(Useful constants: R=8.3145 J/K mol, $h = 6.6 \times 10^{-27}$ erg·sec, $c = 3 \times 10^8$ m·s^{-1}, ln2 = 0.693, ln10 = 2.3)

1. (20%) For the following process, state whether each of the thermodynamic quantities q, w, ΔE and ΔH is greater than, equal to, or less than zero for the system described. Explain your answers briefly.

   (a) An ideal gas expands adiabatically against external pressure of 1 atm.

   (b) An ideal gas expands isothermally against external pressure of 1 atm.

   (c) An ideal gas expands adiabatically into a vacuum

   (d) A liquid at its boiling point is converted reversibly into its vapor, at constant temperature and 1 atm pressure.

   (e) H$_2$ gas and O$_2$ gas are caused to react in a closed bomb at 25℃ and the product water is brought is back to 25℃.

2. (10%) What is amount of solid sodium acetate needed to prepare a buffer at pH5.0 from 1 L of 0.1 M acetic acid? (PK$_a$ of HOAC is 4.75)

3. (10%) Find ΔS and ΔS_{sur} for the reversible isothermal expansion of 1 mol of argon (assumed ideal) from a volume of 100 L to a volume of 400 L at 25℃.

4. (10%) In general, native proteins are in equilibrium with denatured forms:

   Protein(native) ⇌ Protein(denatured)
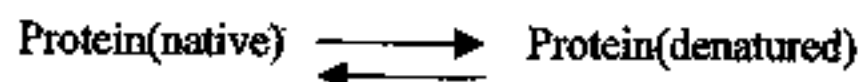
For ribonuclease (a protein), the following concentration data for the two forms were experimentally determined for a total protein concentration of 1x 10^{-3} mol L^{-1}

Temperature (℃)	Native	Denatured
27	9.97x10^{-4} mol L^{-1}	2.5x10^{-6} mol L^{-1}
127	8x10^{-4} mol L^{-1}	2x10^{-4} mol L^{-1}

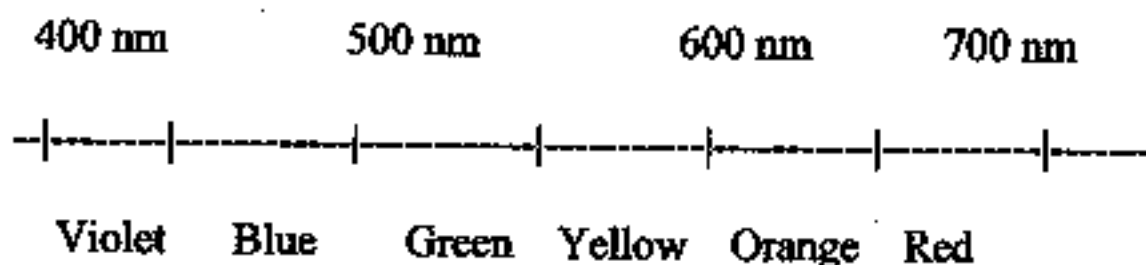Determine ΔH for the reaction, assuming it to be independent for the temperature.

5. (6%) (a) What is the electronic configuration for the ground state of Cu (Atomic number = 29) and its oxidation state? (b) What is the four quantum numbers (n, l, m, s) of the fifteenth electron of Cu atom?

6. (6%) For the orbitals of hydrogen-like atoms listed below, reorganize them in the order of increasing energy.

$$2s, 4d, 3p, 2p, 5f, 3s, 3d, 5p, 4s, 1s, 4f.$$

7. (7%) What color flame would indicate the presence of barium in a sample of unknown composition. Barium atoms can undergo an electronic transition of energy 3.6×10^{-12} erg if barium-containing material is heated on a Bunsen burner flame. (Planck's constant = 6.6×10^{-27} erg/sec)

400 nm	500 nm	600 nm	700 nm

--|------|--------|---------|--------|------|--------|-----

Violet   Blue   Green Yellow Orange Red

(Wavelength range for different colors in the visible spectrum)

8. (5%) Which of the following combinations of quantum numbers represent permissible solutions of the Schrodinger wave equation for the hydrogen atom:

	n	l	m	s
(a)	2	2	0	+1/2
(b)	3	0	1	-1/2
(c)	3	2	-2	-3/4
(d)	4	3	-4	-1/2
(e)	5	2	2	+1/2

9. (6%) The rate of a first order reaction increases from 1.2×10^{-2} sec^{-1} to 1.2 sec^{-1} at 227°C when a catalyst is added to the reaction. Calculate the decrease in the activation enthalpy H, assuming S°, the activation entropy, is not affected by the catalyst.

10. (5%) The half-life for a given reaction was halved as the initial concentration of a reactant was doubled. What is the order (n) for this component? (Don't just give the answer. Show how you get it)

11. (15%) Explain the following terms:

    (a) Beer-Lambert Law

    (b) Franck-Condon Principle

    (c) Pauli Exclusion Principle

    (d) Diffusion-controlled reaction

    (e) Ideal gas