Chemistry 204: Quiz #3

1. Two of your friends are studying (again) and during the session, Friend One says, "We can think of a molecule as a collection of nuclei and delocalized electrons". Before Friend One can continue, Friend Two looks to you and asks, "When did we learn that?" Which of the following should you say to help Friend Two?

   a) "That is a fundamental idea of the molecular orbital theory."
   b) "That is part of the localized electron model we learned about in class."
   c) "This is best demonstrated with the crystal field theory."
   d) "That is a major tenet of hybridization theory."
   e) "We didn't – Friend One just made it up."

2. How many of the following geometries for complex ions in coordinate covalent compounds can exhibit *cis*-*trans* isomerism?

   I. linear
   II. square planar
   III. tetrahedral
   IV. octahedral

   a) 0 b) 1 c) 2 d) 3 e) 4

3. You dissolve a 3.14-g sample of pentaamminechlorochromium(III) chloride in water. What volume of 0.150*M* $AgNO_3$ is required for complete precipitation of AgCl?

   a) 0 mL b) 86.0 mL c) 101 mL d) 172 mL e) 258 mL

4. What is the expected ground state electron configuration for Sc^+?

   a) [Ar] $4s^2 3d^1$
   b) [Ar] $4s^2$
   c) [Ar] $3d^2$
   d) [Ar] $4s^1 3d^1$
   e) [Ar] $4s^2 3d^2$

5. How many of the following octahedral complexes are paramagentic?

   I. Strong-field complexes of Ni^{2+}
   II. Weak-field complexes of Ni^{2+}
   III. Weak-field complexes of Co^{3+}
   IV. Weak-field complexes of Zn^{2+}
   V. Strong-field complexes of Cr^{3+}

   a) 1 b) 2 c) 3 d) 4 e) 5

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6. As discussed in lecture and the text, the magnitude of the splitting of the *d* orbitals in CFT is somewhat dependent on the charge of the metal ion. The text states "NH_3 is a weak-field ligand toward Co^{2+} but acts as a strong-field ligand toward Co^{3+}." Given this, which of the following is true about the difference between the number of unpaired electrons when comparing $[Co(NH_3)_6]^{2+}$ and $[Co(NH_3)_6]^{3+}$?

   a) The difference in the number of unpaired electrons is one (1), and there are more unpaired electrons for $[Co(NH_3)_6]^{2+}$.
   b) The difference in the number of unpaired electrons is one (1), and there are more unpaired electrons for $[Co(NH_3)_6]^{3+}$.
   c) The difference in the number of unpaired electrons is three (3), and there are more unpaired electrons for $[Co(NH_3)_6]^{2+}$.
   d) The difference in the number of unpaired electrons is three (3), and there are more unpaired electrons for $[Co(NH_3)_6]^{3+}$.
   e) The complex ions have the same number of unpaired electrons (the difference is zero (0)).

7. How many of the following is/are optically active? (note: en = ethylenediamine = $NH_2CH_2CH_2NH_2$)

   I. *cis*-$[Co(en)_2Cl_2]^+$
   II. *trans*-$[Co(en)_2Cl_2]^+$
   III. *cis*-$[Co(NH_3)_4Cl_2]^+$
   IV. *trans*-$[Co(NH_3)_4Cl_2]^+$

   a) 0 b) 1 c) 2 d) 3 e) 4

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8. Please answer the questions succinctly, yet fully. Full credit is awarded to complete, coherent answers written in complete sentences. Take some time to draft out an answer on scratch paper before you begin writing.

   a. Describe the general ideas of the crystal field model. Include in this discussion the nature of the ligands and the nature of the bond between the ligands and the metal ion. In addition, include a crystal field diagram for an octahedral complex and explain/justify the relative positions of the *d*-orbitals in the complex ion and in the free ion (make sure to label these).
   b. Models in science are kept as simple as possible, and then they are refined/changed as questions cannot be answered correctly. What are two problems with crystal field theory that require a different model? Briefly describe these problems.
   c. Recall the lecture demonstration in which I added concentrated HCl to an aqueous solution of cobalt(II) ions. The reaction that occurred can be represented as follows.

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow \underset{\text{(tetrahedral)}}{[CoCl_4]^{2-}} + 6H_2O$$

   This reaction is accompanied by a color change (one of the complex ions is blue in solution and the other is red).

      i. Sketch crystal field diagrams for each of the complex ions. Label the *d*-orbitals and include the proper number and placement of electrons. Label each as weak field or strong field. There may be more than one possible answer for each complex ion – explain why.
      ii. Explain the color change. In part a you discussed why such complex ions can exhibit color. For this question, explain why the color changes, and explain if the color change upon the addition of HCl is red→blue or blue→red (you don't have to recall the demonstration – you can determine this). Support your answer using the premises of crystal field theory.

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KEY:

MC: 1. a, 2. c, 3. d, 4. c, 5. d, 6. c, 7. b

8. See videos, lectures, and the textbook.