Scilab Textbook Companion for Thermodynamics for the Practicing Engineer by L. Theodore, F. Ricci Aand T. Van Vliet[1]

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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Chapter 1

Basic Calculations

Scilab code Exa 1.01 Example 1

```
//Problem 1.01:

//initializing the variables:
a1 = 1; // in cm/s2
h = 3600^2/1; // in s2/h2
d = 24^2/1; // in h2/day2
yr = 365^2/1; // in day2/yr2
in = 1/2.54; // in in/cm
ft = 1/12; // in ft/in
mil = 1/5280; // in mile/ft

//calculation:
a2 = a1*h*d*yr*in*ft*mil

printf("\n\nResult\n\n")
printf("\n Thus, 1.0 cm/s2 is equal to %.2E miles/
    yr2\n",a2)
```

Chapter 2

Process Variables

Scilab code Exa 2.02 Example 2

```
//Problem 2.02:

//initializing the variables:
f1 = 55; // in  F
c2 = 55; // in  C

//calculation:
r1 = f1 + 460
c1 = (f1 - 32)*5/9
k1 = (f1 + 460)*5/9
r2 = 1.8*c2 + 492
f2 = 1.8*c2 + 32
k2 = c2 + 273

printf("\n\nResult\n\n")
printf("\n (a) Rankine = %.0f R , (b) Celsius = %.1
    f C and (c) Kelvin = %.0f K\n",r1, c1, k1)
printf("\n (a) Fahrenheit = %.1f F , (b) Rankine = %
    .0f R , and (c) Kelvin = %.0f K\n",f2, r2, k2)
```

Scilab code Exa 2.03 Example 3

```
//Problem 2.03:

//initializing the variables:
mg = 100; // in lb
Pg = 35; // in psig
A = 3; // in in2
gc = 1; // in lb/lbf
Pa = 14.7; // in psi

//calculation:
F = mg/gc
Pli = F/A // in lbf/in2
Plf = Pli*144 // in lbf/ft2
P = Pg + Pa

printf("\n\nResult\n\n")
printf("\n pressure at the base is %.0f lbf/ft2\n",
   Plf)
printf("\n absolute pressure is %.1f psia\n",P)
```

Scilab code Exa 2.04 Example 4

```
//Problem 2.04:

//initializing the variables:
V = 55; // in gal
W = 20; // in lb
AWH = 1.008; // in lb/lbmol
AWO = 15.999; // in lb/lbmol
Na = 6.023E23; // molecules/gmol
```

```
//calculation:
MW = 2*AWH + AWO
pmw = W/MW
gmw = W*454/MW
nm = gmw*Na

printf("\n\nResult\n\n")
printf("\n it contain %.2f lbmol of water\n",pmw)
printf("\n it contain %.1f gmol of water\n",gmw)
printf("\n it contain %.3E molecules of water\n",nm)
```

Scilab code Exa 2.05 Example 5

```
//Problem 2.05:

//initializing the variables:
sgm = 0.92;
dw = 62.4; // in lb/ft3

//calculation:
dm = sgm*dw

printf("\n\nResult\n\n")
printf("\n the density of methanol is %.1f lb/ft3\n"
    ,dm)
```

Scilab code Exa 2.06 Example 6

```
//Problem 2.06:
//initializing the variables:
sg = 0.8
abvis = 0.02;// in cP
```

```
pref = 62.43; // in lb/ft3

//calculation:
p = sg*pref
u = abvis*6.720E-4; // in lb/ft.sec
v = u/p

printf("\n\nResult\n\n")
printf("\n kinematic viscosity of a gas is %.3E ft2/
   sec\n",v)
```

Scilab code Exa 2.07 Example 7

```
//Problem 2.07:
//initializing the variables:
hc = 0.61 // in cal/g− C

//calculation:
hce = hc*452/(252*1.8) // in Btu/lb− F

printf("\n\nResult\n\n")
printf("\n Heat capacity in english units is %.2f
   Btu/lb. F \n",hce)
```

Scilab code Exa 2.08 Example 8

```
//Problem 2.08:

//initializing the variables:
tc = 0.0512 // in cal/m.s. C

//calculation:
k = tc*0.3048*3600/(252*1.8) // in Btu/ft.h. F
```

```
printf("\n\nResult\n\n")
printf("\n thermal conductivity in english units is %.3f Btu/ft.h. F \n",k)
```

Scilab code Exa 2.09 Example 9

```
//Problem 2.09:

//initializing the variables:
D = 5/12; // in ft
p = 50; // in lb/ft3
v = 10; // in fps
u = 0.65*6.720E-4 ; //in lb/ft.sec

//calculation:
Re = D*p*v/u
if (Re>2100) then
    s = 'turbulent';
else
    s = 'laminar';
end
printf("\n\nResult\n\n")
printf("\n Reynolds number for a fluid flowing is %.2E and the flow is %s\n",Re, s)
```

Scilab code Exa 2.10 Example 10

```
//Problem 2.10:

//initializing the variables:
pH = 1

```

```
//calculation:
CH = 10^(-1*pH)
COH = 10^(-14)/CH

printf("\n\nResult\n\n")
printf("\n hydroxyl ion concentration of an aqueous
    solution is %.2E g.ion/L and of hydrogen ion is %
    .1f g.ion/L\n",COH, CH)
```

Scilab code Exa 2.11 Example 11

```
//Problem 2.11:

//initializing the variables:
w= 5000; // in gal
C = 50000; // in gal
Cs = 45000; // in gal
pHmin = 6;
pHn = 7;

//calculation:
CHn = 10^(-1*pHn)
CH = 10^(-1*pHmin)
X = (C/w)*[CH - Cs*CHn/C]
pH = -1*log10(X)

printf("\n\nResult\n\n")
printf("\n the pH of the most acidic waste shipment
    is %.2f \n",pH)
printf("\n This is the final correct answer, final
    answer in book is wrong\n")
```

Chapter 3

Gas Laws

Scilab code Exa 3.01 Example 1

```
//Problem 3.01:

//initializing the variables:
Tc = 100; // in  F
Tf = 300; // in  F
qi = 3500; // in acfm

//calculation:
qf = qi*(Tf + 460)/(Tc + 460)

printf("\n\nResult\n\n")
printf("\n the final (f) volumetric flow rate of a
   gas is %.0f acfm\n",qf)
```

Scilab code Exa 3.02 Example 2

```
//Problem 3.02:

```

```
//initializing the variables:
Pi = 1.0; // in atm
Pf = 3.0; // in atm
qi = 3500; // in acfm

//calculation:
qf = qi*Pi/Pf

printf("\n\nResult\n\n")
printf("\n the final (f) volumetric flow rate of a
   gas is %.0f acfm\n",qf)
```

Scilab code Exa 3.03 Example 3

```
//Problem 3.03:

//initializing the variables:
Pi = 1.0; // in atm
Pf = 3.0; // in atm
Tc = 100; // in  F
Tf = 300; // in  F
qi = 3500; // in acfm

//calculation:
qf = qi*(Pi/Pf)*((Tf + 460)/(Tc + 460))

printf("\n\nResult\n\n")
printf("\n the final (f) volumetric flow rate of a
   gas is %.0f acfm\n",qf)
```

Scilab code Exa 3.04 Example 4

```
//Problem 3.04:
```

```
//initializing the variables:
T1 = 75; // in  F
Pa = 14.7; // in psia
MWair = 29;
T2 = 60; // in  F
T3 = 20;// in  C
P = 1.2; // in atm
MWgas = 29;
Rf = 10.73; // in ft^3.psi/lbmol. R
Rc = 82.06; // in cm^3.atm/lbmol.K

n = 1; // in lbmol
//calculation:
p1 = Pa*MWair/((T1 + 460)*Rf)
V = n*Rf*(T2 + 460)/Pa
p2 = P*MWgas/(Rc*(T3 + 273))

printf("\n\nResult\n\n")
printf("\n density of air is %.4f lb/ft^3",p1)
printf("\n the volume is %.0f ft^3",V)
printf("\n density of gas is %.5f g/cm^3",p2)
```

Scilab code Exa 3.05 Example 5

```
//Problem 3.05:

//initializing the variables:
Vsp = 10.58; // in ft3/lb
Pa = 14.7; // in psia
T = 70; // in  F
R = 10.73; // in ft^3.psi/lbmol. R

//calculation:
MW = R*(460 + T)/(Vsp*Pa)
```

```
printf("\n\nResult\n\n")
printf("\n the molecular weight of the gas is %.2f
    lb/lbmol",MW)
```

Scilab code Exa 3.06 Example 6

```
//Problem 3.06:

//initializing the variables:
qs = 30000; // in scfm at 60  F
P = 1; // in atm
Ts = 60; // in  F
Ta = 1100; // in  F

//calculation:
qa = qs*(Ta + 460)/(Ts + 460)

printf("\n\nResult\n\n")
printf("\n flow rate in actual cubic feet per minute
     is %.0f acfm",qa)
```

Scilab code Exa 3.07 Example 7

```
//Problem 3.07:

//initializing the variables:
qs = 1000; // in acfm
A = 1; // in ft2
P = 1; // in atm
Ts = 70; // in  F
Ta = 300; // in  F

```

```
//calculation:
qa = qs*(Ta + 460)/(Ts + 460)
v = qa/P

printf("\n\nResult\n\n")
printf("\n velocity of the gas is %.0f ft/min",v)
```

Scilab code Exa 3.08 Example 8

```
//Problem 3.08:

//initializing the variables:
pco = 0.15; // in mm of Hg
P = 760; // in mm of Hg

//calculation:
yco = pco/P
ppm = yco*1E6

printf("\n\nResult\n\n")
printf("\n the parts per million of CO in the
   exhaust is %.0f ppm",ppm)
```

Scilab code Exa 3.09 Example 9

```
//Problem 3.09:

//initializing the variables:
T = 230; // in deg celcius
P = 2500; // in psia
Pa = 14.7; // in psia

//calculation:
```

```
//critical values
Tc = 417 // in K
Pc = 76 // in atm
w = 0.074 // acentric factor
Tr = (T + 273)/Tc
Pr = P/(Pa*Pc)

printf("\n\nResult\n\n")
printf("\n the reduced temperature is %.2f and
   reduced pressure is %.2f",Tr,Pr)
```

Scilab code Exa 3.10 Example 10

```
//Problem 3.10:

//initializing the variables:
B = -0.159; // in m3/kgmol
C = 0.009; // in (m3/kgmol)2
T = 400; // in K
P = 40; // in atm

//calculation:
//Virial equation.
//Z = PV/RT = 1 + B/V + C/V^2
//Insert the appropriate values of the terms and
   coefficients. Use R = 0.082 Latm/gmolK = 82.06
   cm3.atm/gmol K
//40*V=(0.082)(400) = 1 + (-0.159)/V +(0.009)/V^2
//(1.22)(V) = 1 + (-0.159)/V + (0.009)/V^2
//Note that the equation cannot simply be explicitly
    solved for V. A trial-and-error solution is \n
   required and any suitable numerical (or
   analytical) technique may be employed.
//V is approximately 0.635 L/gmol
V = 0.635
```

```
printf("\n\nResult\n\n")
printf("\n the specific volume is %.3f L/gmol",V)
```

Scilab code Exa 3.12 Example 12

```
//Problem 3.12:

//initializing the variables:
Pc = 45.4; // in atm
Tc = 343; // in deg R
T = 373; // in K
P = 10; // in atm
w = 0.007

//calculation:
//Redlich Kwong equation in terms of a, b, and V.
//P = [RT/(V - b)] - a/[T^0.5 * V(V + b)]
T = T*1.8
//10 = [(0.73)(671)/(V - b)] - a/[671^0.5*V(V + b)]
a = 10933
b = 0.478
//from these we get and By trial-and-error
V = 48.8; // in ft^3

printf("\n\nResult\n\n")
printf("\n the molar volume is %.1f ft^3",V)
```

Scilab code Exa 3.13 Example 13

```
//Problem 3.13:

//initializing the variables:
```

```
Y1 = 0.4;
Y2 = 0.1;
Y3 = 0.3;
Y4 = 0.07;
Y5 = 0.07;
Y6 = 0.06;
T = 60; // in deg F
P = 1; // in atm
w = 0.020

//calculation:
//The reduced properties are therefore
Tr = 660/(268.8*1.8)
Pr = 350/(46.54*14.7)
//For standard conditions
Trs = 1.074
Prs = 0.021
//Employing the    B    approach:
B0 = 0.083-[0.422/(1.36^1.6)]
B1 = 0.139 - [0.172/(1.36^4.2)]
Za = 1 + (B0+w*B1)*0.511/1.36
//therefore
qs1 = 3000*520*350/(14.7*660*Za)
//The problem can also be solved using the    Z    approach. First note that Tr>1, Pr>1. The following equations from Table 3.4 that are given below are to be employed to solve this problem.
//Z0 = 1.156 - 0.351e^(-Tr) - 0.0885e^Pr
//and
//Z1 = -0.200 + 0.018*Pr*Tr + 0.2*(1-0.2*Pr/Tr + (Pr/Tr)^2 -(Pr/Tr)^3 + (Pr/Tr)^4 - (Pr/Tr)^5)
//For this approach
//Z = Z0 + w*Z1
Z0 = 1.156 - 0.351*%e^(-Tr) - 0.0885*%e^Pr
Z1 = -0.200 + 0.018*Pr*Tr + 0.2*(1-0.2*Pr/Tr + (Pr/Tr)^2 -(Pr/Tr)^3 + (Pr/Tr)^4 - (Pr/Tr)^5)
Z = Z0 + w*Z1
//therefore
```

```
qs2 = 3000*520*350/(14.7*660*Z)

printf("\n\nResult\n\n")
printf("\n the volume flow by B approach is %.0f ft
   ^3/day and \n by the equations provided by Van
   Vliet and Domato is %.0f ft^3/day ",qs1,qs2)
```

Chapter 4

Conservation Laws

Scilab code Exa 4.01 Example 1

```
//Problem 4.01:

//initializing the variables:
mdt = 0.15; // in kg/sec
v = 420; // in m/sec

//calculation:
vxin = v
vxout = 0
vyin = 0
vyout = v
Fxgc = mdt*(vxout - vxin)
Fygc = mdt*(vyout - vyin)

printf("\n\nResult\n\n")
printf("\n The x-direction supporting force is %.1f
   N and The y-direction supporting force is %.1f N"
   ,Fxgc,Fygc)
```

Scilab code Exa 4.02 Example 2

```
//Problem 4.02:

//initializing the variables:
mdt = 0.15; // in kg/sec
v = 420; // in m/sec

//calculation:
vxin = v
vxout = 0
vyin = 0
vyout = v
Fxgc = mdt*(vxout - vxin)
Fygc = mdt*(vyout - vyin)
Fres = (Fxgc^2 + Fygc^2)^0.5
theta = (atan(Fygc/Fxgc))*180/%pi + 180

printf("\n\nResult\n\n")
printf("\n resultant supporting force is %.1f N and
    direction is %.0f degree",Fres,theta)
```

Scilab code Exa 4.03 Example 3

```
//Problem 4.03:

//initializing the variables:
rb = 10000; // in lb/h
rair = 20000; // in lb/h
rm = 2000; // in lb/h

//calculation:
mdtin = rb + rair + rm
mdtout = mdtin

```

```
printf("\n\nResult\n\n")
printf("\n the product gases exit the incinerator at
    %.0f lb/h",mdtout)
```

Scilab code Exa 4.04 Example 4

```
//Problem 4.04:

//initializing the variables:
r1 = 5000; // in scfm
r2 = 3000; // in scfm
T1 = 60; // in deg F
T2 = 70; // in deg F
Ti = 2000; // in F
To = 180; // in F
MWchcl = 112.5;
MWair = 29;

//calculation:
//convert scfm to acfm using Charle's law
R1 = r1*(460 + T2)/(460 + T1)
R2 = r2*(460 + T2)/(460 + T1)
ndt1 = R1/387
ndt2 = R2/387
mdt1 = ndt1*MWchcl*60
mdt2 = ndt2*MWair*60
mdtin = mdt1 + mdt2
mdtout = mdtin

printf("\n\nResult\n\n")
printf("\n products exit the cooler at %.0f lb/h",
    mdtout)
```

Scilab code Exa 4.05 Example 5

```
//Problem 4.05:

//initializing the variables:
e1 = 0.65;
e2 = 0.98;
mdtin = 76; // in lb

//calculation:
mdtout1 = (1 - e1)*mdtin
mdtout2 = (1 - e2)*mdtout1
E = 1 - mdtout2/mdtin

printf("\n\nResult\n\n")
printf("\n overall fractional efficiency is %.3f",E)
```

Scilab code Exa 4.06 Example 6

```
//Problem 4.06:

//initializing the variables:
e1 = 0.65;
e2 = 0.98;
mdtin = 76; // in lb

//calculation:
mdtout1 = (1 - e1)*mdtin
mdtout2 = (1 - e2)*mdtout1
E = 1 - mdtout2/mdtin
perE = E*100

printf("\n\nResult\n\n")
printf("\n overall fractional efficiency at percent
   basis is %.1f percent",perE)
```

Scilab code Exa 4.07 Example 7

```
//Problem 4.07:

//initializing the variables:
mdt1 = 1000; // in lb/min
mdt2 = 1000; // in lb/min
mdt3 = 200; // in lb/min

//calculation:
mdt5 = mdt1 + mdt2 - mdt3
mdt6 = mdt2
mdt = mdt5 - mdt6

printf("\n\nResult\n\n")
printf("\n amount of water lost by evaporation is %
    .0f lb/min",mdt)
```

Scilab code Exa 4.09 Example 9

```
//Problem 4.09:

//initializing the variables:
m = 1800; // in kg
v = 40; // in km/h
F = 5000; // in N

//calculation:
KE1 = (1/2)*m*(v*5/18)^2
KE2 = 0;
s = KE1/F
```

```

printf("\n\nResult\n\n")
printf("\n distance the car will travel before it
    comes to a stop is %.1f m",s)
```

Scilab code Exa 4.10 Example 10

```
//Problem 4.10:

//initializing the variables:
m = 2000; // in lb
d = 1200; // in ft

//calculation:
PE = m*d/2
PEbtu = PE/778.17

printf("\n\nResult\n\n")
printf("\n the change in potential energy is %.0f
    Btu",PEbtu)
```

Scilab code Exa 4.11 Example 11

```
//Problem 4.11:

//initializing the variables:
m = 2000; // in lb
v1 = 8; // in ft/s
v2 = 30; // in ft/s

//calculation:
KE1 = m*v1^2/(2*32.2)
KE2 = m*v2^2/(2*32.2)
```

```
delKE = KE1 - KE2
delKEbtu = delKE/778.17

printf("\n\nResult\n\n")
printf("\n the change in Kinetic energy is %.3f Btu"
   ,delKEbtu)
```

Scilab code Exa 4.12 Example 12

```
//Problem 4.12:

//initializing the variables:
r = 500000; // in gpm
e = 0.30;
d = 3000; // in ft

//calculation:
mdt = r*0.00378*1000/60 // in kg/sec
delPE = mdt*9.8*d*0.3048
P = e*delPE

printf("\n\nResult\n\n")
printf("\n actual power output is %.2E W",P)
```

Chapter 5

stoichimetry

Scilab code Exa 5.01 Example 1

```
//Problem 5.01:

//initializing the variables:

//calculation:
//chemical equation provides a variety of
   qualitative and quantitative information \n
   essential for the calculation of the quantity of
   reactants reacted and products formed \n in a
   chemical process. A balanced chemical equation,
   as noted above, must have the same \n number of
   atoms of each type in the reactants and products.
    Thus, the balanced equation for \n butane is
//C4H10 + (13/2)O2 ---> 4CO2 + 5H2O
//number of carbons in reactants = number of carbons
    in products = 4
//number of oxygens in reactants = number of oxygens
    in products = 13
//number of hydrogens in reactants = number of
   hydrogens in products = 10
//number of moles of reactants is 1 mol C4H10 + 6.5
```

```
    mol O2 = 7.5 mol total
//number of moles of products is 4 mol CO2 + 5 mol
    H2O = 9 mol total
ratio = 9/7.5

printf("\n\nResult\n\n")
printf("\n the mole ratio of reactants to products
    is %.2f ",ratio)
```

Scilab code Exa 5.03 Example 3

```
//Problem 5.03:

//initializing the variables:
MWCS2 = 76.14
MWSO2 = 64.07
MWCO2 = 44
WCS2 = 500; // iin lb
WO2 = 225; // in lb

//calculation:
MWO2 = 2*16
//The initial molar amounts of each reactant is
MACS2 = WCS2/MWCS2
MAO2 = WO2/MWO2
//The amount of O2 needed to consume all the CS2, i.
    e., the stoichiometric amount, is then
O2 = MACS2*3

if (O2 > MAO2) then
    a = 'O2 is Limiting Reactant'
else
    a = 'CS2 is Limiting Reactant'
end

```

```
printf("\n\nResult\n\n")
printf("\n %s", a)
```

Scilab code Exa 5.04 Example 4

```
//Problem 5.04:

//initializing the variables:
MWCS2 = 76.14;
MWSO2 = 64.07;
MWCO2 = 44;
wCS2 = 500; // in lb
wO2 = 225; // in lb
MWO2 = 32;

//calculation:
mr1 = wCS2/MWCS2
mr2 = wO2/MWO2
mp1 = mr2/3
m1r = mp1*MWCS2
mp2 = mr2*1/3
m2p = mp2*MWCO2
mp3 = mr2*2/3
m3p = mp3*MWSO2

printf("\n\nResult\n\n")
printf("\n %.0f lb CO2 produced and %.0f lb SO2
   produced",m2p,m3p)
```

Scilab code Exa 5.06 Example 6

```
//Problem 5.06:

```

```
//initializing the variables:
P = 1; // in atm
tm = 68.6

//calculation:
perO2bymol = 7*100/tm
perHClbymol = 1*100/tm
perH2Obymol = 2*100/tm
ppO2 = perO2bymol/100
ppHCl = perHClbymol/100
ppH2O = perH2Obymol/100

printf("\n\nResult\n\n")
printf("\n patial pressures (for O2 = %.3f atm for
   HCl = %.4f atm and for H2O = %.4f atm)",ppO2,
   ppHCl, ppH2O)
```

Scilab code Exa 5.07 Example 7

```
//Problem 5.07:

//initializing the variables:
P = 1; // in atm
tm = 68.6;
pS = 0.005;
W = 112.5;
MWS = 32;

//calculation:
wS = pS*W
nS = wS/MWS
perSO2bymol = nS*100/tm
ppSO2 = perSO2bymol/100

printf("\n\nResult\n\n")
```

```
printf("\n patial pressures for SO2 = %.2E atm ",
   ppSO2)
```

Scilab code Exa 5.08 Example 8

```
//Problem 5.08:

//initializing the variables:
P = 1; // in atm
tm = 68.6;
pS = 0.005;
W = 112.5;
MWS = 32;

//calculation:
wS = pS*W
nS = wS/MWS
perSO2bymol = nS*100/tm
ppSO2 = perSO2bymol/100
ppm = ppSO2*1E6

printf("\n\nResult\n\n")
printf("\n ppm of SO2 = %.0f",ppm)
```

Scilab code Exa 5.09 Example 9

```
//Problem 5.09:

//initializing the variables:
nCO2 = 7.5
nCO = 1.3
nO2 = 8.1
nN2 = 83.1
```

```
//calculation:
//Determine the amount of oxygen fed for combustion. Since nitrogen does not react (key component), using the ratio of oxygen to nitrogen in air will provide the amount of oxygen fed:
O2f = (21/79)*83.1
//A balanced equation for the combustion of the hydrocarbon in terms of N moles of the hydrocarbon and n hydrogen atoms in the hydrocarbon yields
//NC3Hn + 22.1O2 ---> 7.5CO2 + 1.3CO + 8.1O2 + N(n/2)H2O
//The moles of hydrocarbon, N, is obtained by performing an elemental carbon balance:
//3N = 7.5 + 1.3
N = 8.8/3
//Similarly, the moles of water formed is obtained by performing an elemental oxygen balance:
//2(22.1) = 2(7.5) + 1.3 + 2(8.1) + N(n/2)
//A = N(n/2)
A = 44.2 - 15 - 1.3 - 16.2
//The number of hydrogen atoms, n, in the hydrocarbon is then
n = 2*A/N
//Since n = 8, the hydrocarbon is C3H8, propane.

printf("\n\nResult\n\n")
printf("\n n= %.0f\n",n)
printf("\n the hydrocarbon is C3H8, propane")
```

Scilab code Exa 5.11 Example 11

```
//Problem 5.11:

```

```
//initializing the variables:
wr = 5; // in ton/hr
pcl = 0.02
x = 2000
MWHCl = 36.5
MWCl = 35.5
y = 0.99

//calculation:
Clfeed = wr*pcl*x
HCl = Clfeed*MWHCl/MWCl
maxrate = HCl*(1-y)

printf("\n\nResult\n\n")
printf("\n maximum permissible mass emission rate of
    HCl = %.2f lb HCl/h",maxrate)
```

Scilab code Exa 5.13 Example 13

```
//Problem 5.13:

//initializing the variables:
tm = 50.85; // total lbmol from problem 5.12
T = 500+460;
P = 1; // in atm
R = 0.7302

//calculation:
//Noting that 100 lb of fuel was used as a basis,
   the total lbmol of flue gas produced per pound of
    oil burned is
n = tm/100
//the total volume of flue gas
V = n*R*T/P

```

```
printf("\n\nResult\n\n")
printf("\n the total volume of flue gas = %.2f ft3/
    lboil",V)
```

Scilab code Exa 5.14 Example 14

```
//Problem 5.14:

//initializing the variables:
lbmolCO2 = 7.38
lbmolSO2 = 0.00125
lbmolN2 = 38.03

//calculation:
//total lbmol dry flue gas
tn = lbmolCO2 + lbmolSO2 + lbmolN2
//volume percentage of CO2 in the dry flue gas
perCO2 = lbmolCO2*100/tn

printf("\n\nResult\n\n")
printf("\n volume percentage of CO2 in the dry flue
    gas = %.2f percent",perCO2)
```

Scilab code Exa 5.15 Example 15

```
//Problem 5.15:

//initializing the variables:
MWDCB = 147;
MWTCB = 290

//calculation:
```

```
//for 1 lb of dichlorobenzene (DCB), the following
   mass of HCl is produced:
HCLpd1 = 2/MWDCB
//for 1lb of tetrachlorobiphenyl (TCB), the
   following mass of HCl is produced
HCLpd2 = 4/MWTCB
x = (HCLpd2 - HCLpd1)*100/HCLpd1

printf("\n\nResult\n\n")
printf("\n the consumption of soda ash be increased
   by %.2f percent",x)
```

Chapter 6

The Second Law of Thermodynamics

Scilab code Exa 6.01 Example 1

```
//Problem 6.01:

//initializing the variables:
mc = 20; // in lb
T1 = 100; // in degrees C
T2 = 25; // in Deg C
mw = 6; // in gallons
Cpc = 0.092; // Btu/lb.degF
Cpw = 1.0; // Btu/lb.degF

//calculation:
T = (mc*Cpc*T1 + mw*8.33*Cpw*T2)/(mc*Cpc + mw*8.33*
   Cpw)
Tk = T + 273
dS = mc*Cpc*log(Tk/373)

printf("\n\nResult\n\n")
printf("\n the entropy change of the copper is %.3f
   Btu/deg F",dS)
```

Scilab code Exa 6.02 Example 2

```
//Problem 6.02:

//initializing the variables:
mc = 20; // in lb
T1 = 100; // in degrees C
T2 = 25; // in Deg C
mw = 6; // in gallons
Cpc = 0.092; // Btu/lb.degF
Cpw = 1.0; // Btu/lb.degF

//calculation:
T = (mc*Cpc*T1 + mw*8.33*Cpw*T2)/(mc*Cpc + mw*8.33*
    Cpw)
Tk = T + 273
dS = mw*8.33*Cpw*log(Tk/298)

printf("\n\nResult\n\n")
printf("\n the entropy change of the water is %.3f
    Btu/deg F",dS)
```

Scilab code Exa 6.03 Example 3

```
//Problem 6.03:

//initializing the variables:
mc = 20; // in lb
T1 = 100; // in degrees C
T2 = 25; // in Deg C
mw = 6; // in gallons
```

```
Cpc = 0.092; // Btu/lb.degF
Cpw = 1.0; // Btu/lb.degF

//calculation:
T = (mc*Cpc*T1 + mw*8.33*Cpw*T2)/(mc*Cpc + mw*8.33*
    Cpw)
Tk = T + 273
dSw = mw*8.33*Cpw*log(Tk/298)
dSc = mc*Cpc*log(Tk/373)
dSt = dSw + dSc

printf("\n\nResult\n\n")
printf("\n the total entropy change is %.3f Btu/deg
    F",dSt)
```

Scilab code Exa 6.05 Example 5

```
//Problem 6.05:

//initializing the variables:
n = 5; // in lbmol
T1 = 100; // in degrees F
P1 = 1; // in atm
T2 = 400; // in degrees F
P2 = 10; // in atm
Cpg = 5; // Btu/lb.degF
R = 1.987;

//calculation:
T1 = T1 + 460
T2 = T2 + 460
dS = n*R*log(P1/P2) + n*Cpg*log(T2/T1)

printf("\n\nResult\n\n")
printf("\n the entropy for the irreversible process
```

```
    is %.2f Btu/deg R",dS)
```

Scilab code Exa 6.06 Example 6

```
//Problem 6.06:

//initializing the variables:
n = 5; // in lbmol
T1 = 100; // in degrees F
P1 = 1; // in atm
T2 = 400; // in degrees F
P2 = 10; // in atm
Cpg = 5; // Btu/lb.degF
R = 1.987;

//calculation:
T1 = T1 + 460
T2 = T2 + 460
dS = n*R*log(P1/P2) + n*Cpg*log(T2/T1)

printf("\n\nResult\n\n")
printf("\n the entropy for the irreversible process
    is %.2f Btu/deg R",dS)
```

Scilab code Exa 6.07 Example 7

```
//Problem 6.07:

//initializing the variables:
n = 5; // in lbmol
T1 = 100; // in degrees F
P1 = 1; // in atm
T2 = 400; // in degrees F
```

```
P2 = 10; // in atm
Cpg = 5; // Btu/lb.degF
R = 1.987;

//calculation:
T1 = T1 + 460
T2 = T2 + 460
dS = n*R*log(P1/P2) + n*Cpg*log(T2/T1)
dSt = 0
dSsur = dSt - dS

printf("\n\nResult\n\n")
printf("\n the entropy for the surrounding is %.2f
   Btu/deg R",dSsur)
```

Scilab code Exa 6.09 Example 9

```
//Problem 6.09:

//initializing the variables:
H0 = 28; // in Btu/lb
H1 = 1151; // in Btu/lb
Qh = 700; // in Btu/lb
S0 = 0.056; // in Btu/lb deg R
S1 = 1.757; // in Btu/lb deg R
Th = 300; // in deg F
Tc = 60; // in deg F
P1 = 1; // in atm
T1 = 212; // in deg F
T0 = 60; // in deg F


//calculation:
Qc = H1 - H0 - Qh
//the entropy change of the steam
```

```
dSs = S0 - S1
dSh = Qh/(Th + 460)
dSc = Qc/(Tc + 460)
dSt = dSs + dSh + dSc

printf("\n\nResult\n\n")
printf("\n total entropy change is %.3f Btu/lb deg R
   ",dSt)
```

Scilab code Exa 6.10 Example 10

```
//Problem 6.10:

//initializing the variables:
T1 = 540; // in deg F
T0 = 300; // in deg F
T2 = 300; // in deg F
T3 = 60; // in deg F
m = 1;
Cp = 1;

//calculation:
dSh = m*Cp*log((T0 + 460)/(T1 + 460))
dSc = m*Cp*log((T2 + 460)/(T3 + 460))
//for one exchanger
dSa = dSh + dSc
//there are two similar exchangers
dSb = dSa
dStot = dSa + dSb

printf("\n\nResult\n\n")
printf("\n total entropy change is %.4f Btu/deg R",
   dStot)
```

Scilab code Exa 6.11 Example 11

```
//Problem 6.11:

//initializing the variables:
T1 = 540; // in deg F
T0 = 300; // in deg F
T2 = 300; // in deg F
T3 = 60; // in deg F
TDDF = 0;
m = 1;
Cp = 1;

//calculation:
dShc = m*Cp*log((T0 + 460)/(T1 + 460))
dScc = m*Cp*log((T2 + 460)/(T3 + 460))
//for one exchanger
dSc = dShc + dScc
//exchanger D
dSd = 0
dStot = dSc + dSd

printf("\n\nResult\n\n")
printf("\n total entropy change is %.4f Btu/deg R",
   dStot)
```

Scilab code Exa 6.12 Example 12

```
//Problem 6.12:

//initializing the variables:
T1 = 540; // in deg F
```

```
T0 = 300; // in deg F
T2 = 180; // in deg F
T3 = 60; // in deg F
m1 = 1;
m2 = 2;
Cp = 1;

//calculation:
dSh = m1*Cp*log((T0 + 460)/(T1 + 460))
dSc = m2*Cp*log((T2 + 460)/(T3 + 460))
//for one exchanger
dSe = dSh + dSc
//exchanger F
dSf = dSe
dStot = dSe + dSf

printf("\n\nResult\n\n")
printf("\n total entropy change is %.4f Btu/deg R",
   dStot)
```

Scilab code Exa 6.14 Example 14

```
//Problem 6.14:

//initializing the variables:
T = 298; // in deg F
na = 1;
nb = 3;
nc = 2;
Sa = 26.3; // in Btu/lbmol deg R
Sb = 21.0; // in Btu/lbmol deg R
Sc = 29.9; // in Btu/lbmol deg R

//calculation:
dS = nc*Sc - nb*Sb - na*Sa
```

```
printf("\n\nResult\n\n")
printf("\n entropy change is %.1f Btu/deg R",dS)
```

Chapter 7

Sensible Enthalpy Effects

Scilab code Exa 7.01 Example 1

```
//Problem 7.01:

//initializing the variables:
C = 1;
P = 1;

//calculation:
F = C - P + 2

printf("\n\nResult\n\n")
printf("\n the number of degrees of freedom is %.0f"
    ,F)
```

Scilab code Exa 7.02 Example 2

```
//Problem 7.02:

//initializing the variables:
```

```
H200 = 1170; // in Btu/lbmol
H2000 = 14970; // in Btu/lbmol
n = 20000; // in scfm

//calculation:
ndt = n*1/379
Q = ndt*(H2000 - H200)

printf("\n\nResult\n\n")
printf("\n the heat transfer rate is %.2E Btu/min",Q
    )
```

Scilab code Exa 7.03 Example 3

```
//Problem 7.03:

//initializing the variables:
H200 = 1170; // in Btu/lbmol
H2000 = 14970; // in Btu/lbmol
n = 20000; // in scfm
Cpav = 7.53; // in Btu/lbmol
T1 = 200; // in deg F
T2 = 2000; // in deg F

//calculation:
dT = T2 - T1
ndt = n*1/379
Q = ndt*Cpav*dT

printf("\n\nResult\n\n")
printf("\n the heat transfer rate is %.2E Btu/min",Q
    )
```

Scilab code Exa 7.04 Example 4

```
//Problem 7.04:

//initializing the variables:
mdt = 1200; // in lb/min
Cpav = 0.26; // in Btu/lbmol
T1 = 200; // in deg F
T2 = 1200; // in deg F

//calculation:
dT = T2 - T1
Q = mdt*Cpav*dT

printf("\n\nResult\n\n")
printf("\n the heat transfer rate is %.2E Btu/min",Q
   )
```

Scilab code Exa 7.05 Example 5

```
//Problem 7.05:

//initializing the variables:
Qt = 18.7E6; // in Btu/h
mdt = 72000; // in lb/h
Cpav = 0.26; // in Btu/lb.degF
T1 = 1200; // in deg F

//calculation:
T2 = [-1*Qt/(mdt*Cpav)]+T1

printf("\n\nResult\n\n")
printf("\n the outlet temperature of the gas stream
   is %.0f degF",T2)
```

Scilab code Exa 7.06 Example 6

```
//Problem 7.06:

//initializing the variables:
n = 1000; // in lb/h
MWCO2 = 44;
T1 = 200; // in deg F
T2 = 3200; // in deg F
a = 10.57;
b = 2.10E-3;
c = -1*2.06E5;

//calculation:
T1 = (T1 + 460)/1.8
T2 = (T2 + 460)/1.8
dT = T2 - T1
ndt = n/MWCO2
Q = ndt*1.8*(a*dT +(b/2)*(T2^2 - T1^2) + c*dT/(T2*T1
    ))

printf("\n\nResult\n\n")
printf("\n the heat transfer rate is %.2E Btu/h",Q)
```

Scilab code Exa 7.07 Example 7

```
//Problem 7.07:

//initializing the variables:
n = 1000; // in lb/h
MWCO2 = 44;
T1 = 200; // in deg F
```

```
T2 = 3200; // in deg F
a = 6.214;
b = 10.396E-3;
c = -3.545E-6;

//calculation:
T1 = (T1 + 460)/1.8
T2 = (T2 + 460)/1.8
dT = T2 - T1
ndt = n/MWCO2
Q = ndt*1.8*(a*dT +(b/2)*(T2^2 - T1^2) + (c/3)*(T2^3 - T1^3))

printf("\n\nResult\n\n")
printf("\n the heat transfer rate is %.2E Btu/h",Q)
```

Scilab code Exa 7.08 Example 8

```
//Problem 7.08:

//initializing the variables:
x = 0.5;
T1 = 10; // in deg F
T2 = 60; // in deg F

//calculation:
//qout = 0.5*qin
//Tout = Tup - 60
//Tmix = Tup - 10
//qbyp = qup - qin
//qmix = qup - 0.5*qin
//(qup - qin)*Cp*p*(Tup - Tref) + 0.5*qin*Cp*p*(Tup + 60 - Tref) = (qup - 0.5*qin)*Cp*p*(Tup - Tref + 60)
//Tref = 0
```

```
//soving above we get r = qin/qup
r = 10/35

printf("\n\nResult\n\n")
printf("\n %.1f percent of the river flow, qup, is
   available for cooling",r*100)
```

Scilab code Exa 7.09 Example 9

```
//Problem 7.09:

//initializing the variables:
F1 = 50000; // in lb/h
F2 = 60000; // in lb/h
F3 = 80000; // in lb/h
F4 = 60000; // in lb/h
F5 = 40000; // in lb/h
F6 = 35000; // in lb/h
Cp1 = 0.65; // in Btu/lb.degF
Cp2 = 0.58; // in Btu/lb.degF
Cp3 = 0.78; // in Btu/lb.degF
Cp4 = 0.70; // in Btu/lb.degF
Cp5 = 0.52; // in Btu/lb.degF
Cp6 = 0.60; // in Btu/lb.degF
Tin1 = 70; // in deg F
Tin2 = 120; // in deg F
Tin3 = 90; // in deg F
Tin4 = 420; // in deg F
Tin5 = 300; // in deg F
Tin6 = 240; // in deg F
Tout1 = 300; // in deg F
Tout2 = 310; // in deg F
Tout3 = 250; // in deg F
Tout4 = 120; // in deg F
Tout5 = 100; // in deg F
```

```
Tout6 = 90; // in deg F

//calculation:
Duty1 = F1*Cp1*(Tout1 - Tin1)
Duty2 = F2*Cp2*(Tout2 - Tin2)
Duty3 = F3*Cp3*(Tout3 - Tin3)
Duty4 = F4*Cp4*abs(Tout4 - Tin4)
Duty5 = F5*Cp5*abs(Tout5 - Tin5)
Duty6 = F6*Cp6*abs(Tout6 - Tin6)
heat = Duty1 + Duty2 + Duty3
cool = Duty4 + Duty5 + Duty6
steam = heat - cool

printf("\n\nResult\n\n")
printf("\n As a minimum %.0f Btu/h will have to be
    supplied by steam or another hot medium",steam)
```

Scilab code Exa 7.11 Example 11

```
//Problem 7.11:

//initializing the variables:
n = 1200; // in lb/h
MWCaO = 56;
T1 = 42; // in deg F
T2 = 68; // in deg F
a = 11.67;
b = 1.08E-3;
c = -1*1.565E5;

//calculation:
T1 = (T1 + 460)/1.8
T2 = (T2 + 460)/1.8
dT = T2 - T1
ndt = n/MWCaO
```

```
Q = ndt*(a*dT +(b)*(T2^2 - T1^2) + (c)*dT/(T1*T2))
    *1.8

printf("\n\nResult\n\n")
printf("\n the heat transfer rate is %.0f Btu/h",Q)
```

Scilab code Exa 7.12 Example 12

```
//Problem 7.12:

//initializing the variables:
T = 1000; // in K
a = 0.4687;
b = 9.4870E-2;
c = -1*0.5553E-4;
d = 0.02284E-6;

//calculation:
Cp0 = a + b*T + c*T^2 + d*T^3

printf("\n\nResult\n\n")
printf("\n the heat capacity is %.2f Btu/lbmol.degR"
    ,Cp0)
```

Chapter 8

Latent Enthalpy Effects

Scilab code Exa 8.01 Example 1

```
//Problem 8.01:

//initializing the variables:
T = 0; // in deg C
A = 15.03;
B = 2817;

//calculation:
T = T + 273
P = %e^(A - B/T)

printf("\n\nResult\n\n")
printf("\n the vapor pressure is %.2f mm of Hg",P)
```

Scilab code Exa 8.02 Example 2

```
//Problem 8.02:

```

```
//initializing the variables:
T = 0; // in deg C
A = 16.65;
B = 2940;
C = -35.93;

//calculation:
T = T + 273
P = %e^(A - B/(T + C))

printf("\n\nResult\n\n")
printf("\n the vapor pressure is %.2f mm of Hg",P)
```

Scilab code Exa 8.04 Example 4

```
//Problem 8.04:

//initializing the variables:
T1 = 250; // in deg C
T2 = 260; // in deg C
T3 = 270; // in deg C
T4 = 280; // in deg C
T5 = 290; // in deg C
P1 = 22.01; // in atm
P2 = 24.66; // in atm
P3 = 27.13; // in atm
P4 = 29.79; // in atm
P5 = 32.42; // in atm
vl3 = 0.0408; // in ft3/lb
vg3 = 0.192; // in ft3/lb

//calculation:
dpdT = (P4 - P2)/(T4 - T2)
dv = vg3 - vl3
T3 = T3 + 460
```

```
dH = T3*dv*dpdT*14.7*144/778

printf("\n\nResult\n\n")
printf("\n the enthalpy of vaporization is %.2f Btu/
   lb",dH)
```

Scilab code Exa 8.05 Example 5

```
//Problem 8.05:

//initializing the variables:
T1 = 250; // in deg C
T2 = 260; // in deg C
T3 = 270; // in deg C
T4 = 280; // in deg C
T5 = 290; // in deg C
P1 = 22.01; // in atm
P2 = 24.66; // in atm
P3 = 27.13; // in atm
P4 = 29.79; // in atm
P5 = 32.42; // in atm
vl3 = 0.0408; // in ft3/lb
vg3 = 0.192; // in ft3/lb

//calculation:
dpdT = (P5 - P1)/(T5 - T1)
dpdT13 = (P3 - P1)/(T3 - T1)
dpdT35 = (P5 - P3)/(T5 - T3)
dpdTav = (dpdT13+dpdT35)/2

printf("\n\nResult\n\n")
printf("\n the p‘ vs T derivative is %.3f",dpdTav)
```

Scilab code Exa 8.06 Example 6

```
//Problem 8.06:

//initializing the variables:
Tc = 647; // in K
Tn = 100 + 273; // in K
Pc = 217.6; // in atm
dHe = 970; // in Btu/lb

//calculation:
Tm = Tn/Tc
dH = 2.17*Tn*((log(Pc)) - 1.0)/(0.930 - Tm)
dHn = dH*454/(252*18)
perdiff = (dHn - dHe)*100/dHe

printf("\n\nResult\n\n")
printf("\n the enthalpy of vaporization is %.1f
    percent",perdiff)
```

Scilab code Exa 8.07 Example 7

```
//Problem 8.07:

//initializing the variables:
Tn = 212 + 460; // in deg R
R = 1.987
Tr = 12; // say

//calculation:
dH = Tr*Tn*R

printf("\n\nResult\n\n")
printf("\n the enthalpy of vaporization is %.0f Btu/
    lbmol",dH)
```

Scilab code Exa 8.08 Example 8

```
//Problem 8.08:

//initializing the variables:
T1 = 100; // in deg C
P = 101370; // in Pa
dH100 = 2256.9; // in J/g
T2 = 200; // in deg C

//calculation:
Tr100 = (T1 + 273)/647
Tr200 = (T2 + 273)/647
dH200 = dH100*((1 - Tr200)/(1 - Tr100))^0.38

printf("\n\nResult\n\n")
printf("\n the enthalpy of vaporization is %.0f J/g"
    ,dH200)
```

Scilab code Exa 8.09 Example 9

```
//Problem 8.09:

//initializing the variables:
Tn = 100; // in deg C
P = 101370; // in Pa
dHn = 2200; // in kJ/Kg
Tc = 370; // in deg C
T = 250; // in deg C

//calculation:
```

```
dH250 = dHn*(1 - ((T - Tn)/(Tc - Tn))^2)

printf("\n\nResult\n\n")
printf("\n the enthalpy of vaporization is %.0f kJ/
    kg",dH250)
```

Scilab code Exa 8.10 Example 10

```
//Problem 8.10:

//initializing the variables:
Tw = 60; // in deg F
mdt1 = 1000; // in lb/h
Pw = 1; // in atm
Ps = 40; // in atm
Ts = 1000; // in deg F
Pd = 20; // in atm
Td = 600; // in deg F
H40 = 1572; // in Btu/lb
H20 = 1316; // in Btu/lb
H1 = 1151; // in Btu/lb
Ht60 = 28.1; // in Btu/lb

//calculation:
dHv = mdt1*(H1 - Ht60)
mdt2 = dHv/(H40 - H20)

printf("\n\nResult\n\n")
printf("\n mass flowrate of the utility steam
    required is %.0f lb/h",mdt2)
```

Scilab code Exa 8.11 Example 11

```
//Problem 8.11:

//initializing the variables:
Ts = 90; // in deg F
Cp = 1; // in Btu/lb.deg F
Cpv = 1030; // in Btu/lb
Tr = 115; // in deg F
D1 = 12000000; // in Btu/h
D2 = 6000000; // in Btu/h
D3 = 23000000; // in Btu/h
D4 = 17000000; // in Btu/h
D5 = 31500000; // in Btu/h
d = 8.32; // in lb/gal

//calculation:
Qdt = D1 + D2 + D3 + D4 + D5
F = Qdt/((Tr - Ts)*Cp)
Fgpm = F/(60*d)

printf("\n\nResult\n\n")
printf("\n total flowrate of cooling water is %.0f
    gal/min",Fgpm)
```

Scilab code Exa 8.12 Example 12

```
//Problem 8.12:

//initializing the variables:
Ts = 90; // in deg F
Cp = 1; // in Btu/lb.deg F
Cpv = 1030; // in Btu/lb
Tr = 115; // in deg F
D1 = 12000000; // in Btu/h
D2 = 6000000; // in Btu/h
D3 = 23000000; // in Btu/h
```

```
D4 = 17000000; // in Btu/h
D5 = 31500000; // in Btu/h
d = 8.32; // in lb/gal
a = 0.05;

//calculation:
Qdt = D1 + D2 + D3 + D4 + D5
F = Qdt/((Tr - Ts)*Cp)
B = a*F
V = Qdt/Cpv
M = B + V
Mgpm = 0.002*M

printf("\n\nResult\n\n")
printf("\n the sum of blowdown and the amount
   evaporated is %.0f gal/min",Mgpm)
```

Scilab code Exa 8.13 Example 13

```
//Problem 8.13:

//initializing the variables:
P =500; // in psig
UHD1 = 10000000; // in Btu/h
UHD2 = 8000000; // in Btu/h
UHD3 = 12000000; // in Btu/h
UHD4 = 20000000; // in Btu/h
T1 = 250; // in deg F
T2 = 450; // in deg F
T3 = 400; // in deg F
T4 = 300; // in deg F
Ps1 = 75; // in psig
Ps2 = 500; // in psig
Ts1 = 320; // in deg F
Ts2 = 470; // in deg F
```

```
dHv1 = 894; // in Btu/lb
dHv2 = 751; // in Btu/lb

//calculation:
mdtb1 = UHD1/dHv2
mdtb2 = UHD2/dHv2
mdtb3 = UHD3/dHv2
mdtb4 = UHD4/dHv2
mdtb = mdtb1 + mdtb2 + mdtb3 + mdtb4

printf("\n\nResult\n\n")
printf("\n steam required is %.0f lb/h",mdtb)
```

Chapter 9

Enthalpy of Mixing Effects

Scilab code Exa 9.01 Example 1

```
//Problem 9.01:

//initializing the variables:
w = 50; // in lb
Ws = 200; // in lb
a = 0.5;
Ts = 25;// in deg C

//calculation:
WH2SO4 = w + Ws*a
WH2O = Ws*a
perH2SO4 = (WH2SO4/(WH2SO4 + WH2O))*100
//Referring to Fig. 9.3, construct a straight line
   between the 50% solution and pure H2SO4 at 25 deg
   C (77 deg F). Estimate the final temperature in
   deg F:
T = 140;// in deg F

printf("\n\nResult\n\n")
printf("\n the adiabatic temperature change is %.0f
   deg F",T)
```

Scilab code Exa 9.02 Example 2

```
//Problem 9.02:

//initializing the variables:
w = 50; // in lb
Ws = 200; // in lb
a = 0.5;
Ts = 25;// in deg C

//calculation:
WH2SO4 = w + Ws*a
WH2O = Ws*a
perH2SO4 = (WH2SO4/(WH2SO4 + WH2O))*100
//Referring to Fig. 9.3, construct a straight line
   between the 50% solution and pure H2SO4 at 25 deg
    C (77 deg F). Estimate the final temperature in
   deg F:
T = 140;// in deg F
H140 = -86; // in Btu/lb
H77 = -121.5; // in Btu/lb
Wt = WH2SO4 + WH2O
Q = Wt*(H77 - H140)

printf("\n\nResult\n\n")
printf("\n the heat is %.0f Btu",Q)
```

Scilab code Exa 9.03 Example 3

```
//Problem 9.03:

```

```
//initializing the variables:
w = 65; // in lb
Ws = 125; // in lb
a = 0.45;
Ts = 75;// in deg C

//calculation:
T = 9*Ts/5 - 32
wf = (w*0 + a*Ws)/(Ws + w)
//From Fig. 9.4
Hfinal = 156 // in Btu/lb
Tf = 208 // in deg F

printf("\n\nResult\n\n")
printf("\n the adiabatic temperature change is %.0f
    deg F",Tf)
```

Scilab code Exa 9.04 Example 4

```
//Problem 9.04:

//initializing the variables:
w = 65; // in lb
Ws = 125; // in lb
a = 0.45;
Ts = 75;// in deg C

//calculation:
T = (9*Ts/5) + 32
wf = (w*0 + a*Ws)/(Ws + w)
//From Fig. 9.4
Hfinal = 156 // in Btu/lb
Tf = 208 // in deg F
//From Fig. 9.4, the absolute temperature change, DT
    , is
```

```
DT = Tf - T

printf("\n\nResult\n\n")
printf("\n the adiabatic temperature change is %.0f
   deg F",DT)
```

Scilab code Exa 9.05 Example 5

```
//Problem 9.05:

//initializing the variables:
w = 65; // in lb
Ws = 125; // in lb
a = 0.45;
Ts = 75;// in deg C

//calculation:
T = (9*Ts/5) + 32
wf = (w*0 + a*Ws)/(Ws + w)
//From Fig. 9.4
Hf208 = 156 // in Btu/lb
Hf167 = 118 // in Btu/lb
Q = Hf167 - Hf208
Qr = Q*(Ws + w)

printf("\n\nResult\n\n")
printf("\n the the heat effect is %.0f Btu",Qr)
```

Scilab code Exa 9.07 Example 7

```
//Problem 9.07:

//initializing the variables:
```

```
//calculation:
//Since enthalpy is a point function, it is reasonable to assume that the temperature effects are additive. Therefore, the temperature increases are:
//Scenario 1: DT = DT1.5 − DT0.0
DT1 = 10 - 0
//Scenario 2: DT = DT3.0−DT1.5
DT2 = 15 - 10

printf("\n\nResult\n\n")
printf("\n the discharge temperature increase for scenario 1 is %.0f degC and for scenario 2 is %.0f degC",DT1,DT2)
```

Scilab code Exa 9.08 Example 8

```
//Problem 9.08:

//initializing the variables:
Z = 10000; // in lb/h
x = 0.1;
y = 0.75;
Ts = 75;// in deg C

//calculation:
X = Z*x/y
Y = Z - X
//from Fig. 9.4:
Hz = 81 // in Btu/lb
Hx = 395 // in Btu/lb
Hy = 1150 // in Btu/lb
Q = Hy*Y + Hx*X - Hz*Z

```

```
printf("\n\nResult\n\n")
printf("\n the evaporator heat required, Q is %.0f
   Btu/h",Q)
```

Scilab code Exa 9.09 Example 9

```
//Problem 9.09:

//initializing the variables:
Z = 10000; // in lb/h
x = 0.1;
y = 0.75;
Ts = 340;// in deg F
T = 212; // in deg F
U = 500; // in Btu/h.ft2.deg F

//calculation:
X = Z*x/y
Y = Z - X
//from Fig. 9.4:
Hz = 81 // in Btu/lb
Hx = 395 // in Btu/lb
Hy = 1150 // in Btu/lb
Q = Hy*Y + Hx*X - Hz*Z
A = Q/(U*(Ts - T))

printf("\n\nResult\n\n")
printf("\n the area requirement in the evaporator is
    %.1f ft^2",A)
```

Chapter 10

Chemical Reaction Enthalpy Effects

Scilab code Exa 10.01 Example 1

```
//Problem 10.01:

//initializing the variables:
DH0co2 = -94052; // in cal/gmol
DH0h2o = -57798; // in cal/gmol
DH0ch4 = -17889; // in cal/gmol
DH0o2 = 0; // in cal/gmol
T = 298; // in K

//calculation:
DH0298 = DH0co2 + 2*DH0h2o - 2*DH0o2 - DH0ch4

printf("\n\nResult\n\n")
printf("\n the standard enthalpy of reaction is %.0
    fcal/gmol",DH0298)
```

Scilab code Exa 10.02 Example 2

```
//Problem 10.02:

//initializing the variables:
DH0no = 21570; // in cal/gmol
DH0h2o = -68317; // in cal/gmol
DH0c3h8 = -24820; // in cal/gmol
DH0ch4 = -17889; // in cal/gmol
DH0c2h4= 12496; // in cal/gmol
DH0no2 = 7930; // in cal/gmol
DH0hno3 = -41404; // in cal/gmol
T = 298; // in K

//calculation:
DH02981 = 2*DH0no
DH02982 = DH0ch4 + DH0c2h4 - DH0c3h8
DH02983 = DH0no + 2*DH0hno3 - 3*DH0no2 - DH0h2o

printf("\n\nResult\n\n")
printf("\n Standard heat of reaction 1 is %.0fcal/
   gmol N2 of reaction 2 is %.0f cal/gmol C3H8 and
   of rection 3 is %.0f cal/gmol H2O ",DH02981,
   DH02982, DH02983)
```

Scilab code Exa 10.03 Example 3

```
//Problem 10.03:

//initializing the variables:

//calculation:
//From Table 10.1,
//DH0chex = -1,005,570 cal/gmol
//First, write the combustion reaction:
```

```
//C6H14 + 9.5O2 ---> 6CO2 + 7H2O(l)
//From Table 10.1, one obtains
DH0fC6H14 = -36960 //cal/gmol
DH0fCO2 = -94052 //cal/gmol
DH0fH2O = -68317 //cal/gmol
//Thus,
//DH0c = E(DH0f,p) - E(DH0f,r)
DH0c = 6*DH0fCO2 + 7*DH0fH2O - 1*DH0fC6H14
//The calculation process is verified.

printf("\n\nResult\n\n")
printf("\n From Table 10.1 DH0c(n-hexane) = -1,005,570 cal/gmol, we obtains by calculations DH0c = %.0f cal/gmol \n The calculation process is verified.",DH0c)
```

Scilab code Exa 10.04 Example 4

```
//Problem 10.04:

//initializing the variables:

//calculation:
//The standard heat of combustion for this organic is obtained directly from \nTable 10.1, noting that the H2O and HCl formed are in the liquid and gaseous states,\n respectively:
DH0c = -1600 //kcal/gmol
//First, write a balanced stoichiometric equation for this combustion reaction:
//C14H9Cl5 + 15O2 ---> 14CO2 + 2H2O(l) + 5HCl(g)
//For this reaction,
//DH0c = 14DH0f,CO2 + 2DH0f ,H2O(l) + 5DH0f ,HCl(g) - DH0f ,C14H9Cl5
//From Table 10.1,
```

```
DH0fCO2 = -94.052 //kcal/gmol
DH0fH2O = -68.317 //kcal/gmol
DH0fHCl = -22.063 //kcal/gmol
//Solving this equation for DH0f ,C14H9C15 yields
DH0fC14H9Cl5 = -1*DH0c + 14*DH0fCO2 + 2*DH0fH2O + 5*DH0fHCl //kcal=gmol

printf("\n\nResult\n\n")
printf("\n DH0fC14H9Cl5 = %.3f kcal/gmol ", DH0fC14H9Cl5)
```

Scilab code Exa 10.05 Example 5

```
//Problem 10.05:

//initializing the variables:

//calculation:
//TThe standard heat of combustion for chlorobenzene is obtained from the heats of formation data in Table 10.1. Since
//C6H5Cl + 7O2 ---> 6CO2 + 2H2O + HCl(g)
DH0c = 6*(-94052) + 2*(-57789) - 22063 - 12390
//This stoichiometric reaction is now written for combustion in air. First note that there are 7.0(79/21) or 26.33 lbmol of nitrogen present in the theoretical combustion air
//C6H5Cl + 7O2 + [26.33N2] ---> 6CO2 + 2H2O(g) + HCl(g) + [26.33N2]
//The heat capacity for the flue gas products in the form
//CP = a + b*T + c*T^-2
Da = 264.12
Db = 0.0425
Dc = -1.522E6
```

```
//DCp = Da + Db*T + Dc*T^-2 cal/gmol.K or Btu/lbmol.
   degR
//Equation (10.22) applies in calculating the
   adiabatic flame temperature. The energy liberated
    \non combustion appears as sensible energy in
   heating the flue (product) gas. The sum of \
   nthese two effects is zero if the operation is
   conducted adiabatically , i.e.,
//DH0c + DHp = DH = 0
//Since 25 degC = 298K, the enthalpy change
   associated with heating the flue products is
   given by
//DHp = int(298,T2)[DCp]dT
//T2 = theoretical adiabatic temperature (K)
//Substituting DCp obtained previously and
   integrating yields
//DHp = Da*(T2 - 298) + (Db/2)*(T2^2 - 298^2) - Dc
   *(1/T2 - 1/298)
DH0c = -714361 // cal/gmol
DH0p = -1*DH0c
//by solving the equation trial and error method
T2 = 2519 // K
T2f = 4074 // deg F

printf("\n\nResult\n\n")
printf("\n theoretical adiabatic flame temperature
   is %.0f degF",T2f)
```

Scilab code Exa 10.06 Example 6

```
//Problem 10.06:

//initializing the variables:

//calculation:
```

```
//TThe standard heat of combustion for chlorobenzene is obtained from the heats of formation data in Table 10.1. Since
//C6H5Cl + 7O2 ---> 6CO2 + 2H2O + HCl(g)
DH0c = 6*(-94052) + 2*(-57789) - 22063 - 12390
//This stoichiometric reaction is now written for combustion in air. First note that there are 7.0(79/21) or 26.33 lbmol of nitrogen present in the theoretical combustion air
//C6H5Cl + 7O2 + [26.33N2] ---> 6CO2 + 2H2O(g) + HCl(g) + [26.33N2]
//The heat capacity for the flue gas products in the form
//CP = a + b*T + r*T^2
Da = 230.305
Db = 0.1003175
Dr = -20.36033E-6
//DCp = Da + Db*T + Dr*T^2 cal/gmol.K or Btu/lbmol.degR
//Equation (10.22) applies in calculating the adiabatic flame temperature. The energy liberated \non combustion appears as sensible energy in heating the flue (product) gas. The sum of \nthese two effects is zero if the operation is conducted adiabatically, i.e.,
//DH0c + DHp = DH = 0
//Since 25 degC = 298K, the enthalpy change associated with heating the flue products is given by
//DHp = int(298,T)[DCp]dT
//T = theoretical adiabatic temperature (K)
//Substituting DCp obtained previously and integrating yields
//DHp = Da*(T - 298) + (Db/2)*(T^2 - 298^2) - Dr*(T^3 - 298^3)
DH0c = -714361 // cal/gmol
DH0p = -1*DH0c
//by solving the equation trial and error method
```

```
T = 2511.5 // K
Tf = 4061 // deg F

printf("\n\nResult\n\n")
printf("\n theoretical adiabatic flame temperature is %.0f degF",Tf)
```

Scilab code Exa 10.07 Example 7

```
//Problem 10.07:

//initializing the variables:

//calculation:
//TThe standard heat of combustion for chlorobenzene is obtained from the heats of formation data in Table 10.1. Since
//C6H5Cl + 14O2 ---> 6CO2 + 2H2O + HCl(g) + 7O2
DH0c = 6*(-94052) + 2*(-57789) - 22063 - 12390
//This stoichiometric reaction is now written for combustion in air. First note that there are 7.0(79/21) or 26.33 lbmol of nitrogen present in the theoretical combustion air
//C6H5Cl + 14O2 + [52.6N2] ---> 6CO2 + 2H2O(g) + HCl(g) + 7O2 + [52.6N2]
//The heat capacity for the flue gas products in the form
//CP = a + b*T + c*T^-2
Da = 493.67
Db = 0.0731
Dc = -2.12E6
//DCp = Da + Db*T + Dc*T^-2 cal/gmol.K or Btu/lbmol.degR
//Equation (10.22) applies in calculating the adiabatic flame temperature. The energy liberated
```

```
\non combustion appears as sensible energy in
heating the flue (product) gas. The sum of \
nthese two effects is zero if the operation is
conducted adiabatically, i.e.,
//DH0c + DHp = DH = 0
//Since 25 degC = 298K, the enthalpy change
associated with heating the flue products is
given by
//DHp = int(298,T2)[DCp]dT
//T2 = theoretical adiabatic temperature (K)
//Substituting DCp obtained previously and
integrating yields
//DHp = Da*(T2 - 298) + (Db/2)*(T2^2 - 298^2) - Dc
*(1/T2 - 1/298)
DH0c = -714361 // cal/gmol
DH0p = -1*DH0c
//by solving the equation trial and error method
T2 = 1579 // K
T2f = 2382 // deg F

printf("\n\nResult\n\n")
printf("\n theoretical adiabatic flame temperature
is %.0f degF \n therefore the operating
temperature does exceed the permit requirement of
2100 degF",T2f)
```

Scilab code Exa 10.08 Example 8

```
//Problem 10.08:

//initializing the variables:
EA = 150
T = 298; // in K

//calculation:
```

```
DHc = -1580.56 // in cal/gmol
//DCp = 14*Cpco2 + 2*Cph2o + 5*Cphcl + 22.5*Cpo2 +
    141.05*Cpn2
//DCp = 1318.60 + 0.1899*T - 5.327E6*T^-2
//DHc = 1318.60(T2 - T) + 0.5*0.1899*(T2^2 - T^2) +
    5.327E6(T2^-1 - 298^-1)
//solving this, we get
T2 = 1377 // in k
Tf = 9*(T2 - 273)/5 + 32 // in deg F

printf("\n\nResult\n\n")
printf("\n the operating temperature is %.0fdeg F",
    Tf)
```

Scilab code Exa 10.09 Example 9

```
//Problem 10.09:

//initializing the variables:
EA = 10
x = 0.10
Da = 117
Db = 0.04521
Dr = -6.53E-6
DH0co2 = -94054; // in cal/gmol
DH0h2o = -57798; // in cal/gmol
DH0c2h6o = -56240; // in cal/gmol

//calculation:
DH0298 = 2*DH0co2 + 3*DH0h2o - DH0c2h6o
DHP = -1*DH0298
DHPl = (1 - x)*DHP
//DHPl = Da*(T - 298) + (Db/2)*(T^2 - 298^2) + (Dr
    /3)*(T^3 - 298^3)
//solving this, we get
```

```
T = 2025 // in k
Tf = 9*(T - 273)/5 + 32 // in deg F

printf("\n\nResult\n\n")
printf("\n the flame temperature is %.0fdeg F",Tf)
```

Scilab code Exa 10.10 Example 10

```
//Problem 10.10:

//initializing the variables:

//calculation:
//C2H3Cl + 2.5O2 + [9.4N2] ---> 2CO2 + H2O(g) + HCl(g) + [9.4N2]
//C3H8 + 5O2 + [18.8N2] ---> 3CO2 + 4H2O + [18.8N2]
DH0cC2H3Cl = 2*(-94052) + 1*(-57789) - 22063 + 8400
DH0cC3H8 = 3*(-94052) + 4*(-57789) + 24820
//The heat capacity for the flue gas products in the form
//CP = a + b*T + c*T^-2
Da1 = 87.7416
Db1 = 35.273E-3
Dr1 = -6.446E-6
Da2 = 170.317
Db2 = 63.820E-3
Dr2 = -9.5218E-6
//Calculate the mole fraction of 1-chloroethylene and propane:
MWof1Chloroethylene = 62.5; //lb/lbmol
MWofpropane = 44; //lb/lbmol
//Converting from lb to lbmols on a total 100 lb basis,
mols1chloroethylene =  1.2
molspropane =0.57
```

```
totalmols = 1.77
//Converting mols to mole fraction ,
n1 = 0.679
n2 = 0.321
//DCp = Da + Db*T + Dr*T^2 cal/gmol.K or Btu/lbmol.degR
//Equation (10.22) applies in calculating the adiabatic flame temperature. The energy liberated \non combustion appears as sensible energy in heating the flue (product) gas. The sum of \nthese two effects is zero if the operation is conducted adiabatically , i.e.,
//DH0c + DHp = DH = 0
//Since 25 degC = 298K, the enthalpy change associated with heating the flue products is given by
//DHp = int(298,T2)[DCp]dT
//T = theoretical adiabatic temperature (K)
//Substituting DCp obtained previously and integrating yields
//DH0p = Da*(T - 298) + (Db/2)*(T^2 - 298^2) - Dr*(T^3 - 298^3)
Da = n1*Da1 + n2*Da2
Db = n1*Db1 + n2*Db2
Dr = n1*Dr1 + n2*Dr2
DH0c = n1*DH0cC2H3Cl + n2*DH0cC3H8 // cal/gmol
DH0p = -1*DH0c
//by solving the equation trial and error method
T = 2406 // K
Tf = 3871 // deg F

printf("\n\nResult\n\n")
printf("\n theoretical adiabatic flame temperature is %.0f degF ",Tf)
```

Scilab code Exa 10.11 Example 11

```
//Problem 10.11:

//initializing the variables:
DH0T = -12236; // in cal/gmol

//calculation:
//DH0T = -9140 - 7.596*T + 4.243E-3*T^2 - 0.742E-6*T
    ^3
//solving this, we get
T = 570 // in k
Tc = T - 273 // in deg C

printf("\n\nResult\n\n")
printf("\n the temperature is %.0fdeg C",Tc)
```

Scilab code Exa 10.12 Example 12

```
//Problem 10.12:

//initializing the variables:
T = 250; // in Deg C

//calculation:
Tk = T + 273
//DH0T = -9140 - 7.596*T + 4.243E-3*T^2 - 0.742E-6*T
    ^3
//solving this, we get
DH0523 = -9140 - 7.596*Tk + 4.243E-3*Tk^2 - 0.742E
    -6*Tk^3
Q = DH0523

printf("\n\nResult\n\n")
printf("\n heat must be added to or removed from a
```

```
flow reactor per gmole of product formed is %.0f
   cal/gmol",Q)
```

Scilab code Exa 10.13 Example 13

```
//Problem 10.13:

//initializing the variables:
ndt = 8; // gmol/h
T = 250; // in Deg C

//calculation:
Tk = T + 273
//DH0T = -9140 - 7.596*T + 4.243E-3*T^2 - 0.742E-6*T
   ^3
//solving this , we get
DH0523 = -9140 - 7.596*Tk + 4.243E-3*Tk^2 - 0.742E
   -6*Tk^3
Qdt = ndt*DH0523

printf("\n\nResult\n\n")
printf("\n heat rate must be added to or removed
   from a flow reactor is %.0f cal/h",Qdt)
```

Scilab code Exa 10.15 Example 15

```
//Problem 10.15:

//initializing the variables:
xin2 = 0.0515
xich4 = 0.8111
xic2h6 = 0.0967
xic3h8 = 0.0351
```

```
xic4h10 = 0.0056
HVgn2 = 0; // in Btu/scf
HVgch4 = 1013; // in Btu/scf
HVgc2h6 = 1792; // in Btu/scf
HVgc3h8 = 2590; // in Btu/scf
HVgc4h10 = 3370; // in Btu/scf

//calculation:
HVg = xin2*HVgn2 + xich4*HVgch4 + xic2h6*HVgc2h6 +
   xic3h8*HVgc3h8 + xic4h10*HVgc4h10

printf("\n\nResult\n\n")
printf("\n the gross heating value of the gas
   mixture is %.0f Btu/scf",HVg)
```

Scilab code Exa 10.16 Example 16

```
//Problem 10.16:

//initializing the variables:
c = 0.25
mo = 0.35
w = 0.15
in = 0.25
ql = 0.05
co2 = 0.118
co = 13; // in ppm
o2 = 0.104
NHVc = 14000; // in Btu/lb
NHVmo = 25000; // in Btu/lb
NHVw = 0; // in Btu/lb
NHVin = -1000; // in Btu/lb

//calculation:
NHV = c*NHVc + w*NHVw + mo*NHVmo + in*NHVin
```

```
EA = (1 - ql)*o2*100/(21-o2*100)
T = 60 + NHV/(0.325*[1 + (1+EA)*7.5E-4*NHV])

printf("\n\nResult\n\n")
printf("\n the theoretical flame temperature is %.0f
    deg F",T)
```

Scilab code Exa 10.17 Example 17

```
//Problem 10.17:

//initializing the variables:
T = 1900;// in deg F
ea0 = 0
ea100 = 1

//calculation:
NHV0 = 0.3*(T-60)/(1 - (1+ ea0)*7.5E-4*0.3*(T-60))
NHV100 = 0.3*(T-60)/(1 - (1+ea100)*7.5E-4*0.3*(T-60)
   )

printf("\n\nResult\n\n")
printf("\n NHV for 0 percent Excess air is %.0f Btu/
   lb and for 100 percent is %.0f Btu/lb",NHV0,
   NHV100)
```

Chapter 11

Phase Equilibrium Principles

Scilab code Exa 11.02 Example 2

```
//Problem 11.02:

//initializing the variables:
Tdb1 = 100; // in deg F
Twb = 70; // in deg F
Tdb2 = 80; // in deg F
p = 1; // in atm

//calculation:
//from fig. 11.2
Hi = 0.0090 // lb
Hf = 0.0133 // lb
dH = Hf - Hi

printf("\n\nResult\n\n")
printf("\n moisture added is %.2E lb H2O/lb dry air"
   ,dH)
```

Scilab code Exa 11.03 Example 3

```
//Problem 11.03:

//initializing the variables:
T1 = 120; // in deg F
T2 = 560; // in deg F
mdte = 9000; // in lb/h
MW = 30
MWH2O = 18
R = 0.73

//calculation:
//from fig. 11.2
Hout = 0.0814 // lb H2O/lb bone-dry air
mdtH2O = Hout*mdte
mdtt = mdtH2O + mdte
Yg = (mdte/MW)/(mdtH2O/MWH2O + mdte/MW)
Ywv = (mdtH2O/MWH2O)/(mdtH2O/MWH2O + mdte/MW)
MWB = Yg*MW + Ywv*MWH2O
Pqa = mdtt*R*(460+140)/MWB

printf("\n\nResult\n\n")
printf("\n the moisture content is %.4f lb H2O/lb dry air, the mass flow rate is %.0f lb/h,the volumetric flow rate of the discharge gas is %.2E ft3/h",Hout, mdtH2O, Pqa)
```

Scilab code Exa 11.04 Example 4

```
//Problem 11.04:

//initializing the variables:
T1 = 0; // in deg C
p = 71; // mm of Hg
P = 1; // in atm

```

```
//calculation:
ymax = p/760

printf("\n\nResult\n\n")
printf("\n the maximum concentration is %.4f ",ymax)
```

Scilab code Exa 11.05 Example 5

```
//Problem 11.05:

//initializing the variables:
T1 = 25; // in deg C
xa = 0.05
xb = 0.95
pa = 4150; // in kPa
pb = 16.1; // in kPa

//calculation:
P = xa*pa + xb*pb
ya = xa*pa/P
yb = 1 - ya

printf("\n\nResult\n\n")
printf("\n the pressure is %.1f kPa, composition of
    the first vapor is %.3f ehane  and %.3f hexane ",
    P, ya, yb)
```

Scilab code Exa 11.06 Example 6

```
//Problem 11.06:

//initializing the variables:
T1 = 25; // in deg C
```

```
pa = 111; // in mm of Hg
pb = 92; // in mm of hg
P = 100; // in mm of hg

//calculation:
xa = (P - pb)/(pa - pb)
ya = xa*pa/P


printf("\n\nResult\n\n")
printf("\nthe composition of the liquid phase is %.3f and of vapour phase %.3f",xa, ya)
```

Scilab code Exa 11.08 Example 8

```
//Problem 11.08:

//initializing the variables:
T1 = 25; // in deg C
ph2s = 0.01; // in atm
Pt = 1; // in atm
Hh2s = 483; // in atm/mole fraction

//calculation:
xh2s = ph2s/Hh2s

printf("\n\nResult\n\n")
printf("\nthe maximum mole fraction %.2E",xh2s)
```

Scilab code Exa 11.09 Example 9

```
//Problem 11.09:

```

```
//initializing the variables:

//calculation:
//The partial pressure of ammonia is converted to
    mole fraction in vapor as shown in Table 11.3.
// These results of table 11.3 are plotted in Fig.
    11.7.
//Henry s law constant from the graph is
    approximately 1.485 at x = 0.095. Since
Yactual = 0.148
Ycalculated = 1.485*(0.095)
Percentagreement = Ycalculated*100/Yactual

printf("\n\nResult\n\n")
printf("\n from x = 0 to x = %.3f Henry s law
    equation, y = 1.485x, predicts the equilibrium
    vapor content to within 5 percent of the
    experimental data.",Percentagreement/1000)
```

Scilab code Exa 11.10 Example 10

```
//Problem 11.10:

//initializing the variables:
mdt = 2000; // in acfm
xCl = 0.13;
T1 = 80; // in deg F
xCCl4 = 0.95;
Tav = -70; // in deg F
U = 4; // in Btu/ft2.h.deg F
Cav = 0.125; // Btu/lb.deg F
Hv = 93.7; // Btu/lb(80 deg F)
p0 = 7.74; // mm of Hg T 0 deg F
p18 = 5.64; // mm of Hg T -18 deg F
p40 = 2.23; // mm of Hg T -40 deg F
```

```
//calculation:
//let
n = 100; // in lbmol
nCCl4 = xCl*n
nair = n - nCCl4
//for 95%
nCCl4 = (1 - xCCl4)*nCCl4
yCCl4 = nCCl4/(nair + nCCl4)
PCCl4 = yCCl4*760
mdtair = mdt*(1 - xCl)*60*14.7*29/((460 + T1)*10.73)
mdtCCl4 = mdt*xCl*60*14.7*154/((460 + T1)*10.73)
Qair = mdtair*0.24*(-18 - T1)
QCCl4 = mdtCCl4*Cav*(-18 - T1) + mdtCCl4*xCCl4*(-1*
   Hv)
Q = Qair + QCCl4
LMTD = [(T1 - Tav) - (-18 - Tav)]/(log(150/52))
A = abs(Q)/(U*LMTD)

printf("\n\nResult\n\n")
printf("\n the surface area required is %.0f ft^2",A
   )
```

Scilab code Exa 11.13 Example 13

```
//Problem 11.13:

//initializing the variables:
m = 100; // in lb
p = 40; // in psia
T1 = 77; // in deg F
ppm = 10000; // in ppmv
MCO2 = 44;

//calculation:
```

```
yCO2 = ppm/1E6
pCO2 = yCO2*p*760*14.7
//from fig 11.11
Y = 9.8 // lb CO2/100 lb Seive

printf("\n\nResult\n\n")
printf("\n the adsorbent capacity is %.1f lb CO2/100
    lb Seive",Y)
```

Scilab code Exa 11.14 Example 14

```
//Problem 11.14:

//initializing the variables:

//calculation:
//The equilibrium relationship given in the problem
    statement can be linearized by taking the log (
    logarithm) of both sides of the equation. This
    yields the following equation:
//log(q) = log(K) + n*log(c)
//A plot of log(q) vs log(c) yields a straight line
    if this relationship can be used to represent the
     experimental data. The slope of this line is
    equal to n, while the intercept is log(K). The
    experimental data analyzed using the equation
    above are plotted in Fig. 11.12, showing that the
     data fit this linearized isotherm quite well.
//The equation generated from a regression analysis
    indicates that
n = 1.48
//A = log(K)
A = -0.456
K = 10^A
//provided the units of c and q are mg/L and mg/g,
```

```
respectively. The describing equation is therefore
//q = 0.35c^1.48

printf("\n\nResult\n\n")
printf("\n describing equation is q = %.2f*c^%.2f",K,n)
```

Chapter 12

Vapor Liquid Equilibrium Calculations

Scilab code Exa 12.01 Example 1

```
//Problem 12.01:

//initializing the variables:
xEtOH = 0.3; // mol% ethanol

//calculation:
// from fig 12.2, for xEtOH = 0.3
yEtOH = 0.57
ywater = 1 - yEtOH

printf("\n\nResult\n\n")
printf("\n the liquid mole fractions is %.2f and
    vapor mole fraction is %.2f",ywater, yEtOH)
```

Scilab code Exa 12.02 Example 2

```
//Problem 12.02:

//initializing the variables:
xEtOH = 0.3; // mol% ethanol

//calculation:
xwater = 1 - xEtOH

printf("\n\nResult\n\n")
printf("\n the liquid mole fractions is %.2f ",
    xwater)
```

Scilab code Exa 12.06 Example 6

```
//Problem 12.06:

//initializing the variables:
xb = 0.2; // mol%
p = 280; // in psia
a = 0.4;

//calculation:
BPT = 140; // in deg F
Kp = 1.15
Kb = 0.41
Y = xb*Kb + Kp*(1 - xb)
DPT = 154; // deg F
Kp = 1.30
Kb = 0.50
Xa = xb/Kb + (1-xb)/Kp
T = 145; // in deg F
L = 1 - a
Kp = 1.20
Kb = 0.45
Xz = xb/(L + Kb*a) + (1 - xb)/(L + Kp*a)
```

```

printf("\n\nResult\n\n")
printf("\n bubble point temperature is %.0f deg F, dew point temperature is %.0f deg F and temperature when 40 mole per of the mixture is in the vapor phase is %.0f deg F",BPT, DPT, T)
```

Scilab code Exa 12.08 Example 8

```
//Problem 12.08:

//initializing the variables:
ZC2 = 0.25;
ZC4 = 0.15;
Zy = 0.6;
p = 120; // in psia
a = 4;
T = 40; // in degF

//calculation:
//Write the componential split equation:
//Exi = E{zi/[L + Ki(1-L)]} = 1.0
//Set L and V. The bottoms to boilup ratio is 4/1. Therefore,
L = 0.80
V = 1-L
//Obtain K for ethane (E) and n-butane (B) at 120 psia and 40 degF:
Ke = 2.60
Kb = 0.18
//Calculate xe and xb by employing above Equation:
//xi = zi/[L + Ki*V]
//Substituting
xe = 0.19
xb = 0.18
```

```
//Set Y as the unknown component (see Table 12.6), and then calculate Xy.
Xy = 1 - xe-xb
//Calculate KY by applying Equation (12.4) to component Y
Ky = (Zy/Xy -L)/V

printf("\n\nResult\n\n")
printf("\n the chemical name of the unknown componentcorresponding to KY (120 psia and 408F) with a value of %.2f appears to be propane",Ky)
```

Scilab code Exa 12.09 example 9

```
//Problem 12.09:

//initializing the variables:
//Antoine Eq Coeff for Methanol
Am = 16.5938;
Bm = 3644.3;
Cm = 239.76;
//Antoine Eq Coeff for water
Aw = 16.262;
Bw = 3799.89;
Cw = 226.35;
p = 101.325; // in kpa

//calculation:
//The saturation temperatures:
Tsat_m = (Bm/(Am - log(p))) - Cm
Tsat_w = (Bw/(Aw - log(p))) - Cw
T = 70
xm = (p - %e^(Aw - (Bw/(T + Cw))))/((%e^(Am - (Bm/(T + Cm)))) - %e^(Aw - (Bw/(T + Cw))))
ym = xm*125.07/p
```

```
printf("\n\nResult\n\n")
printf("\n mole fraction at 70 degC xm = %.3f and ym
    = %0.3f \n To generate a T-x, y diagram, plot
    the xm and ym data as the ordinate and
    temperature as the abscissa. See Fig. 12.6.",xm,
    ym)
```

Scilab code Exa 12.10 example 10

```
//Problem 12.10:

//initializing the variables:
//Antoine Eq Coeff for Methanol
Am = 16.5938;
Bm = 3644.3;
Cm = 239.76;
//Antoine Eq Coeff for water
Aw = 16.262;
Bw = 3799.89;
Cw = 226.35;
T = 40; // in degC

//calculation:
xm = 0.3
pdm = (%e^(Am - (Bm/(T + Cm))))
pdw = (%e^(Aw - (Bw/(T + Cw))))
p = xm*pdm + (1 - xm)*pdw
ym = xm*pdm/p
printf("\n\nResult\n\n")
printf("\n mole fraction at 40 degC xm = %.3f and ym
    = %0.3f \n To generate an x y diagram, simply
    plot the xm as the ordinate and ym as the
    abscissa (Fig. 12.9).\n Again, the convention is
    to plot only the more volatile compound on phase
    equilibria diagrams.\n Also, for x y diagrams,
```

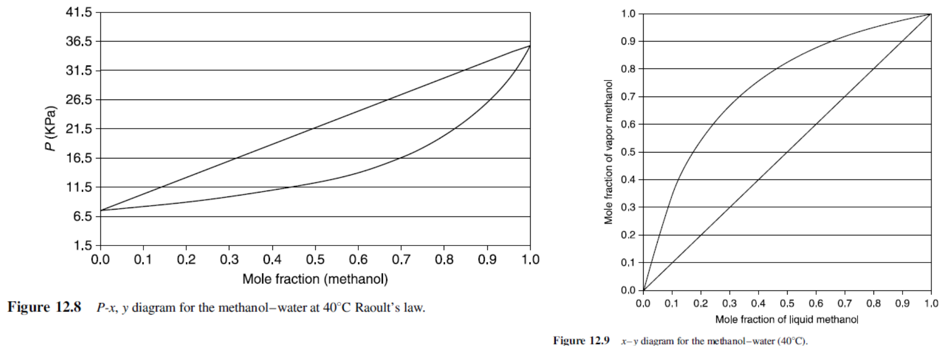

Figure 12.1: example 10

```
it is standard to plot data on a square
coordinate system.",xm, ym)
```

Scilab code Exa 12.11 example 11

```
//Problem 12.11:

//initializing the variables:
//Antoine Eq Coeff for ethanol
Ae = 8.1122;
Be = 1592.864;
Ce = 226.184;
//Antoine Eq Coeff for toulene
At = 6.95805;
Bt = 1346.773;
Ct = 219.693;
p = 760; // mm of Hg
R = 1.987;

//calculation:
//The saturation temperatures:
```

```
Tsat_e = (Be/(Ae - log10(p))) - Ce
Tsat_t = (Bt/(At - log10(p))) - Ct
//
xe = 0.5
xt = 0.5
T = xe*Tsat_e + xt*Tsat_t
//
pde = 10^(Ae - (Be/(T + Ce)))
pdt = 10^(At - (Bt/(T + Ct)))
//
a = 0.5292
bet = 713.57
bte = 1147.86
//
tou_et = bet/(R*(T+273))
tou_te = bte/(R*(T + 273))
Get = %e^(-1*a*tou_et)
Gte = %e^(-1*a*tou_te)
r_e = %e^(0.5^2*(tou_te*(Gte/(xe + xt*Gte))^2 + Get*
    tou_et/(xt + xe*Get)^2))
r_t = %e^(0.5^2*(tou_et*(Get/(xt + xe*Get))^2 + Gte*
    tou_te/(xe + xt*Gte)^2))
//
pde = p/(r_e*xe + r_t*xt*pdt/pde)
//
Tn = Be/(Ae - log10(pde)) - Ce
//
ye = xe*r_e*pde/p

printf("\n\nResult\n\n")
printf("\n mole fraction at T = %.2f degC, xe = %.3f
     and ye = %0.3f \n Return to step 2 and use a
    different value for xe. Continue this until an
    entire T-x, y diagram is formed. \n A T-x, y
    diagram for ethanol and toluene, employing the
    NRTL method can be found in Fig. 12.11\n To
    generate an x  y diagram, simply plot the xe as
    the ordinate and ye as the abscissa.",T, xe, ye)
```

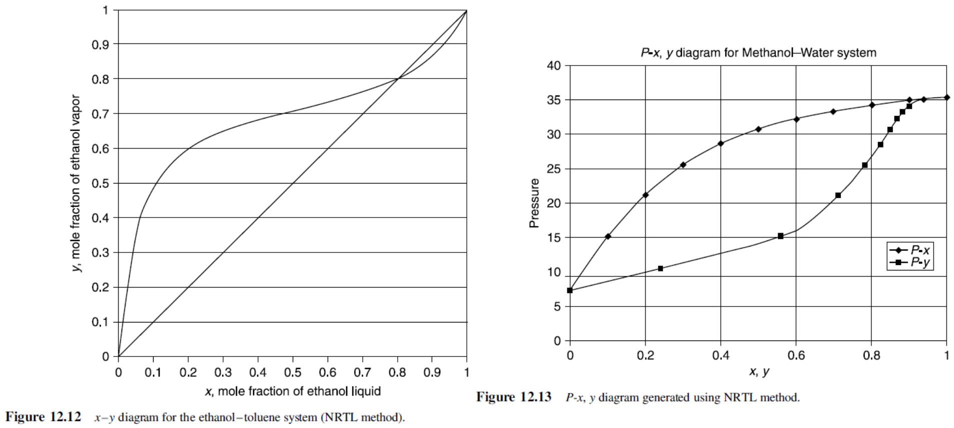

Figure 12.2: example 11

Scilab code Exa 12.12 example 12

```
//Problem 12.12:

//initializing the variables:
//Antoine Eq Coeff for Methanol
Am = 16.5938;
Bm = 3644.3;
Cm = 239.76;
//Antoine Eq Coeff for water
Aw = 16.262;
Bw = 3799.89;
Cw = 226.35;
R = 1.987;
T = 40; //in degC

//calculation:
xm = 0.3
```

```
xw = 0.7
pdm = %e^(Am - (Bm/(T + Cm)))
pdw = %e^(Aw - (Bw/(T + Cw)))
//
a = 0.2994
bmw = -253.88
bwm = 845.21
//
tou_mw = bmw/(R*(T+273))
tou_wm = bwm/(R*(T + 273))
Gmw = %e^(-1*a*tou_mw)
Gwm = %e^(-1*a*tou_wm)
r_m = %e^(0.5^2*(tou_wm*(Gwm/(xm + xw*Gwm))^2 + Gmw*
    tou_mw/(xw + xm*Gmw)^2))
r_w = %e^(0.5^2*(tou_mw*(Gmw/(xw + xm*Gmw))^2 + Gwm*
    tou_wm/(xm + xw*Gwm)^2))
p = xm*pdm + (1 - xm)*pdw
ym = xm*r_m*pdm/p

printf("\n\nResult\n\n")
printf("\n mole fraction at T = %.0f degC, xe = %.3f
     and ye = %0.3f \n To generate a P-x, y diagram,
    plot xm and ym data as the ordinate and pressure
    as the abscissa (see Fig. 12.13).",T, xm, ym)
```

Scilab code Exa 12.13 example 13

```
//Problem 12.13:

//initializing the variables:

//calculation:

printf("\n\nResult\n\n")
printf("\n Combining the curves generated from both
```

```
methods into one figure (see Fig. 12.14), \n it
can be observed that the plot generated using
Raoult s law gives lower values \n of pressure
at the same xm values that the NRTL method gives
for higher values. Also the \n bubble point curve
 from Raoult s law is (as expected) a straight
line compared to the curve generated \n by the
NRTL method, which is concave down.")
```

Scilab code Exa 12.14 example 14

```
//Problem 12.14:

//initializing the variables:
//Antoine Eq Coeff for ethanol
Ae = 8.1122;
Be = 1592.864;
Ce = 226.184;
//Antoine Eq Coeff for toulene
At = 6.95805;
Bt = 1346.773;
Ct = 219.693;
p = 760; // mm of Hg
R = 1.987;

//calculation:
//The saturation temperatures:
Tsat_e = (Be/(Ae - log10(p))) - Ce
Tsat_t = (Bt/(At - log10(p))) - Ct
//
xe = 0.5
xt = 0.5
T = xe*Tsat_e + xt*Tsat_t
//
pde = 10^(Ae - (Be/(T + Ce)))
```

```
pdt = 10^(At - (Bt/(T + Ct)))
//
a = 0.5292
bet = 713.57
bte = 1147.86
//
Ve = 58.68
Vt = 106.85
aet = 1556.45
ate = 210.52
//
E_et = (Vt/Ve)*%e^(-aet/(R*(T+273)))
E_te = (Ve/Vt)*%e^(-ate/(R*(T+273)))
//
r_e = %e^(-log(xe + xt*E_et) + xt*(E_et/(xe + xt*
    E_et) - E_te/(xt + xe*E_te)))
r_t = %e^(-log(xt + xe*E_te) + xe*(E_te/(xt + xe*
    E_te) - E_et/(xe + xt*E_et)))
//
pde = p/(r_e*xe + r_t*xt*(pdt/pde))
//
Tn = Be/(Ae - log10(pde)) - Ce
//
ye = xe*r_e*pde/p

printf("\n\nResult\n\n")
printf("\n mole fraction at T = %.2f degC, xe = %.3f
     and ye = %0.2f \n Return to step 2 and use a
    different value for xe. Continue this until an
    entire T-x, y diagram is formed. \n A T-x, y
    diagram for ethanol and toluene
    employingWilson s method can be found in Fig.
    12.15.\n Note that an azeotrope is formed at x =
    y = 0.8. Generate an x  y diagram from the
    results obtained above.\n Refer to Table 12.18
    for the x  y data. To generate an x  y diagram,
     simply plot the xe as the ordinate and ye as the
     abscissa.",T, xe, ye)
```

Scilab code Exa 12.16 Example 16

```
//Problem 12.16:

//initializing the variables:
pB = 35; // mm of Hg at 0 deg F

//calculation:
//from example 12.15
pA = 70.01; // in mm of Hg
aAB = pA/pB

printf("\n\nResult\n\n")
printf("\n the relative volatility is %.0f",aAB)
```

Chapter 13

Chemical Reaction Equilibrium Principles

Scilab code Exa 13.04 Example 4

```
//Problem 13.04:

//initializing the variables:
DG0fH2O = -54635; // cal/gmol
DG0fHCl = -22778; // cal/gmol

//calculation:
DG0298 = 1*DG0fH2O - 2*DG0fHCl

printf("\n\nResult\n\n")
printf("\n DG0298 of reaction is %.0f cal/gmol",
   DG0298)
```

Scilab code Exa 13.05 Example 5

```
//Problem 13.05:
```

```

//initializing the variables:
DG0fCH3COOH = -93800; // cal/gmol
DG0fCH4 = -12140; // cal/gmol
DG0fCO2 = -94258; // cal/gmol

//calculation:
DG0298 = DG0fCH3COOH - DG0fCH4 - DG0fCO2

printf("\n\nResult\n\n")
printf("\n DG0298 of reaction is %.0f cal/gmol",
    DG0298)
```

Scilab code Exa 13.06 Example 6

```
//Problem 13.06:

//initializing the variables:
DG0 = -20000; // in cal/gmol
Tf = 70; // in deg F
R = 1.99; // cal/gmol.K

//calculation:
Tk = 273 + 5*(Tf - 32)/9
K = %e^(-1*DG0/(R*Tk))

printf("\n\nResult\n\n")
printf("\n chemical reaction equilibrium constant K
    is %.2E",K)
```

Scilab code Exa 13.07 Example 7

```
//Problem 13.07:
```

```
//initializing the variables:
DG0fO2 = 0; // cal/gmol
DG0fCO = -32781; // cal/gmol
DG0fCO2 = -94258; // cal/gmol
Tk = 298; // in K
R = 1.987; // cal/gmol.K

//calculation:
DG0 = DG0fCO - 0.5*DG0fO2 - DG0fCO2
K = %e^(-1*DG0/(R*Tk))

printf("\n\nResult\n\n")
printf("\n chemical reaction equilibrium constant K is %.2E",K)
```

Scilab code Exa 13.10 Example 10

```
//Problem 13.10:

//initializing the variables:
Tk = 1394.3; // in K

//calculation:
//from problem 13.09
//lnK = (-33722/T) + 1.560*lnT - 0.00181*T + 2.42E-7*T^2 + 0.4509
K = %e^((-1*33722)/Tk + 1.560*log(Tk) - 0.00181*Tk + 2.42E-7*Tk^2 + 0.4509)

printf("\n\nResult\n\n")
printf("\n chemical reaction equilibrium constant K is %.2E",K)
```

Scilab code Exa 13.11 Example 11

```
//Problem 13.11:

//initializing the variables:
A = 0.229E-3;
B = 7340;
T = 298; // in K
R = 1.99; // in cal/gmol.K

//calculation:
//The following two results are provided from
    Illustrative Example 13.4:
DG0298 = -9079 // in cal/gmol
DH0298 = -13672 // cal/gmol
//Employ Equation
//lnK = -DH0/RT + (Da/R)*lnT + (Db/2R)*T + (Dr/6R)*T
    ^-2 + I
//Next, DH0 and I must be determined.
//DH0T = DH0298 + int(298,T)(DCpdT)
//For heat capacities of the form
//Cp = a + bT + cT^-2
//Table 7.4 can be employed to generate the
    following terms:
Da = (7.30 + 8.85) - [(2*6.27 + 0.5*7.16)]
Db = 2.46E-3 + 0.16E-3 - [2*1.24E-3 + 0.5*1.0E-3]
Dc = 0.0 - 0.68E5 - [2*0.30E5 + 0.5*(-0.4E5)]
//From this, Equation then becomes:
//DH0T = DH0298 + int(298,T)[Da + (Db)T + (Dc)T^-2]
    dT
//or
//DH0T = DH0298 + Da(T - 298) + (1/2)*Db[T^2 - (298)
    ^2] - Dc(1/T - 1/298)
//Combining the constant terms into DH0 (as in
```

```
    Chapter 10) yields the following:
//DH0T = DH0 + (Da)T + (1/2)*(Db)T^2 -(Dc)T6-1
//where
DH0 = DH0298 - 298*Da - (1/2)*[(298)^2]*Db + (1/298)
    *Dc
//From Equation (13.16)
lnK = -1*DG0298/(R*T)
//Therefore,
I = lnK - DH0/(R*T) - Da/R*log(T) + Db/(2*R)*T + Dc
    /(2*R)*T^-2
//The final form of the equation for K is
//ln(K) = 7048.7/T + (0.0151)*lnT - (9.06E-5)*T -
    (2.714E4)*T^-2 - 8.09

printf("\n\nResult\n\n")
printf("\n The final form of the equation for K is \
    n ln(K) = (%.1f)/T + (%.4f)*lnT - (%.2E)*T - (%.3
    E)*T^-2 - 8.09",-1*DH0/1.99, Da/1.99, abs(Db)
    /(2*1.99), abs(Dc)/(2*1.99))
```

Scilab code Exa 13.12 Example 12

```
//Problem 13.12:

//initializing the variables:
Tk = 500; // in K

//calculation:
//from problem 13.11
//lnK = (7048.7/T) + 0.0151*lnT - 9.06E-5*T - 2.714
    E4*T^-2 - 8.09
K = %e^((7048.7/Tk) + 0.0151*log(Tk) - 9.06E-5*Tk -
    2.714E4/Tk^2 - 8.09)

printf("\n\nResult\n\n")
```

```
printf("\n chemical reaction equilibrium constant K
  is %.0f",K)
```

Scilab code Exa 13.13 Example 13

```
//Problem 13.13:

//initializing the variables:
T = 600; // in K
P = 1; // atm
K = 1.5E32;
DH0 = 103525; // cal/gmol O2
IR = 3.5
aC2H4 = 2.830
aO2 = 6.148
bC2H4 = 28.601E-3
bO2 = 3.102E-3
rC2H4 = -8.726E-6
rO2 = -0.923E-6
DH0C2H4O = -39760; // cal/gmol O2
DH0C2H4 = 12496; // cal/gmol O2
R = 1.987; // cal/gmol.K

//calculation:
DH0 = 2*DH0C2H4O - 2*DH0C2H4 // in cal/gmol O2
  reacted
DG0298 = -96484; // in cal/gmol O2 reacted
DH0 = -103525; // in cal/gmol
//Write the equation for DH0T at 298K in terms of
  DH0, Da, Db, and Dr:
//DH0T = DH0 + Da*T + (Db/2)*T^2 + (Dr/3)*T^3
//
//-987 = 298*Da + 44402*Db + 8.82E6*Dr
//
//Write the equation for DG0T at 298K in terms of
```

```
   DH0, Da, Db, Dr, and IR. At T = 298K and IR =
   3.5,
//DG0T = DH0 -Da*T*lnT - (Db/2)*T^2 - (Dr/6)*T^3 -
   IRT
//
//-8084 = 1698*Da + 44402*Db + 4.41E6*Dr
//
DG0600 = -1*R*T*log(K)
//at T = 600
//
//-17275 = 3839*Da + 1.8E5*Db + 3.6E7*Dr
//
//solving these we get
Da = -5.046
Db = 1.017E-2
Dr = 7.406E-6
aC2H4O = (Da + 2*aC2H4 + aO2)/2
bC2H4O = (Db + 2*bC2H4 + bO2)/2
rC2H4O = (Dr + 2*rC2H4 + rO2)/2

printf("\n\nResult\n\n")
printf("\n a = %.3f, b = %.2E and r = %.2E",aC2H4O,
   bC2H4O, rC2H4O)
```

Scilab code Exa 13.14 Example 14

```
//Problem 13.14:

//initializing the variables:
T = 600; // in K
P = 1; // atm
K = 1.5E32;
DH0 = 103525; // cal/gmol O2
IR = 3.5
aC2H4 = 2.830
```

```
aO2 = 6.148
bC2H4 = 28.601E-3
bO2 = 3.102E-3
rC2H4 = -8.726E-6
rO2 = -0.923E-6
DH0C2H4O = -39760; // cal/gmol O2
DH0C2H4 = 12496; // cal/gmol O2
R = 1.987; // cal/gmol.K

//calculation:
DH0 = 2*DH0C2H4O - 2*DH0C2H4 // in cal/gmol O2 reacted
DG0298 = -96484; // in cal/gmol O2 reacted
DH0 = -103525; // in cal/gmol
//Write the equation for DH0T at 298K in terms of DH0, Da, Db, and Dr:
//DH0T = DH0 + Da*T + (Db/2)*T^2 + (Dr/3)*T^3
//
//-987 = 298*Da + 44402*Db + 8.82E6*Dr
//
//Write the equation for DG0T at 298K in terms of DH0, Da, Db, Dr, and IR. At T = 298K and IR = 3.5,
//DG0T = DH0 -Da*T*lnT - (Db/2)*T^2 - (Dr/6)*T^3 - IRT
//
//-8084 = 1698*Da + 44402*Db + 4.41E6*Dr
//
DG0600 = -1*R*T*log(K)
//at T = 600
//
//-17275 = 3839*Da + 1.8E5*Db + 3.6E7*Dr
//
//solving these we get
Da = -5.046
Db = 1.017E-2
Dr = 7.406E-6
aC2H4O = (Da + 2*aC2H4 + aO2)/2
```

```
bC2H4O = (Db + 2*bC2H4 + bO2)/2
rC2H4O = (Dr + 2*rC2H4 + rO2)/2

printf("\n\nResult\n\n")
printf("\n theoretical values: a = %.3f, b = %.2E and r = %.2E \n Experimental values: \n\ta = 3.364\n\tb = 35.722E-3\n\tr = -12.236E-6 \n\tThe agreement for a and b is excellent; the result is reasonable for r \n in view of its sensitivity to T^3.",aC2H4O, bC2H4O, rC2H4O)
```

Chapter 14

Chemical Reaction Equilibrium Applications

Scilab code Exa 14.02 Example 2

```
//Problem 14.02:

//initializing the variables:

//calculation:
//For this reaction
//R1 = CO2;
//R2 = H2;
//R3 = CH3OH;
//R4 = H2O;
n10 = 3
n20 = 1
n30 = 0
n40 = 1

printf("\n\nResult\n\n")
printf("\n n1 = %.0f - e\n n2 = %.0f - 3e \n n3 = %
    .0f + e \n n4 = %.0f + e",n10,n20,n30,n40)
```

Scilab code Exa 14.04 Example 4

```
//Problem 14.04:

//initializing the variables:
P = 0.5; // in atm
e = 0.3;

//calculation:
p1 = ((3-e)/(5 - 2*e))*P
p2 = ((1-3*e)/(5 - 2*e))*P
p3 = ((e)/(5 - 2*e))*P
p4 = ((1+e)/(5 - 2*e))*P

printf("\n\nResult\n\n")
printf("\n the partial pressures %0.3f, %0.3f, %0.3f
    and %0.3f",p1,p2,p3,p4)
```

Scilab code Exa 14.05 Example 5

```
//Problem 14.05:

//initializing the variables:
P = 0.5; // in atm
e = 0.3;

//calculation:
//From Equation (14.27)
//K = Ky*P^v
//y1 = (3-e)/(5-2e) \n y2 = (1-3e)/(5-2e) \n y3 = e
    /(5-2e) \n y4 = (1+e)/(5-2e)
v = 1+1-3-1
```

```
printf("\n\nResult\n\n")
printf("\n K = [(e/(5−2e))^1*(1+e)/(5−2e))^1/((3−e)/(5−2e))^3*((1−3e)/(5−2e))^1]*P^(%.0f)",v)
```

Scilab code Exa 14.06 Example 6

```
//Problem 14.06:

//initializing the variables:
xCO2 = 0.0314;
xO2 = 0.0584;
P = 1; // in atm
T = 2050; // in deg F

//calculation:
//from example 13.10, at 2050 deg F
K = 9.156E-7
yCO = xCO2*K/xO2^0.5

printf("\n\nResult\n\n")
printf("\n the mole fraction of CO is %.2E",yCO)
```

Scilab code Exa 14.07 Example 7

```
//Problem 14.07:

//initializing the variables:
xCO2 = 0.0314;
xO2 = 0.0584;
P = 1; // in atm
T = 250; // in deg F
```

```
K = 1.015E-33;

//calculation:
yCO = xCO2*K/xO2^0.5
yCOppm = yCO*1E6

printf("\n\nResult\n\n")
printf("\n the mole fraction of CO is %.2E and in ppm %.2E ppm",yCO, yCOppm)
```

Scilab code Exa 14.08 Example 8

```
//Problem 14.08:

//initializing the variables:
pCl2 = 0.0;
pO2 = 0.106;
pH2O = 0.0292;
pHCl = 0.146;
P = 1; // in atm
T = 1250; // in K

//calculation:
//By definition,
//K = Kp = pCl2*pH2O/(pHCl^2*pO2^0.5)
//At equilibrium
//pCl2 = pCl2(initial) + x = x
//The term x represents the increase in the partial pressure of the chlorine due to this equilibrium reaction. In addition,
//pH2O = pH2O(initial) + x = 0.0292 + x
//pHCl = pHCl(initial) - 2x = 0.146 - 2x
//pO2 = pO2(initial) - 0.5x = 0.106 - 0.5x
//Kp can then be expressed as
//Kp = (x)*(0.0292 + x)/((0.146 - 2x)^2*(00.106 -
```

```
0.5x)^0.5)
//Now, calculate Kp at 1250K using the result from the equation above.
lnK = 7048.7/1250 + 0.015*log(1250) - 1250*9.06E-5 - (2.714E4)*1250^-2 - 8.09
K = %e^lnK
Kp = K
//Therefore,
//0.0842 = (x)*(0.0292 + x)/((0.146 - 2x)^2*(00.106 - 0.5x)^0.5)
//Solving for x, which is the equilibrium partial pressure of Cl2, by a trial-and-error calculation yields
x = 0.01050 // in atm
pCl2 = x
//Note that approximately 1% of the discharge flue gas is chlorine a rather sizable amount

printf("\n\nResult\n\n")
printf("\n the equilibrium partial pressure of Cl2 %.5f atm",pCl2)
```

Scilab code Exa 14.09 Example 9

```
//Problem 14.09:

//initializing the variables:
P = 1; // in atm
T = 527; // in deg C
R = 1.987;

//calculation:
//DG0T = 53424 - 2.6*T*lnT + 0.0005*T^2  - 5.0*T
Tk = T + 273
DG0527 = 53424 - 2.6*Tk*log(Tk) + 0.0005*Tk^2  -
```

```
    5.0*Tk
K = %e^(-DG0527/(R*Tk))
Ky = K
e = ((Ky/4)/(1 + Ky/4))^0.5

printf("\n\nResult\n\n")
printf("\n the degree of dissociation is %.2E",e)
```

Scilab code Exa 14.10 Example 10

```
//Problem 14.10:

//initializing the variables:
P = 10; // in atm
T = 527; // in deg C
R = 1.987;
v = 1-2;

//calculation:
//DG0T = 53424 - 2.6*T*lnT + 0.0005*T^2 - 5.0*T
Tk = T + 273
DG0527 = 53424 - 2.6*Tk*log(Tk) + 0.0005*Tk^2 -
    5.0*Tk
K = %e^(-DG0527/(R*Tk))
Ky = K*P^v
e = ((Ky/4)/(1 + Ky/4))^0.5

printf("\n\nResult\n\n")
printf("\n the degree of dissociation is %.2E",e)
```

Scilab code Exa 14.11 Example 11

```
//Problem 14.11:
```

```

//initializing the variables:
P = 2; // in atm
T1 = 373; // in K
nA = 1;
nB = 2.5;
nC = 2;
T2 = 273; // in K
R = 1.987;
v = 1 - 2 -1;

//calculation:
n = nA + nB + nC
yA = nA/n
yB = nB/n
yC = nC/n
K = (yC/(yB*yA^2))*P^v
DG0273 = R*T2*log(K)

printf("\n\nResult\n\n")
printf("\n standard free energy change of this reaction is %.2f cal/gmol",DG0273)
```

Scilab code Exa 14.12 Example 12

```
//Problem 14.12:

//initializing the variables:
T = 500; // in K
R = 1.987;

//calculation:
//DG0T = -13600 + 4.16*T //cal/gmol of N2O4
DG0500 = -13600 + 4.16*T
K = %e^(-1*DG0500/(R*T))
```

```
e = ((K/4)/(1 + K/4))^0.5

printf("\n\nResult\n\n")
printf("\n conversion is %.2f percent",e*100)
```

Scilab code Exa 14.13 Example 13

```
//Problem 14.13:

//initializing the variables:
T = 150; // in deg C
P = 1.5; // in atm
nH2O = 0.9
nC2H4 = 0.1
DG0150c = 2375 // in cal/gmol
FH0298k = -10000; // in cal/gmol
R = 1.987;
v = 1-1-1

//calculation:
Tk = T + 273
K = %e^(-1*DG0150c/(R*Tk))
//yC2H4 = (1-e)/(10-e)
//yH2O = (9-e)/(10-e)
//yC2H5OH = (e)/(10-e)
//KP = yC2H5OH/(yC2H4*yH2O)
//K = e*(10-e)/(2*(1 - e)*(9 - e))
// 1.12*e^2 - 11.2*e + 1.08 = 0
e = 0.0966
yC2H4 = (1-e)/(10-e)
yH2O = (9-e)/(10-e)
yC2H5OH = (e)/(10-e)

printf("\n\nResult\n\n")
printf("\n the equilibrium product mole fraction
```

```
composition of C2H4 is %.4f, of H2O is %.4f and
of C2H5OH is %.3f",yC2H4,yH2O,yC2H5OH)
```

Scilab code Exa 14.15 Example 15

```
//Problem 14.15:

//initializing the variables:
K1 = 152;
K2 = 665;
P = 1; // in atm
nA0 = 1;
a = 1;
nB0 = 3;
b = 4;
nC0 = 0;
c = 2;
g = 1;
nD0 = 0;
d =2;
nE0 = 1;
e = 2;
nF0 = 0;
f = 1;

//calculation:
//For 1 atm and ideal conditions
//K1 = YC^c*YD^d/(YA^a*YB^b) = 152
//K2 = YF^f/(yC^c*YE^e) = 665
//For this case,
n0 = nA0 +nB0 + nC0 + nD0 + nE0 + nF0
//n = n0 + (c+d-b-a)*e1 + (f-e-g)*e2
//n = 5 - e1 - 2e2
//with
//YA = (1-e1)/n
```

```
//YB = (3-4e1)/n
//YC = (2e1-e2)/n
//YD = 2e1/n
//YE = (1-2e2)/n
//YF = e2/n
//The reader is left the exercise of solving for the
    two unknown e1 and e2. Note also that there are
   \n two equations: one for K1 and one for K2.
//The following three constraints apply:
//e1 < 0.512
//e1 < 0.75
//e2 < 0.5
//Answers:
e1 = 0.622
e2 = 0.402

printf("\n\nResult\n\n")
printf("\n e1 = %.3f and e2 = %.3f",e1,e2)
```

Chapter 15

Economic Considerations

Scilab code Exa 15.01 Example 1

```
//Problem 15.01:

//initializing the variables:
FECI93 = 391.2
FECI95 = 425.4
FECI99 = 434.1
c93 = 245000; // in $

//calculation:
c95 = c93*FECI95/FECI93
c99 = c93*FECI99/FECI93

printf("\n\nResult\n\n")
printf("\n Cost(1995) is %.0f $ and Cost(1999) is %.0f $",c95,c99)
```

Scilab code Exa 15.02 Example 2

```
//Problem 15.02:

//initializing the variables:

//calculation:
//The first step is to convert the equipment, installation, and operating costs to total\ncosts by multiplying each by the total gas flow, 100,000 acfm. Hence, for the finned exchanger,
//the total costs are
Equipmentcost = 100000*3.1 // in $
Installationcost = 100000*0.80 // in $
Operatingcost = 100000*0.06 // in $
//Note that the operating costs are on an annualized basis. The equipment cost and the installation\ncost must then be converted to an annual basis using the CRF. From Equation (15.3)
CRF = (0.1)*(1+0.1)^20/[(1+0.1)^20 - 1]
//The annual costs for the equipment and the installation is given by the product of the CRF and\nthe total costs of each:
Equipmentannualcost = 0.11746*Equipmentcost
Installationannualcost = 0.11746*Installationcost
//The calculations for the 4-pass and the 2-pass exchangers are performed in the same manner.\nThe three preheaters can be compared after all the annual costs are added. The tabulated results\nare provided in Table 15.5.
// total annual costs
CF = 65000
C4 = 77385
C2 = 60111

printf("\n\nResult\n\n")
printf("\n According to the analysis, Total Annual Costs for Finned exchanger = $%.0f, for 4-Pass Exchanger = $%.0f and for 2-Pass Exchanger = $%.0f.\nTherefore 2-pass exchanger is the most
```

```
economically attractive device since the annual
cost is the lowest.",CF,C4,C2)
```

Scilab code Exa 15.03 Example 3

```
//Problem 15.03:

//initializing the variables:

//calculation:
//For both units
CRF = (0.12)*(1+0.12)^12/[(1+0.12)^12 - 1]
//Annual capital and installation costs for the
   liquid injection (LI) unit are
LIcosts = (2625000 + 1575000)*0.1614
//Annual capital and installation costs for the
   rotary kiln (RK) unit are
RKcosts = (2975000 + 1700000)*0.1614
//A comparison of costs and credits for both
   incinerators is given in Table 15.7.

PLI = 272000
PRK = 420000

printf("\n\nResult\n\n")
printf("\n Profits for Liquid Injection = $%.0f/yr
   and for Rotary Kiln = $%.0f/yr.\nTherefore a
   rotary kiln incinerator is recommended.",PLI,PRK)
```

Scilab code Exa 15.04 Example 4

```
//Problem 15.04:

```

```
//initializing the variables:
A = 10;
B = 100000;

//calculation:
// Since there are two contributing factors to the cost model, one may write the \n following equation for the profit, P
//P = A(t - tc) - B/(TH - t);
TH = 500
tc = 100
//For breakeven operation, set P = 0 so that
//(t - tc)*(TH - t) = B/A
//This may be rewritten as
//t^2 - (TH + tc)*t + [(B/A) + TH*tc] = 0
//The solution to this quadratic equation for A and B, is
t1 = (TH+tc)/2 + ([(TH+tc)^2 - 4*1*(B/A + TH*tc)]^0.5)/2
t2 = (TH+tc)/2 - ([(TH+tc)^2 - 4*1*(B/A + TH*tc)]^0.5)/2
//To maximize the profit, take the first deriative of P with respect to t and set it equal to zero, i.e.,
//dP/dt = A - B/(TH - t)^2 = 0
//Solving,
//(TH - t)^2 = B/A
t = TH - (B/A)^0.5
//Upon analyzing the first derivative with t values greater than and less than 400 degF, one observes \n that the derivative changes sign from + ---> - at about t = 400, indicating a relative maximum.
//Similarly, for A = 10, B = 4000,
//tBE = 499 degF, 101 degF
//tmax = 480 degF
//For A = 10, B = 400,000,
//tBE = 300 degF
//tmax = 300 degF
```

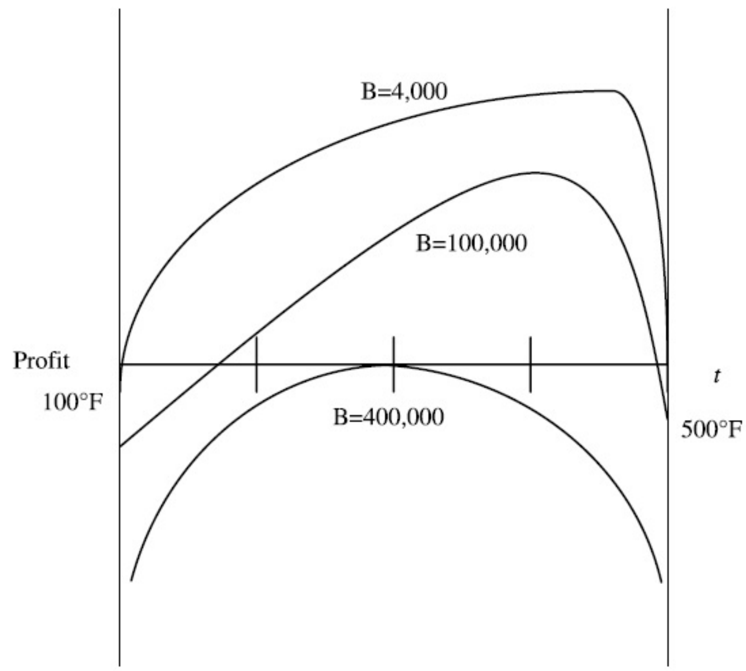

Figure 15.2 Heat exchanger results.

Figure 15.1: Example 4

```
//Graphical results for the three scenarios is shown
    in Fig. 15.2.

printf("\n\nResult\n\n")
printf("\n Graphical results for the three scenarios
    is shown in Fig 15.2")
```

Chapter 17

Other ABET Topics

Scilab code Exa 17.03 Example 3

```
//Problem 17.03:

//initializing the variables:
p = 50; // psig
T = 25; // in deg C
Tk = 25+273; // in K
Pi = 5; //in psig
R = 1.987; // in cal/gmol.K

//calculation:
//combustion reaction equation for 1 mole of pentane
    with stoichiometric air:
//C5H12 + 8O2 + [30.1N2] ---> 5CO2 + 6H2O + [30.1N2]
// note that
nO2 = 8
nC5H12 = 1
nCO2 = 5
nH2O = 6
nN2 = (0.79/0.21)*nO2
//number of moles initially and finally present, and
    the change in the number of moles:
```

```
nin = nC5H12 + nO2 + nN2
nout = nCO2 + nH2O + nN2
//the constant volume heat capacity as a function of
    the constant pressure heat capacity
//(see Table 17.2):
//Cv = Cp -R
//the change in internal energy by integrating the
    internal energy change equation, i.e.,
//dU = CvdT
//The integrated form of the left-hand side below is
    provided on the right-hand side
//int(Tin,Tout)[E(niCv,i)out]dT = [(4.542)(30.1) +
    (3.329)(5) + (4.893)(6)](Tout - 298) + [(0.149E
    -2)(30.1) + (1.42E-2)(5) + (0.345E-2)(6)](Tout^2
    - 298^2) + [(-0.0227E-5)(30.1) + (-0.8362E-5)(5)
    + (-0.0483E5)(6)](Tout^3 - 298^3)/3 + [(1.784E9)
    (5)](Tout^4 - 298^4)/4

//Solve the equation obtained on the RHS of the
    above equation for Tout by trial-and-error until
    the \n equation has the value of the internal
    energy of reaction at 25 degC given previously:
//By trial-and-error calculation,
Tout = 2870
//the final pressure in the vessel:
Pf = (14.7+Pi)*(41.1/39.1)*(Tout/Tk) - 14.7

printf("\n\nResult\n\n")
printf("\n Since the final pressure of %.1f psig is
    less\nthan the burst pressure of 200 psig, the
    vessel can withstand the explosion. ",Pf)
```

Scilab code Exa 17.04 Example 4

```
//Problem 17.04:
```

```

//initializing the variables:
e = 0.5
m = 2200; // in kg
sigma = 5.67E-8; // in J/m2.K4.s
DH0fp = -103.85; // in kJ/gmol
DH0fo = 0; // in kJ/gmol
DH0fn = 0; // in kJ/gmol
DH0fc = -393.51; // in kJ/gmol
DH0fw = -241.826; // in kJ/gmol
Cpp = 0; // in J/gmol.K
Cpo = 33.635; // in J/gmol.K
Cpn = 31.840; // in J/gmol.K
Cpc = 50.919; // in J/gmol.K
Cpw = 39.672; // in J/gmol.K
p = 50; // psig
T = 25; // in deg C
R = 1.987; // in cal/gmol.K
I = 10; // in kW/m2
i = 4; // kW/m2

//calculation:
mO2 = m*2.2*10*32*2/44
mt = mO2 + m*2.2
D = 9.56*(mt)^0.325
t = 0.196*mt^0.349
DH0 = (3*DH0fc + 4*DH0fw -5*DH0fo - DH0fp)
    *1000*1000*m/44 // in J
np = m/44
no = 5*np
nc = 3*np
nw = 4*np
nn = 500*0.79/0.21
DT = DH0/((no*Cpo + nw*Cpw + nc*Cpc + nn*Cpn)*1000)
T2 = abs(DT) + T + 273
rsq = (D/(3.048*2))^2*(e*sigma*(T2^4)/I)
r = (rsq*2.7778E-7*3600)^0.5*10/3
ri = ((D/(3.048*2))^2*(e*sigma*(T2^4)/i)*2.7778E
```

```
   -7*3600)^0.5*10/3

printf("\n\nResult\n\n")
printf("\n the size of the fireball is %.0f ft and
   duration of the fireball is %.1f sec, for I = 10
   kW/m2 r = %.0f ft and for I = 4 kW/m2 r = %.0f ft
   ",D,t,r, ri)
```

Chapter 19

Exergy The Concept of Quality Energy

Scilab code Exa 19.02 Example 2

```
//Problem 19.02:

//initializing the variables:
T = 400; // in deg F
P = 3; // in atm
To = 70; // in deg F
Po = 1; // in atm
Cp = 6.986; // Btu/lbmol.degR
Cv = 5.000; // in Btu/lbmol.degR
A = 0.5; // in ft2
m = 100; // in lbf
R = 0.732; // in ft3.atm/lbmol.degR
R1 = 1.986; // in Btu/lbmol.degR

//calculation:
V = 1*R*(T + 460)/P
Veq = 1*R*(To + 460)/Po
dV = V - Veq
dU = 1*Cv*(T - To)
```

```
dS = 1*Cp*log((T + 460)/(To + 460)) + 1*R1*log(Po/P)
X = dU + Po*2.74*dV - (To+460)*dS
Peq = Po*14.7 + m/(A*144)
Veq1 = 1*10.73*(To + 460)/Peq

printf("\n\nResult\n\n")
printf("\n the exergy of the system is %.0f Btu and
   Veq = %.1f ft^3 ",X, Veq1)
```

Scilab code Exa 19.03 Example 3

```
//Problem 19.03:

//initializing the variables:
mdt = 40000; // in kg/hr
Ti = 500; // in deg C
Pi = 2500; // in kPa
Qdt = -0.25; // in MW
To = 175; // in deg C
Po = 250; // in kPa
Tr = 25; // in deg C
Pr = 101.325; // in kPa
H1 = 3461.7; // in kJ/kg
H2 = 2816.7; // in kJ/kg
Heq = 104.8; // in kJ/kg
S1 = 7.324; // inkJ/kg.K
Seq = 0.367; // inkJ/kg.K

//calculation:
mdt = mdt/3600
Q = Qdt*1000/mdt
Ws = H2 - H1 - Q
X1 = H1 - Heq - (Tr+273)*(S1 - Seq)

printf("\n\nResult\n\n")
```

```
printf("\n the shaftwork produced by the turbine is %.1f kJ/kg and the exergy = %.1f kJ/kg ",abs(Ws),X1)
```

Scilab code Exa 19.04 Example 4

```
//Problem 19.04:

//initializing the variables:
mdt = 40000; // in kg/hr
Ti = 500; // in deg C
Pi = 2500; // in kPa
Qdt = -0.25; // in MW
To = 175; // in deg C
Po = 250; // in kPa
Tr = 25; // in deg C
Pr = 101.325; // in kPa
H1 = 3461.7; // in kJ/kg
H2 = 2816.7; // in kJ/kg
Heq = 104.8; // in kJ/kg
S1 = 7.324; // inkJ/kg.K
Seq = 0.367; // inkJ/kg.K
S2 = 7.289; // in kJ/kg.K

//calculation:
Wsrev = H2 - H1 - (Tr+273)*(S2 - S1)


printf("\n\nResult\n\n")
printf("\n the maximum shaftwork attainable by the steam turbine is %.1f kJ/kg ",abs(Wsrev))
```