

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.

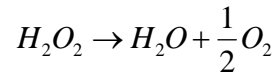
- (a) Write down the reaction for full decomposition.
- (b) Calculate the adiabatic flame temperature (T_f) using the attached tables. Interpolate or extrapolate, when needed.

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 ($h = c_p T$) 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:



(b) From the tables read cp_{O_2} and cp_{H_2O} at 298°K:

$$cp_{O_2} = 29.378 \text{ J} \cdot \text{K} / \text{mol} \quad \Delta h_{H_2O}^\circ = 291.826 \frac{\text{KJ}}{\text{mol}}$$

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

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

$$-187.9 \frac{\text{KJ}}{\text{mol}} = \left(cp_{H_2O} T_1 + \Delta h_{f_{H_2O}}^\circ \right) + \frac{1}{2} (cp_{O_2} T_1)$$

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

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

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

h_{after} :

start at 1200°K

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

(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 · K and 1300 · K:

Interpolate:

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