Homework 1

Distributed: Wednesday, January 17, 2001 **Due: Wednesday, January 24, 2001**

This homework assumes you have already done the suggested textbook problems (see http://ir.chem.cmu.edu/chem106/).

Please show your work.

Boeing is developing an Airborne Laser (ABL) flying platform. This is a modified Boeing 747-400 aircraft that carries chemical lasers. The lasers will be used to shoot down Scud-like missiles. Regarding this plane, Lt. Gen. Robert H. Foglesong said "It would not be smart to ever let our airmen enter a fair fight -- the ABL is another step toward ensuring we have an unfair advantage over our enemies." For more information, see:

Press release: http://www.boeing.com/news/releases/2000/news_release_000122a.html
Web site for project: http://www.airbornelaser.com

a) (2 pts) First, we will consider the amount of energy needed to burn a hole in the metal casing of a missile. We will use a very simple model, and assume that to burn a hole, we need to heat a 50cm by 50cm patch of the titanium alloy shell to 2000K (The Ti-Al combination melts at 1800 ^{o}K) . Assume also that the shell is 0.5 cm thick. We'll assume the heat capacity and density of the alloy are the same as that of Titanium (C_v(Titanium) 0.5226 J/(g K); density (Titanium) = 4.5 g/cm^3) .

How much energy (in J's) is required to heat a 50cm x 50cm patch of Titanium that is 0.5cm thick from 200K to 2000K?

b) (3pts) Suppose that instead of burning a hole in the missile, you decide to heat up the on-board computer to a point where it stops functioning. We'll model the computer as a 550g block of Silicon (C_v(Silicon)= 0.705 J/(g K)).

Consider aiming the laser beam on the casing that surrounds the tracking system. In this scenario, the hot (2000K) patch of Titanium discussed in part (a) is in contact with a 550g block of Silicon at 200K. What is the temperature at equilibrium (assuming no heat is lost to the surroundings)? If a computer stops functioning at 100^{o}C, will the computer survive a laser hit with the energy calculated in part (a)?

The COIL laser, the primary weapon choice for the ALB, uses a two-step process to produce excited iodine atoms. First, chlorine gas is reacted with a solution containing hydrogen peroxide (H_2O_2) and potassium hydroxide (which exists in solution as K^+ and OH^-). This produces excited oxygen molecules (O_2*) according to the following reaction:

$$Cl_{2\,(g)} + H_2O_{2\,(aq)} + 2\,K^+_{(aq)} + 2OH^-_{(aq)} \rightarrow O_2^*{}_{(g)} + 2K^+_{(aq)} + 2Cl^-_{(aq)} + 2\,H_2O_{(l)} \quad \text{(reaction 1)}$$

The excited oxygen molecules then collide with iodine atoms. In the collision, the oxygen molecules transfer their energy to the iodine atoms (the oxygen returns to normal "cold" O_2 and the iodine becomes excited (I*)).

$$O_2^* + I \rightarrow O_2 + I^* \qquad \text{(reaction 2)}$$

c) (3pts)The heat of formation ($?H_f^o$) of the excited oxygen molecule (O_2*) is measured to be 95.83 kJ/mole. Using this, and the data in Appendix D of the textbook, calculate the $?H^o$ for reaction 1

Because reaction 1 is exothermic, the COIL laser must be water-cooled to prevent damage to the circuitry and optical components. In an effort to reduce the heat created by operating the laser, researchers have proposed modifying reaction 1 by replacing the Chlorine gas $Cl_{2\,(g)}$ with either Fluorine $F_{2\,(g)}$ or Bromine $Br_{2\,(g)}$.

d) (2 pts) Which modification do you recommend: Flourine or Bromine, and why? *Please support your answers with calculations.*