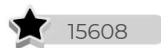


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## MC-Tema-9.pdf

*Ejercicios Libro Mot. Cohete*



**3º Motores Cohete**



**Grado en Ingeniería Aeroespacial**

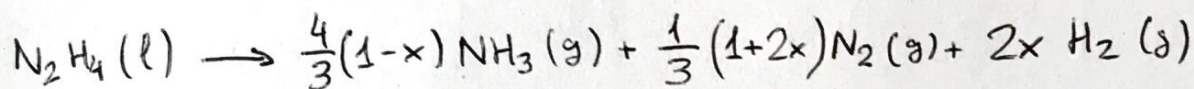


**Escuela Técnica Superior de Ingeniería Aeronáutica y del Espacio  
Universidad Politécnica de Madrid**

# Problema 9.1.

(\*)

1º) MCPL



2º)  $\varepsilon = 40$

3º) Se descompone 40% ~~NH<sub>3</sub>~~ <sup>NH<sub>3</sub></sup> al ingresar en la tobera

4º)  $T_e = T_{\text{ref}} = 298,15 \text{ K}$

5º) Datos

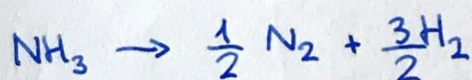
$$C_{p,\text{NH}_3} = 57 \frac{\text{J}}{\text{mol} \cdot \text{K}} ; C_{p,\text{H}_2} = 28 \frac{\text{J}}{\text{mol} \cdot \text{K}} ; \Delta_f h^\circ_{\text{N}_2\text{H}_4} = 50,63 \frac{\text{kJ}}{\text{mol}}$$

$$\Delta_f h^\circ_{\text{NH}_3} = -45,90 \frac{\text{kJ}}{\text{mol}} ; M_{\text{N}} = 14 \frac{\text{g}}{\text{mol}} ; M_{\text{H}} = 1 \frac{\text{g}}{\text{mol}}$$

¿Isp en vacío?

$$\varepsilon = 40 \rightarrow \frac{P_3}{P_c} =$$

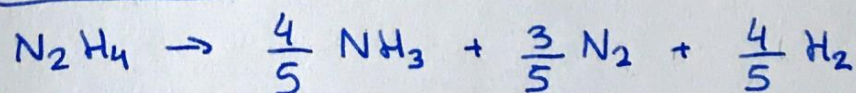
Descomposición NH<sub>3</sub> (Amoníaco)



Descomposición N<sub>2</sub>H<sub>4</sub> (Hidracina)  $x=1 \rightarrow \text{Esteg.}$



Solo se descompone 40% NH<sub>3</sub>  $\rightarrow x=0,4$



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Como  $I_{sp} = C^* C_E \rightarrow C^* = \frac{\sqrt{RT_c}}{P(\gamma)}$  Hay que sacar  $T_c$  y  $\gamma$

$\sum \Delta H_{react} = \sum \Delta H_{prod}$  Adiabático

$$\Delta_f h_{N_2H_4}^{\circ} = \frac{4}{5} \left( \Delta_f h_{NH_3}^{\circ} + C_{p,NH_3} \Delta T \right) + \frac{3}{5} \left( \cancel{\Delta_f h_{N_2}^{\circ}} + C_{p,N_2} \Delta T \right) + \frac{4}{5} \left( \cancel{\Delta_f h_{H_2}^{\circ}} + C_{p,H_2} \Delta T \right)$$

0

$$\Delta_f h_{N_2H_4} = \Delta T \left( \frac{4}{5} C_{p,NH_3} + \frac{3}{5} C_{p,N_2} + \frac{4}{5} C_{p,H_2} \right) + \frac{4}{5} \Delta_f h_{NH_3}^{\circ}$$

$$\Delta T = \frac{\Delta_f h_{N_2H_4} - \frac{4}{5} \Delta_f h_{NH_3}^{\circ}}{\frac{4}{5} C_{p,NH_3} + \frac{3}{5} C_{p,N_2} + \frac{4}{5} C_{p,H_2}} = 1015,7 \text{ K}$$

$$T_c = T_{ref} + \Delta T = \boxed{1314 \text{ K} = T_c}$$

$$\bar{C}_p = \frac{\frac{4}{5} C_{p,NH_3} + \frac{3}{5} C_{p,N_2} + \frac{4}{5} C_{p,H_2}}{\frac{4}{5} + \frac{3}{5} + \frac{4}{5}} = \boxed{39,1 \frac{\text{J}}{\text{mol} \cdot \text{K}} = \bar{C}_p}$$

$$\gamma = \frac{C_p}{C_v} \rightarrow R = C_p - C_v \Rightarrow C_v = C_p - R \rightarrow \gamma = \frac{C_p}{C_p - R} \rightarrow \cancel{\frac{C_p}{C_p - R}}$$

$$\boxed{\gamma = 1,27} \rightarrow P(\gamma) = \sqrt{\gamma} \left( \frac{1+\gamma}{2} \right)^{-\frac{\gamma+1}{2(\gamma-1)}} \Rightarrow \boxed{P(\gamma) = 0,662}$$

$$\cancel{C_p} \rightarrow \frac{P_c}{P_c}$$



# ENCENDER TU LLAMA CUESTA MUY POCO



$$P_g = \frac{R}{\bar{M}} \Rightarrow \bar{M} = \frac{\frac{4}{5} \times 17 + \frac{3}{5} \times 23 + \frac{4}{5} \times 2}{\frac{11}{5}} = 14,545 \frac{\text{g}}{\text{mol}}$$

CONT. PROBLEMA 9.1

$$R = 571,6 \frac{\text{J}}{\text{kg} \cdot \text{K}}$$

$$\varepsilon = 40 \rightarrow \frac{P_s}{P_c} = 1,587 \times 10^{-3}$$

$$C_E = P(\gamma) \sqrt{\quad} + \varepsilon \frac{P_s}{P_c} = 1,82$$

$$C^* = \frac{\sqrt{RT_c}}{P(\gamma)} = 1309,14 \text{ m/s}$$

$$I_{sp} = C^* C_E$$

$$I_{sp} = 2382,63 \text{ m/s} = 243 \text{ s}$$

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# Problema 9.2

1º) MCPL = Hidráulica monopropul.

2º) Incrementador empuje

$$\frac{\dot{W}}{\dot{m}} = 2 \frac{\text{MJ}}{\text{kg}}$$

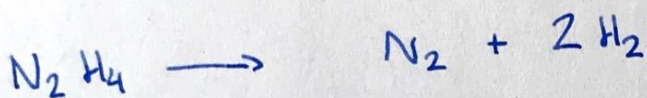
3º) En equilibrio solo  $\text{N}_2, \text{H}_2$

4º)  $\varepsilon = 90$

5º) Datos:

$$C_{\text{PNH}_3} = 57 \frac{\text{J}}{\text{mol} \cdot \text{K}} ; C_{\text{PN}_2} = 30 \frac{\text{J}}{\text{mol} \cdot \text{K}} ; C_{\text{PH}_2} = 28 \frac{\text{J}}{\text{mol} \cdot \text{K}}$$

$$\Delta_f h_{\text{N}_2\text{H}_4} = 50,63 \frac{\text{kJ}}{\text{mol}} ; \Delta_f h_{\text{NH}_3} = -45,90 \frac{\text{kJ}}{\text{mol}}$$



$$\sum \Delta H_{\text{react}} = \sum \Delta H_{\text{prod}}$$

$$\Delta_f h_{\text{N}_2\text{H}_4} = \cancel{\Delta_f h_{\text{N}_2}^0} + C_{\text{PN}_2} \Delta T + 2 \cancel{\Delta_f h_{\text{H}_2}^0} + 2 C_{\text{PH}_2} \Delta T$$

$$\Delta T = \frac{\Delta_f h_{\text{N}_2\text{H}_4} - \cancel{\Delta_f h_{\text{N}_2}^0}}{C_{\text{PN}_2} + 2 C_{\text{PH}_2}} = 588,72 \rightarrow T_c = 886,87 \text{ K}$$

$$\bar{C}_p = \frac{C_{\text{PN}_2} + 2 C_{\text{PH}_2}}{1 + 2} = \boxed{28,67 \frac{\text{J}}{\text{mol} \cdot \text{K}} = \bar{C}_p}$$

$$R = 79,24 \frac{\text{J}}{\text{kg} \cdot \text{K}}$$

$$\bar{M} = \frac{2 \times 14 + 2 \times 2}{3} = \boxed{10,67 \frac{\text{g}}{\text{mol}} = \bar{M}}$$

$$\gamma = 1,41 \quad \Gamma(\gamma) = 0,686$$



$$C^* = \frac{\sqrt{RT_1}}{P(x)} = 1212 \text{ m/s} = C_1^*$$

$$\varepsilon = 90 \rightarrow \frac{P_3}{P_c} = 2,839 \times 10^{-4}$$

Suponemos vacío

$$C_\varepsilon = 1,74$$

El incrementador de empuje a media carga  $\eta = 0,5$

$$\bar{Q} (T_{c2} - T_{c1}) = 0,5 \underbrace{\left( \frac{\dot{W}}{\dot{m}} \right)}_Q \rightarrow T_{c2} = 1258,17 \text{ K}$$

$$\Delta H = Q$$