Problem 1

Monopropellants, like Hydrazine (N_2H_4) and Hydrogen Peroxide (H_2O_2) are attractive for rocket propulsion systems because of their relative simplicity and good performance.

Highly concentrated solutions of H_2O_2 in water are unstable and decompose violently when exposed to impurities and/or active surfaces. Such an energetic decomposition is desirable in a rocket, but care has to be taken when handling the solution.

The decomposition reaction of 100% pure H_2O_2 produces water vapor and oxygen gas.

(a) Write down the reaction for full decomposition.

(b) Calculate the adiabatic flame temperature (T_f) using the attached tables. Interpolate or extrapolate, when needed.

NOTES:

- H_2O_2 is injected in its liquid state at 298°K and has a heat of formation of -187.9 KJ/mol.

-To help you find an initial T_f, use a linear approximation for the enthalpy ($h = c_pT$) with the specific heat values (in J/K/mol) of H_2O and O_2 at 298°K.

Solutions. Problem 1

(a) Full decomposition of H_2O_2 should read:

$$H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2$$

(b) From the tables read cp_{O2} and cp_{H2O} at 298°K:

$$cp_{O2} = 29.378\ J/\cdot K/mol \qquad \Delta h^o_{H2O} = 291.826\frac{KJ}{mol}$$

$$cp_{H_2O} = 33.598\ J/\cdot K/mol$$

To estimate an initial search temperature ($T_1 = T_f - T_{ref}$):

$$-187.9\frac{KJ}{mol} = \left(cp_{H_2O}T_1 + \Delta h^\circ_{f_{H_2O}}\right) + \frac{1}{2}\left(cp_{O2}T_1\right)$$

$$T_1 = \frac{(-187.9 + 241.826)\times 1000}{33.598 + (0.5)29.378} = 1120\cdot K \qquad \text{then } T_f = 1418\ K$$

Use tables to find $h_{before} = h_{after}$

$$h_{before} = \frac{-187.9\ KJ/mol}{0.084\ Kg/mol} = -5.526\frac{MJ}{Kg}$$

h_{after}:

start at 1200°K

$$h_{after} = \frac{(34.574 - 241.826)1000 + 0.5(29.768 + 0)1000}{1(0.018) + 0.5(0.032)} = -5.657\frac{MJ}{Kg}$$

(need more, more positive)

at 1300°K $$h_{after} = \frac{(39.028 - 241.826)1000 + 0.5(38.352 + 0)1000}{1(0.018) + 0.5(0.032)} = -5.474 \frac{MJ}{Kg}$$

(need less, more negative)

Answer is between $1200 \cdot K$ and $1300 \cdot \mathrm{K}$:

Interpolate:

$$T_f = 1200 + (1300 - 1200)\left(\frac{5.657 - 5.526}{5.657 - 5.474}\right) = \underline{\underline{1271 \cdot K}}$$