1. (a) The ionization energies of Na, K, Rb, Cs (in no particular order) are 382, 409, 419, 495 kJ/mol. Match the appropriate formula to each ionization energy. Explain. (8%)
   (b) The lattice energies of Na_2S, K_2S, Rb_2S, Cs_2S, CaS, CaSe (in no particular order) are -1850, -1949, -2052, -2203, -2862, -3119 kJ/mol. Match the appropriate formula to each lattice energy. Explain. (10%)
   (c) Cs_2S has the heat of formation -360 kJ/mol. The molar enthalpy of sublimation for S is 277 kJ/mol. The first and second electron affinities of $S_{(g)}$ are -200 and 532 kJ/mol, respectively. Using the data you choose for the ionization energy of Cs and the lattice energy of Cs_2S in (a) and (b), set up the Born-Haber cycle and calculate the molar enthalpy of sublimation (kJ/mol) for Cs. (10%)
   (d) According to the statement in (c), the first electron affinity for sulfur is exothermic, but the second is endothermic. Give the explanation. (8%)

2. (a) Compare the molecular shape, the hybrid orbital on the central atom and the net dipole moment for ClO_3^- and ClO_3^+ (12%)
   (b) An element X forms the ion XF_3^- with a non-zero dipole moment. The atoms of XF_3^- are approximately in one plane. Give an example of an element that could be X. Explain how you reached your answer. (10%)

3. The cyanate ion (OCN^-) and the fulminate ion (CNO^-) have the same chemical formulas but have vastly different properties. Metal salts of one of these ions are commonly used as an explosive.
   (a) C is the central atom in OCN^- and N is the central atom in CNO^-, draw the Lewis structures for both of them, including reasonable resonance forms. Provide the formal charge for each atom. (8%)
   (b) Which ion is likely to be explosive? Explain.(6%)

4. Given the following equation:

$$4\,NH_{3(g)} + 7\,O_{2(g)} \rightleftharpoons 4\,NO_{2(g)} + 6\,H_2O_{(g)} \quad \Delta H = -1130\ kJ/mol$$

   (a) For the forward direction, do you think the entropy change of the system (ΔS_{sys}) is positive, zero or negative? How about the entropy change of the surrounding (ΔS_{surr}) ? Explain your answers. (8%)
   (b) Choose the conditions that will give the optimized yield of NO_2? (A) low pressures and low temperatures (B) high pressures and low temperatures (C) low pressures and high temperatures (D) high pressures and high temperatures. (2%)

5. H_3AsO_4 is a weak triprotic acid. The three acid ionization constants are 5.0×10^{-3}, 9.3×10^{-8}, and 3.0×10^{-12}, respectively.
   (a) If the initial concentration of H_3AsO_4 is 0.100 M, calculate the equilibrium concentrations of H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$ and H_3O^+ (10%)
   (b) Comparing the first acid ionization constant (K_{a1}) of H_3PO_4 and H_3AsO_4, which has a greater value? Explain your choice. (8%)