changing the ligand in a transition metal complex alter its colour?

Answer:
Different ligands cause different extents of splitting of the d-orbitals (Δ), affecting the energy and wavelength of light absorbed. This changes the colour of light transmitted and hence the observed colour of the complex.

18: Why does a change in the oxidation state of a transition metal ion lead to a colour change?

Answer:
Changing the oxidation state alters the number of d-electrons in the metal ion and the strength of the interaction with ligands. This modifies the crystal field splitting energy (Δ), changing the wavelength of light absorbed and the observed colour.

19: Explain why the spectrochemical series helps predict the colour of transition metal complexes.

Answer:
The spectrochemical series ranks ligands based on their ability to split the d-orbitals. Strong field ligands cause larger crystal field splitting energies (Δ), absorbing higher energy (shorter wavelength) light, while weak field ligands cause smaller Δ values, absorbing lower energy (longer wavelength) light. This helps predict the colour of the complex based on the light absorbed and transmitted.