1. Write the chemical formula for each of the following: (8%)
   (a) thiocyanate ion (b) boric acid (c) trisilane
   (d) hexaaquachromium trichloride.
2. Which of the following gas-phase reactions can proceed spontaneously? Explain. (4%)
   (a) $Kr + He^+ \longrightarrow Kr^+ + He$ (b) $Si + Cl^+ \longrightarrow Si^+ + Cl$.
3. Explain the observation that the energy difference between the $^2S_{1/2}$ state of $1s^2 2s^1$ and the $^2P_{1/2}$ state of $1s^2 2p^1$ for Li is 14904 cm^{-1}, whereas for Li^{2+} the $^2S_{1/2}$ state of $2s^1$ and the $^2P_{1/2}$ state of $2p^1$ differ by only 2.4 cm^{-1}. (6%)
4. Which of the following in each pair will have the larger bond angle? Why? (8%)
   (a) CH_4, NH_3; (b) OF_2, OCl_2; (c) NH_3, NF_3; (d) PH_3, NH_3.
5. The bond dissociation energy of C_2 (599 KJ/mol) decreases slightly on forming C_2^+ (513 KJ/mol), and increases greatly on forming C_2^- (818 KJ/mol). Why? (6%).
6. Explain why the anhydrous acid $HICl_4$ cannot be isolated, but the crystalline hydrate $HICl_4 \cdot 4H_2O$ may be obtained from ICl_3 in aqueous HCl. (5%).
7. Treatment of $CrCl_3$(s) with NH_3(l) yields very largely the complex $[Cr(NH_3)_5Cl]Cl_2$(s), but if a small quantity of elemental potassium is first dissolved in the NH_3(l), the product is largely $[Cr(NH_3)_6]Cl_3$. Explain by giving a possible mechanism. (6%).
8. Determine the point group of the following: (8%)
   (a) CH_3Cl (b) CH_2Cl_2 (c) CH_2BrCl (d) $XeOF_4$ (e) BrF_3 (f) NSF_3
   (g) $B_3N_3H_6$ (h) cis-$[CoF_4Cl_2]^{3-}$.
9. Explain the following: (18%)
   (a) The Ag^+ ion is larger in a square planar environment than it is in a tetrahedral one. For Ni^{2+} the reverse is true.
   (b) $Ni(CN)_4^{2-}$ is a square planar complex while $NiCl_4^{2-}$ is a tetrahedral complex.

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(c) $Fe(NO_2)_6^{4-}$ is an inert complex while FeF_6^{4-} is labile.

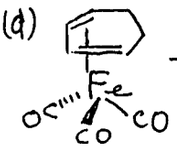
10. How many d-d bands would you expect for a d^1 ion in an enviroment with (a) tetrahedral symmetry, Td; (b) trigonal symmetry, C_{3v}, derived from Td by elongation along one C_3 axis? Explain. (6%).

11. Describe the differences between 4f and 5f orbitals. (5%).

12. Predict reasonable products) for the following reactions. (5%)

(a) $Mn_2(CO)_{10} + H_2 \longrightarrow ?$ (b) $NaC_5H_5 + Fe(CO)_5 \longrightarrow ?$

(c) $(\pi\text{-}C_5H_5)Ru(CO)(PPh_3)(CH_2Ph) + HCl \longrightarrow ?$

(d)  $+ PPh_3 \xrightarrow{Me_3NO} ?$ (e) $(\pi\text{-}C_5H_5)Re(NO)(PPh_3)(CH_3) + P(CH_3)_3 \rightarrow ?$

13. Which of the two complexes has the lower energy CO stretching frequency in the IR spectrum? (5%)

(a) $[Mo(CO)_5Cl]^-$ or $Tc(CO)_5Cl$ (b) $Fe(CO)_5$ or $Fe(CO)_4Cl_2$ (c) $W(CO)_6$ or $W(CO)_4(PPh_3)_2$

(d) $Mo(CO)_4(PMe_3)_2$ or $Mo(CO)_4(PF_3)_2$ (e) $(\pi\text{-}C_5H_5)(CO)_2Fe\text{-}Br$ or $[(\pi\text{-}C_5H_5)(CO)_2Fe]^-$.

14. Treatment of $CH_3Mn(CO)_5$ with $Ph_2PCH_2PPh_2$ gives a product which has the formula, $C_5H_3MnO_4(Ph_2PCH_2PPh_2)$. The IR spectrum shows ν_{CO} at 1999, 1916 (broad), and 1588 cm^{-1}. The ^1H NMR spectrum shows, in addition to phenyl protons, a singlet at δ 2.34 and a twelve line pattern at about δ 4.60. (a) Deduce the two possible products (b) Use the physical data to determine the real product. (6%)

15. In 1983, Borgman reported that n-pentane can add oxidatively with $(\pi\text{-}C_5Me_5)Ir(PMe_3)$, the reductive-elimination product of $(\pi\text{-}C_5Me_5)Ir(PMe_3)H_2$, to give four different products. Write the structures of these products. (4%)

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