Part I: Analytical Chemistry

1. More than five types of general mass analyzers are used in mass spectrometry. Please name a describe two of them, from the principles of mass analysis. (10 pts)

2. Please define following term: (10 pts; 2 for each)
   a. isocratic and gradient elution.
   b. reserved-phase HPLC column.
   c. gel permeation chromatography.
   d. retention time.
   e. chiral stationary phases.

3. Which of the following statements with regard to AA are **false**: (10 pts)
(a) The so-called Achilles' heel (weakness) in flame-AA mainly addresses atomization process wi flame.
(b) More than 99.99% of all atoms are in the ground state.
(c) Increasing flame temperature dramatically decreases the ground state population.
(d) Increasing flame temperature dramatically improves the sensitivity in alkaline metal detection.
(e) Increasing flame temperature dramatically increases the number of atoms in the excited states.
(f) AA methods are primarily concerned with adsorption of radiation by ground state atoms.

4. Electrothermal AA has better sensitivity than flame-AA due to: (10 pts)
(a) Better atomization efficiency than nebulizer
(b) Average residence time of the atoms in the optical path is longer than in the flame.
(c) More sample can be introduced per analysis.
(d) Atomization of the sample occurs in a period of only a few milliseconds.
(e) Better detector.

5. Which of the following statements are **false**? (10 pts)
(a) voltammetry is based upon the measurement of a current that develops under complete concentration polarization.
(b) Voltammety differs from electrogravimetry and coulometry in that with the latter ones the concentration polarization is kept at minimum.
(c) In voltammety a large consumption of analyte results in the end.
(d) In electrogravimetry essentially all of the analyte is converted to another state.
(e) In potentiometry a large current flow through the voltmeter.

Part II. Physical Chemistry

1. Quick questions
   a. What is the point group symmetry of H_2O? (2pts)
   b. Does O_2 molecule have any pure rotational spectrum in microwave region? (2pts)
   c. Does CO molecule have any vibrational spectrum in IR region? (2pts)
   d. What is the number of vibrational degrees of freedom of SO_4^{2-}.(2pts)
   e. Please explain the difference between fluorescence and phosphorescence. (2pts)
   f. What is the difference between Fermions and Bosons in terms of the symmetry of their wave functions? (2pts)

2. For an atom with $2s^12p^1$ configuration, please write down all of the term symbols (including multiplicity, total angular momentum) corresponding to this configuration. (8pts)

3. For the planar radical:CH_2CHCH_2, please use Hückel molecular orbital approximation to determine π electron energy levels. Please use α to denote the Coulomb integral and β to denote the resonance integral; i.e., please write down the energy values in terms of α and β. (10 pts)

4. There is a reaction: $2A \rightarrow 2B+D$. The mechanism is as follows:
   $A \leftrightarrow B+C$ (Rate Constant: $k_1 \rightarrow$, $k_1 \leftarrow$)
   $A+C \rightarrow B+D$ (Rate Constant: k_2)
   Please use Steady State Approximation to show that (if $k_2 \gg k_{-1}$) the production rate of $D=k[A]$ (1^{st} order reaction). (8pts)

5. If a gas engine operates with 1 mole ideal gas in the following conditions:
   State (a) : Pressure=2 atm, Volume=1 liter
   State (b) : Pressure=1 atm, Volume=2 liter
   Path 1: State (a) → (b), P + V = constant
   Path 2: State (a) → (b), PV=RT
   Let's suppose every step is reversible. What are ΔE(change of energy), q(heat), and w(work) for each path? (6pts) (Define: $\Delta E=q-w$)

6. For the vaporization of 1 mole water at 1atm, ΔH_{vap} =43.54 kJ Mol^{-1} at 298K, ΔH_{vap}=40.69 kJ Mol^{-1} at 373K. Heat capacity: $C_p(H_2O_{(l)})$= 75.3 J $Mol^{-1}K^{-1}$. What is the heat capacity for $H_2O_{(g)}$? (6pts)