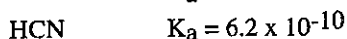
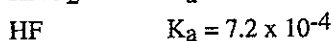
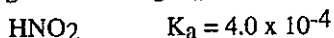


**Part I. Choose the best answer and one answer only (40 %)**

1. The Bohr model of the atom works reasonably well in the calculation of energy levels in hydrogen. What other electron systems can be described by this model?

- (a) all elements in the lithium family (b) all elements in the helium family (c) any one electron system  
(d) only hydrogen and helium (e) only hydrogen

2. Using the following  $K_a$  values, indicate the correct order of base strength.



- (a)  $\text{CN}^- > \text{NO}_2^- > \text{Cl}^- > \text{F}^-$  (b)  $\text{Cl}^- > \text{F}^- > \text{NO}_2^- > \text{CN}^-$  (c)  $\text{CN}^- > \text{F}^- > \text{NO}_2^- > \text{Cl}^-$   
(d)  $\text{CN}^- > \text{NO}_2^- > \text{F}^- > \text{Cl}^-$  (e) none of these is correct

3. For a weak acid, HX,  $K_a = 1.75 \times 10^{-5}$ . Calculate the pH of a 1.00 M solution of HX in water.

- (a) 6.00 (b) 2.38 (c) 4.76 (d) 2.50 (e) none of these

4. Which of the following statements is false?

- (a) A fluorine atom has a smaller radius than a chlorine atom.  
(b) A neon atom has a smaller radius than an oxygen atom.  
(c) A fluorine atom has a smaller first ionization energy than an oxygen atom.  
(d) A potassium atom has a smaller first ionization energy than a lithium atom.  
(e) All statements are true.

To answer questions 5 and 6, consider the reaction  $2\text{N}_2\text{O}_5(\text{g}) \rightarrow 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$

at 25 °C for which the following data are relevant:

|                        | $\Delta H^\circ_f$ | $S^\circ$     |
|------------------------|--------------------|---------------|
| $\text{N}_2\text{O}_5$ | 11.29 kJ/mol       | 355.3 J/K mol |
| $\text{NO}_2$          | 33.15 kJ/mol       | 239.9 J/K mol |
| $\text{O}_2$           | ?                  | 204.8 J/K mol |

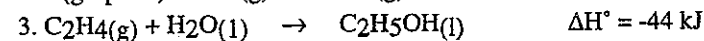
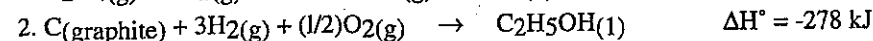
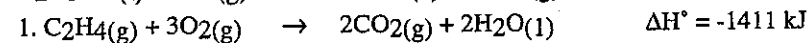
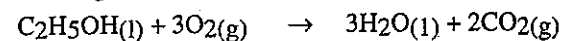
5. Calculate  $\Delta S^\circ$  for the reaction. (a) 89.5 J/K (b) 249.2 J/K (c) 453.8 J/K (d) 249.2 J/K (e) -115.6 J/K

6. Calculate  $\Delta G^\circ$  for the reaction at 25 °C. (a) -135 kJ (b) 98.7 kJ (c) -25.2 kJ (d) -11.2 kJ (e) 0

7. Under conditions of constant pressure, the heat flow that occurs during a chemical change is equal to:

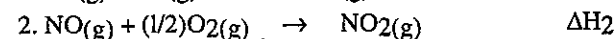
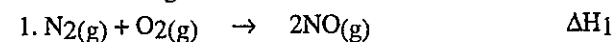
- (a)  $\Delta E$  (b)  $\Delta T$  (c)  $\Delta H$  (d)  $\Delta V$  (e)  $\Delta W$

8. Using Hess's Law and equations 1-3 below, find  $\Delta H^\circ$  at 25 °C for the oxidation of  $\text{C}_2\text{H}_5\text{OH}(\text{l})$ :



- (a)  $\Delta H^\circ = 44 \text{ kJ}$  (b)  $\Delta H^\circ = 632 \text{ kJ}$  (c)  $\Delta H^\circ = -1367 \text{ kJ}$  (d)  $\Delta H^\circ = -1742 \text{ kJ}$  (e) none of these

9. Given the following two reactions at 298 K and 1 atm, which of the statements is true?



- (a)  $\Delta H^\circ_f$  for  $\text{NO}_2(\text{g}) = \Delta H_2$  (b)  $\Delta H^\circ_f$  for  $\text{NO}(\text{g}) = \Delta H_1$  (c)  $\Delta H_1^\circ = \Delta H_2$  (d)  $\Delta H^\circ_f$  for  $\text{NO}_2(\text{g}) = \Delta H_2 + (1/2)\Delta H_1$   
(e) none of these is true

10. Which set of 4 quantum numbers,  $n$ ,  $l$ ,  $m_l$ , and  $s$ , are unacceptable for any system?

- (a) 1 0 0 1/2 (b) 1 0 0 -1/2 (c) 4 3 3 1/2 (d) 6 2 0 -1/2 (e) 4 2 3 1/2

11. How many bonding and antibonding electrons are there in the  $[F_2]^{2-}$  molecular ion?

- (a) 12 and 8 (b) 10 and 10 (c) 11 and 9 (d) 9 and 11 (e) 8 and 12

12. The oxidation number of phosphorus, in  $PO_2Cl$ , is

- (a) -3 (b) +3 (c) -5 (d) +5 (e) +4

13. The correct name for  $C_3O_2$  is

- (a) carbon oxide (b) tricarbon oxide (c) carbon dioxide (d) tricarbon dioxide (e) carbon (II) oxide

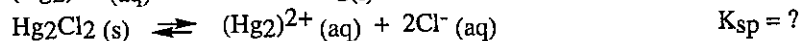
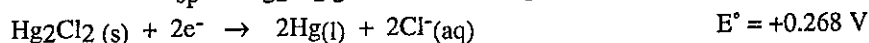
14. How does  $NaH$  behave in the presence of water?

- (a) as a base (b) as an acid (c) is neutral (d) is amphoteric (e) as an oxidizing agent

15. Which one of the following complex ions is paramagnetic?

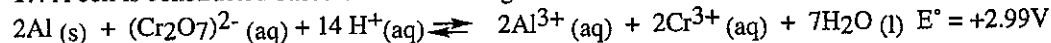
- (a)  $[Fe(CN)_6]^{4-}$  (b)  $[Zn(NH_3)_4]^{2+}$  (c)  $[CrO_4]^{2-}$  (d)  $[FeF_6]^{4-}$  (e)  $[TiCl_6]^{2-}$

16. Calculate  $K_{sp}$  for  $Hg_2Cl_2$  given the following data:



- (a)  $2.02 \times 10^{-18}$  (b)  $1.16 \times 10^{-18}$  (c)  $4.04 \times 10^{-18}$  (d)  $5.55 \times 10^{-19}$  (e)  $7.72 \times 10^{-18}$

17. A cell is constructed based on the following reaction



Calculate the pH of the cathode compartment if the cell emf is measured to be +3.01 V when  $[Cr^{3+}] = 0.15 M$ ,  $[Al^{3+}] = 0.30 M$ ,  $[H^+] = ?$ , and  $[(Cr_2O_7)^{2-}] = 0.55 M$

- (a) 0.94 (b) 0 (c) 1.5 (d) 3.6 (e) 4.8

18. Calculate the pH of a mixture of 50.0 mL of 0.100 M  $CH_3CO_2H$  ( $K_a = 1.75 \times 10^{-5}$ ) and 50.0 mL of 0.100 M  $NaOH$ .

- (a) 7.000 (b) 5.272 (c) 9.123 (d) 8.728 (e) 7.282

19. What mode of decay is found in heavy elements that is not found in light elements?

- (a) beta capture (b) beta emission (c) positron emission (d) alpha emission (e) neutrino formation

20. The melting and boiling points increase for the homologous series  $(C_nH_{2n+2})$  starting with  $n=5$  to  $n=15$  because of an increase in

- (a) hydrogen bonding (b) dipole-dipole forces (c) dipole-induced dipole forces (d) London forces  
(e) the number of double bonds

### Part II. (20%)

1. A simple way to examine deviations from ideality is to look at the compressibility factor ( $z$ ).

$$z = PV/nRT$$

The most common behavior involves an initial negative deviation followed by positive deviations, as shown in following figure. Consider oxygen gas at  $0^\circ C$  as an example. Under conditions where  $z$  is less than 1, the gas pressure is \_\_\_\_\_ (lower or higher) than that of an ideal gas because of

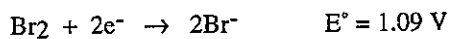
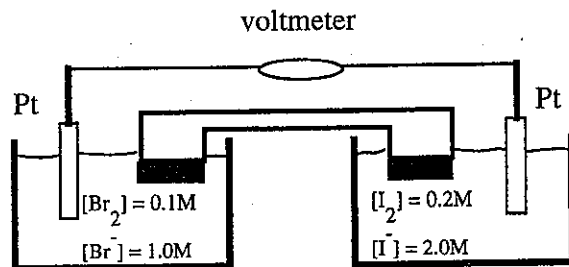
\_\_\_\_\_ . When  $z$  begins to increase, we are seeing the effect

2. (a) The order of acidity of boron halides ( $BF_3$ ,  $BCl_3$ , and  $BBr_3$ ) is \_\_\_\_\_

(b) The order of acidity of  $H_3AsO_3$ ,  $H_2SO_4$ ,  $H_2SeO_3$ ,  $HClO_4$ ,  $H_2SO_3$  is \_\_\_\_\_

(c) The point group of benzene is \_\_\_\_\_

3. Refer to the cell diagrammed below.



- (a) What is the value of  $E_{\text{cell}}$ ? \_\_\_\_\_
- (b) What species is oxidized? \_\_\_\_\_
- (c) Which electrode (left or right) is the cathode? \_\_\_\_\_
- (d) What is the value of the equilibrium constant at  $25^\circ\text{C}$  for the net chemical reaction? \_\_\_\_\_

**Part III. (40%)**

1. For the  $\text{OSF}_4$  molecule

- (a) Draw the Lewis structure.
- (b) Give the geometry of the molecule including expected distortions.
- (c) Indicate the polarity of the molecule.

2. For the molecule  $\text{NO}$

- (a) Draw the molecular orbital energy diagram.
- (b) Give the molecular orbital description.
- (c) Give the bond order in this molecule.
- (d) Compare the bond energies in  $\text{NO}^+$ ,  $\text{NO}$ ,  $\text{NO}^-$ .
- (e) Give the magnetic properties of  $\text{NO}^+$ ,  $\text{NO}$ ,  $\text{NO}^-$ .

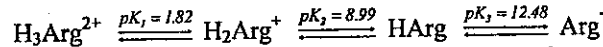
3. Explain the following items: (a) concentration cell (b) blackbody radiation (c) Heisenberg uncertainty principle (d) electron affinity (e) degenerate

4. Calculate the pH of a  $5 \times 10^{-5} \text{ M}$  solution of phenol ( $K_a = 1.05 \times 10^{-10}$ ).

分析化學部分 (50%)

1. (12%) 單選(答錯倒扣一分)

- (a) (3%) 1 ppm of  $\text{Cu}^{2+}$  (atomic weight = 63.5) is equivalent to  
 ① 63.5 ng/L ② 63.5  $\mu\text{g/L}$  ③ 63.5 mg/L ④ 1 ng/L ⑤ 1  $\mu\text{g/L}$  ⑥ 1 mg/L
- (b) (3%) If a weak base is too weak to titrate in water, which solvent in the following would be more suitable than water for the titration of this base with  $\text{HClO}_4$  as the titrant?  
 ① acetone ② methanol ③ ethanol ④ ammonia ⑤ acetic acid
- (c) (2%) Which of the following electrode is where only oxidation reactions will take place?  
 ① anode ② cathode ③ reference electrode ④ counter electrode  
 ⑤ working electrode ⑥ auxiliary electrode ⑦ NHE
- (d) (4%) The amino acid arginine has the following forms:

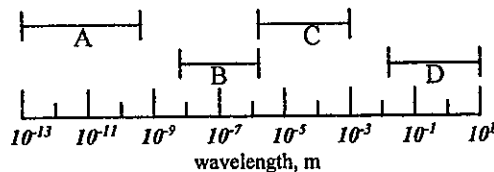


What would be the approximate ratio of the dominant form to the overall arginine at  $\text{pH} = 10.0$ ?  
 ① 40% ② 50% ③ 60% ④ 70% ⑤ 80% ⑥ 90% ⑦ 100%

2. (8%) 單選(答錯倒扣一分)

The following diagram shows four wavelength ranges of electromagnetic radiation.

- (a) (2%) Which one is the range employed in IR spectroscopy?  
 ① range A ② range B ③ range C ④ range D ⑤ none of these ranges
- (b) (2%) Which one is the range employed in UV/Vis spectrometry?  
 ① range A ② range B ③ range C ④ range D ⑤ none of these ranges
- (c) (2%) Which one is the range employed in chemiluminescence measurements?  
 ① range A ② range B ③ range C ④ range D ⑤ none of these ranges
- (d) (2%) Which one is the range employed in ESCA?  
 ① range A ② range B ③ range C ④ range D ⑤ none of these ranges



3. (5%) Calculate the pH of a solution prepared by dissolving 14.998 g of  $\text{NaH}_2\text{PO}_4$  (fw 149.98 g) and 17.196 g  $\text{Na}_2\text{HPO}_4$  (fw 171.96 g) in 500 mL deionized water. (The  $K_1$ ,  $K_2$ , and  $K_3$  for phosphoric acid are  $7.11 \times 10^{-3}$ ,  $6.34 \times 10^{-8}$ , and  $4.2 \times 10^{-13}$ , respectively.)

4. (6%) The following calibration data were obtained by an instrumental method for the determination of  $\text{Pb}^{2+}$  in aqueous solution.

(a) (3%) Calculate the calibration sensitivity.

(b) (3%) Calculate the detection limit for this method.

| $[\text{Pb}^{2+}]$ (ppm) | No. of Replications | Mean Analytical Signal, S | standard deviation, ppm |
|--------------------------|---------------------|---------------------------|-------------------------|
| 0.00                     | 25                  | 0.031                     | 0.0044                  |
| 2.00                     | 5                   | 0.131                     | 0.0039                  |
| 4.00                     | 5                   | 0.231                     | 0.0052                  |
| 6.00                     | 5                   | 0.331                     | 0.0046                  |
| 8.00                     | 5                   | 0.431                     | 0.0050                  |
| 10.00                    | 5                   | 0.531                     | 0.0048                  |

5. (a) (3%) Define "internal standard methods".

(b) (3%) Why is the internal standard method often employed in plasma emission spectrometry?

6. (4%) Use the data in the following table and Beer's law to evaluate the missing quantities (a) and (b). (The molecular weight of the analyte is 250.)

| A          | % T           | $\epsilon$         | b    | c   |
|------------|---------------|--------------------|------|-----|
| absorbance | transmittance | molar absorptivity | (cm) | (M) |
| 0.842      | (a)           | $7.73 \times 10^3$ | 2.00 | (b) |

7. (5%) The efficiency of chromatographic columns can be approximated by the expression  $H = B/u + C_S u + C_M u$  where  $H$  is the plate height, and  $u$  is the linear velocity of the mobile phase,  $B$  is the longitudinal diffusion term,  $C_S$  and  $C_M$  are the mass-transfer coefficients.

(a) (3%) According to this equation, is it correct to say that a column without packing particles has a better column efficiency than those with packing particles? You need to provide your reason.

(b) (2%) Why does the minimum in a plot of plate height versus flow rate occur at lower flow rates with liquid chromatography than with gas chromatography?

8. (4%) Draw a schematic diagram of a Michelson interferometer. The diagram should include mirrors, light source, detector, and sample.

## 物理化學部分(50%)

9. (10 points) The vapor pressure of nitric acid is as follows:

|        |      |      |     |     |     |     |     |      |
|--------|------|------|-----|-----|-----|-----|-----|------|
| T/°C   | 0    | 20   | 40  | 50  | 70  | 80  | 90  | 100  |
| P/Torr | 14.4 | 47.9 | 133 | 208 | 467 | 670 | 937 | 1282 |

What is the normal boiling point and the enthalpy of vaporization of nitric acid?

Note: Clausius-Clapeyron equation is good for this question.

10. (7 points) Estimate the lifetime of a state that gives rise to a line of width of  $0.1 \text{ cm}^{-1}$

11. (16 points) Explain the following terms: (a) Secular determinant (b) Hückel approximation (c) Coulomb integral (d) Resonance integral (e) Variational principle (f) Born-Oppenheimer approximation (g) Semi-empirical quantum calculation (h) Fermi level.

12. (7 points) The wavefunction  $\Phi(\phi)$  for the motion of a particle on a ring is of the form  $\Phi(\phi) = N e^{im\phi}$ . Determine the normalization constant N.

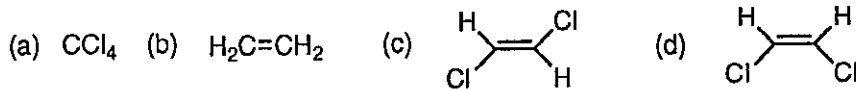
13. (10 points) The following data have been obtained for the decomposition of  $\text{N}_2\text{O}_5(\text{g})$  at  $67^\circ\text{C}$  according to the reaction  $2\text{N}_2\text{O}_5 \longrightarrow 4\text{N}_2(\text{g}) + \text{O}_2(\text{g})$ . Determine the order of the reaction, the rate constant, and the half life. It is not necessary to obtain the result graphically, you may do a calculation using estimates of the rates of change of concentration.

|   |       |       |       |       |       |       |
|---|-------|-------|-------|-------|-------|-------|
| t/time                                      | 0     | 1.00  | 2.00  | 3.00  | 4.00  | 5.00  |
| $[\text{N}_2\text{O}_5]/(\text{molL}^{-1})$ | 1.000 | 0.705 | 0.497 | 0.349 | 0.246 | 0.173 |

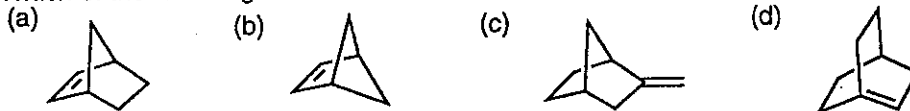
## 有機化學部分

I. Choose the best answer and ONE answer only. (40%; 2% each)

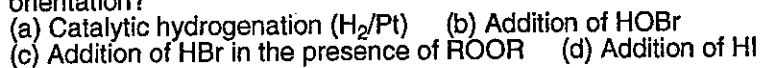
1. Which of the following molecule will have a net dipole moment?



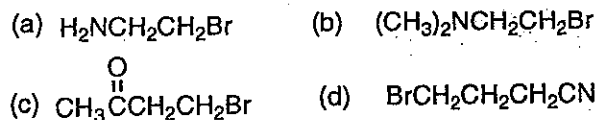
2. Which of the following alkenes violates Bredt's rule?



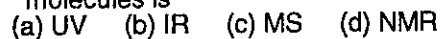
3. Which of the following additions to 2-methylpropene occurs with anti-Markovnikov orientation?



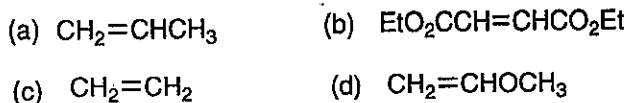
4. Which of the following alkyl halides would be suitable for formation of a Grignard reagent?



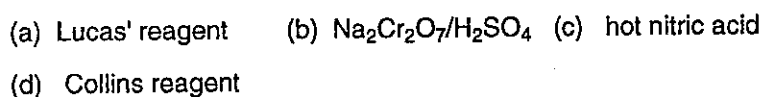
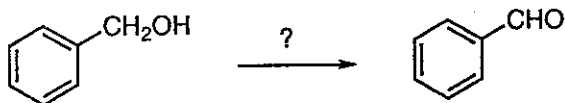
5. The kind of spectroscopy which is best for determining the functional groups in a molecules is





6. Which of the following compounds would be the most reactive dienophile?



7. The following reaction is best accomplished with:



8. Which of the following dienes would undergo a Diels-Alder reaction?  
(a) 3-methylenecyclohexene (b) 3-methyl-1,4-cyclohexadiene  
(c) 2-methyl-1,3-cyclohexadiene (d) 1,4-cyclohexadiene
9. Which of the following compounds is the strongest acid?  
(a) 1-pentene (b) 1,4-pentadiene (c) cycloheptatriene (d) cyclopentadiene
10. The reagent which will differentiate between a ketone and an aldehyde is  
(a) 2,4-D reagent (b) Tollen's reagent (c)  $\text{Br}_2/\text{CCl}_4$  (d) sodium
11. The test that can differentiate between primary alcohol and tertiary alcohol is  
(a) Tollen's test (b) Baeyer test (c) Sodium fusion test (d) Lucas test
12. Which compound would be expected to show IR absorption at  $2250\text{ cm}^{-1}$ ?  
(a)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$  (b)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  (c)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$   
(d)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{C}(\text{O})\text{NH}_2$
13. The most basic amine.  
(a)  $\text{CH}_3\text{CH}_2\text{NH}_2$  (b)  (c)  (d)  $(\text{CH}_3)_3\text{N}$
14. A carboxylic acid can be converted to an ester by reaction with  
(a) diazomethane (b) diborane (c) thionyl chloride  
(d) bromine and phosphorous tribromide
15. Cyclic amides are called  
(a) lactones (b) lactams (c) aminals (d) imines
16. Nucleophilic acyl substitution reactions usually occur  
(a) with inversion of configuration (b) by an elimination-addition mechanism  
(c) with retention of configuration (d) by an addition-elimination mechanism
17. The two compounds below are best described as  
$$\begin{array}{c} \text{NH} \\ || \\ \text{CH}_3\text{COH} \end{array} \quad \text{and} \quad \begin{array}{c} \text{O} \\ || \\ \text{CH}_3\text{CNH}_2 \end{array}$$
  
(a) diastereomers (b) enantiomers (c) tautomers (d) cis, trans isomers



(橫書式)

國立中山大學八十七學年度碩博士班招生考試試題

科目：有機化學與無機化學 (化學所) 共 5 頁 第 3 頁

18. Penicillins contain

- (a) a  $\beta$ -lactam ring (b) a  $\beta$ -lactone ring (c) a thioester group  
(d) a cyclopentene ring

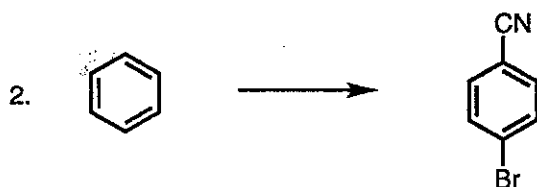
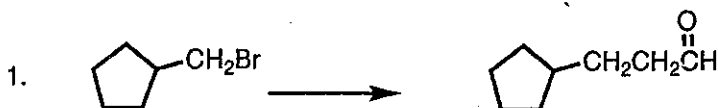
19. The reaction of LDA with acetone produces

- (a) an enol (b) an ylide (c) an enolate ion (d) alkylation

20. The reaction which is usually catalyzed by acid

- (a) Halogenation of ketone (b) Dieckman cyclization (c) Michael reaction  
(d) Cannizzaro reaction

II. Show how you would accomplish the following multi-step synthetic conversions.  
(10%)



無機化學部分

III. Read and then choose a correct item for the following questions. (33pts)

- Which of the following descriptions is correct?
  - The atomic number of Zn is 29.
  - There are 7 valence electrons in  $N^-$ .
  - The atomic radius of I is smaller than that of F.
  - The first ionization energy of He is greater than the second ionization energy of it.
  - The ground state electron configuration of Li is  $[He]2s^1$ .
- Which of the following descriptions is correct?
  - The chemical bonding in  $N_2$  molecule is the type of polar covalent bond.
  - The lattice energy of NaCl may be viewed as the bonding energy of NaCl.
  - The bond order of  $He_2^+$  is one.
  - There is hydrogen bonding between ethanol and benzene.
  - Resonance increases the energy of the molecule above that of any single contributing structure.
- Which of the following molecules has the greatest bond angle?
  - $BeH_2$
  - $CH_2$
  - $NH_2$
  - $OH_2$
  - $BH_2$ .
- Which of the following descriptions is correct?
  - Cation radii decrease on going down a group.
  - The radii of ions with the same charge increase across the Periodic Table.
  - When an ion can occur in environments with different coordination numbers, its radius increases as the coordination number increases.
  - For a cation in a given coordination number, its ionic radius increases with increasing oxidation number.
  - When a compound with the radius ratio of cation to anion is 0.5, the coordination number of this compound is two.
- Which of the following descriptions is correct?
  - The acidity of sulfuric acid in ethanol is greater than in  $H_2O$ .
  - $Fe^{3+}_{(aq)}$  is more basic than  $Fe^{2+}_{(aq)}$ .
  - $NH_4^+$  is less acidic than  $NH_2^-$  in ammonia.
  - $Na_3PO_4$  is an acid in  $H_2O$ .
  - $SiO_2$  is more basic than  $Ca_3(PO_4)_2$ .
- The name of  $[(NH_3)_5CrOCr(NH_3)_5]^{4+}$  is
  - $\eta$ -oxo-bis(pentaammine chromium(III))
  - $\kappa$ -oxo-di(pentaammine chromium(II))
  - $\mu$ -oxo-bis(pentaammine chromium(III))
  - $\mu$ -oxo-di(pentaammine chromium(II))
  - hapto*-oxo-bis(pentaammine chromium(III))

7. Which of the following descriptions is correct?

- (1)  $\text{Co}^{2+}_{(\text{aq})}$  is more labile than  $\text{Ba}^{2+}_{(\text{aq})}$ .
- (2)  $\text{Hg}^{2+}$  is a soft base in  $\text{HgI}_2$ .
- (3) Diethylenetriamine is a didentate ligand.
- (4) The position of  $\text{NH}_3$  is higher than that of  $\text{OH}_2$  in spectrochemical series.
- (5)  $[\text{MnO}_4]^-$  is a square planar complex.

8. Which of the following descriptions is wrong?

- (1) Mg is easier to be oxidized than Mn.
- (2)  $E^0(\text{Cu}^+/\text{Cu})=+0.52\text{V}$  and  $E^0(\text{Cu}^{2+}/\text{Cu}^+)=+0.16\text{V}$ , thus  $\text{Cu}^+$  is not stable in aqueous solution.
- (3) If a vertical line existed in a Pourbaix diagram, a  $K_a$  or  $K_{sp}$  may be derived from it.
- (4)  $[\text{Fe}(\text{OH}_2)_6]^{3+}_{(\text{aq})}$  is more resistant to reduction than  $[\text{Fe}(\text{CN})_6]^{3-}_{(\text{aq})}$ .
- (5) Both the oxidation potential and reduction potential of water lowered in more basic solution.

9. Which of the following descriptions is wrong?

- (1) The energy of  $^1\text{MLCT}$  excited state in a molecule is always higher than that of corresponding  $^3\text{MLCT}$  excited state.
- (2) The ground term for the configuration  $3d^5$  of  $\text{Mn}^{2+}$  is  $^6\text{S}$ .
- (3) Hund's rule states that the electron repulsions are weaker in a complex than in a free ion.
- (4) Ligand-field transitions in an octahedral complex are Laporte forbidden.
- (5) The electronic absorption spectra of f-block complexes are usually very sharp.

10. Which of the following descriptions is wrong?

- (1) Reduction of  $[\text{CoCl}(\text{NH}_3)_5]^{2+}$  with  $\text{Cr}^{2+}_{(\text{aq})}$  proceeds through the inner-sphere mechanism.
- (2) The trans effect of  $\text{CN}$  is greater than that of  $\text{CH}_3$  in the compound  $(\text{CH}_3)_3\text{SiCN}$ .
- (3) Substitution of  $[\text{Pt}(\text{PR}_3)_4]^{2+}$  with  $2\text{Cl}^-$  gives cis- $[\text{PtCl}_2(\text{PR}_3)_2]$ .
- (4) The rate of substitution by  $\text{H}_2\text{O}$  on  $[\text{Mn}(\text{OH}_2)_6]^{2+}$  is faster than that on  $[\text{Ir}(\text{NH}_3)_6]^{3+}$ .
- (5)  $\text{NH}_3$  is a nucleophile and  $\text{Ag}^+$  is an electrophile.

11. Which one is the most probable compound?

- (1)  $\text{Ru}_3(\text{CO})_3$  (2)  $\text{Ru}_3(\text{CO})_6$  (3)  $\text{Ru}_3(\text{CO})_9$  (4)  $\text{Ru}_3(\text{CO})_{12}$  (5)  $\text{Ru}_3(\text{CO})_{15}$

IV. Characterize all the bonding theories you have learned as brief as possible, and then use the proper theory to explain the color of  $\text{KMnO}_4$  and that the acid strength of  $\text{Ag}^+$  and  $\text{Ca}^{2+}$  in aqueous solution toward  $\text{NH}_3$  and  $\text{F}^-$  is reversed. (17pts)