AME 436	Assigned: Wednesday 1/28/09
Problem Set #1	• Due Friday 2/6/09 at 4:30 pm in OHE 430J • Email to the grader (Thada Suksila, ame436@yahoo.com) or fax to 213-740-8071 if you're off campus • DEN students submit through the usual channels

Problem #1 (25 points)

a) For the following fuel/oxidant combinations and presumed products balance the following reactions and calculate the stoichiometric fuel to oxidant ratios on a molar basis and on a mass basis:

Fuel + oxidant	Presumed products
H_2 + air	H_2O and N_2
CH_4 + air	CO_2, H_2O and N_2
CH_4 + air	CO, H_2 and N_2
CH_4 + N_2O	CO_2, H_2O and N_2
C_8H_{18} + NH_4NO_3 (ammonium nitrate)	N_2, H_2O and CO_2
CH_3NO_2 (nitromethane) + air	CO_2, H_2O and N_2

Use the property data in the table below.

Species	Δh_f^o (kJ/mole)	Mole. Wt. (g/mole)	Species	Δh_f^o (kJ/mole)	Mole. Wt. (g/mole)
CH_4	-74.87	16	O_2	0.00	32
H_2O	-241.84	18	N_2O	81.55	44
H_2	0.00	2	O_3	142.26	32
CO	-110.54	28	CO_2	-393.51	44
NH_4NO_3	-365.56	80	C_8H_{18}	-250.29	114

CH_3NO_2	-112.97	61	N_2	0.00	28

b) For the stoichiometric fuel/oxidant/product combinations above, calculate the heating value in Joules per kg of fuel. You'll need the enthalpies of formation and molecular weights for these species. **Watch units – kilojoules vs. Joules, kilograms vs. grams, moles vs. kilograms**

Problem #2 (25 points)

For a carbon monoxide-oxygen (not air!) mixture with equivalence ratio 0.35, initial temperature 500K and initial pressure 5 atm:

a) Assuming constant specific heats and all CO burns to form CO_2, determine the constant volume adiabatic flame temperature for this mixture. The average of C_v of the CO / O_2 mixture at 500K is 735 J/kgK.
b) Determine the final pressure.
c) Repeat Problem 2a assuming the combustion products are CO, O, O_2, O_3 and CO_2 using GASEQ. The procedure is as follows:

1. At the top of the page, under "Problem type" select "adiabatic T and composition at const v"
2. Under "Reactants" enter "CO" and hit return
3. Under "Reactants" enter "O2" and hit return
4. In the list of reactants click on "CO" then enter the number of moles of CO needed to obtain an equivalence ratio of 0.35
5. In the list of reactants click on "O2" then enter the number of moles of O2 needed to obtain an equivalence ratio of 0.35
6. In the box below the reactants box, enter the reactant temperature and pressure (500K, 5 atm in this case)
7. Under "Products" enter "CO" and hit return; repeat for O, O_2, O_3 and CO_2
8. Click on the "calculate" button

d) Show that the equilibrium concentrations of CO, O_2 and CO_2 predicted by GASEQ are consistent with a hand calculation (Lecture 3 notes, page 9). (You should find that the temperature is higher than 2500K, which is the maximum the tables on page 8 show, but if you double-click on the tables on page 8, you'll open up an excel spreadsheet which has the data up to 6000K. You can also get this table via a direct link from my website: http://ronney.usc.edu/AME436S09/GasThermoData.xls).
e) Why is the flame temperature and pressure so much lower in part c) than in a)? (There are two main reasons, both of which were discussed in class).

Problem #3 (15 points) (last year's final exam)

On Planet X the constant-pressure specific heats (C_p) of air and all other gases are 10% **higher** than they are on earth. All other properties of the atmosphere are exactly the same as on earth, in particular the mole-based ideal gas constant ($\Re$), molecular weight (M), thermal conductivity (k), density (ρ), mole fraction of O_2 in the atmosphere, etc. In particular, state whether each of these properties will be higher, lower or the same on Planet X, and if different, by less than, more than, or exactly a factor of 10%.

a) Gas specific heat ratio (γ)

b) Heating value of methane burning in air

c) Constant-volume adiabatic flame temperature

Problem #4 (15 points) (from last year's midterm exam)

On Jupiter is an atmosphere of 60% hydrogen (H_2) and 40% helium (He) (60%/40% on a molar basis) at a pressure of 0.2 MPa (2 earth atmospheres) total pressure at 200K . Deep underground are deposits of pure O_2 that the Jovians (residents of Jupiter) pump out of the ground. Unfortunately, most of the O_2 wells are located in politically unstable regions of Jupiter, so this O_2 is a valuable resource which they call "fuel." The hydrogen/helium mixture in the atmosphere, which they call "air," is "free" as far as Jovians are concerned.

Thermodynamic data: average mixture properties $\gamma = 1.3$, R = 300 J/kgK, $C_V = 1000$ J/kgK

	H_2	O_2	He	H_2O
Δh_f^o (kJ/mole)	0	0	0	-241.83
Molecular weight (g/mole)	2	32	4	18

a) What is the "heating value" (in J/kg) of the O_2 "fuel" that they burn with the H_2 –He "air," assuming the combustion products are only H_2O and He?

b) What is the stoichiometric "fuel" to "air" mass ratio?

c) What is the constant-**pressure** adiabatic flame temperature of stoichiometric "fuel" + "air" mixtures?

Problem #5 (20 points) (from a previous year's midterm)

In a combustion experiment at 10 atm total pressure, the measured flame temperature was 3500K and the following combustion product mole fractions were measured:

H_2O: 0.52059 H_2: 0.29432

H and OH are also present in the products, but the mole fractions are unknown. No other chemical species are present in the products.

a) If it can be assumed that the products are in chemical equilibrium, determine the mole fraction of H in the products.
b) Determine the mole fraction of OH in the products.
c) Determine the H/O atom ratio {i.e. the total amount of H (in the form of H, H_2, H_2O or OH) to the total amount of O (in the form of H_2O or OH)}.
d) If the **reactants** (not **products**) were H_2 and O_2 only, what was the equivalence ratio of the reactants?

Again, use the equilibrium constant data from the tables on page 8, lecture 3 or from http://ronney.usc.edu/AME436S09/GasThermoData.xls).