Tutorial 4

The liquid hydrogen fuel in the Space Shuttle main engine is pressurized to the very high combustion chamber pressure by a turbopump which is driven by a turbine. The gas driving this turbine is generated in a “preburner”, into which the flow rates of oxygen and hydrogen are 43 kg/sec and 40.2 kg/sec. Determine the equivalence ratio of this combustion reaction. Also conclude whether it is fuel rich combustion or oxidizer rich combustion.

Space Shuttle’s main engine burns hydrogen and oxygen to generate the thrust. For simplicity, assume that the equivalence ratio is 1 and the reactants enter the chamber at 298 K. Determine the adiabatic flame temperature in the combustion chamber. (Standard heat of formation of H_2O = -241.997 kJ/mol, C_p of H_2O = 53.9 kJ/kmol-K).

The experimental data shows that the equilibrium products coming out of nozzle are as follows:

$$2H_2 + O_2 \rightarrow 1.83\, H_2O + 0.17\, H_2 + 0.085\, O_2$$

Determine the actual flame temperature corresponding to above equilibrium reaction. What is the effect on c* value? (Cp values for H2 and O2 are 35.811 and 38.9 kJ/kmolK respectively)

A semi-cryogenic engine burns liquid kerosene and oxygen in its combustor at φ=1. Kerosene can be approximated by $C_{12}H_{24}$. For simplicity, assume vapours of kerosene and gaseous oxygen are present at reference temperature of 298 K prior to combustion and combustion is complete. Determine the stoichiometric fuel-oxidizer ratio and adiabatic flame temperature. Standard heat of formation of octane is -159 kJ/mol.

	Heat of formation (kJ/mol)	Cp kJ/kmol.K
CO_2	-393.978	60.43
H_2O	-241.997	53.9

Estimate the adiabatic flame temperature of methane-air combustion with equivalence ratio of 1.2. The reactants are at reference state before combustion.

Species	CH4	CO2	H2O	N2
Heat of formation kJ/mol	-74.83	-393.978	-241.997	--
Cp kJ/molK	0.0358	0.0562	0.0439	0.0337