1. A 0.48 g sample of iron ore is dissolved in acid, the iron oxidized to the +3 state, and then precipitated as the hydrous oxide, $Fe_2O_3 \cdot XH_2O$. The precipitate is filtered, washed, and ignited to Fe_2O_3, which is found to weight 0.25 g. Calculate the percent of iron (Fe) in the sample. Atomic weight Fe: 55.9, O: 16.0.   (5%)

2. A bottle which contains 200 ml of 0.100 M NaOH absorbs 1.00 mmol of CO_2 from the air. If the solution is now titrated with standard acid, what normality of the solution will be found (A) if using phenolphthalein indicator. (B) if using methyl orange indicator?   (10%)

3. Calculate the molar solubility (mol/liter) of CaF_2 in (A) water (B) 0.010 M $CaCl_2$, giving the K_{sp} as 4×10^{-11} and neglecting hydrolysis of the floride ion.   (10%)

4. Briefly describe the following terms: (a) Echelle grating; (b) hollow cathode lamp, (c) Optical wedge; (d) molecular ion; (e) Beer's law   (10%)

5. What is the effect of slit width on absorption measurements? (4%)

6. Design an analytical method to analyze THMs (total halomethanes) in drinking water. (5%)

7. Briefly describe the operational principle of supercritical fluid extraction and Soxhlet extraction. Compare their advantages and disadvantages on the analysis of monomers in polymeric materials such as vinyl chloride in polyvinyl chloride.   (6%)
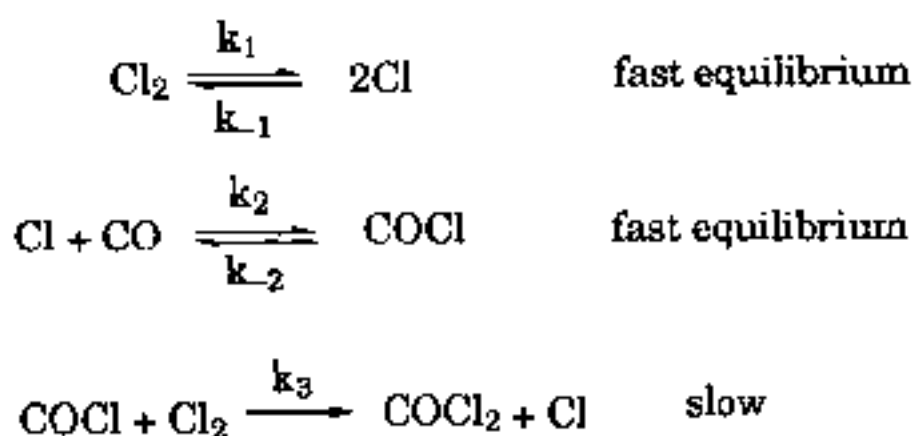
8. Using the relationship

$$\ln(K) = -\frac{\Delta H^o}{RT} + \frac{\Delta S^o}{R}$$

show that for a system at equilibrium the equilibrium will shift to the right for an endothermic process when the temperature is increase. (5%)

9. In the gas phase the production of phosgene from chlorine and carbon monoxide proceeds by the following mechanism: (6%)

$$Cl_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2Cl \qquad \text{fast equilibrium}$$

$$Cl + CO \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} COCl \qquad \text{fast equilibrium}$$

$$COCl + Cl_2 \xrightarrow{k_3} COCl_2 + Cl \qquad \text{slow}$$

Overal
reaction : $CO + Cl_2 \rightarrow COCl_2$
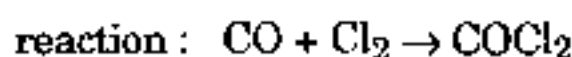
(a) Write the rate law for this reaction
(b) Which species are intermediates?

10. Calculate the shortest distance between lattice points in the body-centered and face-centered cubic lattices (give answer in terms of the unit distance a). (6%)

11. Evaluate the difference between C_p and C_v (C_p-C_v) for a gas that obeys the equation of state $P(\overline{V} - b) = RT$. (4%)

12. For the Fe, Fe^{++} electrode ε^0 is 0.440, and for the Fe^{++}, Fe^{3+} electrode ε^0 is –0.771. What must be the value for the Fe, Fe^{3+} electrode? (4%)

13. For one component of a binary liquid mixture draw the following three curves (or lines) vs its mole fraction: (a) the vapor pressure (b) Henry's law (c) Raoults law. (3%)

14. What is the entropy of n molecules of CO at 0 K? (3%)

15. The rate constant for the isomerization reaction. (3%)
    $$CH_3NC \rightarrow CH_3CN$$
    is $5.5 \times 10^{-15} s^{-1}$ at 300 K, assuming the prefactor is independent of temperature, what is the rate constant at 900K,?

16. Draw the velocity distribution of H_2 and CO_2 at 300K and 1000K in a same figure. (2%)

17. What are the ground state term of (a) H_2O, (b) C_2H_2, (c) O_2, (d) S_2H_2, (nonplanar), (e) BF_3, (f) H_2, (g) $Tc([Kr]5s^2 4d^5)$, (h) Co(atomic number=27)? (4%)

18. Suppose that an oscillator (with the reduced mass μ) is governed by the potential (4%)

    $$V(x) = \begin{cases} \dfrac{k}{2}(x^2 + y^2) & 0 \leq x \leq a \text{ and } 0 \leq y \leq a \\ \infty & \text{otherwise} \end{cases}$$

    (a) What are the eigenfunctions? You only have to write it in terms of the wave-functions of one dimensional harmonic oscillator with the proper constraints and modifications if it is necessary.
    (b) What are the corresponding eigenvalues?
    (c) What is the energy and its degeneracy of the fourth energy level?

19. The vibrational frequency of H_2 molecule is $\bar{\omega} = 4320$ cm^{-1}. What is the vibrational frequency of D_2 molecule? (2%)

20. The characteristic rotational temperature Θ_r is defined as $h/8\pi^2 Ick$ that is the rotational constant devided by the Boltzmann constant k, (4%)

(a) What is the rotational energy E_J in terms of Θ_r and the rotational quantum number J?

(b) What is the degenercy, call it g_J, of a rotational quantum number J?

(c) For N_2 $\Theta_r = 22.6K$, what is the most probable J at 300 K?