BAB VI

NERACA PANAS

6.1 Reaktor-01

Data kapasitas panas bahan

Komponen	A	B	C	D
$C_3H_5(COOR)_3$	278,686	2,5434	-5,4355E-03	4,9240E-06
RCOOH	86,29	3,5237	-7,3217E-03	6,1001E-06
CH_3OH	40,152	0,3105	-1,0291E-03	1,4598E-06
NaOH	87,639	-4,8368E-04	-4,5423E-06	1,1863E-09
H_2O	92,053	-3,9953E-02	-2,1103E-04	5,3469E-07
CH_3COOR	270,763	2,3436	-5,4898E-03	5,4072E-06
$C_3H_8O_3$	90,105	0,8601	-1,9745E-03	1,8068E-06
NaCOOH	0,5293			

Dengan $Cp = A + BT + CT^2 + DT^3 + ET^4$

Dimana Cp dalam J/gmol.K dan T dalam K.

Data panas pembentukan bahan, ΔHf^o pada suhu 25^{o}C

Komponen	ΔHf (kJoule/mol)
$C_3H_5(COOR)_3$	-910,900
RCOOH	-730,297
CH_3OH	-239,100
NaOH	-425,600
H_2O	-242,185
CH_3COOR	-401,110
$C_3H_8O_3$	-584,865
NaCOOH	-158,312

Persamaan neraca panas pada reaktor :

Rate of input – rate of output + rate of generation = rate of accumulation

Pada keadaan *steady*, tidak ada akumulasi, sehingga persamaan diatas dapatdituliskan menjadi :

$$Q_{in} - Q_{out} + Q_R + Q = 0$$

Dimana :

Q_{in} = panas yang dimiliki umpan masuk reaktor

Q_{out} = panas yang dimiliki oleh produk keluar reactor

Q_R = panas reaksi

Q = panas yang ditransfer ke lingkungan

Hasil perhitungan neraca massa di R-01 sebagai berikut:

Menghitung panas masuk (Q.in)

- $C_3H_5(COOR)_3$

  T.in = 70℃ = 343 K

  T.ref = 25℃ = 298 K

  Massa masuk = 44.269,7170 kg/jam $\times \frac{1\ kg}{848\ kmol}$

  = 52.204.8549 mol/jam

  Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

  = $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

  = m (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

  = 52.204.8549 mol/jam (278,686 (343 □ 298) + $\frac{2,5434}{2}$ ($343^2 - 298^2$) +

  $\frac{-5,435.10^{-3}}{3}$ ($343^3 - 298^3$) + $\frac{4,924.10^{-6}}{3}$ (343^4-298^4))

  = 1.638.576.631,0520 J/jam × $\frac{0,00023901\ kcal}{1j}$

  = 391.636,2006 kcal/jam

- RCOOH

  T.in = 70℃ = 343 K

  T.ref = 25℃ = 298 K

  Massa masuk = 110,9517 kg/jam × $\frac{1kg}{270\ kmol}$

  = 0,4109 kmol/jam ×$\frac{1000\ mol}{1kmol}$

= 410.9321 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp \ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 410.9321mol/jam x (86,29 (343 - 298) + $\frac{3,5237}{2}$ ($343^2 - 298^2$) +

$\frac{-7,321.10^{-3}}{3}$ ($343^3 - 298^3$) + $\frac{6,1001.10^{-6}}{4}$ ($343^4 - 298^4$))

= 12.281.050,7321 J/jam x $\frac{0,00023901\ kcal}{1j}$

= 2.935,2939 kcal/jam

- CH^3OH

  T.in = 70℃ = 343 K

  T.ref = 25℃ = 298 K

  Massa masuk = 10.023,3321 kg/jam × $\frac{1kg}{32\ kmol}$

  = 313,2291 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

  = 313.229,1294 mol/jam

  Q.in = $m \int_{T.ref}^{T.in} Cp \ dT$

  = $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

  = m (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

  = 313.229,1294 mol/jam x (40,152 (343 - 298) + $\frac{0,3105}{2}$

  ($343^2 - 298^2$) + $\frac{-1,0291.10^{-3}}{3}$ ($343^3 - 298^3$) + $\frac{1,4598.10^{-6}}{4}$

  ($343^4 - 298^4$))

  = 1.156.767.194 J/jam × $\frac{0,00023901\ kcal}{1\ j}$

  = 276,478,9272 kcal/jam

- NaOH

  T.in = 70℃ = 343 K

T.ref = 25℃ = 298 K

Massa keluar = 442,6972 kg/jam × $\frac{1\ kg}{40\ kmol}$

= 11,0674 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= 11.067,492 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

$= m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 11.067,492 mol/jam × (87,639 (343-298) + $\frac{-4,836.10^{-4}}{2}$ (343^2 – 298^2) + $\frac{-4,5423.10^{-6}}{3}$ (343^3 – 298^3) + $\frac{1,1863.10^{-9}}{4}$ (343^4 - 298^4))

= 43.356.813,3935 J/jam × $\frac{0,00023901\ kcal}{1\ j}$

= 10,362.7120 kcal/jam

- H_2O

T.in = 70℃ = 343 K

T.ref = 25℃ = 298 K

Massa masuk = 599,0379 kg/jam × $\frac{1\ kg}{18\ kmol}$

= 33,2799 kmol/jam × $\frac{1000\ mol}{1kmol}$

= 33.279,8854 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

$= m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 33.279,8854 mol/jam × 92,053 (343 - 298) $\frac{-3,995.10^{-2}}{2}$ (343^2 – 298^2) + $\frac{-2,1103.10^{-4}}{3}$ (343^3 – 298^3) + $\frac{5,3469.10^{-7}}{4}$ (3434 - 2984))

= 112.656.769,3331 J/jam × $\frac{0,00023901\ kcal}{1\ j}$

= 26.926,0944 kcal/jam

Maka, jumlah panas masuk total (Q.in total)

Q.in total = Q.in $C_3H_5(COOR)_3$ + Q.in RCOOH + Q.in CH3OH + Q.in NaOH + Q.in H_2O

= (391.636,2006 + 2.935,2939 + 276,478,9272 + 10,362.7120 + 26.926,0944) kcal/jam

= 708.339,2282kcal/jam

Menghitung panas reaksi (Qr)

ΔHr = (Σ δi Δhfi) produk – (Σ δi Δhfi) reaktan

= (3ΔHf CH3COOR + ΔHf C3H8O3) - (ΔHf C3H5(COOR)3 + 3ΔHf CH3OH)

= (3(-401,110) + (-584,865)) – ((-910,900) +3(-239,100)

= -159,9954 kJ/mol × $\frac{0,23901\ kcal}{1\ J}$ x $\frac{1000\ mol}{1\ kmol}$

= -38.240,5123 kcal/kmol

$C_3H_5(COOR)_3$ bereaksi (m) = 35,0730 kmol/jam, Maka;

Qr = m × (– ΔHr)

= 34,5945 kmol/jam × (– (–38.240,5123 kcal/kmol))

= 1.322.911,8566 kcal/jam

ΔHr = (Σ δi Δhfi) produk – (Σ δi Δhfi) reaktan

= (ΔHf NaCOOR + ΔHf H2o) - (ΔHf RCOOR + ΔHf NaOH)

= ((-158,312) + (-242,185)) – ((-730,297) +(-425,600))

= 755,4002 kJ/mol × $\frac{0,23901\ kcal}{1\ J}$ x $\frac{1000\ mol}{1\ kmol}$

= 180.548,1937 kcal/kmol

RCOOH bereaksi (m) = 0,4166 kgmol/jam

Qr = m × (– ΔHr)

= 0,4109 kmol/jam × (– (180.548,1937 kcal/kmol))

= -74.193,0514 kcal/jam

Qr total = 1.322.911,8566 kcal/jam + (-74.193,0514 kcal/jam)

= 1.248.718,8051 kcal/jam

Menghitung panas keluar (Q.out)

- $C_3H_5(COOR)_3$

T.in = 70℃ = 343 K

T.ref = 25℃ = 298 K

Massa keluar = 14.933,5709 kg/jam × $\frac{1\ kg}{848\ kmol}$

= 17,6103 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= 17.610,3430 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 17.610,3430 mol/jam × (278,686 (343 - 298) + $\frac{2,5434}{2}$ ($343^2 - 298^2$)

+ $\frac{-5,435.10^{-3}}{3}$ ($343^3 - 298^3$) + $\frac{4,924.10^{-6}}{4}$ (343^4 - 298^4))

= 552.743.545,4011 J/jam × $\frac{0,00023901\ kcal}{1\ J}$

= 132.111,2348 kcal/jam

- RCOOH

T.in = 70℃ = 343 K

T.ref = 25℃ = 298 K

Massa keluar = 0 kg/jam × $\frac{1\ kg}{270\ kmol}$

= 0 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 0 mol/jam × ((86,29 (343 - 298) + $\frac{3,5237}{2}$ ($343^2 - 298^2$) + $\frac{-7,321.10^{-3}}{3}$

$(343^3 - 298^3) + \frac{6{,}1001.10^{-6}}{4} (343^4 - 298^4))$

= 0 J/jam × $\frac{0{,}00023901\ kcal}{1\ J}$

= 0 kcal/jam

- CH3OH

T.in = 70℃ = 343 K

T.ref = 25℃ = 298 K

Massa keluar = 6.702,2590 kg/jam × $\frac{1\ kg}{32\ kmol}$

= 209,4456 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= 209.445,5938 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3 + \frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 209.445,5938 mol/jam × 40,152 (343 - 298) + $\frac{0{,}3105}{2}$ $(343^2 - 298^2)$

$\frac{-1{,}0291.10^{-3}}{3} (343^3 - 298^3) + \frac{1{,}4598.10^{-6}}{4} (343^4 - 298^4))$

= 773.490.615,3734 J/jam × $\frac{0{,}00023901\ kcal}{1\ J}$

= 184.871,9920 kcal/jam

- NaOH

T.in = 70℃ = 343 K

T.ref = 25℃ = 298 K

Massa keluar = 426,2599 kg/jam × $\frac{1\ kg}{40\ kmol}$

= 10,6565 kmol/jam $\frac{1000\ mol}{1\ kmol}$

= 10.656,4971 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3 + \frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 10.656,4971 mol/jam × 87,639 (343 - 298) + $\frac{-4{,}836.10^{-4}}{2}$ ($343^2 - 298^2$) +

$\frac{-4{,}5423.10^{-6}}{3}$ ($343^3 - 298^3$) + $\frac{1{,}1863.10^{-9}}{4}$ (3434 - 2984))

= 41.746.980,9089 J/jam x $\frac{0{,}00023901\ kcal}{1\ J}$

= 9.977,9459 kcal/jam

- H_2O

T.in = 70°C = 343 K

T.ref = 25°C = 298 K

Massa keluar = 606,4347 kg/jam × $\frac{1\ kg}{18\ kmol}$

= 33,6908 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= 33.690,8175 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}T^3$ + $\frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 33.690,8175 mol/jam × ((92,053 (343 - 298) + $\frac{-3{,}995.10^{-2}}{2}$ ($343^2 - 298^2$)

+ $\frac{-2{,}1103.10^{-4}}{3}$ ($343^3 - 298^3$) + $\frac{5{,}3469.10^{-7}}{4}$ (343^4 - 298^4))

= 114.047.828,3498 J/jam × $\frac{0{,}00023901\ kcal}{1\ J}$

= 27.258,5715 kcal/jam

- CH_3COOR

T.in = 70°C = 343 K

T.ref = 25°C = 298 K

Massa keluar = 29.474,5241 kg/jam × $\frac{1\ kg}{18\ kmol}$

= 103,7835 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= 103.783,5356 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}$T^3 + $\frac{D}{4}$T^4 +)$\int_{Tref}^{T.in}$

= 103.783,5356 mol/jam × ((270,763 (343 - 298) + $\frac{2,3436}{2}$ (343^2 – 298^2)

+ $\frac{-5,4898.10^{-3}}{3}$ (3433 – 2983) + $\frac{5,4072.10^{-6}}{4}$ (3434 - 2984))

= 2.970.000.260,4936 J/jam × $\frac{0,00023901\ kcal}{1\ J}$

= 709.859,7623 kcal/jam

- $C_3H_8O_3$

T.in = 70°C = 343 K

T.ref = 25°C = 298 K

Massa keluar = 3.182,6951 kg/jam × $\frac{1\ kg}{18\ kmol}$

= 34,5945 kmol/jam x $\frac{1000\ mol}{1\ kmol}$

= 34.594,5119 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

= $m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{c}{3}$T^3 + $\frac{D}{4}$T^4 +)$\int_{Tref}^{T.in}$

= 34.594,5119 mol/jam × ((90,105 (343 - 298) + $\frac{0,8601}{2}$ (343^2 – 298^2)

+ $\frac{-1,9745.10^{-3}}{3}$ (343^3 – 298^3) + $\frac{1,8068.10^{-6}}{4}$ (3434 - 2984))

= 346.189.874,2756 J/jam × $\frac{0,00023901\ kcal}{1\ J}$

= 82.742,8419 kcal/jam

- NaCOOH

T.in = 70°C = 343 K

T.ref = 25°C = 298 K

Massa keluar = 119,9922 kg/jam × $\frac{1\ kg}{292\ kmol}$

= 0,4109 kmol/jam × $\frac{1000\ mol}{1\ kmol}$

= 410,9321 mol/jam

Q.in = $m \int_{T.ref}^{T.in} Cp\ dT$

$= m \int_{T.ref}^{T.in} (A + BT + CT2 + DT\ 3)dT$

= m x (AT + $\frac{B}{2}$ T^2 + $\frac{C}{3}T^3 + \frac{D}{4}T^4$ +)$\int_{Tref}^{T.in}$

= 410,9321 mol/jam × (0,5293 (343 - 298))

= 9.787,7866 J/jam × $\frac{0{,}00023901\ kcal}{1\ J}$

= 2,3394 kcal/jam

Maka, jumlah panas keluar total (Q.out total)

Q.out total = Q.out $C_3H_5(COOR)_3$ + Q.out RCOOH + Q.out CH_3OH +
Q.out NaOH + Q.out H2O + Q.out CH_3COOR + Q.out
C3H8O3 + Q.out NaCOOH

= (132.111,2348 + 0 + 184.871,9920 + 9.977,9459 + 27.258,5715
+ 709.859,7623 + 82.742,8419 + 2,3394) kcal/jam

= 1.146.824,6876 kcal/jam

Neraca panas di R-01

Q.in – Q.out + Qr + Q = 0

Q = Q.out – Qr – Q.in

= (1.146.824,6876 – 1.248.718,8051 – 708.339,2282) kcal/jam

= -810.233,3456 kcal/jam

Q bernilai negatif menunjukkan panas yang dilepas dari reaktor (sistem).

Q pendingin = |Q| – Qloss

= (810.233,3456 – 2.553,7134) kcal/jam

= 807.679,6323 kcal/jam

Tabel 6.1 Neraca panas pada Reaktor 01

Komponen	Masuk (kcal/jam)	Keluar (kcal/jam)
C3H5(COOR)3	391.636,2006	132.111,2348
CH3OH	276.478,9272	184.871,9920
RCOOH	2.935,2939	-
NaOH	10.362,7120	9.977,9459
CH3COOR		709.859,7623

$C_3H_8O_3$		82.742,8419
NaCOOH		2,3394
H_2O	26.926,0944	27.258,5715
Panas Reaksi (Q.r)	1.248.718,8051	
Panas Hilang (Q.loss)	-	2.553,7134
Q Pendingin	-	807.679,6323
Total	**1.957.058,0333**	**1.957.058,0333**

6.2 Mixer-01

Tabel 6.2 Neraca panas pada Mixer-01

Komponen	Masuk (kcal/jam)		Keluar (kcal/jam)
	Fresh feed	*Recycle*	
CH_3OH	32.544,1424	151.438,8764	173.437,0108
H_2O	4.887,9265	5.902,3357	17.070,3705
NaOH	2.304,2141	-	6.570,1137
Total	**197.077,4951**		**197.077,4951**

6.3 Mixer-02

Tabel 6.3 Neraca panas pada Mixer-02

Komponen	Masuk (kcal/jam)	Keluar (kcal/jam)
H_3PO_4	30,3348	198,1769
H_2O	3.130,6680	20.388,6506
Bleaching Earth	4.704,8015	30.022,1841
$C_3H_5(COOR)_3$	615.339,2479	573.227,3409
RCOOH	9.181,3067	8.550,0064
Total	**632.386,3589**	**632.386,3589**

6.4 Tangki Pencuci-01

Tabel 6.4 Neraca panas pada Tangki Pencuci-01

Komponen	Masuk (kcal/jam)	Keluar (kcal/jam)
$C_3H_5(COOR)_3$	7,832.3963	6,202.3651
CH_3OH	140,998.3534	110,830.6500
H_2O	132,058.9492	403,341.9422
CH_3COOR	1,049,745.8109	832,465.4886
$C_3H_8O_3$	122,360.7200	97,218.7102
NaCOOH	0.0520	1.8884
NaOH	9,977.5284	8,060.4614
Panas Hilang (Q.loss)		4,852.3042
Total	**1,462,973.8102**	**1,462,973.8102**

6.5 Evaporator-01

Tabel 6.5 Neraca panas pada *Evaporator-01*

Komponen	Masuk (kcal/jam)	Keluar(kcal/jam)
C3H5(COOR)3	4.284,5400	9.398,8052
CH3COOR	843.412,1437	1.848.793,6573
CH3OH	101.731,5912	1.238.611,8243
H2O	4.012,0246	64.596,0404
Panas dari steam	2.207.960,0277	-
Total	**3.161.400,3272**	**3.161.400,3272**

6.6 *Heater*-01

Tabel 6.6 Neraca panas pada *Heater*-01

Komponen	Masuk (kcal/jam)	Keluar (kcal/jam)
CH_3OH	173.437,0108	276.478,9272
NaOH	6.570,1137	10.362,7120
H_2O	17.070,3705	26.905,2080

Beban panas pendingin	116.669,3521	
Total	**313.746,8472**	**313.746,8472**

6.7 *Heater*-02

Tabel 6.7 Neraca panas pada *Heater*-02

Komponen	Masuk (kcal/jam)	Keluar (kcal/jam)
$C_3H_5(COOR)_3$	85.754,8467	573.227,3409
RCOOH	1.282,8864	8.632,5694
Beban panas pemanas	494.822,1773	
Total	**581.859,9103**	**581.859,9103**

6.8 *Cooler*-01

Tabel 6.8 Neraca panas pada *Cooler*-01

Komponen	Masuk (kcal/jam)	Keluar (kcal/jam)
C3H5(COOR)3	573.227,3409	391.636,2006
RCOOH	4.305,4670	2.935,2939
Beban panas pemanas		182.961,3134
Total	**577.532,8079**	**577.532,8079**

6.9 *Cooler*-02

Tabel 6.9 Neraca panas pada *Cooler*-02

Komponen	**Masuk (kcal/jam)**	**Keluar (kcal/jam)**
C3H5(COOR)3	6.351,4647	2.938,8781
CH3COOH	1.361.666,5976	628.663,2784
Beban panas pemanas		736.415,9059
Total	**1.368.018,0624**	**1.368.018,0624**