fuel equivalence ratio.

$$\phi = \frac{(A/F)_{stoic}}{(A/F)_{act.}} = \frac{(F/A)_{act}}{(F/A)_{stoc.}}$$

$$\phi = 1 \quad \Rightarrow \quad \text{stoich.}$$
$$\phi < 1 \quad \Rightarrow \quad \text{fuel lean}$$
$$\phi > 1 \quad \Rightarrow \quad \text{fuel rich}$$

% stoichiometric air: $\quad \dfrac{100\%}{\phi}$

% excess air : $\quad \dfrac{(1-\phi)}{\phi} \; 100\%$

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heat   (if exothermic)
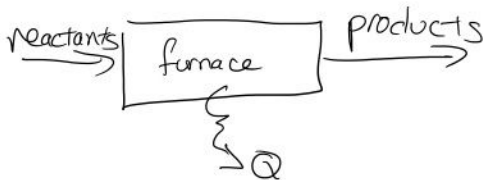
$$Q - W = \Delta E$$
$$-Q = \Delta h = H_{prod} - H_{react}$$

Standard enthalpy: the sum of + the
energy associated w/ chemical bonds,
the __enthalpy of formation__ h_f , and
a temperature dependent enthalpy
called the __sensible enthalpy change__ Δh_s

$$\overline{h}_i(T) = \overline{h}^{\,o}_{f,i}(T_{ref}) + \Delta \overline{h}_{s,i}(T)$$

Standard   enthalpy of formation   sensible
enthalpy @ T   at STP (T_{ref}, p^o) enthalpy
for i for i for $T_{ref} - T$

$$\overline{T} \qquad \qquad \overline{T} \qquad \qquad \overline{T}^{\,o}$$

$$\Delta h_{s,i} \equiv h_i(T) - h_{f,i}(T_{ref})$$

$$\overline{h}_f^{\,o} \rightarrow STP \ (298K, \ 1\,atm)$$

O: O_2

H: H_2

C: graphite

$$\left(\overline{h}_{f,O_2}^{\,o}\right)_{298} = 0$$

○ : Bond Dissociation Energy O_2 @ 298K
$$= 498,370 \ kJ/kmol_{O_2}$$

$$1\,O_2 \rightarrow 2\,O$$
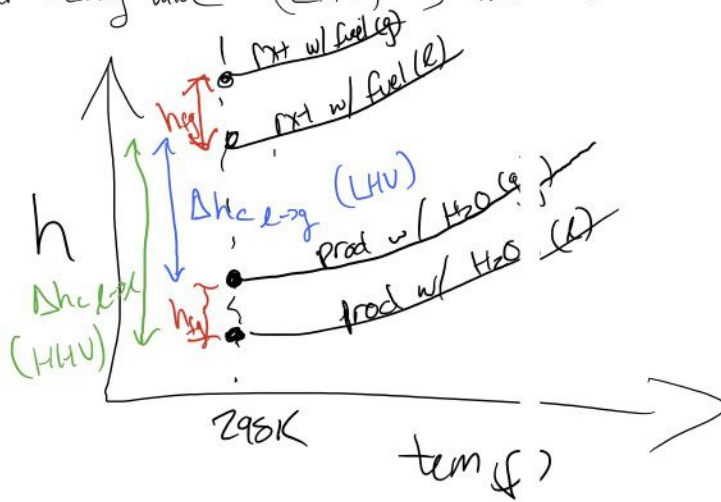$$\hookrightarrow \left(\overline{h}_{f,O}^{\,o}\right) = 249,195 \ kJ/kmol_{\,O}$$
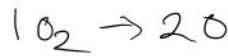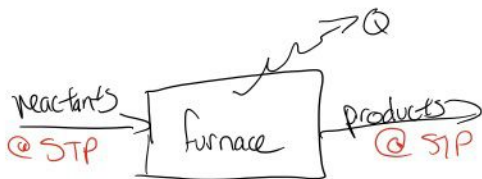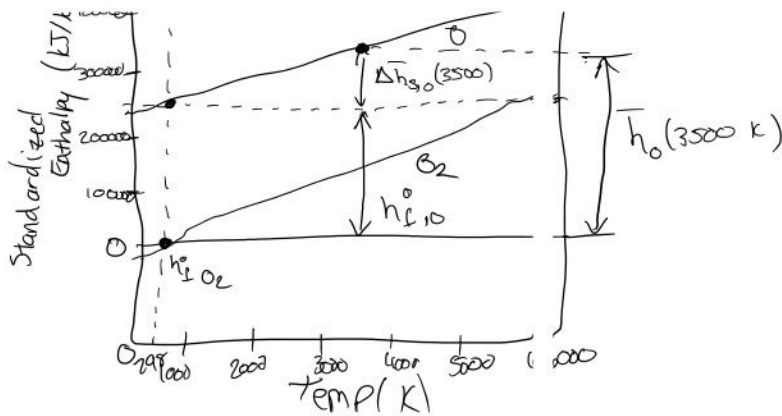
$$h_{prod} - h_{rxt} = -q \equiv \Delta h_{rxn}$$

$$\Delta h_{rxn} = -\Delta h_{comb.}$$

$\hookrightarrow$ heating value

- upper heating value (HHV) $\rightarrow$ all water is liq.
- lower heating value (LHV) $\rightarrow$ all water is vapor.

HHV > LHV

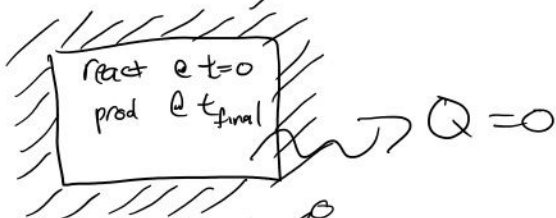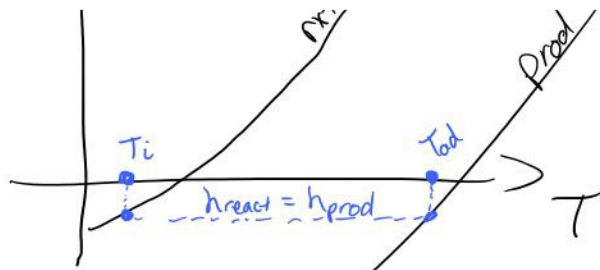Vaporized fuel has $\uparrow \Delta h_c$
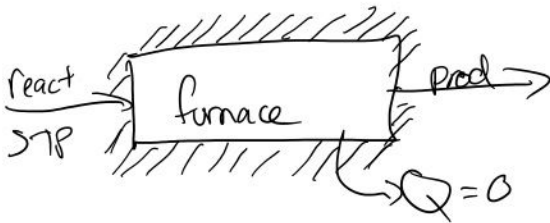
— assume adiabatic
— rxt. @ STP
— Const P.

$$\cancel{Q} - \cancel{w} = \Delta h \Rightarrow h_{prod} = h_{rxt}$$

$$h_{rxn}(T_i, P) = h_{prod}(T_{ad}, P?)$$

$h \uparrow$

Graph showing curves labeled "rxt" and "prod" vs T, with points T_i and T_{ad}, dashed line $h_{react} = h_{prod}$

$$Q = 0$$

react @ $t=0$
prod @ t_{final}

$$\cancel{Q}^0 - \cancel{W}^0 = \Delta E = U_{prod} - U_{rxt}$$

$$\rightarrow U_{rxt}(T_i, P_i) = U_{prod}(T_{ad}, P_f)$$

$$\rightarrow H_{react} = U_{rxt} + P_i V$$

$$| \quad - \quad || \qquad \sqcup \quad | \; - V(P_i - P_n) = 0$$

$$\text{M}_{rxt} - \text{l}_{prod} \quad \vee \quad | \cdot \cdot \quad + \cdot$$

$$PV = nRT$$

$$H_{rxt} - H_{prod} - R_u(T_i \, n_{rxt} - T_{ad} \, n_{prod}) = 0$$

$$m_{rxt} = m_{mix} = m_{prod}$$

$$n_{rxt} \, MW_{rxt} = n_{prod} \, MW_{prod}$$

$$h_{rxt} - h_{prod} - R_u\left(\frac{T_i}{MW_{rxt}} - \frac{T_{ad}}{MW_{prod}}\right) = 0$$

$$C_x H_y + z O_2 \rightarrow x CO_2 + \frac{y}{2} H_2O$$

CH_4

$CH_3O-H \rightarrow CH_3O + OH$

$CH_2 \qquad CH_3 CH \qquad CH_2O$

$CH_3 \xrightarrow{} C_2H_6 \xrightarrow{} H_2CO + H_2C$

CO
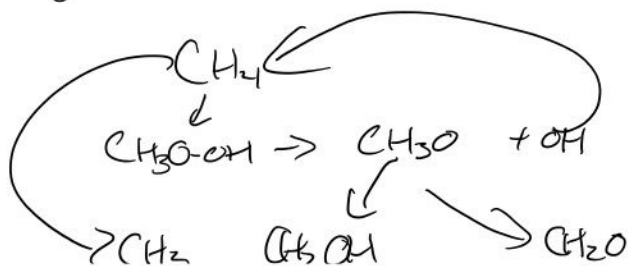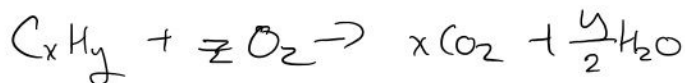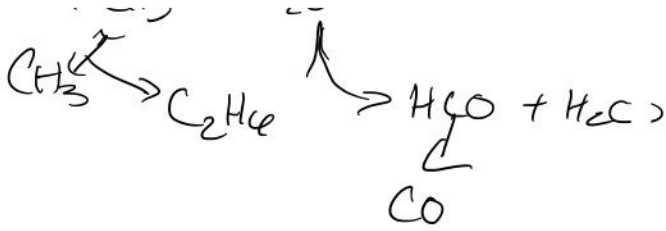
what is true?

- mass is conserved
- elements are conserved
- 1st 2nd laws apply

$$CO + \tfrac{1}{2}O_2 \leftrightharpoons CO_2$$

$$T \uparrow \Rightarrow CO_2 \to CO + \tfrac{1}{2}O_2$$

$$\alpha = \%$$

$$(CO + \tfrac{1}{2}O_2) \to \left((1-\alpha)CO_2 + \alpha CO + \tfrac{\alpha}{2}O_2\right)$$

$$CO + \tfrac{1}{2}O_2 \to CO_2 \qquad \Delta h_e < 0$$
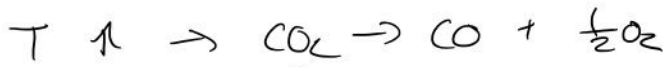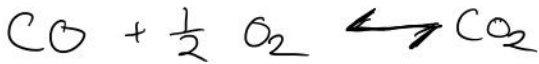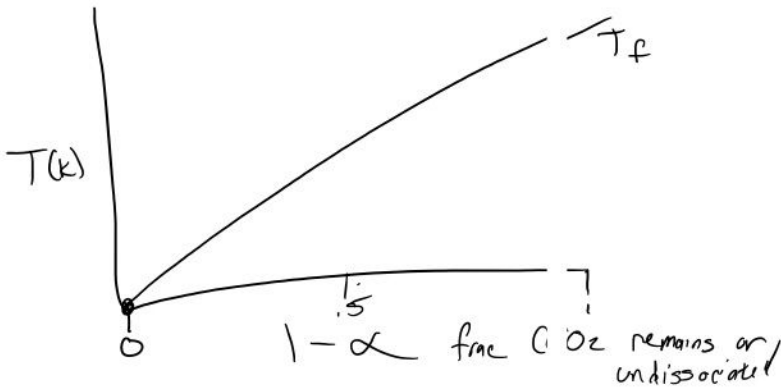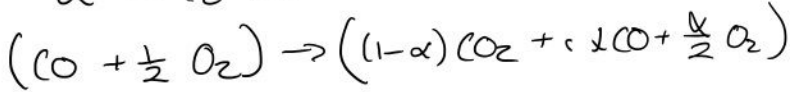
$T(k)$ vs $1-\alpha$ frac CO_2 remains or undissociated, with T_f curve and $.5$ marked

$$S_{final} = S_{mix}(T_f, P) = \sum_{prod} N_i \, \overline{S_i}(T_f, P)$$

$$= (1-\alpha)\,\overline{S}_{CO_2} + \alpha \; \overline{S}_{CO} + \tfrac{\alpha}{2}\overline{S}_{O_2}$$

$$\overline{S_i} = \overline{S_i}(T_{ref}) + \int_{T_{ref}}^{T_f} \overline{C_{p_i}}\frac{dT}{T} - - R_u \ln\left(\frac{P_i}{P_o}\right)$$

S_{max}

$$(dS)_{U,V,m} = 0 \quad @ \quad eq.$$

NASA Gas E_q $\Leftarrow$