2.813 Practice Quiz 1 – Spring 2011
(Please note, this is longer than an typical quiz)

1. ***CO2 from Humanity**: Make an estimate of how much CO2 all of humanity exhales in a year in metric tones. How does this compare with the total for anthropogenic emissions?*

   There are a few different ways to approach this problem, so this is just one solution. We are going to imagine people as engines that process food as fuel, and evaluate the carbon created by processing that fuel. First, let's figure out the amount of fuel a person consumes. Let's say that the average person consumes roughly 2000 calories a day. A dietary calorie is actually 1 kilocalorie, which is equal to 4184 joules. So a person consumes

   $$2000 \times 4184 \times 365 = 3.05GJ$$

   of energy in a year in their food. Let's assume that that food is mostly sugar for our estimate, with the chemical formula $C_6H_{12}O_6$. Smil says that sugars are 99% accessible for humans, so basically all the sugars are converted to CO2 and H20. The chemical exergy of $C_6H_{12}O_6$ is about 2930 kJ/mol, while the exergy of CO2 is about 20, H2O (liquid) is about 10. So, the reaction produces about 2900 kJ/mol. (All from Szargut) So, about

   $$\frac{3.05GJ}{2900kJ/mol} = 1050mol$$

   moles of sugar is converted per person per year. Each mole of sugar produces 6 moles of CO2. 1 mole CO2 = 44g, so

   $$1050mol \times 6 \times 44g/mol = 277kg/person/year$$

   Assuming 6.5 billion people on the planet, that gives

   $$277kg \times 6.5bil = 1.8GT\ CO2/year$$

   That's about 7% of world anthropogenic carbon.

2. *What temperature (K) is required to use carbon-to-carbon monoxide reduction to reduce Zinc oxide to Zinc?*

   Go to the Ellingham diagram, and find the intersection of the reaction lines $2Zn+O_2=2ZnO$ and $2C+O_2=2CO$, which is about 1200K.

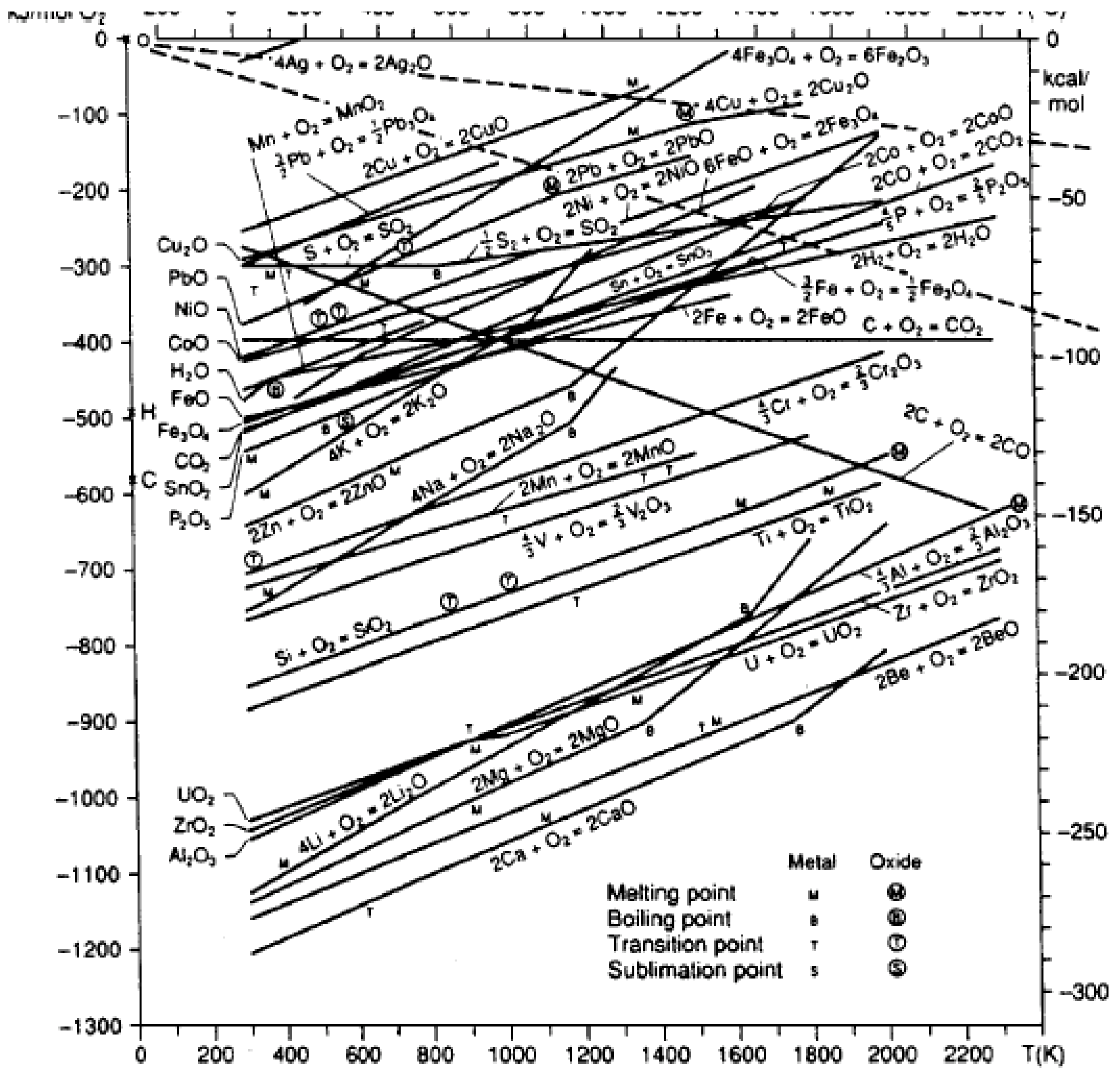

Figure 2 Ellingham diagram for oxides

3. *Do an exergy analysis of the reaction 2Cu2S+3CO2(g) -> 2Cu2O+2SO2, an important reaction in copper smelting.*

   Use Szargut tables to do the exergy analysis.

   $$2(791.8)+3(3.97)=2(124.4)+2(313.4)+\Delta B$$
   $$\Delta B=719.91 \text{ kj/mol}$$

   Since the change in exergy is from a high value to low, this is a spontaneous reaction. It is also exothermic, that is, you get heat energy out of this reaction.

4. *In our discussion of "The Mobilization of Materials by Human and Natural Activities", we mentioned that volcanism isn't considered by Klee and Graedel. How does it compare to other natural mobilization?*

   The lecture "The Mobilization of Materials by Human and Natural Activities" gives the volume of Krakatoa's 1883 explosion as 20km^3. The density of the crust is approximately 2.7g/cm^3.

$$20km^3 \times 2.7\tfrac{g}{cm3} \times \left(\frac{100,000cm}{km}\right)^3 = 54 \times 10^{15} g$$

Comparatively, erosion causes about 1.5 x 10^{15} g/yr of crust mobilization. The year that Krakatoa erupted, it dominated the natural flow of crust, but how often does an event of that magnitude occur? If we consider such an eruption as a once-every-fifty years event, then it's about on par with erosion. If we consider it a once-in-a-millennium event, then it's not as significant.

5. *Currently the world produces about 100 Mt of NH_3 fertilizer. According to Smil, the energy requirements are about 40 GJ/t NH_3. How does this compare with the minimum work required to make NH_3 (i.e. exergy)?*

   Use Szargut to find the exergy value of 337.9 kJ/mol and molecular mass of 17 g/mol.

$$337.9 kJ/mol \times \left(\frac{1{,}000{,}000 g/T}{17 g/mol}\right) = 19.8 GJ/T$$

   So, the current process for nitrogen fertilizer is relatively efficient (almost 50%)!

6. *Imagine we want to make hydrogen (H_2) for fuel. How do the electrolysis of water and the steam reforming of methane compare? (The reactions in consideration are H_2O -> H_2 +1/2O2 and CH_4+H_2O -> 4H_2 + CO_2.) Why does the second reaction appear more favorable? What is the trade-off?*

   Use values from Szargut. For the first reaction the required energy input is

$$1(0.9)=1(236.1)+1/2(3.97)+\Delta B$$
$$\Delta B=-237.185 \text{ kj/mol } H_2$$

   For the second reaction,

$$1/4(831.65)+1/2(9.5)=1(236.1)+1/4(19.87)+\Delta B$$
$$\Delta B=-28.405 \text{ kj/mol } H_2$$

   So the first reaction requires an additional exergy input of 240 kj/mol to produce a mol of H_2, while the second requires only 28 kj per mole. In the second reaction, we are using methane, a high exergy fuel, to create the hydrogen. We could just be burning methane directly!