Example

Reconsider the dubious bovine flatulence problem, but this time assume *complete combustion*. The enthalpy of reaction for methane is –802,290 kJ/kmol-CH_4 at 25°C (298 K) and 1 atm. As before, both the methane and the air enter at 1 bar and 25°C, and the products leave the chamber at 500 K and 1 atm.

(a) Find the heat transfer rate per unit molar flow rate of fuel for the process.
(b) Find the higher heating value, HHV.
(c) Find the higher heating value, LHV.

(a) NEED A NEW RXN!

$$CH_4 + a(O_2 + 3.76N_2) \rightarrow b\,CO_2 + c\,H_2O + d\,N_2$$

C: $1 = b$

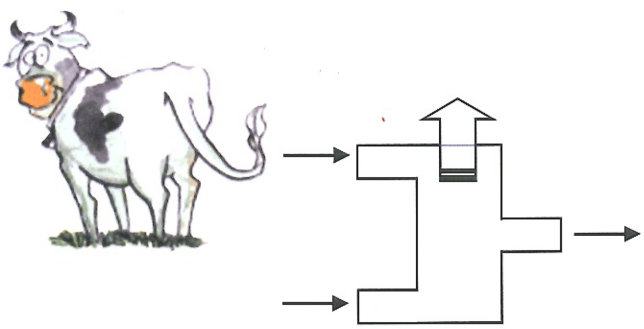
H: $4 = 2c \qquad c = 2$

O: $2a = 2b + c = 2(1) + (2)$

$a = 2$

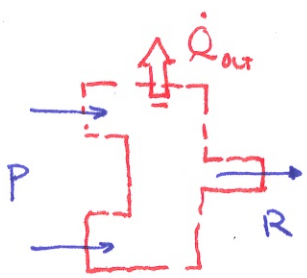
N: $(a)(3.76)(2) = d(N_2)$

(2) " " = " $\quad d = 7.52$



BALANCED RXN

$$CH_4 + 2O_2 + 7.52N_2 \rightarrow CO_2 + 2H_2O + 7.52N_2$$



Cons. of energy

$$0 = -\dot{Q}_{OUT} - 0 + \sum_R \dot{n}\bar{h} - \sum_P \dot{n}\bar{h}_P$$

$$\frac{\dot{Q}_{OUT}}{\dot{n}_{CH_4}} = \frac{\sum_R \dot{n}\bar{h} - \sum_P \dot{n}\bar{h}}{\dot{n}_{CH_4}}$$

$$\frac{\dot{Q}_{OUT}}{\dot{n}_{CH_4}} = \underbrace{\left[\sum_R \nu_i\bar{h}_i - \sum_P \nu_i\bar{h}_i\right]_{298}}_{\equiv -\bar{h}^\circ_{RP}} + \sum_R \nu_i\cancelto{0}{(\bar{h}(298) - \bar{h}(298))} - \sum_P \nu_i(\bar{h}(500\,K) - \bar{h}(298))$$

$$= 802{,}290\ \frac{kJ}{kmol} - \left[(1)(17{,}689 - 9364) + (2)(16{,}828 - 9904) + 7.52(14{,}581 - 8669)\right]$$

$$= \boxed{735,659 \text{ kJ/kmol}}$$

(b) FIRST DETERMINE PHASE of H_2O IN PRDTS

$$P_v(T=?\ ) \leq P_{SAT}(T_{\text{ADIAB FLAME!}} \approx 2500\text{K!!})$$

IT'S VAPOR PHASE, THEN!! $\longrightarrow$ ALMOST ALWAYS.

SO LHV FIRST!

$$LHV = -h^\circ_{RP} = \frac{-\bar{h}^\circ_{RP}}{M_{CH_4}} = \frac{+802,290 \text{ kJ}/\cancel{\text{kmol}}}{16.04 \text{ kg}/\cancel{\text{kmol}}}$$

$$= \boxed{50,018 \text{ kJ/kg}} \longleftarrow (c)$$

$$HHV = LHV + \frac{m_{WAT,PDT}}{m_{fuel}} h_{fg\,WAT}$$

$$= LHV + \frac{n_{WAT} M_{WAT}}{n_f M_f} h_{fg} = 50,018 + \frac{(2)(18.02)}{(1)(16.04)}(2442)$$

$$= \boxed{55,505 \text{ kJ/kg}}$$