

Colour, complexes and catalysis in the d-block

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems cover electron configurations, oxidation states, ligands and complex ions, colour, catalysis and manganate(VII) and dichromate titrations. They progress from recall to multi-step calculations and explanations.

They suit A Level, IB Chemistry, CBSE Class 11-12 and WAEC or NECO senior students. Show every step and write units.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.2.5

Problem 1 Electron configurations (easy)

1. Write the electron configuration of an iron atom in the form $[\text{Ar}] 3d^x 4s^y$.
2. Write the configuration of Fe^{2+} and Fe^{3+} .
3. Write the configuration of a copper atom.

Problem 2 Is it a transition element? (easy)

Decide whether each is a transition element and justify: scandium (forms Sc^{3+}), titanium (Ti^{4+} and Ti^{3+}), zinc (Zn^{2+}), copper (Cu^{2+}).

Problem 3 Match the colours (easy)

Match each ion to its colour: $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$, MnO_4^- with pale green, purple, pink, pale blue.

Problem 4 Oxidation state and coordination number (easy)

For each complex give the oxidation state of the metal and the coordination number:

$[\text{Fe}(\text{CN})_6]^{4-}$, $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$, $[\text{CuCl}_4]^{2-}$, $[\text{Ag}(\text{NH}_3)_2]^+$.

Problem 5 Classify the ligands (easy)

Classify as monodentate, bidentate or hexadentate: H_2O , Cl^- , ethanedioate $\text{C}_2\text{O}_4^{2-}$, EDTA^{4-} , NH_3 .

Problem 6 Writing complex formulae (medium)

1. Write the formula of the complex ion of Ni^{2+} with three ethane-1,2-diamine (en) ligands, including charge and coordination number.

2. Write the formula of the complex with Cr^{3+} , four NH_3 and two Cl^- and give its charge.
3. Write the formula of the compound of that complex with chloride ions.

Problem 7 Colour and energy gap (medium)

A solution of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ has $\Delta E = 3.98 \times 10^{-19} \text{ J}$ per ion.

1. Calculate the wavelength absorbed ($h = 6.63 \times 10^{-34} \text{ J s}$, $c = 3.00 \times 10^8 \text{ m s}^{-1}$).
2. Predict the colour of the solution given that 500 nm is blue-green.
3. Explain what happens to the electrons.

Problem 8 Dichromate titration (medium)

25.0 cm^3 of iron(II) sulfate solution needs 18.60 cm^3 of 0.0150 mol dm^{-3} potassium dichromate(VI). $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 6\text{Fe}^{3+} + 7\text{H}_2\text{O}$.

1. Calculate $n(\text{Cr}_2\text{O}_7^{2-})$.
2. Calculate the concentration of Fe^{2+} .

Problem 9 A homogeneous catalyst (medium)

Aarav studies $\text{S}_2\text{O}_8^{2-} + 2\text{I}^- \rightarrow 2\text{SO}_4^{2-} + \text{I}_2$, which is slow, and speeds it up with Fe^{3+} .

1. Write two equations showing how Fe^{3+} catalyses the reaction.
2. Show they add to give the overall equation.
3. Explain why the uncatalysed reaction is slow.

Problem 10 Contact process (medium)

Vanadium(V) oxide catalyses $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$.

1. Write the two steps: $\text{SO}_2 + \text{V}_2\text{O}_5 \rightarrow \text{SO}_3 + \text{V}_2\text{O}_4$ and $\text{V}_2\text{O}_4 + \text{O}_2 \rightarrow \text{V}_2\text{O}_5$ (balance).
2. State the change in oxidation state of vanadium in the first step.
3. Explain why the catalyst is not used up.

Problem 11 Copper and ammonia (medium)

Wanjiru adds ammonia solution drop by drop and then in excess to copper(II) sulfate solution.

1. Describe the two observations.
2. Write ionic equations for both changes.

Problem 12 Copper and chloride (medium)

Adding concentrated hydrochloric acid to $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ gives a yellow-green solution:

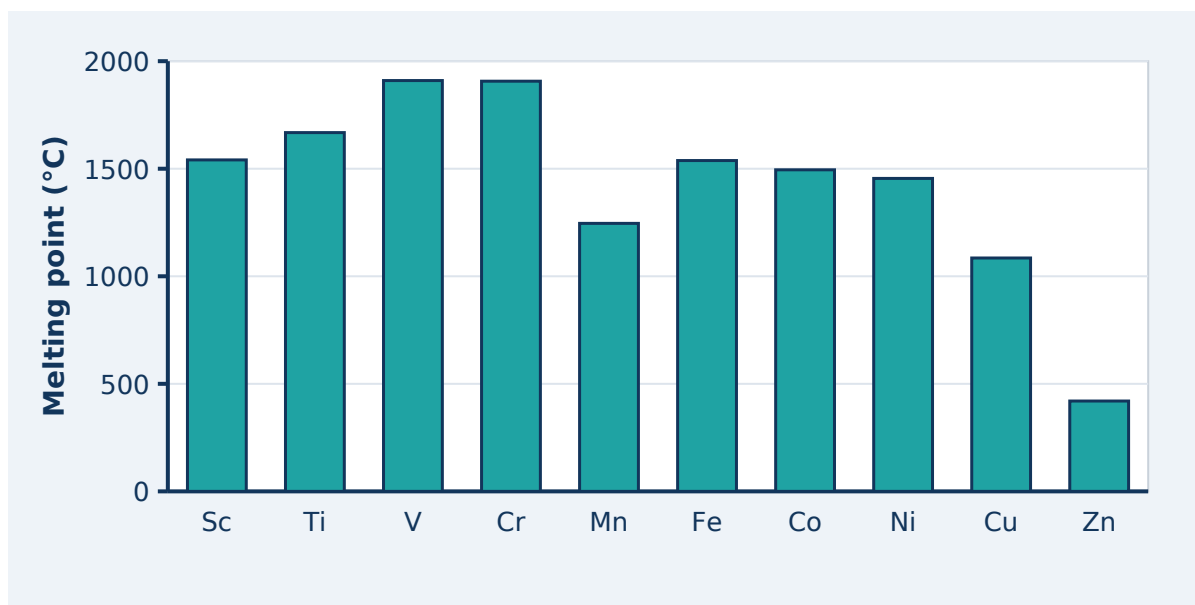


1. Show that the equation balances for charge.
2. Explain the change in coordination number.
3. Predict the colour change on diluting with water, and explain.

Problem 13 Manganese oxidation states (medium)

Give the oxidation state of manganese in MnO_4^- , MnO_4^{2-} , MnO_2 and Mn^{2+} , and match them to colours: purple, green, brown solid, pale pink.

Problem 14 Trends across the first row (medium)



Melting points of the first row d-block elements.

The figure shows melting points of the first row d-block elements.

1. Identify the element with the highest melting point and the lowest.
2. Calculate the difference between the highest and the lowest.
3. State what the high values show about metallic bonding.

Problem 15 Spot the errors (medium)

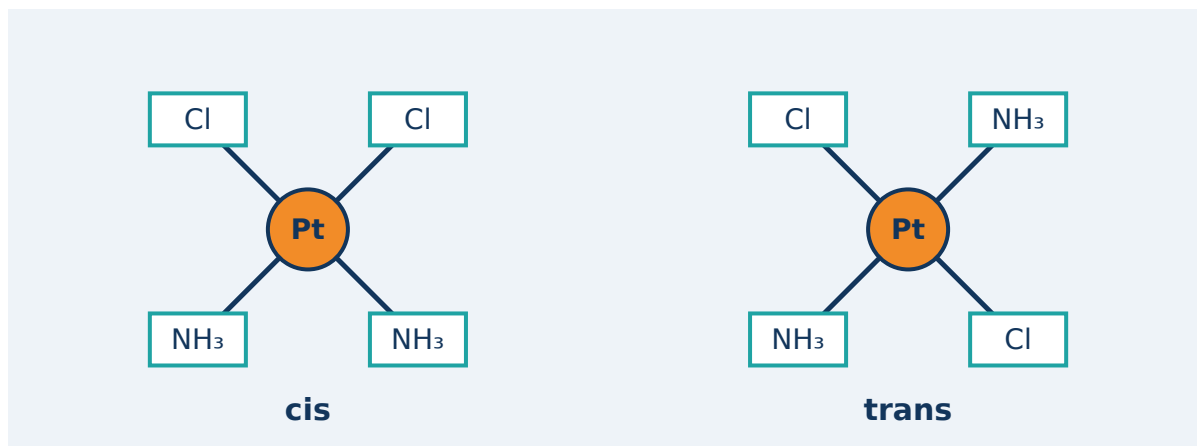
Mei wrote three statements. Identify and correct the error in each.

1. Chromium is $[\text{Ar}] 3d^4 4s^2$.
2. Zinc is a transition metal because it is in the d-block.
3. In forming Fe^{2+} , iron loses two 3d electrons first.

Problem 16 Chromium chemistry (hard)

Chromium(III) ions in solution are green. Excess sodium hydroxide gives green $[\text{Cr}(\text{OH})_6]^{3-}$. Hydrogen peroxide in alkali then gives yellow chromate(VI), CrO_4^{2-} . Acidifying gives orange dichromate: $2\text{CrO}_4^{2-} + 2\text{H}^+ \rightleftharpoons \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$.

1. Give the oxidation state of chromium in each ion.
2. State why the chromate(VI) to dichromate change is not redox.
3. Predict the colour change when alkali is added to dichromate, and explain.

Problem 17 Cisplatin (hard)

Two arrangements of $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$.

$\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is square planar.

1. State the oxidation state of platinum.
2. Name the type of stereoisomerism shown in the figure.
3. The cis form binds to DNA by replacing both Cl^- with nitrogen donors; explain why the trans form cannot do this.

Problem 18 Tablet analysis (hard)

Bilal crushes a 2.00 g iron tablet (iron(II) sulfate) and makes it up to 250 cm³ with dilute sulfuric acid. A 25.0 cm³ portion needs 21.60 cm³ of 0.0100 mol dm⁻³ KMnO_4 (5 Fe^{2+} per MnO_4^-).

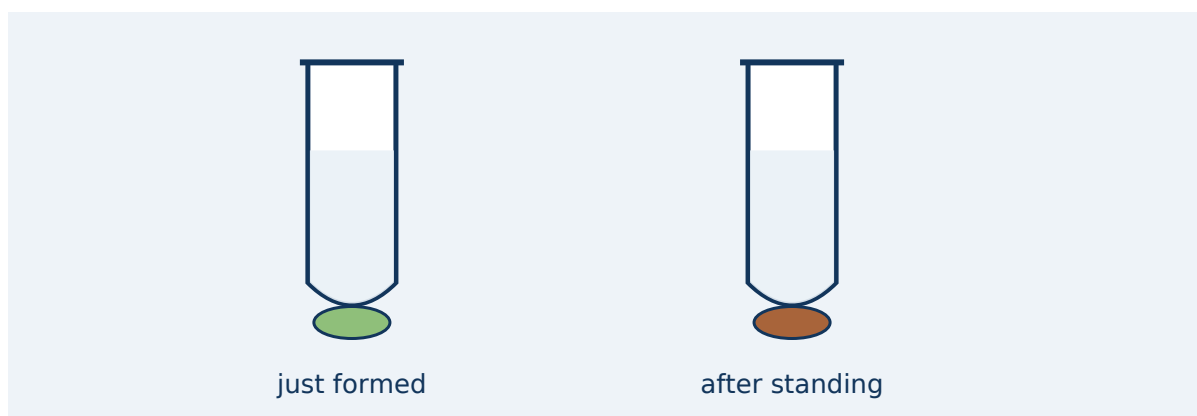
1. Calculate $n(\text{Fe}^{2+})$ in the 25.0 cm³ portion.
2. Calculate $n(\text{Fe}^{2+})$ in the tablet.
3. Calculate the percentage of FeSO_4 ($M_r = 151.9$) in the tablet.

Problem 19 The chelate effect (hard)

$[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 3\text{en} \rightarrow [\text{Ni}(\text{en})_3]^{2+} + 6\text{H}_2\text{O}$ has $\Delta H = -12 \text{ kJ mol}^{-1}$ and $\Delta S = +120 \text{ J K}^{-1} \text{ mol}^{-1}$ at 298 K.

1. Explain why ΔS is positive by counting particles.
2. Calculate $\Delta G = \Delta H - T\Delta S$.
3. State whether the reaction is feasible.

Problem 20 Identify solution P (hard)



The precipitate from solution P with sodium hydroxide.

Solution P is pale green. Sodium hydroxide gives a green precipitate that turns brown on standing in air. Barium chloride in dilute hydrochloric acid gives a white precipitate.

1. Identify the two ions.
2. Write the ionic equation for the green precipitate.
3. Balance: $\text{Fe}(\text{OH})_2 + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_3$