

ME 18b, HW 6

Due May 20, 2008 (by 5 pm)

We will not have class on Tuesday, May 20. Please drop homework in my box.

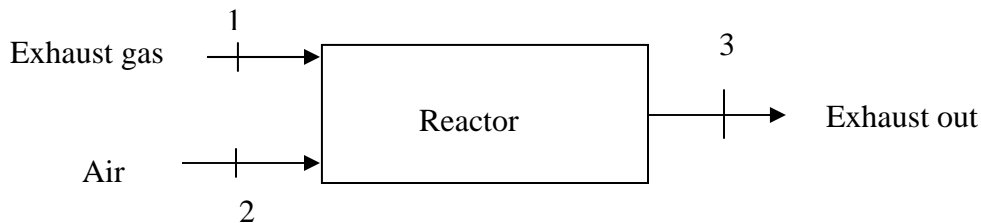
Reading: Chapters 14 and 15 in Sonntag, Borgnakke & Van Wylen.

6.1 Burning of a fuel (S, B & V 14.31)

A fuel, C_xH_y , is burned with dry air, and the product composition is measured on a dry mole basis to be: 9.6% CO_2 , 7.3% O_2 , 83.1% N_2 . Find the fuel composition (x/y) and the percent theoretical air used.

6.2 Exhaust gases from an IC engine (S,B & V 14.36; answer in book)

The hot exhaust gas from an internal combustion engine is analyzed and found to have the following percent composition on a volumetric basis at the engine exhaust manifold: 10% CO_2 , 2% CO , 13% H_2O , 3% O_2 , 72% N_2 . This gas is fed to an exhaust gas reactor and mixed with a certain amount of air to eliminate the carbon monoxide, as shown in the figure. It has been determined that a mole fraction of 10% oxygen in the mixture at state 3 will ensure that no CO remains. What must be the ratio of volumetric flow rates entering the reactor?



6.3 Methanol combustion.

An alternative to using petroleum or natural gas as fuels is methanol (CH_3OH), which can be produced from coal. Consider a combustion process in which **liquid** methanol is burned with 120% theoretical air in a steady flow process. The reactants enter the combustion chamber at $25^\circ C$, and the products exit at $60^\circ C$. The pressure is constant at 100 kPa.

- Calculate the fuel air ratio.
- Calculate the heat transfer per kilomole of methanol, using the enthalpy of formation of methanol (Table A.15) and the gas tables (Tables A.12). (The book does not tell you, but use $\bar{h}_{fg} = 8846 \text{ kJ/kmol}$ for methanol.)
- Does the water in the products condense?
- If the products were at $50^\circ C$, does the water condense? What is the heat transfer per kilomole of methanol for this exit temperature? For the change in enthalpy of the liquid water use $\Delta \bar{h} = M_{H_2O} [h_f(50^\circ C) - h_f(25^\circ C)]$.

6.4 Space Shuttle Engines.

Each of the main engines on the Space Shuttle burns liquid hydrogen (H_2) and liquid oxygen (O_2) at a **mass ratio** of 1 kg H_2 to 6 kg O_2 .

- a) Write a balanced chemical equation for the reaction. If there is excess O_2 , the products are H_2O and O_2 . If there is deficient O_2 the products are H_2O and H_2 . Assume that there is no dissociation of the products.
- b) The fuel and oxidizer pumps increase the pressure of the H_2 and the O_2 to 20 MPa. The oxygen and hydrogen enter a pre-burner that increases their temperatures to 900 K; these gaseous reactants at 900 K then enter the combustion chamber. If the temperature in the combustion chamber is 3400 K, what is the heat transfer to or from the combustion chamber in kJ per 1 kilogram of H_2 fuel? Assume that the combustion process happens at a constant pressure.
- c) Assume that there is no heat transfer in the combustion chamber. Find the adiabatic flame temperature.