MATERI PERTEMUAN 6

MATA KULIAH: TEKNIK REAKSI KIMIA II

Prof. Ir. HERLIATI, M.T., Ph.D

BASIC CALCULATION OF ENERGY BALANCE ON REACTOR

DESCLAIMER

Data yang digunakan pada konten ini berdasarkan referensi:

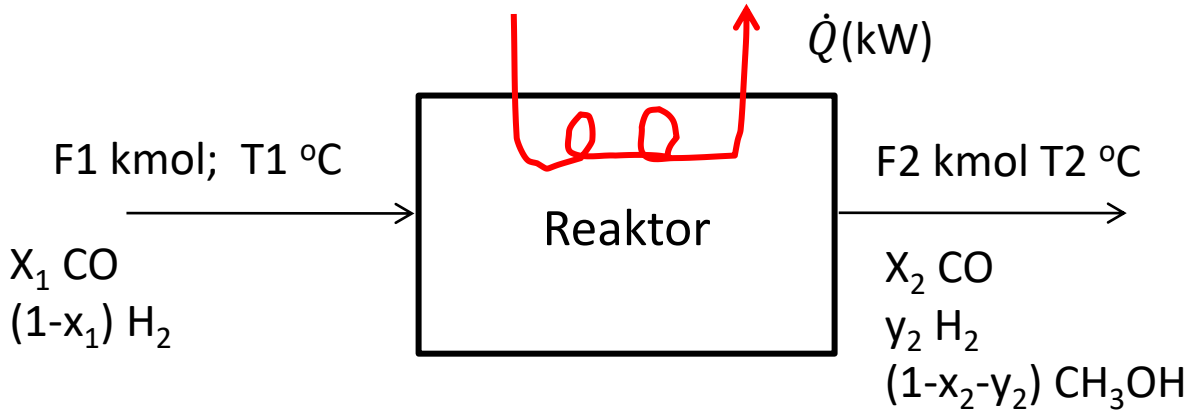
"Elementary Principles Of Chemical Processes"

Authors: Richard M. Felder, Ronald W. Rousseau

Edisi: ke-3

Proses Pembuatan metanol

- ✓ Perubahan Entalpi Reaktan (ΔH_R)
- ✓ Perubahan Entalpi Produk (ΔH_P)
- ✓ Perubahan Entalpi Reaksi Standar (ΔH^0_{298})

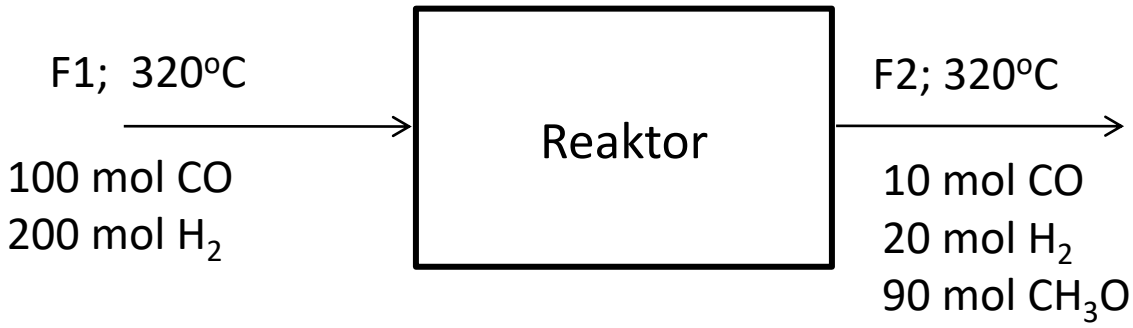


Proses Pembuatan metanol

Tentukan panas reaktor pada proses pembuatan methanol yang berlangsung pada suhu operasi 320^{o}C secara isotermal dengan reaksi sbb:

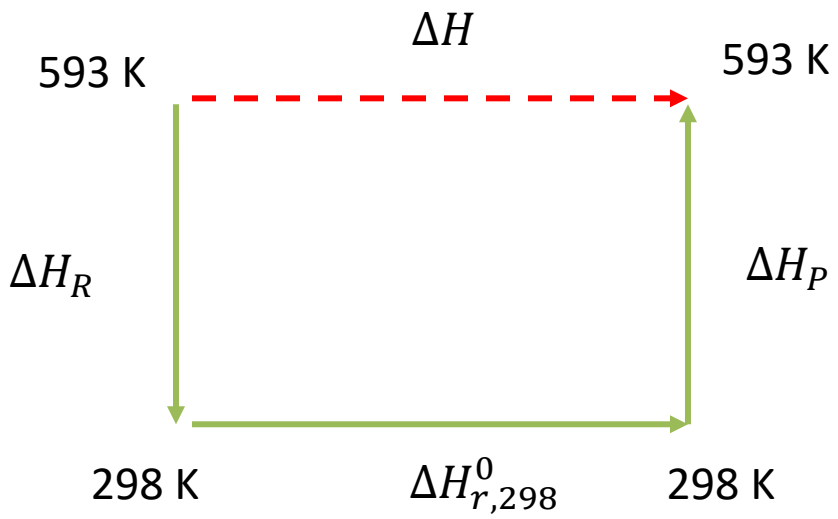
$$CO + 2H_2 \rightarrow CH_3OH$$

Jika umpan terdiri dari 100 mol/menit CO dan 200 mo/menit Hidrogen dimana konversi dari CO adalah sebesar 90 %.



Proses Pembuatan metanol

320°C = 320+273 = 593K



Hukum Hess:

$$\Delta H = \Delta H_R + \Delta H^0_{r,298} + \Delta H_P$$

$\Delta H_R = perubahan\ entalpi\ reaktan$
$\Delta H_P = perubahan\ entalpi\ produk$
$\Delta H^0_{298} = perubahan\ entalpi\ reaksi\ standar$

Formula untuk menentukan panas sensibel

$$Q = \Delta H = n \int_{T_1}^{T_2} Cp.\, dT$$

$$Cp = a + bT + cT^2 + dT^3 \text{ ; kJ/mol.K}$$

data konstanta a, b, c, d diperoleh dari **Tabel B2**

Substances	a	b	c	d
CO	0.02895	0.00000411	3.548E-09	-2.22E-12
H_2	0.02884	7.65E-08	3.288E-09	-8.698E-13
CH_3OH	0.04293	0.00008301	-1.87E-08	-8.03E-12

Menentukan ΔH_R

$$\Delta H_R = \sum_{i=1}^{z} n_i \int_{593}^{298} Cp_i . dT$$

$$Cp = a + bT + cT^2 + dT^3$$

data konstanta a, b, c, d diperoleh dari Tabel B2

$$\Delta H_R = n_{CO} \int_{593}^{298} (\mathrm{a} + \mathrm{bT} + \mathrm{c}T^2 + \mathrm{d}T^3) dT + n_{H_2} \int_{593}^{298} (\mathrm{a} + \mathrm{bT} + \mathrm{c}T^2 + \mathrm{d}T^3) dT$$

Menentukan ΔH_R

$$\Delta H_R = (n_{CO}) \left[a(T_{ref} - T_1) + \frac{1}{2} b\left(T_{ref}^2 - T_1^2\right) + \frac{c}{3}\left(T_{ref}^3 - T_1^3\right) + \frac{c}{4}\left(T_{ref}^4 - T_1^4\right) \right] +$$

$$(n_{H2}) \left[a(T_{ref} - T_1) + \frac{1}{2} b\left(T_{ref}^2 - T_1^2\right) + \frac{c}{3}\left(T_{ref}^3 - T_1^3\right) + \frac{c}{4}\left(T_{ref}^4 - T_1^4\right) \right]$$

$$= -2395{,}432 \text{ kJ}$$

Menentukan ΔH_P

$$\Delta H_P = \sum_{i=1}^{z} n_i \int_{298}^{593} Cp_i . dT$$

$$\Delta H_P = n_{CO} \int_{298}^{593} (\mathrm{a} + \mathrm{bT} + \mathrm{c}T^2 + \mathrm{d}T^3) dT + n_{H_2} \int_{298}^{593} (\mathrm{a} + \mathrm{bT} + \mathrm{c}T^2 + \mathrm{d}T^3) dT$$

$$+ n_{CH_3OH} \int_{298}^{593} (\mathrm{a} + \mathrm{bT} + \mathrm{c}T^2 + \mathrm{d}T^3) dT$$

Menentukan ΔH_P

$$\Delta H_R = (n_{CO}) \left[a(T_2 - T_{ref}) + \frac{1}{2} b\left(T_2^2 - T_{ref}^2\right) + \frac{c}{3}\left(T_2^3 - T_{ref}^3\right) + \frac{c}{4}\left(T_2^4 - T_{ref}^4\right) \right] +$$

$$(n_{H2}) \left[a(T_2 - Tref) + \frac{1}{2} b\left(T_2^2 - T_{ref}^2\right) + \frac{c}{3}\left(T_2^3 - T_{ref}^3\right) + \frac{c}{4}\left(T_2^4 - T_{ref}^4\right) \right] +$$

$$(n_{CH3OH}) \left[a(T_2 - Tref) + \frac{1}{2} b\left(T_2^2 - T_{ref}^2\right) + \frac{c}{3}\left(T_2^3 - T_{ref}^3\right) + \frac{c}{4}\left(T_2^4 - T_{ref}^4\right) \right]$$

$$= 2264{,}74 \text{ kJ}$$

Menentukan perubahan entalpi reaksi standar $\Delta H^0_{r,298}$

$$\Delta H^0_{r,298} = (\sum_{i=1}^{z} n_i \Delta H f^0_{298})_{produk} - (\sum_{i=1}^{z} n_i \Delta H f^0_{298})_{reaktan}$$

Data $\Delta H^0_{r,298}$ = dapat diperoleh dari **Tabel B1**

Substances	$\Delta H^0_{f,298}$, **kJ/mol**
CO	-110,52
H_2	0
CH_3OH	-201,2

Menentukan perubahan entalpi reaksi standar $\Delta H^0_{r,298}$

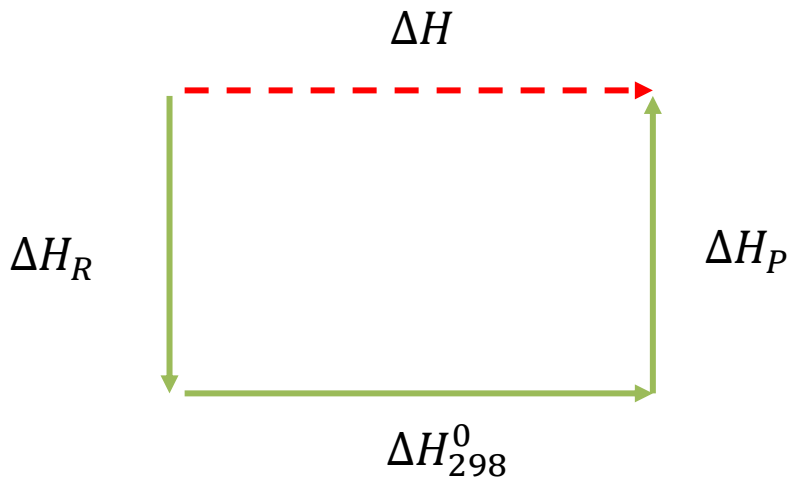
$$\Delta H^0_{r,298} = (\sum_{i=1}^{z} n_i \Delta H f^0_{298})_{produk} - (\sum_{i=1}^{z} n_i \Delta H f^0_{298})_{reaktan}$$

$CO + 2H_2 \rightarrow CH_3OH$

$$\Delta H^0_{r,298} = n_{CH3OH}.\Delta H f^0_{298,CH3OH} - n_{CO}.\Delta H f^0_{298,CO}$$

$$= (90)(-201{,}2) - (90)(-110{,}52) = -8161{,}2\ kJ$$

Menentukan Panas Total Reaktor



$$\Delta H = \Delta H_R + \Delta H^0_{298} + \Delta H_P$$

$$Q = \Delta H = -2395{,}432 + 2264{,}74 + (-8161{,}2) = -8291{,}892 \text{kJ/menit}$$

Berapa panas yang diserap oleh pendingin

Azas Black

Qp = Qsistem $= 8291{,}892$kJ/menit $= -138{,}198$ kJ/s

Digunakan dowterm A sebagai pendingin

$Cp_{dowterm}$ = 2,7 kJ/kg/K; ΔT = 150

$$Q_p = \dot{m}\, C_p \Delta T$$

$$\dot{m} = \frac{138{,}198}{(2{,}7)(150)} = 0{,}341\ kg/detik$$

Tabel Neraca Panas Pada Reaktor

Basis perhitungan 1 Menit Operasi

Komponen	Input, kJ	Output, kJ
ΔH Reaktan	2395	
ΔH^0_{298}	8161	
ΔH Produk		2265
Q pendingin		8292
Total	**10557**	**10557**

SOAL

Klorin dihasilkan dengan reaksi

$4\ HCl + O_2 \rightarrow\ 2H_2O + 2\ Cl_2$

Umpan reaktor terdiri dari 65 % mol HCl, 25 % O_2 dan sisanya N_2. Umpan masuk reaktor pada suhu 450 ^oC. Jika konversi HCl 85 % dimana proses dijaga agar isotermal. Tentukan panas reaktor untuk 100 kmol campuran umpan reaktor.