Neraca energi dengan reaksi kimia

Part 2

REAKSI ADIABATIS

- adalah reaksi yang dijalankan dalam suatu tempat dimana tidak ada panas yang ditambahkan atau dihilangkan.
- Reaksi adiabatis dijalankan dalam reaktor tanpa pemanas maupun pendingin, sehingga:

  a. Jika reaksi bersifat endotermis (membutuhkan panas) maka reaksi akan menurunkan suhu produk reaktor.

  b. Jika reaksi bersifat eksotermis (menghasilkan panas) maka reaksi akan menaikkan suhu produk reaktor.
- Neraca Panas reaksi adiabatis:

$$\Delta H_R = 0$$

$$\Delta H_R = \Delta H1 + \Delta Hr^o + \Delta H2$$

9.5-3 *Energy Balance on an Adiabatic Reactor*

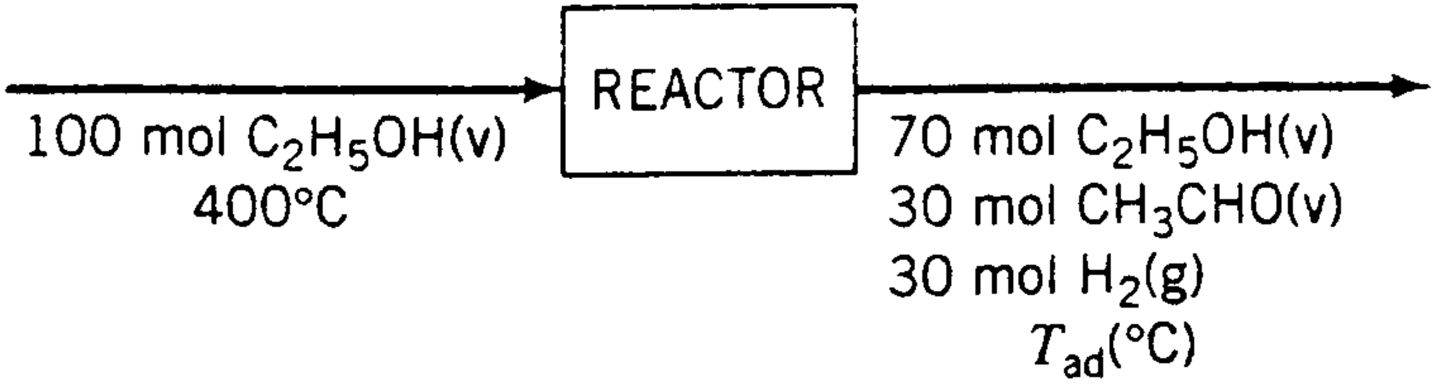
The dehydrogenation of ethanol to form acetaldehyde

$$C_2H_5OH(v) \rightarrow CH_3CHO(v) + H_2(g)$$

is carried out in a continuous adiabatic reactor. Ethanol vapor is fed to the reactor at 400°C, and a conversion of 30% is obtained. Calculate the product temperature.

Basis: 100 mol Feed

Material balances lead to the information on the flowchart shown here.



HEATING VALUE

- Adalah nilai negatif dari panas pembakaran standar
- HIGHER HEATING VALUE (HHV) atau TOTAL HEATING VALUE atau GROSS HEATING VALUE adalah $-\Delta H_c^o$ dengan H_2O (l) sebagai hasil pembakaran
- LOWER HEATING VALUE (LHV) atau NET HEATING VALUE adalah nilai dengan H_2O (g) sebagai hasil pembakaran

$$HHV = LHV + n\,\Delta\hat{H}_v(H_2O,\ 25°C)$$

$$\Delta\hat{H}_v(H_2O,\ 25°C) = 44.013\ \text{kJ/mol}$$
$$= 18{,}934\ \text{Btu/lb-mole}$$

- **Jika bahan bakar merupakan campuran maka**

$$HV = \sum x_i (HV)_i$$

- X_i merupakan fraksi massa atau fraksi mol

Table 9.6-1 Typical Heating Values of Common Fuels

Fuel	*Higher Heating Value* kJ/g	*Higher Heating Value* Btu/lb_m
Wood	17	7700
Soft coal	23	10,000
Hard coal	35	15,000
Fuel oil, gasoline	44	19,000
Natural gas	54	23,000
Hydrogen	143	61,000

Contoh 9.6-1 F-R

Calculation of a Heating Value

A natural gas contains 85% methane and 15% ethane by volume. The heats of combustion of methane and ethane at 25°C and 1 atm with water *vapor* as the assumed product are given below:

$$CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(v): \quad \Delta\hat{H}_c^\circ = -802 \text{ kJ/mol}$$

$$C_2H_6(g) + \tfrac{7}{2}O_2(g) \rightarrow 2\,CO_2(v) + 3\,H_2O(v): \quad \Delta\hat{H}_c^\circ = -1428 \text{ kJ/mol}$$

Calculate the higher heating value (kJ/g) of the natural gas.

Since the heating value per unit mass of the fuel is desired, we will first calculate the composition on a mass basis:

$$1 \text{ mol fuel} \Longrightarrow \begin{array}{l} 0.85 \text{ mol } CH_4 \Longrightarrow 13.6 \text{ g } CH_4 \\ 0.15 \text{ mol } C_2H_6 \Longrightarrow \underline{4.5 \text{ g } C_2H_6} \\ \qquad\qquad\qquad\qquad\quad 18.1 \text{ g total} \end{array}$$

Thus

$$x_{CH_4} = 13.6 \text{ g } CH_4 / 18.1 \text{ g} = 0.751 \text{ g } CH_4/\text{g fuel}$$

$$x_{C_2H_6} = 1 - x_{CH_4} = 0.249 \text{ g } C_2H_6/\text{g fuel}$$

The higher heating values of the components are calculated from the given heats of combustion (which are the negatives of the lower heating values) as follows:

$$(HHV)_{CH_4} = (LHV)_{CH_4} + n_{H_2O}(\Delta\hat{H}_v)_{H_2O}$$

$$= \left[802 \frac{\text{kJ}}{\text{mol } CH_4} + \frac{2 \text{ mol } H_2O}{\text{mol } CH_4}\left(44.013 \frac{\text{kJ}}{\text{mol } H_2O}\right)\right] \frac{1 \text{ mol}}{16.0 \text{ g } CH_4}$$

$$= 55.6 \text{ kJ/g}$$

$$(HHV)_{C_2H_6} = \left[1428 \frac{\text{kJ}}{\text{mol } C_2H_6} + \frac{3 \text{ mol } H_2O}{\text{mol } C_2H_6}\left(44.013 \frac{\text{kJ}}{\text{mol } H_2O}\right)\right] \frac{1 \text{ mol}}{30.0 \text{ g } C_2H_6}$$

$$= 52.0 \text{ kJ/g}$$

The higher heating value of the mixture is from Equation 9.6-3:

$$HHV = x_{CH_4}(HHV)_{CH_4} + x_{C_2H_6}(HHV)_{C_2H_6}$$

$$= [(0.751)(55.6) + (0.249)(52.0)]\ \text{kJ/g} = \boxed{54.7\ \text{kJ/g}}$$

Latihan 1

- Elpiji (40% propana dan 60% butana) dibakar dengan udara. Pembakaran dilakukan secara stoikiometrik dan sempurna. Elpiji dan udara masuk pembakaran pada 25 ^oC, sedang gas hasil pembakaran keluar pada 900 ^oC. Tentukan panas yang dikeluarkan dari 100 mol elpiji yang dibakar.
- Diketahui ΔH_f^o senyawa
  - C_3H_8 (g)= -103,8 kJ/mol
  - C_4H_{10} (g)= -124,7 kJ/mol
  - H_2O (g) = -241,83 kJ/mol
  - CO_2 (g) = -393,5 kJ/mol
- Kapasitas panas senyawa
  - C_3H_8 (g) = 0,068 kJ/mol.K
  - C_4H_{10} (g) = 0,0923 kJ/mol.K
  - N_2 (g) = 0,029 kJ/mol.K
  - O_2 (g) = 0,0291 kJ/mol.K
  - H_2O (g) = 0,03346 kJ/mol.K
  - CO_2 (g) = 0,03611 kJ/mol.K

Latihan 2

- Dalam desain awal suatu boiler, metana pada 25 °C dibakar sempurna dengan menggunakan udara 20% berlebih yang masuk dengan suhu sama. Kecepatan umpan metana 450 kmol/jam. Gas panas hasil pembakaran keluar dapur pada suhu 300 °C dan dibuang ke atmosfer. Panas yang diperoleh (Q) digunakan untuk membuat steam superheated pada tekanan 17 bar dan suhu 250 °C.

  a. Hitung komposisi gas keluar dapur

  b. Hitung kapasitas panas rata-rata gas buang

  c. Hitung panas yang diperoleh (Q)

  d. Hitung kecepatan produksi steam

- Data :

  Kapasitas panas

  N_2 (g) = 0,029 kJ/mol.K

  O_2 (g) = 0,0291 kJ/mol.K

  H_2O (g) = 0,03346 kJ/mol.Klatihan

  CO_2 (g) = 0,03611 kJ/mol.K

  CH_4 (g) = 0,0431 kJ/mol.K

  Panas pembakaran standar metana (g) = -890,6 kJ/mol

Latihan 3 (PR)

A coal contains 73.0 wt% C, 4.7% H (not including the hydrogen in the coal moisture), 3.7% S, 6.8% H_2O, and 11.8% ash. The coal is burned at a rate of 50,000 lb_m/h in a power plant boiler with air 50% in excess of that needed to oxidize all the carbon in the coal to CO_2. The air and coal are both fed at 77°F and 1 atm. The solid residue from the furnace is analyzed and is found to contain 28.7 wt% C, 1.6% S, and the balance ash. The coal sulfur oxidized in the furnace is converted to $SO_2(g)$. Of the ash in the coal, 30% emerges in the solid residue and the balance is emitted with the stack gases as fly ash. The stack gas and solid residue emerge from the furnace at 600°F. The higher heating value of the coal is 18,000 Btu/lb_m.

(a) Calculate the mass flow rates of all components in the stack gas and the volumetric flow rate of this gas. (Ignore the contribution of the fly ash in the latter calculation, and assume that the stack gas contains a negligible amount of CO.)

(b) Assume that the heat capacity of the solid furnace residue is 0.22 $Btu/(lb_m \cdot °F)$, that of the stack gas is the heat capacity per unit mass of nitrogen, and 35% of the heat generated in the furnace is used to produce electricity. At what rate in MW is electricity produced?