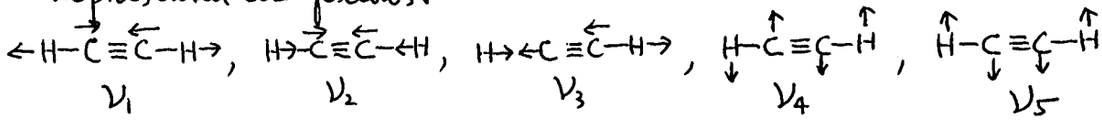
1. Define or explain of the following: (12%)
   (a) Franck-Condon principle (b) Zero-point energy
   (c) Charge-transfer absorption (d) Negative deviations from Raoult's law
2. Explain why the dielectric constant of acetone at 25°C, 20.7, is less than that of methanol, 32.6, even though the dipole moment of acetone, 2.80 D, is greater than that of methanol, 1.70 D. (6%)
3. (a) List the symmetry elements of the CCl_4 molecule. (5%)
   (b) List the operators associated with the S_3 element and their equivalents, if any. How many distinct operations are produced? (5%)
4. What is the sufficient condition for optical isomer to occur? (5%)
5. The spacing of a series of lines in the microwave spectrum of AlH is constant at 12.604 cm^{-1}.
   (a) Calculate the moment of inertia. (4%)
   (b) Calculate the internuclear distance of the molecule. (4%)
   (c) What would be the effect upon the microwave spectrum of the expansion of the dimension of the molecule by a factor of 100? Assume that the mass and electrical properties remain the same. (4%)
   (atomic weight of Al = 27.0 g/mole, C = 3.0×10^{10} cm/sec)
6. Acetylene, C_2H_2, has seven normal modes of vibration, two of which are doubly degenerate. These normal modes may be represented as follows:



   (a) Which are the doubly degenerate vibrations? (b) Which vibrations are infrared active? (c) Which vibrations are Raman active? Explain your answers. (12%).
7. Why do we say that one of the factors that influences reaction rate is the nature of the reactants? (5%)

8. The decomposition of C_2H_5Cl is a first order reaction having $k = 3.2 \times 10^{-2}$ sec^{-1} at 550°C and $k = 9.3 \times 10^{-2}$ sec^{-1} at 575°C. What is the activation energy, in kilocalories per mole, for this reaction? ($R = 1.987$ cal mol^{-1} K^{-1}) (8%).

9. Calculate the root-mean-square speed of oxygen molecules having a kinetic energy of 10 KJ mol^{-1}. At what temperature would this be the root-mean-square speed? ($R = 8.314$ J mole^{-1}K^{-1}, atomic weight of O = 16.0 g/mole) (8%).

10. The following standard oxidation potentials are given:

$$Cu(s) = Cu^{+} + e^{-}, \quad E^{\circ} = -0.521 \text{ V}$$
$$Cu^{+} = Cu^{++} + e^{-}, \quad E^{\circ} = -0.153 \text{ V}$$
$$Cu(s) + 2NH_3(aq) = Cu(NH_3)_2^{+} + e^{-}, \quad E^{\circ} = +0.12 \text{ V}$$
$$Cu(NH_3)_2^{+} + 2NH_3(aq) = Cu(NH_3)_4^{++} + e^{-}, \quad E^{\circ} = +0.10 \text{ V}$$

(a) Calculate the value of the equilibrium constant for the reaction:
$$Cu(s) + Cu^{++} = 2Cu^{+}$$ (4%)

(b) Calculate the value of E° for the half-reaction:
$$Cu(s) = Cu^{++} + 2e^{-}$$ (4%)

(c) Calculate the value of the equilibrium constant for the reaction:
$$Cu^{++} + 4NH_3(aq) = Cu(NH_3)_4^{++}$$ (6%)

($R = 8.314$ J mole^{-1}K^{-1}, $\mathfrak{F} = 96500$ C mole^{-1})

11. In the photobromination of cinnamic acid to dibromocinnamic acid, using blue light of 435.8 nm at 30.6°C, a light intensity of 1.4×10^{-3} J sec^{-1} produced a decrease of 0.075 millimole of Br_2 during an exposure of 1105 sec. The solution absorbed 80.1% of the light passing through it. What is the quantum yield? ($h = 6.62 \times 10^{-34}$ J·s) (8%).