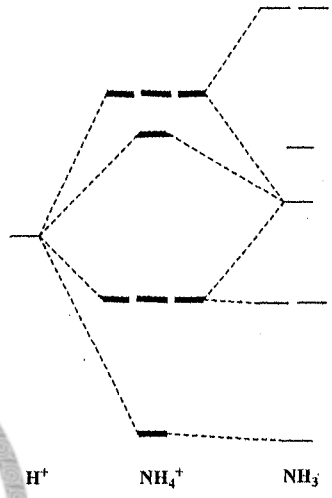
1. Both ^{31}P and ^{19}F have 100% natural abundance with nuclear spin 1/2. Discuss the structure and the spectra of ^{31}P, ^{19}F NMR for PF_5. (10%)

2. How do you distinguish the isomers of $Pt(CO)_2Br_2$ experimentally? (10%)

3. The MO energy diagrams of H^+, ammonium and ammonia is shown below.
   (a) Filled in the electrons and label the frontier orbitals of ammonium ion. (5%)
   (b) Does ammonia meets the requirement of Lewis base or Lewis acid? (5%)
   (c) Explain the acid-base chemistry of ammonia with the MO theory. (10%)



4. The substitution reaction of $Cr(CO)_6$ with PPh_3 follows the rate law below.
   $-d[Cr(CO)_6]/dt = a[PPh_3][Cr(CO)_6]/\{b[CO] + c[PPh_3]\}$
   (a) Describe the point group and the carbonyl vibration modes of the product. (5%)
   (b) Propose a mechanism and prove it matches with the given rate law. (10%)

5. Heck coupling reaction of PhI with $CH_2=CHPh$ yields stilbene, $PhCH=CHPh$, is catalyzed by Pd(0) complex. The reaction is known to first undergo a reaction of oxidative addition.
   (a) Draw a catalytic cycle of three fundamental steps to describe the Heck reaction, and why the first step is called oxidative addition? (10%)
   (b) What kind of reactions the 2nd and the 3rd steps belong to? (5%)

6 Discuss the stability of Li_2O, CaO, and CsO_2 and explain. (10%)

7 The structure of heme is shown below
   (a) How many sp^2 carbon atoms in heme? (5%)
   (b) Draw the simplified MO diagram of $Fe(III)N_6$. (10%)
   (c) What is the low-spin electronic configuration of the iron center and predict its energy difference of d-d transition in terms of cm^{-1}. (5%)