Practice Test Questions 12
Co-ordination Chemistry and Colour

1. The phosphanes are a group of compounds containing only phosphorus and hydrogen atoms. They and their derivatives (in which one or more H has been replaced by groups of atoms) are excellent ligands.

(a) Draw the Lewis structure for phosphane (PH_3).

(b) Draw the Lewis structure for triphosphane (P_3H_5).

(c) Why are these compounds good ligands?

2. Ozone (O_3) can act as either a bidentate ligand or a monodentate ligand, but the azide anion (N_3^-) can only act as a monodentate ligand.

(a) Define the terms "monodentate ligand" and "bidentate ligand".

(b) Draw one valid Lewis structure for O_3.
Include any non-zero formal charges on the appropriate atoms.

(c) Draw one valid Lewis structure for N_3^-.
Include any non-zero formal charges on the appropriate atoms.

(d) Briefly explain why O_3 can act as a bidentate ligand but N_3^- cannot.

3. Complete the following table.

Formula	**Oxidation State of Transition Metal**
$MgK[Co(CO_3)_3]$	
$[Cr(H_2O)_2(NH_3)_4]^{3+}$	
$[NiBr_2(CN)_2]^{2-}$	
$[Cu(H_2O)_4]SO_4 \cdot H_2O$	

4. Each of the electron configurations below belongs to a transition metal with an oxidation state of +2. Identify these metals.

(a) [Ar] $3d^6$ (b) [Ar] $3d^{10}$

(c) [Ar] $3d^5$ (d) [Ar] $3d^8$

5. Copper has two common oxidation states, +1 and +2.

(a) Using orbital box diagrams, show the electron configuration for the *d* electrons of copper in each of these oxidation states.

(b) For each oxidation state, indicate whether the copper is paramagnetic or diamagnetic.

(c) Copper compounds with one of these oxidation states are typically brightly coloured. Identify this 'colourful' oxidation state and explain your choice.

6. A common undergraduate lab involves the preparation of a co-ordination complex from an iron(III) solution and a potassium thiocyanate (KSCN) solution.

(a) Draw a Lewis structure for a thiocyanate (SCN^-) ligand.

(b) Predict whether this ligand will be monodentate, bidentate or chelating. Justify your choice.

(c) Solutions of this complex are typically analyzed by spectrophotometry as they absorb light with a wavelength of 447 nm. Do you expect the solutions to be orange or blue? Justify your choice.

7. The complex to the right has no net charge.

(a) What is the oxidation state of iron in this complex?

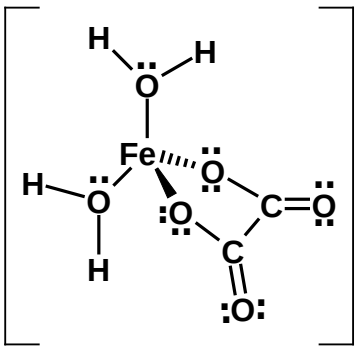
(b) Write the electron configuration for iron in this oxidation state.

(c) What is the co-ordination number of iron in this complex?

(d) What is the molecular geometry at one of the carbon atoms?

(e) What is the approximate H-O-Fe bond angle?

(f) Would you expect this complex to have a stereoisomer? Why or why not?



8. Write a balanced chemical equation for each of the reactions described below. *Include states of matter.*

(a) Nickel(II) nitrate is dissolved in water giving a green solution. *An octahedral complex is responsible for the green colour.*

(b) Solutions of copper(II) nitrate and aqueous ammonia are mixed giving a deep blue solution. *The mole ratio of copper(II) nitrate to aqueous ammonia is 1:4 and reaction is complete.*

9. *cis*-$[MnCl_2(OH_2)_4]$ is a red crystalline solid.

(a) Draw *cis*-$[MnCl_2(OH_2)_4]$.
You must clearly show its geometry. You do not have to show lone pairs.

(b) What is the co-ordination number for manganese in this complex?

(c) Write the electron configuration for manganese(II). ***Use the noble gas abbreviation.***

(d) If the *d* electrons in this complex are in a high spin configuration, draw an energy level diagram for those *d* electrons.

(e) Briefly, explain why this complex is coloured.

10. You have two beakers which used to be labeled, but the labels have fallen off. One beaker contains a violet solution while the other contains a colourless solution. The labels say "aqueous solution of chromium(III) sulfate" and "aqueous solution of scandium(III) sulfate".

(a) Which label belongs on which beaker?

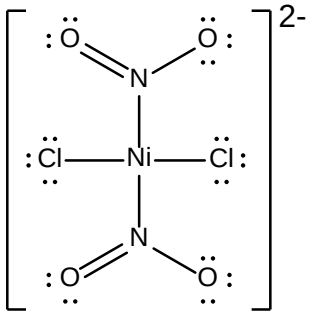
(b) Explain the logic you used to assign the labels to the two solutions.
Hint: The cations are present as their hexaaqua complexes dissolved in water.

11. You find two flasks, one containing a blue solution and the other containing a yellow solution. Two labels, which appear to have come off these flasks, are on the same shelf. One says $[Co(H_2O)_6]^{3+}$ and the other says $[Co(en)_3]^{3+}$. Answer the following questions as you determine which solution is which.
("en" is short for "ethylenediamine" which has the formula $NH_2CH_2CH_2NH_2$)

(a) Which of the two solutions is absorbing higher energy light, the yellow one or the blue one? ***Briefly***, justify your answer.

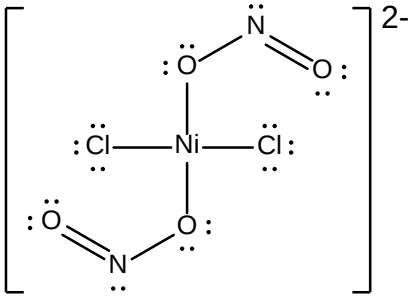
(b) The blue solution contains which of the two complexes? ***Briefly***, justify your answer.

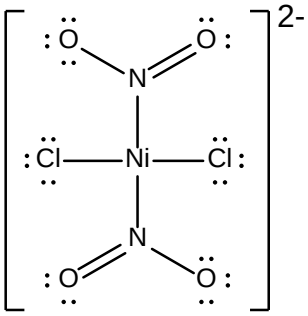
12. The nickel atom in the co-ordination complex shown below is square planar.

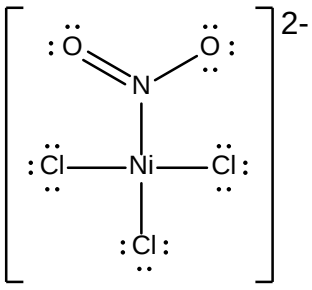


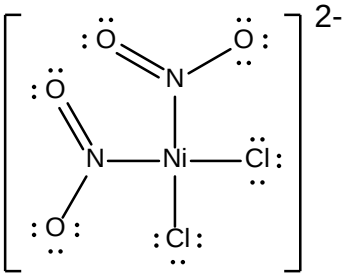
(a) Identify the relationship between each of the structures shown below and the structure shown above. Each of the structures below is either:

- an isomer of the structure above,
- a resonance structure of the structure above, or
- neither.

i. 

ii. 

iii. 

iv. 

(b) To the left of each structure in part (a), write *cis*, *trans* or n/a (short for "not applicable") to describe the stereochemistry about the nickel atom.