Scilab Textbook Companion for Elementary Principles Of Chemical Processes by R. M. Felder And R. W. Rousseau[1]

Created by
Chaitanya Potti
CL 152
Chemical Engineering
IIT bombay
College Teacher
Student Of Iit Bombay
Cross-Checked by

July 17, 2017

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Elementary Principles Of Chemical Processes

Author: R. M. Felder And R. W. Rousseau

Publisher: Wiley India Pvt. Ltd., New Delhi.

Edition: 3

Year: 2010

ISBN: 978-81-265-1582-0

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.

Contents

List of Scilab Codes

List of Figures

Chapter 2

Introduction To Engineering Calculations

check Appendix AP 97 for dependency:

221.sci

Scilab code Exa 2.2.1 Conversion of acceleration

```
1 clc
2 pathname=get_absolute_file_path('2_2_1.sce')
3 filename=pathname+filesep()+'221.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 AcclFinal=AcclInitial*((3600*24*365)^2)/10^5;
7 //the calculations involved are the conversion
    factors
8 printf(" \n final acceleration=%E Km/Yr^2",AcclFinal
    )
```

Convert an acceleration of 1 cm/s^2 to its equivalent in km/yr^2.

Figure 2.1: Conversion of acceleration

check Appendix AP 96 for dependency:

231.sci

Scilab code Exa 2.3.1 Conversion between system of units

```
1 clc
2 //this program is used to convert lb.ft/min^2 to kg.
    cm/s^2
3 pathname=get_absolute_file_path('2_3_1.sce')
4 filename=pathname+filesep()+'231.sci'
5 exec(filename)
6 Final=Initial*0.453593*100/(3.281*60*60)
7 //the calculations involved are conversion factors
8 disp("final=")
9 disp(Final); disp("kg.cm/s^2")
```

Convert 23 $lb_m \cdot ft/min^2$ to its equivalent in $kg \cdot cm/s^2$.

Figure 2.2: Conversion between system of units

Water has a density of 62.4 lb_m/ft^3. How much does 2.000 ft^3 of water weigh (1) at sea level and 45° latitude and (2) in Denver, Colorado, where the altitude is 5374 ft and the gravitational acceleration is 32.139 ft/s^2?

Figure 2.3: Weight and Mass

---

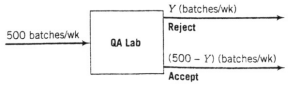
check Appendix AP 95 for dependency:

241.sci

Scilab code Exa 2.4.1 Weight and Mass

```
1 clc
2 //this program is used to calculate weight of water
    at different places
3 pathname=get_absolute_file_path('2_4_1.sce')
4 filename=pathname+filesep()+'241.sci'
5 exec(filename)
6 mass=volume*density;
```

Five hundred batches of a pigment are produced each week. In the plant's quality assurance (QA) program, each batch is subjected to a precise color analysis test. If a batch does not pass the test, it is rejected and sent back for reformulation.



Week	1	2	3	4	5	6	7	8	9	10	11	12
$\hat{Y}$	17	27	18	18	23	19	18	21	20	19	21	18

Figure 2.4: Statistical Quality Control

```
7  printf("mass of the water = volume x density=%f lbm"
       ,mass)
8  printf(" \n At sealevel, g=32.174 ft/s^2")
9  g=32.174;
10 weight=mass*g/32.174;
11 printf(" \n weight at sealevel= %f lbf \n",weight)
12 printf(" \n At denver, g=32.139 ft/s^2")
13 g=32.139;
14 weight=mass*g/32.174;
15 printf("\n weight at denver= %f lbf",weight)
16 //the division with 32.174 is to convert lbm.ft/s^2
       to lbf
```

---

check Appendix AP 94 for dependency:

252.sci

Scilab code Exa 2.5.2 Statistical Quality Control

```
1 clc
2 pathname=get_absolute_file_path('2_5_2.sce')
3 filename=pathname+filesep()+'252.sci'
4 exec(filename)
5 //Here We used standard library functions mean and
      st_deviation
```

Rotameter calibration data (flow rate versus rotameter reading) are as follows:

Flow Rate $\dot{V}$(L/min)	Rotameter Reading R
20.0	10
52.1	30
84.6	50
118.3	70
151.0	90

1. Draw a calibration curve and determine an equation for $\dot{V}(R)$.
2. Calculate the flow rate that corresponds to a rotameter reading of 36.

Figure 2.5: Fitting a straight line to Flow meter Calibration Data

```
6  ybar=mean(y);
7  sy=st_deviation(y);
8  defaultvalue=ybar+3*sy+1;
9  printf("the maximum allowed value of y i.e. bad
       batches in a week is %d \n", defaultvalue)
10 disp("in case of 2 standard deviations");
11 defaultvalue=ybar+2*sy+1;
12 printf("the limiting value of y i.e. bad batches in
       a week is %d",defaultvalue)
```

check Appendix AP 93 for dependency:

271.sci

Scilab code Exa 2.7.1 Fitting a straight line to Flow meter Calibration Data

```
1  clc
2  pathname=get_absolute_file_path('2_7_1.sce')
3  filename=pathname+filesep()+'271.sci'
4  exec(filename)
5  //this program uses least squares fit to solve for
       slope and intercept.
```

A mass flow rate $\dot{m}$(g/s) is measured as a function of temperature T(°C).

T	10	20	40	80
$\dot{m}$	14.76	20.14	27.73	38.47

There is reason to believe that $\dot{m}$ varies linearly with the square root of T:

$$\dot{m} = aT^{1/2} + b$$

Use a straight-line plot to verify this formula and determine a and b.

Figure 2.6: Linear-Curve Fitting on non linear data

```
6  //hence the value differs from textbook a bit.
7  sx=sum(x);sx2=sum(x^2);sy=sum(y);sxy=sum(x.*y);n=
       length(x);
8  A=[sx,n;sx2,sx];B=[sy;sxy];p=A\B;
9  m=p(1,1);b=p(2,1);
10 clf()
11 xtitle('2.7_1.sce','Vdot(L/min)','R','boxed')
12 plot2d(x,y,style=3)
13 disp("in case 2, R=36")
14 R=36;
15 V=m*R+b;
16 printf("then V=%f",V);
```

---

check Appendix AP 92 for dependency:

272.sci

Scilab code Exa 2.7.2 Linear-Curve Fitting on non linear data

```
clc
pathname=get_absolute_file_path('2_7_2.sce')
filename=pathname+filesep()+'272.sci'
exec(filename)
disp(sqrtT);
sx=sum(sqrtT);sx2=sum(T);sy=sum(M);sxy=sum(sqrtT.*M)
   ;n=length(T);
A=[sx,n;sx2,sx]; B=[sy;sxy]; p=A\B;
a=p(1,1);b=p(2,1);
clf()
xtitle('2.7.2.sce','T1/2','mdot','boxed')
plot2d(sqrtT,M,style=3);
printf("slope=%f",a);
printf("\n intercept=%f",b);
```

Chapter 3

Processes and Process Variables

check Appendix AP 91 for dependency:

```
311.sci
```

Scilab code Exa 3.1.1 Mass, Volume and Density

```
clc
pathname=get_absolute_file_path('3_1_1.sce')
filename=pathname+filesep()+'311.sci'
exec(filename)
density=13.546*62.43
printf("density of mercury=%f lbm/ft^3",density);
//the multiplication factor is to convert density
   from gm/cc to lbm/ft^3.
volume=mass/(.454*density) ; //ft^3
//the division by 0.454 is to convert mass in kg to
   lbm.
printf(" \n The volume of %d kg of mercury is %f ft
   ^3",mass,volume)
```

Calculate the density of mercury in lb_m/ft^3 from a tabulated specific gravity, and calculate the volume in ft^3 occupied by 215 kg of mercury.

Figure 3.1: Mass, Volume and Density

---

check Appendix AP 90 for dependency:

312.sci

Scilab code Exa 3.1.2 Effect of Temperature on Liquid Density

```
1 clc
2 pathname=get_absolute_file_path('3_1_2.sce')
3 filename=pathname+filesep()+'312.sci'
4 exec(filename)
5 disp("we know that V(T)=Vo[1+0.18182x10^(-3)xT
    +0.0078x10^(-6)xTxT]")
6 Vat0=Vat20/(1+0.18182*10^(-3)*T1 +0.0078*10^(-6)*T1*
    T1)
7 //the function is defined with the variable as
    temperature
```

In Example 3.1-1, 215 kg of mercury was found to occupy 0.560 ft^3 at 20°C. (1) What volume would the mercury occupy at 100°C? (2) Suppose the mercury is contained in a cylinder having a diameter of 0.25 in. What change in height would be observed as the mercury is heated from 20°C to 100°C?

$$V(T) = V_0\left(1 + 0.18182 \times 10^{-3}T + 0.0078 \times 10^{-6}T^2\right)$$

Figure 3.2: Effect of Temperature on Liquid Density

```
8  function[volume]=volume(T)
9      volume=Vat0*(1+0.18182*10^(-3)*T +0.0078*10^(-6)
          *T*T);
10 endfunction
11 printf(" vat20=%f",volume(T1))
12 printf(" \n vat100=%f",volume(T2))
13 change=((volume(T2))-(volume(T1)))*4/(%pi*D*D)
14 printf(" \n change in the height of mercury level=
     %f ft",change)
15 //the answer is a bit different due to rounding off
     of volume(T2) in textbook
```

check Appendix AP 89 for dependency:

331.sci

Scilab code Exa 3.3.1 Conversion between mass and moles

How many of each of the following are contained in 100.0 g of CO_2 (M = 44.01)? (1) mol CO_2; (2) lb-moles CO_2; (3) mol C; (4) mol O; (5) mol O_2; (6) g O; (7) g O_2; (8) molecules of CO_2.

Figure 3.3: Conversion between mass and moles

```
clc
pathname=get_absolute_file_path('3_3_1.sce')
filename=pathname+filesep()+'331.sci'
exec(filename)
moles=mass/M
printf("\n no.of moles=%f",moles)
lbmole=moles/453.6
printf("\n no.of lb moles=%f",lbmole)
Cmoles=moles
printf("\n no.of moles of carbon=%f",Cmoles)
Omoles=2*moles
printf("\n no.of moles of oxygen=%f",Omoles)
O2moles=moles
printf("\n no.of moles of dioxygen=%f",O2moles)
gramsO=Omoles*16
printf("\n no.of grams of oxygen=%f",gramsO)
gramsO2=O2moles*32
printf("\n no.of grams of oxygen=%f",gramsO2)
moleculesCO2=moles*6.02*10^(23)
printf("\n no.of molecules of CO2 = %E",moleculesCO2
   )
```

---

check Appendix AP 88 for dependency:

332.sci

A solution contains 15% A by mass ($x_A = 0.15$) and 20 mole% B ($y_B = 0.20$).

Figure 3.4: Conversion using mass and mole fractions

Scilab code Exa 3.3.2 Conversion using mass and mole fractions

```
clc
pathname=get_absolute_file_path('3_3_2.sce')
filename=pathname+filesep()+'332.sci'
exec(filename)
massA=mass*xA
printf(" \n Mass of A in %d kg of solution = %f kg A
   ",mass,massA)
flowrateA=flowrate1*xA
printf(" \n Mass flow rate of A in a stream flowing
   at %d lbm/h =%f lbm A/h",flowrate1,flowrateA)
flowrateB=flowrate2*yB
printf(" \n Molar flowrate of B in a stream flowing
   at %d mol/min = %f molB/min",flowrate2,flowrateB)
Totalflowrate=molarB/yB
printf(" \n Total flow rate of a solution with %d
   kmolB/s=%f",molarB,Totalflowrate)
MassSolution=massofA/xA
printf(" \n Mass of solution that contains %d lbm of
    A = %f",massofA,MassSolution)
```

check Appendix AP 87 for dependency:

333.sci

Scilab code Exa 3.3.3 Conversion from a composition by mass to a molar composition

A mixture of gases has the following composition by mass:

O_2	16%	(x_{O_2} = 0.16 g O_2/g total)
CO	4.0%	
CO_2	17%	
N_2	63%	

What is the molar composition?

Figure 3.5: Conversion from a composition by mass to a molar composition

Calculate the average molecular weight of air (1) from its approximate molar composition of 79% N_2, 21% O_2 and (2) from its approximate composition by mass of 76.7% N_2, 23.3% O_2.

Figure 3.6: Calculation of an average molecular weight

```
clc
pathname=get_absolute_file_path('3_3_3.sce')
filename=pathname+filesep()+'333.sci'
exec(filename)
molO2=massO2/MO2
molCO=massCO/MCO
molCO2=massCO2/MCO2
molN2=massN2/MN2
TotalMol=molO2+molCO+molCO2+molN2
printf("\n molefraction of O2=%f",molO2/TotalMol)
printf("\n molefraction of CO=%f",molCO/TotalMol)
printf("\n molefraction of CO2=%f",molCO2/TotalMol)
printf("\n molefraction of N2=%f",molN2/TotalMol)
```

check Appendix AP 86 for dependency:

334.sci

A 0.50-molar aqueous solution of sulfuric acid flows into a process unit at a rate of 1.25 m^3/min. The specific gravity of the solution is 1.03. Calculate (1) the mass concentration of H_2SO_4 in kg/m^3, (2) the mass flow rate of H_2SO_4 in kg/s, and (3) the mass fraction of H_2SO_4.

Figure 3.7: Conversion between mass, molar and volumetric flowrates

Scilab code Exa 3.3.4 Calculation of an average molecular weight

```
clc
pathname=get_absolute_file_path('3_3_4.sce')
filename=pathname+filesep()+'334.sci'
exec(filename)
Mbar=yN2*MN2+(1-yN2)*MO2
printf(" \n average molecular weight of air from
   molar composition=%f",Mbar)
InvMbar=xN2/28 + (1-xN2)/32
printf(" \n average molecular weight of air from
   mass composition=%f",1/InvMbar)
```

check Appendix AP 85 for dependency:

335.sci

Scilab code Exa 3.3.5 Conversion between mass, molar and volumetric flowrates

```
clc
pathname=get_absolute_file_path('3_3_5.sce')
filename=pathname+filesep()+'335.sci'
exec(filename)
mass_conc=conc*98
```

Express a pressure of 2.00×10^5 Pa in terms of mm Hg.

Figure 3.8: Calculation of pressure as head of fluid

```
6 printf("mass concentration of sulfuric acid=%f kg/m
    ^3",mass_conc)
7 mass_flowrate=rate*mass_conc/60
8 printf(" \n Mass flow rate of sulfuric acid=%f kg/s"
    ,mass_flowrate)
9 massfraction=1/(rate*D*1000/60)
10 printf(" \n Mass fraction of sulfuric acid=%f",
    massfraction)
```

check Appendix AP 84 for dependency:

341.sci

Scilab code Exa 3.4.1 Calculation of pressure as head of fluid

```
1 clc
2 pathname=get_absolute_file_path('3_4_1.sce')
3 filename=pathname+filesep()+'3_4_1.sci'
4 exec(filename)
5 Pressure=Pressure*1000/(13600*9.807)
6 printf("Pressure =%E mm of Hg",Pressure)
```

check Appendix AP 83 for dependency:

342.sci

What is the pressure 30.0 m below the surface of a lake? Atmospheric pressure (the pressure at the surface) is 10.4 m H_2O, and the density of water is 1000.0 kg/m^3. Assume that g is 9.807 m/s^2.

Figure 3.9: Pressure below the surface of a fluid

Consider the interval from 20°F to 80°F.

1. Calculate the equivalent temperatures in °C and the interval between them.
2. Calculate directly the interval in °C between the temperatures.

Figure 3.10: Temperature Conversion

Scilab code Exa 3.4.2 `Pressure below the surface of a fluid`

```
1 clc
2 pathname=get_absolute_file_path('3_4_2.sce')
3 filename=pathname+filesep()+'342.sci'
4 exec(filename)
5 Ph=P0+D*g*h
6 printf("Pressure at the bottom of the lake=%E N/mˆ2"
    ,Ph)
```

check Appendix AP 82 for dependency:

`352.sci`

Scilab code Exa 3.5.2 `Temperature Conversion`

```
1 clc
2 pathname=get_absolute_file_path('3_5_2.sce')
3 filename=pathname+filesep()+'352.sci'
4 exec(filename)
5 //In this code I used a function to achieve the
    conversion
```

```
6  function[centigrade]=conversion(fahrenheit)
7      centigrade=(fahrenheit-32)/1.8
8  endfunction
9  difference=conversion(80)-conversion(20)
10 printf("Equivalent temperature of %d-%d temperature
       in C =%f",T2,T1,difference)
11 deltaTF=T2-T1
12 deltaTC=deltaTF/1.8
13 printf(" \n By second method, result=%f",deltaTC)
```

Chapter 4

Fundamentals Of Material Balances

check Appendix AP 81 for dependency:

```
421.sci
```

Scilab code Exa 4.2.1 The General Balance Equation

```
1 clc
2 pathname=get_absolute_file_path('4_2_1.sce')
3 filename=pathname+filesep()+'421.sci'
4 exec(filename)
5 printf("All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
```

Each year 50,000 people move into a city, 75,000 people move out, 22,000 are born, and 19,000 die. Write a balance on the population of the city.

Figure 4.1: The General Balance Equation

One thousand kilograms per hour of a mixture of benzene (B) and toluene (T) containing 50% benzene by mass is separated by distillation into two fractions. The mass flow rate of benzene in the top stream is 450 kg B/h and that of toluene in the bottom stream is 475 kg T/h. The operation is at steady state. Write balances on benzene and toluene to calculate the unknown component flow rates in the output streams.

The process can be depicted schematically as follows:

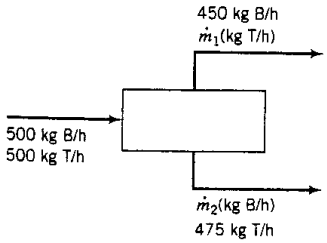


Figure 4.2: Material Balances on a Continuous Distillation Process

```
6 accumulation = input+generation-output-consumption
7 disp(" We know that accumulation=input+generation-
    output-consumption")
8 printf(" Hence, Each year population decreases by %d
    people",-accumulation)
```

---

check Appendix AP 80 for dependency:

422.sci

Scilab code Exa 4.2.2 Material Balances on a Continuous Distillation Process

```
1 clc
2 pathname=get_absolute_file_path('4_2_2.sce')
3 filename=pathname+filesep()+'422.sci'
4 exec(filename)
5 printf("All the values in the textbook are
    Approximated hence the values in this code differ
    from those of Textbook")
```

Two methanol–water mixtures are contained in separate flasks. The first mixture contains 40.0 wt% methanol, and the second contains 70.0 wt% methanol. If 200 g of the first mixture is combined with 150 g of the second, what are the mass and composition of the product?

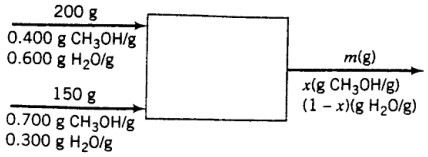


Figure 4.3: Balances on a batch mixing process

```
disp("Using benzene balance,")
m2dot=inputBenzene-UpStreamBenzene
printf(" m2dot=%d kg/h",m2dot)
disp("Using Toluene balance")
m1dot=inputToluene-DownStreamToluene
printf(" m1dot= %d kg/h",m1dot)
disp("To check we can perform Overall mass balance")
```

check Appendix AP 79 for dependency:

423.sci

Scilab code Exa 4.2.3 Balances on a batch mixing process

```
clc
pathname=get_absolute_file_path('4_2_3.sce')
filename=pathname+filesep()+'423.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
m=m1+m2
printf(" \n Total mass after mixing m=%d g",m)
```

Air is bubbled through a drum of liquid hexane at a rate of 0.100 kmol/min. The gas stream leaving the drum contains 10.0 mole% hexane vapor. Air may be considered insoluble in liquid hexane. Use an integral balance to estimate the time required to vaporize 10.0 m^3 of the liquid.

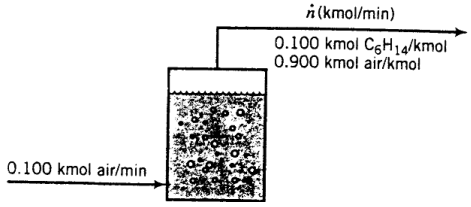


Figure 4.4: Integral balance on a semi batch process

```
8 x=(m1*x1 + m2*x2)/m
9 printf(" \n The composition of the methanol in the
    product is %f and water is %f",x,1-x)
```

---

check Appendix AP 78 for dependency:

`424.sci`

Scilab code Exa 4.2.4 `Integral balance on a semi batch process`

```
1 clc
2 pathname=get_absolute_file_path('4_2_4.sce')
3 filename=pathname+filesep()+'424.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 ndot=rate/(1-x1)
7 deltaN= -vol*d*10^3 /M
8 tf=deltaN/(-0.1 * ndot)
9 printf(" \n The time Required for the Total process=
    %d min",tf)
```

An experiment on the growth rate of certain organisms requires an environment of humid air enriched in oxygen. Three input streams are fed into an evaporation chamber to produce an output stream with the desired composition.

A: Liquid water, fed at a rate of 20.0 cm^3/min
B: Air (21 mole% O_2, the balance N_2)
C: Pure oxygen, with a molar flow rate one-fifth of the molar flow rate of stream B

The output gas is analyzed and is found to contain 1.5 mole% water. Draw and label a flowchart of the process, and calculate all unknown stream variables.

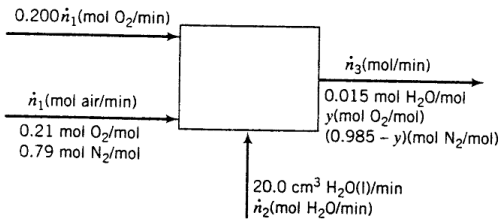


Figure 4.5: Flowchart of an Air Humidification and Oxygenation Process

---

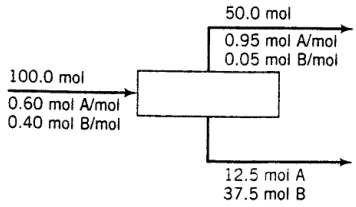
check Appendix AP 77 for dependency:

```
431.sci
```

Scilab code Exa 4.3.1 Flowchart of an Air Humidification and Oxygenation Process

```
1 clc
2 pathname=get_absolute_file_path('4_3_1.sce')
3 filename=pathname+filesep()+'431.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 n2=Vdot*DH2O/MH2O
7 printf("n2=%f mol/min",n2)
8 disp("Using Water Balance,")
```

A 60–40 mixture (by moles) of A and B is separated into two fractions. A flowchart of the process is shown here.



It is desired to achieve the same separation with a continuous feed of 1250 lb-moles/h. Scale the flowchart accordingly.

Figure 4.6: Scale-up of a separation process flowchart

```
9  n3=n2/x
10 printf("n3=%f mol/min",n3)
11 disp("Using total mole balance,")
12 n1=(n3-n2)/(1+x1)
13 printf("n1=%f mol/min",n1)
14 disp("Using N2 balance,")
15 y=1-x-0.79*n1/n3
16 printf("y=%f mol O2/mol",y)
```

---

check Appendix AP 76 for dependency:

`432.sci`

Scilab code Exa 4.3.2 Scale-up of a separation process flowchart

```
1 clc
2 pathname=get_absolute_file_path('4_3_2.sce')
3 filename=pathname+filesep()+'432.sci'
4 exec(filename)
```

An aqueous solution of sodium hydroxide contains 20.0% NaOH by mass. It is desired to produce an 8.0% NaOH solution by diluting a stream of the 20% solution with a stream of pure water. Calculate the ratios (liters H_2O/kg feed solution) and (kg product solution/kg feed solution).

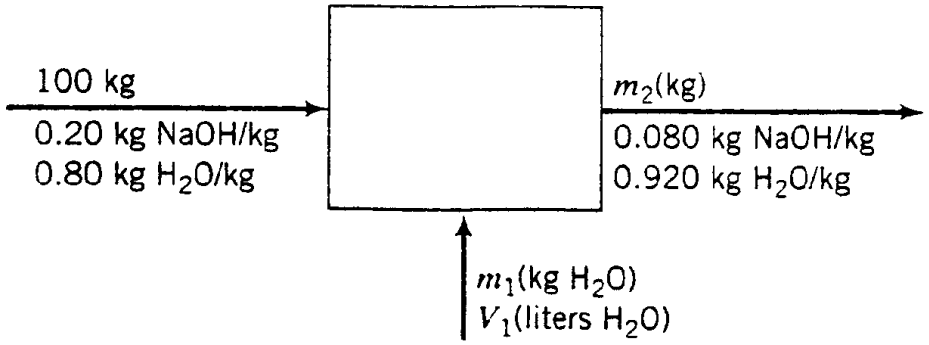


Figure 4.7: Balances on a mixing unit

```
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  multiply=FinalBasis/basis
7  Feed=100*multiply
8  TopStream=50*multiply
9  BottomStream1=12.5*multiply
10 BottomStream2=37.5*multiply
11 printf(" \n Final Basis=%d lb-moles /h",Feed)
12 printf(" \n Final Top Stream Feed=%d lb-moles /h",
       TopStream)
13 printf(" \n Final Bottom Stream Feed 1 =%d lb-moles
       A/h",BottomStream1)
14 printf(" \n Final Bottom Stream Feed 2 =%d lb-moles
       B/h",BottomStream2)
```

---

check Appendix AP 75 for dependency:

433.sci

Scilab code Exa 4.3.3 Balances on a mixing unit

```
1 clc
2 pathname=get_absolute_file_path('4_3_3.sce')
3 filename=pathname+filesep()+'433.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp("Using NaOH balance")
7 m2=inputx*basis/outputx
8 printf("m2=%f Kg NaOH",m2)
9 disp("Using Total mass balance")
10 m1=m2-basis
11 printf("m1=%f Kg Water",m1)
12 V1=m1/D
13 printf(" \n V1=%f Litres",V1)
14 Ratio1=V1/basis
15 Ratio2=m2/basis
16 printf(" \n Ratio of lt water/Kg Feed = %f lt water/
    Kg Feed",Ratio1)
17 printf(" \n Ratio of Kg product/Kg Feed = %f Kg
    product/Kg Feed",Ratio2)
```

---

check Appendix AP 74 for dependency:

435.sci

Scilab code Exa 4.3.5 Material Balances on a Distillation Column

A liquid mixture containing 45.0% benzene (B) and 55.0% toluene (T) by mass is fed to a distillation column. A product stream leaving the top of the column (the *overhead product*) contains 95.0 mole % B, and a bottom product stream contains 8.0% of the benzene fed to the column (meaning that 92% of the benzene leaves with the overhead product). The volumetric flow rate of the feed stream is 2000 L/h and the specific gravity of the feed mixture is 0.872. Determine the mass flow rate of the overhead product stream and the mass flow rate and composition (mass fractions) of the bottom product stream.

We will explicitly illustrate the implementation of the steps of the procedure just outlined.

1. ***Choose a basis.*** Having no reason to do otherwise, we choose the given feed stream flow rate (2000 L/h) as the basis of calculation.
2. ***Draw and label the flowchart.***

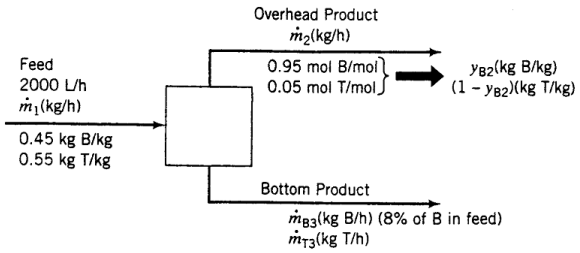


Figure 4.8: Material Balances on a Distillation Column

```
clc
pathname=get_absolute_file_path('4_3_5.sce')
filename=pathname+filesep()+'435.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
mass1=outputBasis*M1*outputx
mass2=outputBasis*M2*(1-outputx)
mass=mass1+mass2
yB2=mass1/mass
m1=basis*D
printf(" \n m1=%f Kg/h",m1)
mB3=z*inputx*m1
printf(" \n mB3=%f Kg/h",mB3)
disp("Using Benzene balance,")
m2=(inputx*m1-mB3)/yB2
printf(" \n m2=%f Kg/h",m2)
```

```
17 disp("Using Toluene balance,")
18 mT3=(1-inputx)*m1-(1-yB2)*m2
19 printf(" \n mT3=%f Kg/h",mT3)
20 m3=mB3+mT3
21 printf(" \n m3=%f Kg/h",m3)
22 yB3=mB3/m3
23 printf(" \n yB3=%f kg B/kg",yB3)
24 yT3=1-yB3
25 printf(" \n yT3=%f kg T/kg",yT3)
```

---

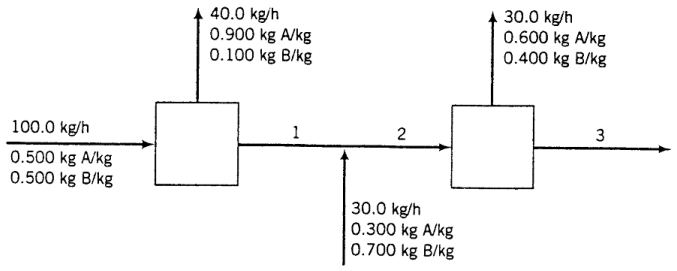
check Appendix AP 73 for dependency:

441.sci

Scilab code Exa 4.4.1 Two- Unit Process

```
1 clc
2 pathname=get_absolute_file_path('4_4_1.sce')
3 filename=pathname+filesep()+'441.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp("using Overall Mass balance, ")
7 m3=inputMass1+inputMass2-outputMass1-outputMass2
8 printf("m3=%d Kg/h",m3)
9 disp("using Overall balance on A, ")
10 x3=(inputMass1*inputx1+inputMass2*inputx2-
    outputMass1*outputx1-outputMass2*outputx2)/m3
11 printf("m3=%f Kg A/kg",x3)
12 disp("using Mass balance on Unit 1, ")
13 m1=inputMass1-outputMass1
14 printf("m1=%d Kg/h",m1)
15 disp("using A balance on Unit 1, ")
```

A labeled flowchart of a continuous steady-state two-unit process is shown below. Each stream contains two components, A and B, in different proportions. Three streams whose flow rates and/or compositions are not known are labeled 1, 2, and 3.



Calculate the unknown flow rates and compositions of streams 1, 2, and 3.

Basis—Given Flow Rates

The systems about which balances might be written are shown on the following representation of the flowchart:

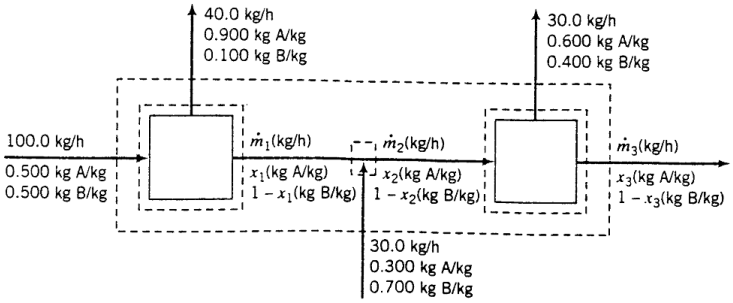


Figure 4.9: Two- Unit Process

A mixture containing 50.0 wt% acetone and 50.0 wt% water is to be separated into two streams—one enriched in acetone, the other in water. The separation process consists of extraction of the acetone from the water into methyl isobutyl ketone (MIBK), which dissolves acetone but is nearly immiscible with water. The description that follows introduces some of the terms commonly used in reference to liquid extraction processes. The process is shown schematically below.

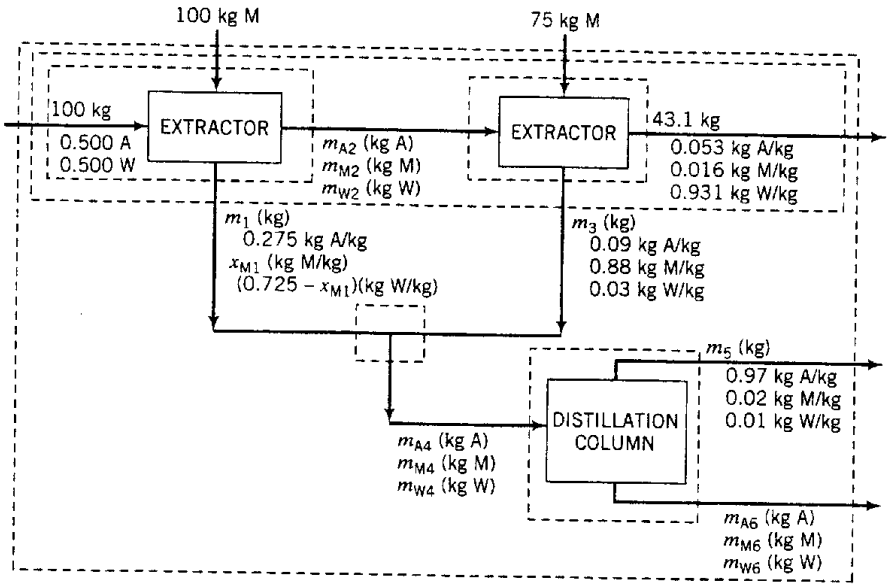


Figure 4.10: An Extraction-Distillation Process

```
16 x1=(inputMass1*inputx1-outputMass1*outputx1)/m1
17 printf("x1=%f Kg A/kg",x1)
18 disp("using Mass balance on mixing point, ")
19 m2=inputMass2+m1
20 printf("m2=%d Kg/h",m2)
21 disp("using A balance on mixing point, ")
22 x2=(inputMass2*inputx2+m1*x1)/m2
23 printf("x2=%f Kg A/kg",x2)
```

---

check Appendix AP 72 for dependency:

442.sci

Scilab code Exa 4.4.2 An Extraction-Distillation Process

```
clc
pathname=get_absolute_file_path('4_4_2.sce')
filename=pathname+filesep()+'442.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("Using Balances around two-extraxtor system,")
disp("Balance on total mass,")
printf("%d + %d + %d = %f + m1+m3",massin,M1,M2,
    massout)
disp("Balance on A")
printf("%d * %f = %f * %f + m1 %f + m3 %f",massin,
    inputx,massout,outputxA,m1xA,m3xA)
A=[1 1;m1xA,m3xA]
b=[massin+M1+M2-massout;massin*inputx - massout*
    outputxA]
C=A\b
m1=C(1,1)
m3=C(2,1)
printf(" \n m1=%f Kg",m1)
printf(" \n m3=%f Kg",m3)
disp("Balance on M")
xM1=(massin+M2-massout*outputxM-m3*m3xM)/m1
printf("xM1=%f kg MIBK/kg",xM1)
disp("Balances around Extract mixing point, ")
disp("Balance on A")
mA4=m1*m1xA+m3*m3xA
printf(" \n mA4=%f Kg Acetone",mA4)
disp("Balance on M")
mM4=m1*xM1+m3*m3xM
printf(" \n mM4=%f Kg MIBK",mM4)
```

```
28 disp("Balance on W")
29 mW4=m1*(m1xM-xM1) + m3*m3xW
30 printf(" \n mW4=%f Kg Water",mW4)
31 disp("Balances around the First extractor")
32 disp("Balance on  A")
33 mA2=massin*inputx-m1*m1xA
34 printf(" \n mA2=%f Kg Acetone",mA2)
35 disp("Balance on  M")
36 mM2=massin-x1*xM1
37 printf(" \n xM1=%f Kg MIBK",xM1)
38 disp("Balance on  W")
39 mW2=massin*inputx- m1*(m1xM-xM1)
40 printf(" \n mW2=%f Kg Water",mW2)
```

check Appendix AP 71 for dependency:

```
451.sci
```

Scilab code Exa 4.5.1 Material and Energy Balances on an Air Conditioner

```
1 clc
2 pathname=get_absolute_file_path('4_5_1.sce')
3 filename=pathname+filesep()+'451.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
      from those of Textbook")
6 disp("Overall dry Air balance,")
7 n1=x3*basis/x1
8 printf("n1=%f mol Fresh feed",n1)
9 disp("Overall mole balance,")
10 n3=n1-basis
11 printf("n3=%f mol Water condensed",n3)
12 disp("Mole balance on mixing point,")
```

Fresh air containing 4.00 mole% water vapor is to be cooled and dehumidified to a water content of 1.70 mole% H_2O. A stream of fresh air is combined with a recycle stream of previously dehumidified air and passed through the cooler. The blended stream entering the unit contains 2.30 mole% H_2O. In the air conditioner, some of the water in the feed stream is condensed and removed as liquid. A fraction of the dehumidified air leaving the cooler is recycled and the remainder is delivered to a room. Taking 100 mol of dehumidified air delivered to the room as a basis of calculation, calculate the moles of fresh feed, moles of water condensed, and moles of dehumidified air recycled.

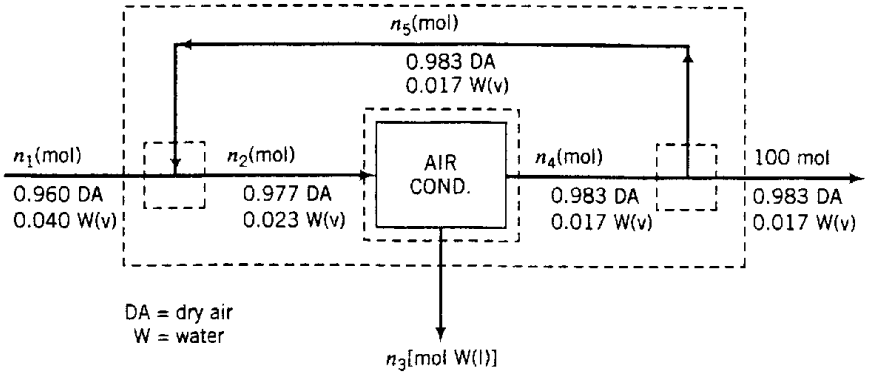


Figure 4.11: Material and Energy Balances on an Air Conditioner

```
13 disp("n1+n5=n2")
14 disp("Water balance on mixing point")
15 printf(" %f n1+ %f n5 = %f n2",1-x1,1-x3,1-x2)
16 A=[1 -1;1-x2,-(1-x3)]
17 b=[n1;(1-x1)*n1]
18 C=A\b
19 n2=C(1,1)
20 n5=C(2,1)
21 printf(" \n n2=%f mol",n2)
22 printf(" \n n5=%f mol Recycled",n5)
```

---

check Appendix AP 70 for dependency:

452.sci

Forty-five hundred kilograms per hour of a solution that is one-third K_2CrO_4 by mass is joined by a recycle stream containing 36.4% K_2CrO_4, and the combined stream is fed into an evaporator. The concentrated stream leaving the evaporator contains 49.4% K_2CrO_4; this stream is fed into a crystallizer in which it is cooled (causing crystals of K_2CrO_4 to come out of solution) and then filtered. The filter cake consists of K_2CrO_4 crystals and a solution that contains 36.4% K_2CrO_4 by mass; the crystals account for 95% of the total mass of the filter cake. The solution that passes through the filter, also 36.4% K_2CrO_4, is the recycle stream.

1. Calculate the rate of evaporation, the rate of production of crystalline K_2CrO_4, the feed rates that the evaporator and the crystallizer must be designed to handle, and the *recycle ratio* (mass of recycle)/(mass of fresh feed).
2. Suppose that the filtrate were discarded instead of being recycled. Calculate the production rate of crystals. What are the benefits and costs of the recycling?

1. ***Basis: 4500 kg/h Fresh Feed.***

Let K denote K_2CrO_4 and W denote water. The flowchart is shown below; included on it are dashed boxes denoting the overall system and subsystems about which balances may be written.

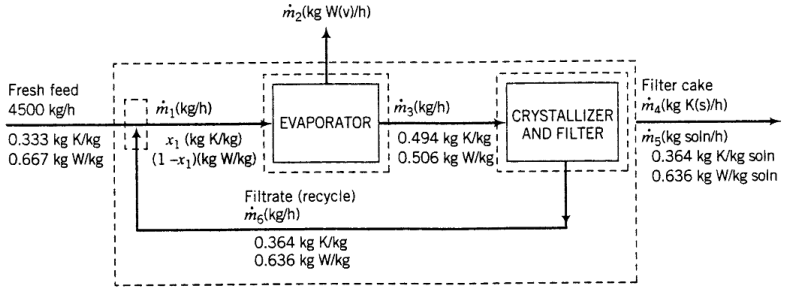


Figure 4.12: An Evaporatiove Crystallization Process

Scilab code Exa 4.5.2 An Evaporatiove Crystallization Process

```
clc
pathname=get_absolute_file_path('4_5_2.sce')
filename=pathname+filesep()+'452.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
m6x=m5x
printf("Given, m4=%f (m4+m5)",x)
disp("using Overall K2CrO4 balance, ")
printf("%f * %f = m4+ %f m5",feedx,feed,m6x)
A=[1-x,-x;1,m6x]
b=[0;feedx*feed]
C=A\b
m4=C(1,1)
m5=C(2,1)
printf(" \n m4=%f K2CrO4 crystals/h",m4)
printf(" \n m5=%f entrained solution/h",m5)
disp("Overall Total mass balance , ")
m2=feed-m4-m5
printf("m2=%f Kg H2O evaporated/h",m2)
disp("Mass balance around the crystallizer,")
disp("m3=m4+m5+m6")
disp("Water balance around the crystallizer, ")
printf(" %f m3= %f m5 + %f m6",1-m3x,1-m5x,1-m6x)
D=[1 -1;1 (-1+m6x)/(1-m3x)]
e=[m4+m5;(1-m5x)*m5/(1-m3x)]
F=D\e
m3=F(1,1)
m6=F(2,1)
printf(" \n m3=%f Kg/h fed to the crystallizer",m3)
printf(" \n m6=%f Kg/h ",m6)
ratio=m6/feed
printf(" \n ratio=%f Kg recycle/ Kg fresh feed",
    ratio)
disp("mass balance around Recycle-fresh feed mixing
```

Acrylonitrile is produced in the reaction of propylene, ammonia, and oxygen:

$$C_3H_6 + NH_3 + \tfrac{3}{2}O_2 \rightarrow C_3H_3N + 3H_2O$$

The feed contains 10.0 mole% propylene, 12.0% ammonia, and 78.0% air. A fractional conversion of 30.0% of the limiting reactant is achieved. Taking 100 mol of feed as a basis, determine which reactant is limiting, the percentage by which each of the other reactants is in excess, and the molar amounts of all product gas constituents for a 30% conversion of the limiting reactant.

Basis: 100 mol Feed

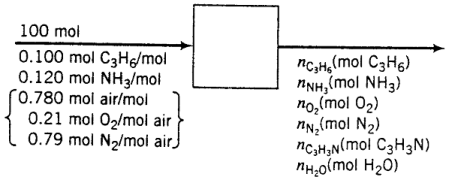


Figure 4.13: Reaction Stoichiometry

```
    point , ")
34 m1=feed+m6
35 printf("m1=%f kg/h feed to the evaporator",m1)
36 disp("With out recycle , ")
37 disp("m3=622 Kg/h")
38 disp("m5=2380 Kg/h")
```

---

check Appendix AP 69 for dependency:

461.sci

Scilab code Exa 4.6.1 Reaction Stoichiometry

```
1 clc
2 pathname=get_absolute_file_path('4_6_1.sce')
3 filename=pathname+filesep()+'461.sci'
4 exec(filename)
```

```
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  nP=basis*xP
7  nN=basis*xN
8  nO2=basis*xA*0.21
9  if(nN/nP>1)
10     disp("NH3 is in excess")
11 else
12     disp("Propene is in excess")
13 end
14 if(nO2/nP>1)
15     disp("O2 is in excess")
16 else
17     disp("propene is in excess")
18 end
19 nO2reacted=nP*1.5
20 nNreacted=nP*1
21 ExcessAmmonia=(nN-nNreacted)*100/nNreacted
22 ExcessO2=(nO2-nO2reacted)*100/nO2reacted
23 printf(" \n percentage excess Ammonia=%f",
       ExcessAmmonia)
24 printf(" \n percentage excess Oxygen=%f",ExcessO2)
25 nPout=(1-x)*nP
26 printf(" \n no.of moles of Propylene left= %d mol",
       nPout)
27 E=nP-nPout
28 nNout=nN-E
29 nO2out=nO2-1.5*E
30 nAc=E
31 nW=3*E
32 printf(" \n no.of moles of Ammonia left= %f mol",
       nNout)
33 printf(" \n no.of moles of oxygen left= %f mol",
       nO2out)
34 printf(" \n no.of moles of ACN formed= %d mol",nAc)
35 printf(" \n no.of moles of water formed= %d mol",nW)
```

The reactions

$$C_2H_6 \rightarrow C_2H_4 + H_2$$
$$C_2H_6 + H_2 \rightarrow 2\,CH_4$$

take place in a continuous reactor at steady state. The feed contains 85.0 mole% ethane (C_2H_6) and the balance inerts (I). The fractional conversion of ethane is 0.501, and the fractional yield of ethylene is 0.471. Calculate the molar composition of the product gas and the selectivity of ethylene to methane production.

Basis: 100 mol Feed

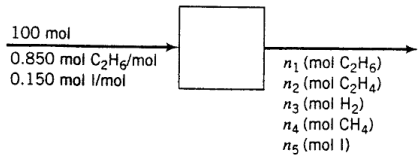


Figure 4.14: Yield and Selectivity in a Dehydrogenation Reactor

check Appendix AP 68 for dependency:

`463.sci`

Scilab code Exa 4.6.3 `Yield and Selectivity in a Dehydrogenation Reactor`

```
clc
pathname=get_absolute_file_path('4_6_3.sce')
filename=pathname+filesep()+'463.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
n1=(1-conv1)*basis*x
n2=conv2*basis*x
E1=n2
E2=basis*x - E1-n1
n3=E1-E2
n4=2*E2
```

Propane is dehydrogenated to form propylene in a catalytic reactor:

$$C_3H_8 \rightarrow C_3H_6 + H_2$$

The process is to be designed for a 95% overall conversion of propane. The reaction products are separated into two streams: the first, which contains H_2, C_3H_6, and 0.555% of the propane that leaves the reactor, is taken off as product; the second stream, which contains the balance of the unreacted propane and 5% of the propylene in the first stream, is recycled to the reactor. Calculate the composition of the product, the ratio (moles recycled)/(mole fresh feed), and the single-pass conversion.

Basis: 100 mol Fresh Feed

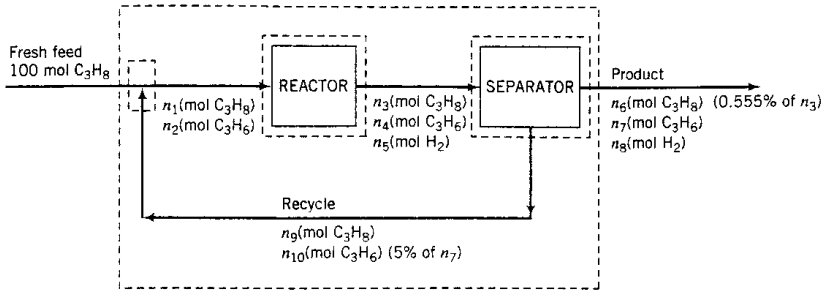


Figure 4.15: Dehydrogenation of propane

```
12 n5=basis*(1-x)
13 nt=n1+n2+n3+n4+n5
14 selectivity=n2/n4
15 printf("selectivity=%f mol Ethene/mol methane",
    selectivity)
```

---

check Appendix AP 67 for dependency:

472.sci

Scilab code Exa 4.7.2 Dehydrogenation of propane

```
1 clc
```

```
pathname=get_absolute_file_path('4_7_2.sce')
filename=pathname+filesep()+'472.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("Overall Propane conversion, ")
n6=(1-E)*basis
printf("n6=%d mol propane",n6)
disp("Overall C balance, ")
n7=basis - n6
printf("n7=%d mol propene",n7)
disp("Overall H balance ,")
n8=(basis*8-n6*8-n7*6)/2
printf("n8=%d mol H2",n8)
PercentagePropane=n6*100/(n6+n7+n8)
printf("\n Mole percentage of propane=%f",
    PercentagePropane)
PercentagePropene=(100-PercentagePropane)/2
printf("\n Mole percentage of propene=mole
    percentage of hydrogen=%f",PercentagePropene)
disp("Using given relations among separator
    variables,")
n3=n6/0.00555
n10=0.05*n7
printf(" \n n3=%d mol Propane",n3)
printf(" \n n10=%f mol Propene",n10)
disp("using Propane balance about separaation unit")
n9=n3-n6
printf("n9=%d mol Propane",n9)
n1=basis+n9
disp("Using Propane balance about mixing point,")
printf("n1=%d mol H2",n1)
RecycleRatio=(n9+n10)/basis
printf(" \n recycle ratio=%d mol recycle/mol fresh
    feed",RecycleRatio)
SinglePass=(n1-n3)*100/n1
printf(" \n single-pass conversion=%f ",SinglePass)
```

Methanol is produced in the reaction of carbon dioxide and hydrogen:

$$CO_2 + 3\,H_2 \longrightarrow CH_3OH + H_2O$$

The fresh feed to the process contains hydrogen, carbon dioxide, and 0.400 mole% inerts (I). The reactor effluent passes to a condenser that removes essentially all of the methanol and water formed and none of the reactants or inerts. The latter substances are recycled to the reactor. To avoid buildup of the inerts in the system, a purge stream is withdrawn from the recycle.

The feed to the *reactor* (not the fresh feed to the process) contains 28.0 mole% CO_2, 70.0 mole% H_2, and 2.00 mole% inerts. The single-pass conversion of hydrogen is 60.0%. Calculate the molar flow rates and molar compositions of the fresh feed, the total feed to the reactor, the recycle stream, and the purge stream for a methanol production rate of 155 kmol CH_3OH/h.

Basis: 100 mol Combined Feed to the Reactor

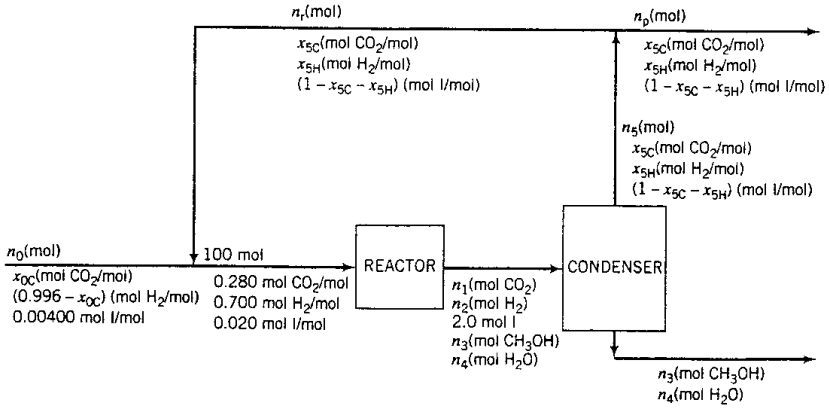


Figure 4.16: Recycle and Purge in Synthesis of Methanol

---

check Appendix AP 66 for dependency:

`473.sci`

Scilab code Exa 4.7.3 `Recycle and Purge in Synthesis of Methanol`

```
1 clc
2 pathname=get_absolute_file_path('4_7_3.sce')
```

```
filename=pathname+filesep()+'473.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
disp("Reactor analysis, ")
n2=(1-single_pass)*basis*inputxH2
printf("n2=%d mol H2",n2)
disp("H2 balance")
consH2=basis*inputxH2-n2
printf("H2 moles consumed=%d mol H2",consH2)
disp("CO2 balance")
n1=basis*inputxCO2-consH2/3
printf("n1=%d mol CO2",n1)
disp("Methanol balance")
n3=consH2/3
printf("n3=%d mol Methanol",n3)
disp("H2O balance")
n4=consH2/3
printf("n4=%d mol H2O",n4)
disp("condenser analysis")
disp("Total mole balance")
n5=n1+n2+molI
printf("n5=%d mol",n5)
disp("CO2 balance")
x5C=n1/n5
printf("x5C=%d mol CO2/mol",x5C)
disp("H2 balance")
x5H=n2/n5
printf("x5H=%d mol CO2/mol",x5H)
x1=1-x5C-x5H
printf("x1=%d mol I/mol",x1)
disp("Fresh Feed-Recycle mixing point analysis")
disp("Total mole balance")
printf("n0+nr=%d",basis)
disp("I balance")
printf("n0 %f + nr %f = %d",Ix,x1,molI)
A=[1 1;Ix x1]
```

A stack gas contains 60.0 mole% N_2, 15.0% CO_2, 10.0% O_2, and the balance H_2O. Calculate the molar composition of the gas on a dry basis.

Figure 4.17: Composition on Wet and Dry Basis

```
b=[basis;molI]
C=A\b //Here We solve two linear equations
   simultaneously
n0=C(1,1)
nr=C(2,1)
printf(" \n n0=%f mol fresh feed",n0)
printf(" \n nr= %f mol recycle",nr)
x0C=(basis*inputxCO2-nr*x5C)/n0
printf(" \n x0C=%f mol CO2/mol",x0C)
x0H=1-x0C-Ix
printf(" \n x0h=%f mol H2/mol",x0H)
disp("Recycle-Purge splitting Analysis")
disp("Total mole balance")
np=n5-nr
printf("np=%f mol purge",np)
disp("Flow chart scaling")
Factor=final/n3
printf("Factor for scaling=%f Kmol/h/mol",Factor)
```

check Appendix AP 65 for dependency:

481.sci

Scilab code Exa 4.8.1 Composition on Wet and Dry Basis

```
clc
pathname=get_absolute_file_path('4_8_1.sce')
filename=pathname+filesep()+'481.sci'
```

One hundred mol/h of butane (C_4H_{10}) and 5000 mol/h of air are fed into a combustion reactor. Calculate the percent excess air.

Figure 4.18: Theoretical and Excess Air

```
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  disp("part 1")
7  wet=xN2wet+xCO2wet+xO2wet
8  xN2dry=xN2wet/wet
9  xCO2dry=xCO2wet/wet
10 xO2dry=xO2wet/wet
11 printf(" \n xN2 dry = %f mol N2/mol dry gas",xN2dry)
12 printf(" \n xO2 dry = %f mol O2/mol dry gas",xO2dry)
13 printf(" \n xCO2 dry = %f mol CO2/mol dry gas",
       xCO2dry)
```

---

check Appendix AP 64 for dependency:

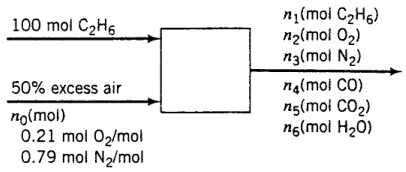
482.sci

Scilab code Exa 4.8.2 Theoretical and Excess Air

```
1  clc
2  pathname=get_absolute_file_path('4_8_2.sce')
3  filename=pathname+filesep()+'482.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  nO2Theoretical=basisButane*6.5
7  nAirTheoretical=nO2Theoretical*4.76
```

Ethane is burned with 50% excess air. The percentage conversion of the ethane is 90%; of the ethane burned, 25% reacts to form CO and the balance reacts to form CO_2. Calculate the molar composition of the stack gas on a dry basis and the mole ratio of water to dry stack gas.

Basis: 100 mol C_2H_6 Fed



$$C_2H_6 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$$

$$C_2H_6 + \frac{5}{2}O_2 \longrightarrow 2CO + 3H_2O$$

Figure 4.19: Combustion of Ethane

```
8 percent=(basisAir-nAirTheoretical)*100/
    nAirTheoretical
9 printf(" \n percent excess air=%f",percent)
```

check Appendix AP 63 for dependency:

483.sci

Scilab code Exa 4.8.3 Combustion of Ethane

```
1 clc
2 pathname=get_absolute_file_path('4_8_3.sce')
3 filename=pathname+filesep()+'483.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp(" 50% excess air")
```

```
nO2theoretical=basis*3.5
n0=nO2theoretical*(1+excess)/0.21
printf(" n0=%d mol air fed",n0)
disp("90% ethane conversion")
n1=(1-E1)*basis
printf("No. of moles of ethane unreacted= %d",n1)
disp("25% conversion to CO")
n4=E2*(basis-n1)*2
printf("n4= %d mol CO",n4)
disp("nitrogen balance")
n3=0.79*n0
printf("n3= %d mol N2",n3)
disp("Atomic carbon balance")
n5=2*basis-2*n1-n4
printf("n5= %d mol CO2",n5)
disp("Atomic hydrogen balance")
n6=(basis*6-n1*6)/2
printf("n6= %d mol H2O",n6)
disp("Atomic oxygen balance")
n2=(nO2theoretical*1.5*2-n4-n5*2-n6)/2
printf("n2= %d mol O2",n2)
dry=n1+n2+n3+n4+n5
wet=dry+n6
y1=n1/dry
printf("\n y1= %f mol C2H6/mol",y1)
y2=n2/dry
printf("\n y2= %f mol O2/mol",y2)
y3=n3/dry
printf("\n y3= %f mol N2/mol",y3)
y4=n4/dry
printf("\n y4= %f mol CO/mol",y4)
y5=n5/dry
printf("\n y5= %f mol CO2/mol",y5)
ratio=n6/dry
printf(" \n ratio=%f mol H2O/mol dry stack gas",
   ratio)
```

---

check Appendix AP 62 for dependency:

A hydrocarbon gas is burned with air. The dry-basis product gas composition is 1.5 mole% CO, 6.0% CO_2, 8.2% O_2, and 84.3% N_2. There is no atomic oxygen in the fuel. Calculate the ratio of hydrogen to carbon in the fuel gas and speculate on what the fuel might be. Then calculate the percent excess air fed to the reactor.

Basis: 100 mol Product Gas

Since the molecular composition of the fuel is unknown, we label its atomic species composition. We also recognize that since the fuel is a hydrocarbon, water must be one of the combustion products.

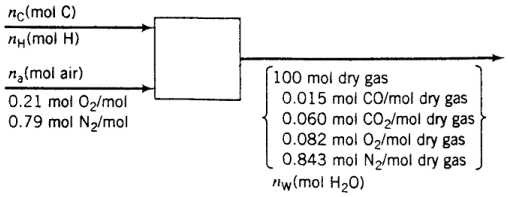


Figure 4.20: Combustion of a Hydrocarbon fuel of Unknown Composition

484.sci

Scilab code Exa 4.8.4 Combustion of a Hydrocarbon fuel of Unknown Composition

```
1  clc
2  pathname=get_absolute_file_path('4_8_4.sce')
3  filename=pathname+filesep()+'484.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  disp("N2 balance")
7  na=basis*xN2/0.79
8  printf("na=%f mol air",na)
9  disp("Atomic C balance")
10 nc=basis*xCO + basis*xCO2
11 printf("nc=%f mol C",nc)
12 disp("Atomic O balance")
13 nw=0.21*na*2-basis*(xCO + xCO2*2 + xO2*2)
```

```
14 printf("nw=%f mol oxygen",nw)
15 disp("Atomic H2 balance")
16 nh=nw*2
17 printf("nh=%f mol H2",nh)
18 ratio=nh/nc
19 printf("\n C/H ratio in fuel=%f mol H/mol C",ratio)
20 disp("percent excess air")
21 nO2theoretical=nc + nh/4
22 printf("nO2 theoretical=%f mol O2",nO2theoretical)
23 nO2fed=0.21*na
24 printf(" \n nO2fed=%f mol O2",nO2fed)
25 percent=(nO2fed-nO2theoretical)*100/nO2theoretical
26 printf("\n percentage excess air=%f excess air",
   percent)
```

---

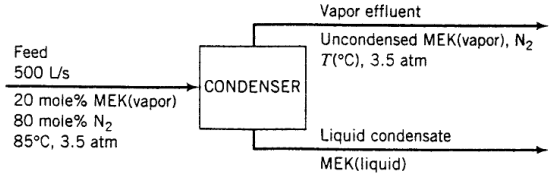
check Appendix AP 61 for dependency:

491.sci

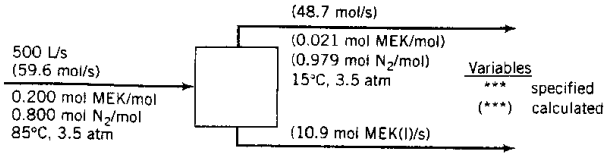
Scilab code Exa 4.9.1 Material Balances in Process Design and Process Operation

```
1 clc
2 pathname=get_absolute_file_path('4_9_1.sce')
3 filename=pathname+filesep()+'491.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
6 disp("Design")
7 MEKin1=feed*x
8 MEKout1=TopFlow1*outputx1 + BottomFlow1
9 closure1=MEKout1*100/MEKin1
10 printf("closure1=%d percent",closure1)
11 disp("Experiment")
```

Methyl ethyl ketone (MEK) is to be recovered from a gas mixture containing 20.0 mole% MEK and 80.0 mole% N_2 at 85°C and 3.5 atm. In a proposed process design, a stream of this mixture is fed to a condenser at a rate of 500 L/s and is cooled at constant pressure, causing most of the MEK to condense.

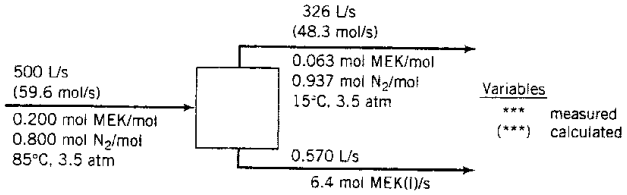


The design engineer (a) converts the volumetric flow rate of the feed stream to a molar flow rate using the *ideal gas equation of state*, an approximate relationship between the pressure, temperature, volumetric flow rate, and molar flow rate of a gas (Chapter 5); (b) specifies a condenser temperature of 15°C; (c) calculates the mole fraction of MEK in the vapor product using *Raoult's law*—an approximate relationship between the compositions of liquid and vapor phases in equilibrium with each other at a specified temperature and pressure (Chapter 6); and (d) calculates the molar flow rates of the vapor and liquid products from nitrogen and MEK balances (input = output). The results follow.



Values without parentheses are specified quantities and those with parentheses are calculated.

A condenser is then installed and run at the design temperature and pressure. The volumetric flow rates of the feed stream and the vapor and liquid product streams are measured with rotameters (see p. 46), and the MEK mole fractions in the feed and vapor effluent streams are measured with a gas chromatograph. The feed stream flow rate is set to 500 liters/s and enough time is allowed to pass for the product stream rotameter readings to reach steady levels. The feed and product gas flow rates are then converted to molar flow rates using the ideal gas equation of state, and the product liquid flow rate is converted to a molar flow rate using a tabulated MEK density and the molecular weight of MEK. Here are the results.



1. Calculate the MEK balance closures for the condenser design and the experimental condenser.
2. List possible reasons for the differences between the design predictions and the experimental values of the output stream variables and for the failure of the experimental system balance to close.

Figure 4.21: Material Balances in Process Design and Process Operation

```
12 MEKin2=feed*x
13 MEKout2=TopFlow2*outputx2 + BottomFlow2
14 closure2=MEKout2*100/MEKin2
15 printf("closure2=%d percent",closure2)
```

Chapter 5

Single Phase Systems

check Appendix AP 60 for dependency:

511.sci

Scilab code Exa 5.1.1 density calculation

```
1 clc
2 pathname=get_absolute_file_path('5_1_1.sce')
3 filename=pathname+filesep()+'511.sci'
4 exec(filename)
5 invPbar=wtperct/Dwater + (1-wtperct)/Dsulfuric
6 printf("Density calculated using volume additvity=%f
    ",1/invPbar)
7 Pbar=wtperct*Dwater + (1-wtperct)*Dsulfuric
8 printf(" \n Density calculated using mass additivity
    =%f",Pbar)
```

Determine the density in g/cm^3 of a 50 wt% aqueous solution of H_2SO_4 at 20°C, both by (1) looking up a tabulated value and (2) assuming volume additivity of the solution components.

Figure 5.1: density calculation

One hundred grams of nitrogen is stored in a container at 23.0°C and 3.00 psig.

1. Assuming ideal gas behavior, calculate the container volume in liters.
2. Verify that the ideal gas equation of state is a good approximation for the given conditions.

Figure 5.2: ideal gas equation

---

check Appendix AP 59 for dependency:

```
521.sci
```

Scilab code Exa 5.2.1 ideal gas equation

```
clc
pathname=get_absolute_file_path('5_2_1.sce')
filename=pathname+filesep()+'521.sci'
exec(filename)
n=weight/MN2 //mol
V=n*R*T*14.7/P //lt
printf("assuming ideal gas behaviour, volume=%f
    litres",V)
Vcap=V/n
if(Vcap>5)
    disp("ideal gas equation yields error less than
        1 % for diatomic gas")
else
    disp("ideal gas equation yields error greater
        than 1 % for diatomic gases")
end
```

---

check Appendix AP 58 for dependency:

```
522.sci
```

Butane (C_4H_{10}) at 360°C and 3.00 atm absolute flows into a reactor at a rate of 1100 kg/h. Calculate the volumetric flow rate of this stream using conversion from standard conditions.

Figure 5.3: volumetric flow rate

Scilab code Exa 5.2.2 volumetric flow rate

```
1 clc
2 pathname=get_absolute_file_path('5_2_2.sce')
3 filename=pathname+filesep()+'522.sci'
4 exec(filename)
5 ndot=Vdot/M //kmol/h
6 vdot=ndot*22.4*T/(273*P)
7 printf("The volumetric flow rate of the stream=%f m
    ^3/h",vdot)
```

---

check Appendix AP 57 for dependency:

523.sci

Scilab code Exa 5.2.3 volume in final state

```
1 clc
2 pathname=get_absolute_file_path('5_2_3.sce')
3 filename=pathname+filesep()+'523.sci'
4 exec(filename)
5 V2=V1*P1*T2/(P2*T1)
6 printf("Volume in final state=%f ft^3",V2)
```

Butane (C_4H_{10}) at 360°C and 3.00 atm absolute flows into a reactor at a rate of 1100 kg/h. Calculate the volumetric flow rate of this stream using conversion from standard conditions.

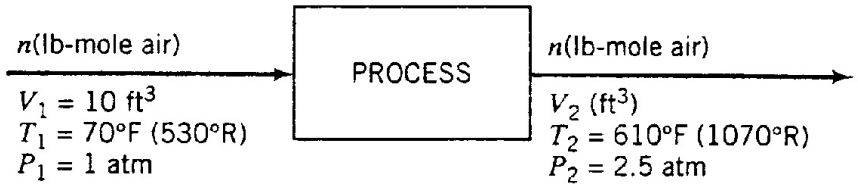


Figure 5.4: volume in final state

The flow rate of a methane stream at 285°F and 1.30 atm is measured with an orifice meter. The calibration chart for the meter indicates that the flow rate is 3.95×10^5 SCFH. Calculate the molar flow rate and the true volumetric flow rate of the stream.

Figure 5.5: true volumetric flowrate

---

check Appendix AP 56 for dependency:

524.sci

Scilab code Exa 5.2.4 true volumetric flowrate

```
1 clc
2 pathname=get_absolute_file_path('5_2_4.sce')
3 filename=pathname+filesep()+'524.sci'
4 exec(filename)
5 //SCFH means ft^3(STP)/h
6 ndot=3.95*10^5/359
7 printf(" Molar flowrate=%E lb-moles/hr",ndot)
8 V2dot=V1dot*T2*P1/(T1*P2)
```

Liquid acetone (C_3H_6O) is fed at a rate of 400 L/min into a heated chamber, where it evaporates into a nitrogen stream. The gas leaving the heater is diluted by another nitrogen stream flowing at a measured rate of 419 m^3(STP)/min. The combined gases are then compressed to a total pressure P = 6.3 atm gauge at a temperature of 325°C. The partial pressure of acetone in this stream is p_a = 501 mm Hg. Atmospheric pressure is 763 mm Hg.

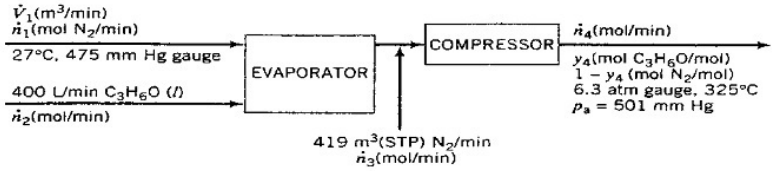


Figure 5.6: Material Balances on an Evaporator-Compressor

```
9 printf(" \n True volumetric flowrate=%E ft^3/h",
    V2dot)
```

---

check Appendix AP 55 for dependency:

525.sci

Scilab code Exa 5.2.5 Material Balances on an Evaporator-Compressor

```
1 clc
2 pathname=get_absolute_file_path('5_2_5.sce')
3 filename=pathname+filesep()+'525.sci'
4 exec(filename)
5 printf("All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 n2cap=flowinA*Dacetone/Macetone
7 printf(" \n Molar flowrate of Acetone=%f mol Acetone
    /min",n2cap)
8 P=Pfinal*760 + 763
```

Two gram-moles of nitrogen is placed in a three-liter tank at −150.8°C. Estimate the tank pressure using the ideal gas equation of state and then using the virial equation of state truncated after the second term. Taking the second estimate to be correct, calculate the percentage error that results from the use of the ideal gas equation at the system conditions.

Figure 5.7: Truncated Virial Equation

```
y4=Pacetone/P
printf(" \n Mole fraction of Acetone in the final
    flow= %f mol Acetone/mol",y4)
printf(" \n Mole fraction of Nitrogen in the final
    flow= %f mol Nitrogen/mol",1-y4)
n3cap=flowinN/0.0224
n4cap=n2cap/y4
disp("By using Overall Molar balance,")
n1cap=n4cap-n2cap-n3cap
V1cap=n1cap*0.0224*T1*760/(1*273*P1)
printf("Volumetric Flowrate of Nitrogen = %f
    Nitrogen/min",V1cap)
```

---

check Appendix AP 54 for dependency:

`531.sci`

Scilab code Exa 5.3.1 `Truncated Virial Equation`

```
clc
pathname=get_absolute_file_path('5_3_1.sce')
filename=pathname+filesep()+'531.sci'
exec(filename)
printf("All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
Pideal=0.08206*T/Vcap
```

A gas cylinder with a volume of 2.50 m^3 contains 1.00 kmol of carbon dioxide at $T = 300$ K. Use the SRK equation of state to estimate the gas pressure in atm.

Figure 5.8: SRK Equation of State

```
printf(" \n The value of pressure as per Ideal gas
    equation = %f atm",Pideal)
Tr=T/Tc
B0=0.083 - (0.422/(Tr)^1.6)
B1=0.139 - (0.172/(Tr)^4.2)
B=0.08206*Tc*(B0+w*B1)/Pc
Pvirial=0.08206*T*(1+ B/Vcap)/Vcap
printf("\n The value of pressure as per Virial gas
    equation = %f atm",Pvirial)
e=(Pideal-Pvirial)*100/Pvirial
printf(" \n Percentage error due to Ideal gas
    Equation = %f",e)
```

check Appendix AP 53 for dependency:

532.sci

Scilab code Exa 5.3.2 SRK Equation of State

```
clc
pathname=get_absolute_file_path('5_3_2.sce')
filename=pathname+filesep()+'532.sci'
exec(filename)
printf("All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
Vcap=V/n
a=0.42747*(R*Tc)^2 /Pc
```

Fifty cubic meters per hour of methane flows through a pipeline at 40.0 bar absolute and 300.0 K. Use z from page 2-144 of *Perry's Chemical Engineers' Handbook* to estimate the mass flow rate in kg/h.

Figure 5.9: Tabulated Compressibility Factors

```
b=0.08664*R*Tc/Pc
m=0.48508+ 1.5171*w -0.1561*w*w
Tr=T/Tc
alpha=(1+ m*(1-sqrt(Tr)))^2
P=(R*T/(Vcap-b))-(alpha*a/(Vcap*(Vcap+b)))
printf(" \n Pressure of gas calculated using SRK
    equation= %f atm",P)
```

check Appendix AP 52 for dependency:

541.sci

Scilab code Exa 5.4.1 Tabulated Compressibility Factors

```
clc
pathname=get_absolute_file_path('5_4_1.sce')
filename=pathname+filesep()+'541.sci'
exec(filename)
printf("All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
z=0.934
printf(" \n From the Table, z= %f",z)
ncap=P*Vcap*101.325/(z*R*T*1.01325)
mcap=ncap*M
printf(" \n Mass flow rate of Methane = %f Kg/hr",
    mcap)
```

One hundred gram-moles of nitrogen is contained in a 5-liter vessel at −20.6°C. Estimate the pressure in the cylinder.

Figure 5.10: Generalized Compressibility Chart

check Appendix AP 51 for dependency:

542.sci

Scilab code Exa 5.4.2 Generalized Compressibility Chart

```
clc
pathname=get_absolute_file_path('5_4_2.sce')
filename=pathname+filesep()+'542.sci'
exec(filename)
printf("All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
Tr=T/Tc
Pr=P/Pc
Vrideal=V*Pc/(n*R*Tc)
printf(" \n Tr= %f",Tr)
printf(" \n Pr= %f",Pr)
printf("\n Vrideal=%f",Vrideal)
z=1.77
printf("\n From the graphs, z=%f",z)
P=z*R*T*n/V
printf(" \n Pressure in the cylinder = %f atm",P)
```

check Appendix AP 50 for dependency:

543.sci

A mixture of 75% H_2 and 25% N_2 (molar basis) is contained in a tank at 800 atm and −70°C. Estimate the specific volume of the mixture in L/mol using Kay's rule.

Figure 5.11: Kay's rule

Scilab code Exa 5.4.3 Kay's rule

```
clc
pathname=get_absolute_file_path('5_4_3.sce')
filename=pathname+filesep()+'543.sci'
exec(filename)
printf("All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
disp("Applying newton corrections for Hydrogen,")
TcaH2=TcH2+8
PcaH2=PcH2+8
Tcbar=yH2*TcaH2 + yN2*TcN2
Pcbar=yH2*PcaH2 + yN2*PcN2
Trbar=T/Tcbar
Prbar=P/Pcbar
printf(" \n Trbar=%f",Trbar)
printf(" \n Pcbar=%f",Pcbar)
Zm=1.86
printf(" \n From the graph, Zm=%f",Zm)
Vcap=Zm*R*T/P
printf(" \n Specific Volume of Mixture= %f L/mol",
   Vcap)
```

Chapter 6

Multiphase Systems

check Appendix AP 49 for dependency:

```
611.sci
```

Scilab code Exa 6.1.1 Vapour Pressure estimation using Clausius-Clapeyron Equation

```
clc
pathname=get_absolute_file_path('6_1_1.sce')
filename=pathname+filesep()+'611.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
```

The vapor pressure of benzene is measured at two temperatures, with the following results:

$$T_1 = 7.6°C, \qquad p_1^* = 40 \text{ mm Hg}$$

$$T_2 = 15.4°C, \qquad p_2^* = 60 \text{ mm Hg}$$

Calculate the latent heat of vaporization and the parameter B in the Clausius–Clapeyron equation and then estimate p^* at 42.2°C using this equation.

Figure 6.1: Vapour Pressure estimation using Clausius-Clapeyron Equation

Air and liquid water are contained at equilibrium in a closed chamber at 75°C and 760 mm Hg. Calculate the molar composition of the gas phase.

Figure 6.2: Composition of a Saturated Gas-Vapour System

```
    from those of Textbook")
disp("let deltaHv/R = S")
S= - (T1*T2* log(P2/P1))/(T1-T2)
deltahv=S*R
printf(" \n Latent Heat of Vaporization=%d",deltahv)
B=log(P1) + S/T1
printf("\n B=%f",B)
P=exp(-S/T + B)
printf("\n P* at %f K = %f",T,P)
```

check Appendix AP 48 for dependency:

631.sci

Scilab code Exa 6.3.1 Composition of a Saturated Gas-Vapour System

```
clc
pathname=get_absolute_file_path('6_3_1.sce')
filename=pathname+filesep()+'631.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
y=Pstar/P
printf(" \n Molar composition of Water is %f and Air
    is %f",y,1-y)
```

check Appendix AP 47 for dependency:

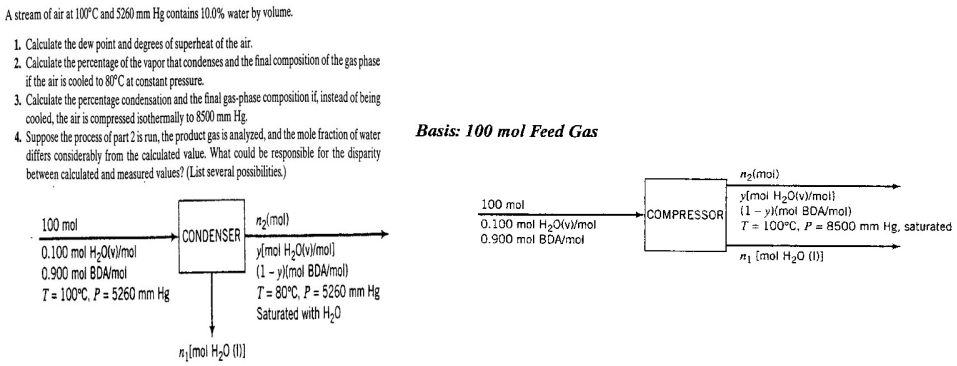


Figure 6.3: Material Balances around a Condenser

632.sci

Scilab code Exa 6.3.2 Material Balances around a Condenser

```
clc
pathname=get_absolute_file_path('6_3_2.sce')
filename=pathname+filesep()+'632.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
P=y*PT
if(P<760)
    disp("The Vapour is Super heated")
elseif(P=760)
    disp("The vapour is At Dew point")
else
    disp("The vapour is not Super heated")
end
disp("From tables Tdp=90 C")
```

Humid air at 75°C, 1.1 bar, and 30% relative humidity is fed into a process unit at a rate of 1000 m^3/h. Determine (1) the molar flow rates of water, dry air, and oxygen entering the process unit, (2) the molal humidity, absolute humidity, and percentage humidity of the air, and (3) the dew point.

Figure 6.4: Humidity calculations

```
15 disp("Superheat = 100-90=10 C ")
16 disp("Using Raoult law at the outlet")
17 y1=355/PT
18 printf("y1=%f",y1)
19 disp("Balance on Dry Air")
20 n2=basis*(1-y)/(1-y1)
21 printf("n2=%f mol",n2)
22 disp("Total mole balance")
23 n1=basis-n2
24 printf("n1=%f mol",n1)
25 printf(" \n Percentage condesation=%f",n1*100/(y*
     basis))
26 Psaturation=760/y
27 printf("\n Any increase in pressure above %d mm of
     Hg must cause condensation ",Psaturation)
28 printf(" \n For the next part of the problem use the
     same code by modifying PT to be 8500 mm of Hg")
```

---

check Appendix AP 46 for dependency:

633.sci

Scilab code Exa 6.3.3 Humidity calculations

```
1 clc
2 pathname=get_absolute_file_path('6_3_3.sce')
3 filename=pathname+filesep()+'633.sci'
```

```
4 exec(filename)
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
      from those of Textbook")
6 P=hr*P75
7 y=P/Porig
8 ndot=PorigBar*Vdot/(R*T)
9 ndotWater=ndot*y
10 printf(" \n Molar flowrate of Water=%f Kmol/h",
     ndotWater)
11 ndotBDA=ndot*(1-y)
12 printf(" \n Molar flowrate of Dry Air=%f Kmol/h",
     ndotBDA)
13 ndotO2=ndotBDA*0.21
14 printf(" \n Molar flowrate of Oxygen=%f Kmol/h",
     ndotO2)
15 hm=P/(Porig-P)
16 ha=hm*18/29
17 hmdot=P75/(Porig-P75)
18 hp=100*hm/hmdot
19 printf(" \n Molal Humidity=%f mol water/mol BDA",hm)
20 printf(" \n Absolute Humidity=%f kg water/kg BDA",ha
     )
21 printf(" \n Percentage Humidity=%f",hp)
```

check Appendix AP 45 for dependency:

641.sci

Scilab code Exa 6.4.1 Absorption of Sulphur dioxide

```
1 clc
2 pathname=get_absolute_file_path('6_4_1.sce')
3 filename=pathname+filesep()+'641.sci'
```

A gas stream consisting of 100 lb-mole/h of an SO_2–air mixture containing 45 mole% SO_2 is contacted with liquid water in a continuous absorber at 30°C. The liquid leaving the absorber is analyzed and found to contain 2.00 g of SO_2 per 100 g of H_2O. Assuming that the gas and liquid streams leaving the absorber are in equilibrium at 30°C and 1 atm, calculate the fraction of the entering SO_2 absorbed in the water and the required water feed rate.

Basis: Given Feed Rate of Gas

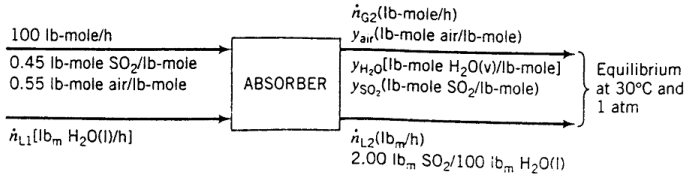


Figure 6.5: Absorption of Sulphur dioxide

```
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  yH2O=PH2O/P
7  ySO2=PSO2/P
8  yAir=1-yH2O-ySO2
9  disp("Using Air balance, ")
10 nG2=(1-x)*basis/yAir
11 printf("nG2=%f lbm/h",nG2)
12 xSO2=y/102
13 xH2O=1-xSO2
14 disp("Using SO2 balance, ")
15 nL2=(basis*x-nG2*ySO2)*M1/(xSO2)
16 printf("nL2=%d lbm/h",nL2)
17 disp("Using H2O balance, ")
18 nL1=nG2*yH2O*M2 + nL2*xH2O
19 printf("nL1=%d lbm H2O/h",nL1)
20 SO2Absorbed=nL2*xSO2
21 SO2Fed=basis*x*M1
22 Fraction=SO2Absorbed/SO2Fed
23 printf(" \n Fraction SO2 absorbed= %f lbm SO2
       absorbed/lbm SO2 fed",Fraction)
```

Use either Raoult's law or Henry's law to solve the following problems.

1. A gas containing 1.00 mole% ethane is in contact with water at 20.0°C and 20.0 atm. Estimate the mole fraction of dissolved ethane.
2. An equimolar liquid mixture of benzene (B) and toluene (T) is in equilibrium with its vapor at 30.0°C. What is the system pressure and the composition of the vapor?

Figure 6.6: Raoult's Law and Henry's Law

---

check Appendix AP 44 for dependency:

642.sci

Scilab code Exa 6.4.2 Raoult's Law and Henry's Law

```
clc
pathname=get_absolute_file_path('6_4_2.sce')
filename=pathname+filesep()+'642.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
x=y*P/H
PBstar=10^(6.906- 1211/(T+220.8))
PTstar=10^(6.9533- 1343.9/(T+219.38))
PB=xB*PBstar
PT=(1-xB)*PTstar
Ptotal=PB+PT
yB=PB/Ptotal
yT=PT/Ptotal
printf(" \n Total system pressure=%f mm of Hg",
    Ptotal)
printf(" \n Compsoition of benzene=%f",yB)
```

One hundred fifty kilograms of a saturated aqueous solution of $AgNO_3$ at 100°C is cooled to 20°C, thereby forming $AgNO_3$ crystals, which are filtered from the remaining solution. The wet filter cake, which contains 80% solid crystals and 20% saturated solution by mass, passes to a dryer in which the remaining water is vaporized. Calculate the fraction of the $AgNO_3$ in the feed stream eventually recovered as dry crystals and the amount of water that must be removed in the drying stage.

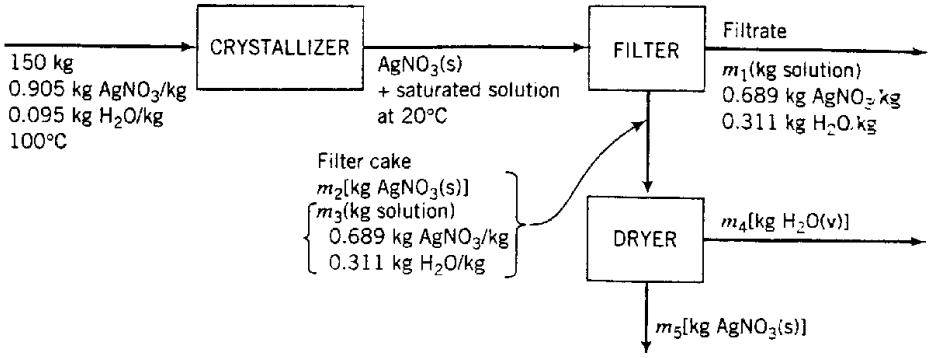


Figure 6.7: Crystallization and Filtration

```
16 printf(" \n Compsoition of toluene=%f",yT)
```

check Appendix AP 43 for dependency:

651.sci

Scilab code Exa 6.5.1 Crystallization and Filtration

```
1 clc
2 pathname=get_absolute_file_path('6_5_1.sce')
3 filename=pathname+filesep()+'651.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp("COmposition of Filter cake,")
```

```
disp("m2=4m3")
disp("Water balance around the crystallizer,")
printf("\n %f kg H2O = %f m1 + %f m1",basis*inputx,
   outputx,outputx)
disp("Mass balance around crystallizer, ")
printf(" \n %d=m1+m2+m3",basis)
A=[0 1 -4;outputx 0 outputx;1 1 1]
b=[0;basis*inputx;basis]
C=A\b
//Here we solved two linear equations simultaneously
m1=C(1,1)
printf(" \n m1=%f Kg",m1)
m2=C(2,1)
printf(" \n m2=%f Kg",m2)
m3=C(3,1)
printf(" \n m3=%f Kg",m3)
disp("Overall AgNO3 balance,")
m5=(1-inputx)*basis - (1-outputx)*m1
printf("m5=%f kg AgNO3 crystals recovered",m5)
percentage=m5*100/(basis*(1-inputx))
printf(" \n Percentage recovery=%f",percentage)
disp("Overall mass balance")
m4=basis-m1-m5
printf("m4=%d Kg water removed in the Dryer",m4)
```

check Appendix AP 42 for dependency:

652.sci

Scilab code Exa 6.5.2 Material Balances on a Crystallizer

```
clc
pathname=get_absolute_file_path('6_5_2.sce')
filename=pathname+filesep()+'652.sci'
```

An aqueous potassium nitrate solution containing 60.0 wt% KNO_3 at 80°C is fed to a cooling crystallizer in which the temperature is reduced to 40°C. Determine the temperature at which the solution reaches saturation and the percentage of the potassium nitrate in the feed that forms crystals.

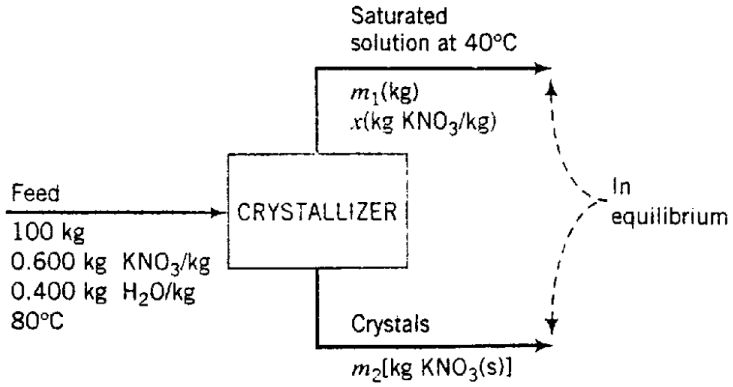


Figure 6.8: Material Balances on a Crystallizer

```
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  outputx=S/(S+100)
7  printf("x=%f Kg KNO3/Kg",outputx)
8  disp("Water balance")
9  m1=basis*(1-inputx)/(1-outputx)
10 printf(" \n m1=%f Kg",m1)
11 disp("Mass balance")
12 m2=basis-m1
13 printf(" \n m2=%f kg",m2)
14 percentage=m2*100/(basis*inputx)
15 printf(" \n Percentage of KNO3 in the feed that
       crystallizes is %f",percentage)
```

---

check Appendix AP 41 for dependency:

653.sci

An aqueous solution of magnesium sulfate at 104°C containing 30.1 wt% $MgSO_4$ is fed to a cooling crystallizer that operates at 10°C. The stream leaving the crystallizer is a slurry of solid magnesium sulfate heptahydrate particles [$MgSO_4 \cdot 7H_2O(s)$] suspended in a liquid solution. Tabulated solubility data for magnesium sulfate [*Perry's Chemical Engineers' Handbook* (see footnote 1), p. 18-35] show that a saturated solution at 10°C contains 23.2 wt% $MgSO_4$. Determine the rate at which solution must be fed to the crystallizer to produce 1 metric ton (1 tonne, 1000 kg) of magnesium sulfate heptahydrate per hour.

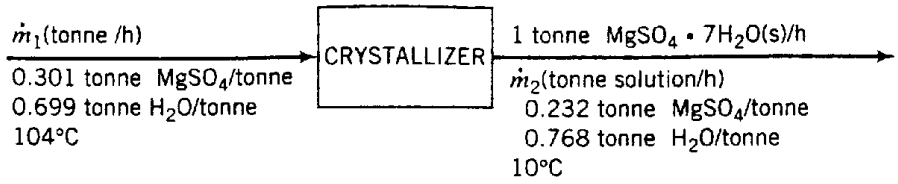


Figure 6.9: Production of a Hydrated Salt

Scilab code Exa 6.5.3 Production of a Hydrated Salt

```
clc
pathname=get_absolute_file_path('6_5_3.sce')
filename=pathname+filesep()+'653.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("Total mass balance")
disp("m1=1+m2")
disp("MgSO4 balance")
printf(" \n %f m1 = %d* %f / %f + m2 %f",inputx,
    basis,M,M1,outputx)
A=[1 -1;inputx -outputx]
b=[1;basis*M/M1]
C=A\b
//Here we solved two linear equations simultaneously
m1=C(1,1)
```

A solution of 5.000 g of a solute in 100.0 g of water is heated slowly at a constant pressure of 1.00 atm and is observed to boil at 100.421°C. Estimate the molecular weight of the solute, the effective solvent vapor pressure at 25°C, and the solution freezing point at 1 atm. The necessary properties of water can be found in Table B.1.

Figure 6.10: Colligative Property Calculations

```
15 m2=C(2,1)
16 printf(" \n m1=%f Tonne/h",m1)
17 printf(" \n m2=%f Tonne/h",m2)
```

check Appendix AP 40 for dependency:

654.sci

Scilab code Exa 6.5.4 Colligative Property Calculations

```
1  clc
2  pathname=get_absolute_file_path('6_5_4.sce')
3  filename=pathname+filesep()+'654.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  x=(Tf-100)*40656/(R*373.16^2)
7  y=m2/18.016
8  Ms=m1*(1-x)/(y*x)
9  printf(" \n Ms=%f",Ms)
10 deltaTm=R*(273.16)^2 *x/6009.5
11 Tms=0-deltaTm
12 printf(" \n Tms=%f",Tms)
13 Pstar=(1-x)*23.756
14 printf(" \n Solvent Vapour pressure=%f mm Hg",Pstar)
```

Two hundred cubic centimeters of an acetone–water mixture that contains 10.0 wt% acetone is mixed with 400.0 cm^3 of chloroform at 25°C, and the phases are then allowed to settle. What percentage of the acetone is transferred from the water to the chloroform?

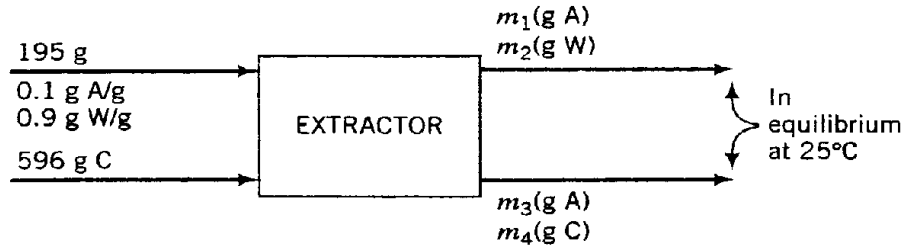


Figure 6.11: Extraction of Acetone from Water

check Appendix AP 39 for dependency:

661.sci

Scilab code Exa 6.6.1 Extraction of Acetone from Water

```
clc
pathname=get_absolute_file_path('6_6_1.sce')
filename=pathname+filesep()+'661.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
Dbar=DA*DW/(x*DW + (1-x)*DA)
mass1=V1*Dbar
mass2=V2*DC
disp("C balance")
m4=mass2
printf(" \n m4=%f",m4)
disp("W balance")
m2=(1-x)*mass1
```

One thousand kilograms of a 30.0 wt% solution of acetone in water and a second stream of pure methyl isobutyl ketone (MIBK) is fed to a mixer. The mixture is then fed to a settler where two phases form and are withdrawn separately at 25°C. How much MIBK must be fed to the process to reduce the acetone concentration in the water-rich phase to 5 wt%, assuming that the fluids remain in the settler long enough for equilibrium to be achieved?

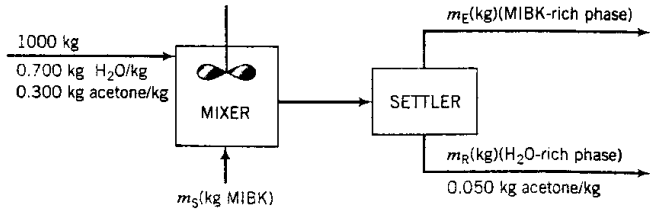


Figure 6.12: Extraction of Acetone from Water: Use of Phase Diagram

```
14 printf(" \n m2=%f",m2)
15 disp("A balance")
16 printf("m1+m3=%f * %f",x,mass1)
17 disp("Distribution Cooefficient ,K=m3*(m1+m2)/m1*(m3
   +m4)")
18 disp("On solving, ")
19 m1=2.7
20 m3=16.8
21 percentage=m3*100/(x*mass1)
22 printf(" \n m1=%f",m1)
23 printf(" \n m3=%f",m3)
24 printf(" \n percentage of acetone transferred to
   chloroform=%f",percentage)
```

---

check Appendix AP 38 for dependency:

662.sci

Scilab code Exa 6.6.2 Extraction of Acetone from Water: Use of Phase Diagram

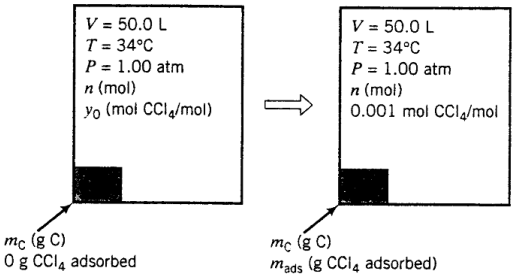
```
clc
pathname=get_absolute_file_path('6_6_2.sce')
filename=pathname+filesep()+'662.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("Mass balance")
printf("ms + %d = mE + mR",basis)
disp("acetone balance")
printf("%f *%d = %f mE + %f mR",inputxA,basis,
    outputxA2,outputxA1)
disp("Water balance")
printf(" \n %f *%d = %f mE + %f mR",1-inputxA,basis
    ,1-outputxA2-outputxM2,1-outputxA1-outputxM1)
A=[1 1 -1;outputxA2 outputxA1 0;1-outputxA2-
    outputxM2 1-outputxA1-outputxM1 0]
b=[basis;inputxA*basis;(1-inputxA)*basis]
C=A\b
//Here We solved three linear equations
    simultaneously
mE=C(1,1)
mR=C(2,1)
mS=C(3,1)
printf(" \n mE=%f Kg",mE)
printf(" \n mR=%f Kg",mR)
printf(" \n mS=%f Kg MIBK",mS)
```

check Appendix AP 37 for dependency:

671.sci

Scilab code Exa 6.7.1 Balances on an Adsorption Process

A 50.0-liter tank contains an air–carbon tetrachloride mixture at 1 atm absolute, 34°C, and 30.0% relative saturation. Activated carbon is placed in the tank to adsorb CCl_4. The temperature of the tank contents is maintained at 34°C, and clean air is continuously supplied to the tank throughout the process to maintain the total pressure at 1.00 atm. The process may be shown schematically as follows:



Calculate the minimum amount of activated carbon needed to reduce the CCl_4 mole fraction in the gas to 0.001. Neglect the volume of the activated carbon and the adsorbed CCl_4. Why would the actual amount placed in the tank be larger than the calculated value?

Figure 6.13: Balances on an Adsorption Process

```
clc
pathname=get_absolute_file_path('6_7_1.sce')
filename=pathname+filesep()+'671.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
n=P*V/(R*T)
printf(" \n No.of moles=%f mol",n)
y0=y*Pstar/Pmm
printf(" \n Y0=%f mol CCl4/mol",y0)
Pfinal=xF*Pmm
b=0.096*Pfinal
Xstar=0.794*b/(1+b)
printf(" \n Mass of CCl4 adsorbed to Carbon at
   equilibrium=%f g CCl4 ads/g C",Xstar)
Mads=(y0*n- xF*n)*154
printf(" \n Mass of CCl4 adsorbed=%f g",Mads)
Mc=Mads/Xstar
printf(" \n Mass of carbon Required=%f g",Mc)
```

Chapter 7

Energy And Energy Balances

check Appendix AP 36 for dependency:

721.sci

Scilab code Exa 7.2.1 Kinetic Energy Transported by a Flowing Stream

```
1 clc
2 pathname=get_absolute_file_path('7_2_1.sce')
3 filename=pathname+filesep()+'721.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
      from those of Textbook")
6 u=Vdot*100^2 /(%pi*(ID/2)^2 *3600)
7 mdot=Vdot*10^3 /3600
```

Water flows into a process unit through a 2-cm ID pipe at a rate of 2.00 m^3/h. Calculate $\dot{E}_k$ for this stream in joules/second.

Figure 7.1: Kinetic Energy Transported by a Flowing Stream

Crude oil is pumped at a rate of 15.0 kg/s from a point 220 meters below the earth's surface to a point 20 meters above ground level. Calculate the attendant rate of increase of potential energy.

Figure 7.2: Potential Energy increase of a flowing fluid

```
8 Ek=mdot*u^2 /2
9 printf(" \n Ek=%f J/s",Ek)
```

check Appendix AP 35 for dependency:

722.sci

Scilab code Exa 7.2.2 Potential Energy increase of a flowing fluid

```
1 clc
2 pathname=get_absolute_file_path('7_2_2.sce')
3 filename=pathname+filesep()+'722.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 Power=mdot*g*(z2-z1)
7 printf(" \n Power=%d J/s",Power)
```

check Appendix AP 34 for dependency:

741.sci

Scilab code Exa 7.4.1 Calculation of Enthalpy

The specific internal energy of helium at 300 K and 1 atm is 3800 J/mol, and the specific molar volume at the same temperature and pressure is 24.63 L/mol. Calculate the specific enthalpy of helium at this temperature and pressure, and the rate at which enthalpy is transported by a stream of helium at 300 K and 1 atm with a molar flow rate of 250 kmol/h.

Figure 7.3: Calculation of Enthalpy

Five hundred kilograms per hour of steam drives a turbine. The steam enters the turbine at 44 atm and 450°C at a linear velocity of 60 m/s and leaves at a point 5 m below the turbine inlet at atmospheric pressure and a velocity of 360 m/s. The turbine delivers shaft work at a rate of 70 kW, and the heat loss from the turbine is estimated to be 10^4 kcal/h. Calculate the specific enthalpy change associated with the process.

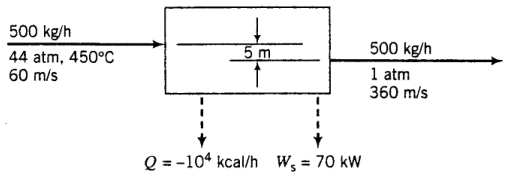


Figure 7.4: Energy Balance on a Turbine

```
1 clc
2 pathname=get_absolute_file_path('7_4_1.sce')
3 filename=pathname+filesep()+'741.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 Hcap=U+P*Vcap*101.3
7 H=ndot*Hcap*10^3
8 printf(" \n Specific Enthalpy=%d J/mol",Hcap)
9 printf("\n Enthalpy of Helium=%E J/h",H)
```

check Appendix AP 33 for dependency:

742.sci

The following entries are taken from a data table for saturated methyl chloride:

State	T(°F)	P(psia)	$\hat{V}$(ft^3/lb$_m$)	$\hat{H}$(Btu/lb$_m$)
Liquid	−40	6.878	0.01553	0.000
Vapor	0	18.90	4.969	196.23
Vapor	50	51.99	1.920	202.28

1. What reference state was used to generate the given enthalpies?
2. Calculate $\Delta\hat{H}$ and $\Delta\hat{U}$ for the transition of saturated methyl chloride vapor from 50°F to 0°F.
3. What assumption did you make in solving question 2 regarding the effect of pressure on specific enthalpy?

Figure 7.5: Use of Tabulated Enthalpy Data

Scilab code Exa 7.4.2 Energy Balance on a Turbine

```
clc
pathname=get_absolute_file_path('7_4_2.sce')
filename=pathname+filesep()+'742.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
Ek=mdot*10^(-3)*(u2^2-u1^2)/2
Ep=mdot*g*deltaZ/10^3
Qdot=Qdot/(0.239*3600)
Hdot=Qdot-Ws-Ek-Ep
printf(" \n DeltaH=%f KW",Hdot)
Hcap=Hdot/mdot
printf("\n Specific Enthalpy=%f Kj/Kg",Hcap)
```

check Appendix AP 32 for dependency:

751.sci

Scilab code Exa 7.5.1 Use of Tabulated Enthalpy Data

Steam at 10 bar absolute with 190°C of superheat is fed to a turbine at a rate $\dot{m}$ = 2000 kg/h. The turbine operation is adiabatic, and the effluent is saturated steam at 1 bar. Calculate the work output of the turbine in kilowatts, neglecting kinetic and potential energy changes.

Figure 7.6: Energy Balance on a Steam Turbine

```
clc
pathname=get_absolute_file_path('7_5_1.sce')
filename=pathname+filesep()+'751.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
deltaH=H0-H50
deltaU=deltaH+((Pfinal*Vfinal-Pinitial*Vinitial)
    *1.987/10.73)
printf(" \n change in Specific Enthalpy=%f Btu/lbm",
    deltaH)
printf(" \n change in Specific Internal Energy=%f
    Btu/lbm",deltaU)
```

check Appendix AP 31 for dependency:

753.sci

Scilab code Exa 7.5.3 Energy Balance on a Steam Turbine

```
clc
pathname=get_absolute_file_path('7_5_3.sce')
filename=pathname+filesep()+'753.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
```

Two streams of water are mixed to form the feed to a boiler. Process data are as follows:

Feed stream 1	120 kg/min @ 30°C
Feed stream 2	175 kg/min @ 65°C
Boiler pressure	17 bar (absolute)

The exiting steam emerges from the boiler through a 6-cm ID pipe. Calculate the required heat input to the boiler in kilojoules per minute if the emerging steam is saturated at the boiler pressure. Neglect the kinetic energies of the liquid inlet streams.

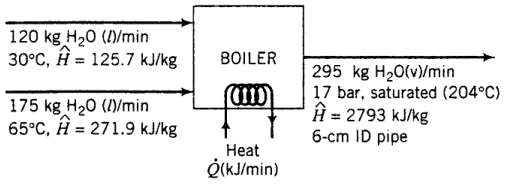


Figure 7.7: Energy Balance on a One-Component Process

```
6  disp("From Steam tables, ")
7  Hin=3201 //Kj/Kg
8  Hout=2675 //Kj/Kg
9  Ws= -mdot*(Hout-Hin)/3600
10 printf("Work delivered by Turbine to surroundings=%d
       Kw",Ws)
```

check Appendix AP 30 for dependency:

761.sci

Scilab code Exa 7.6.1 Energy Balance on a One-Component Process

```
1  clc
2  pathname=get_absolute_file_path('7_6_1.sce')
3  filename=pathname+filesep()+'761.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
       from those of Textbook")
```

A liquid stream containing 60.0 wt% ethane and 40.0% *n*-butane is to be heated from 150 K to 200 K at a pressure of 5 bar. Calculate the required heat input per kilogram of the mixture, neglecting potential and kinetic energy changes, using tabulated enthalpy data for C_2H_6 and C_4H_{10} and assuming that mixture component enthalpies are those of the pure species at the same temperature.

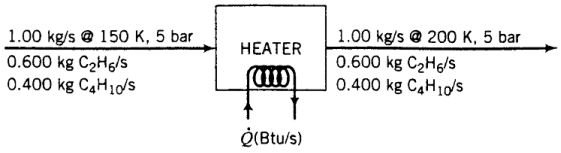


Figure 7.8: Energy Balance on a Two-Component Process

```
6  deltaH=m3*H3-m1*H1-m2*H2
7  disp("From tables, Vdot=0.1166 m^3/kg")
8  Vdot=0.1166
9  A=%pi*(ID/2)^2 /10^4
10 u=m3*Vdot/(A*60)
11 Ek=m3*u^2 /(2*10^3)
12 Qdot=deltaH+Ek
13 printf("Heat required=%E Kj/min",Qdot)
```

check Appendix AP 29 for dependency:

762.sci

Scilab code Exa 7.6.2 Energy Balance on a Two-Component Process

```
1 clc
2 pathname=get_absolute_file_path('7_6_2.sce')
3 filename=pathname+filesep()+'762.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
```

Saturated steam at 1 atm is discharged from a turbine at a rate of 1150 kg/h. Superheated steam at 300°C and 1 atm is needed as a feed to a heat exchanger; to produce it, the turbine discharge stream is mixed with superheated steam available from a second source at 400°C and 1 atm. The mixing unit operates adiabatically. Calculate the amount of superheated steam at 300°C produced and the required volumetric flow rate of the 400°C steam.

Specific enthalpies of the two feed streams and the product stream are obtained from the steam tables and are shown below on the flowchart.

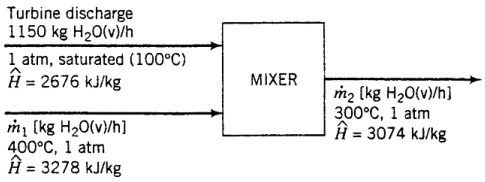


Figure 7.9: Simultaneous Material and Energy Balances

```
6 Qdot=basis*(x*Hout1+(1-x)*Hout2-x*Hin1-(1-x)*Hin2)
7 printf(" \n Heat required=%f KJ/Kg",Qdot/basis)
```

check Appendix AP 28 for dependency:

763.sci

Scilab code Exa 7.6.3 Simultaneous Material and Energy Balances

```
1 clc
2 pathname=get_absolute_file_path('7_6_3.sce')
3 filename=pathname+filesep()+'763.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp("Mass balance on Water,")
7 disp("m3+m1=m2")
8 disp("Energy balance,")
```

Water flows through the system shown here at a rate of 20 L/min. Estimate the pressure required at point ① if friction losses are negligible.

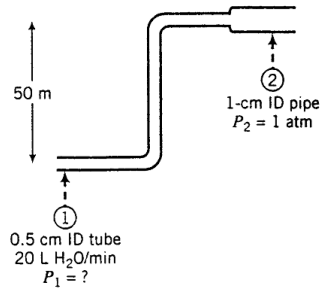


Figure 7.10: Bernoulli's Equation

```
9  disp("m3*H3+m1*H1=m2*H2")
10 A=[1,-1;H2,-H1]
11 b=[m3;m3*H3]
12 C=A\b
13 //here we solved two linear equations simultaneously
     .
14 m2=C(1,1)
15 m1=C(2,1)
16 printf(" Input flowrate,m1=%f Kg/h",m1)
17 printf(" \n Output flowrate, m2=%f Kg/h",m2)
18 disp("From tables,Vdot=3.11 m^3/kg")
19 Vdot=3.11
20 printf(" Volumetric input flowrate=%f m^3/h",m1*Vdot
     )
```

---

check Appendix AP 27 for dependency:

771.sci

Scilab code Exa 7.7.1 Bernoulli's Equation

Gasoline (ρ = 50.0 lb_m/ft^3) is to be siphoned from a tank. The friction loss in the line is $\hat{F}$ = 0.80 $ft \cdot lb_f/lb_m$. Estimate how long it will take to siphon 5.00 gal, neglecting the change in liquid level in the gasoline tank during this process and assuming that both point ① (at the liquid surface in the gas tank) and point ② (in the tube just prior to the exit) are at 1 atm.

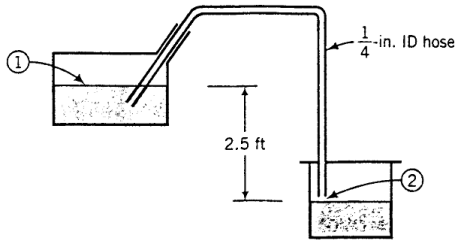


Figure 7.11: Siphoning

```
1  clc
2  pathname=get_absolute_file_path('7_7_1.sce')
3  filename=pathname+filesep()+'771.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  u1=Vdot*10^4 /(10^3 *60*%pi*(ID1/2)^2)
7  u2=Vdot*10^4 /(10^3 *60*%pi*(ID2/2)^2)
8  deltaP=-((u2^2 - u1^2)/2 + g*deltaZ)*10^3
9  P1=P2-deltaP
10 printf(" \n P1=%E Pa",P1)
```

check Appendix AP 26 for dependency:

`772.sci`

Scilab code Exa 7.7.2 Siphoning

```
1  clc
```

Water flows from an elevated reservoir through a conduit to a turbine at a lower level and out of the turbine through a similar conduit. At a point 100 m above the turbine the pressure is 207 kPa, and at a point 3 m below the turbine the pressure is 124 kPa. What must the water flow rate be if the turbine output is 1.00 MW?

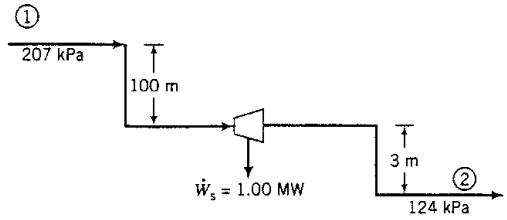


Figure 7.12: Hydraulic Power Generation

```
2 pathname=get_absolute_file_path('7_7_2.sce')
3 filename=pathname+filesep()+'772.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 u2=sqrt(2*32.174*(-F-g*deltaZ/32.174))
7 Vdot=u2*%pi*(ID/2)^2 /144
8 t=V*0.1337/(Vdot*60)
9 printf("Total time taken=%f min",t)
```

check Appendix AP 25 for dependency:

773.sci

Scilab code Exa 7.7.3 Hydraulic Power Generation

```
1 clc
2 pathname=get_absolute_file_path('7_7_3.sce')
3 filename=pathname+filesep()+'773.sci'
```

```
4 exec(filename)
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
      from those of Textbook")
6 mdot= -Ws/(deltaP/D + g*deltaZ)
7 printf(" \n Water flow rate=%f kg/s",mdot)
```

Chapter 8

Balances On Nonreactive Processes

check Appendix AP 24 for dependency:

```
831.sci
```

Scilab code Exa 8.3.1 Evaluation of an Internal Energy Change from Tabulated Heat

```
1 clc
2 pathname=get_absolute_file_path('8_3_1.sce')
3 filename=pathname+filesep()+'831.sci'
```

Calculate the heat required to raise 200 kg of nitrous oxide from 20°C to 150°C in a constant-volume vessel. The constant-volume heat capacity of N_2O in this temperature range is given by the equation

$$C_v \text{ (kJ/kg·°C)} = 0.855 + 9.42 \times 10^{-4} T$$

where T is in °C.

Figure 8.1: Evaluation of an Internal Energy Change from Tabulated Heat Capacity

Assuming ideal gas behavior, calculate the heat that must be transferred in each of the following cases.

1. A stream of nitrogen flowing at a rate of 100 mol/min is heated from 20°C to 100°C.
2. Nitrogen contained in a 5-liter flask at an initial pressure of 3 bar is cooled from 90°C to 30°C.

Figure 8.2: Cooling of an ideal gas

```
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook \n ")
6 function[Cv]=fun(T)
7     Cv=0.855+ T*9.42*10^(-4)
8 endfunction
9 [Ucap,err]=intg(Ti,Tf,fun)  //intg is an inbult
    function used for definite integration
10 Q=mass*Ucap
11 printf("Heat Required=%f KJ",Q)
```

check Appendix AP 23 for dependency:

832.sci

Scilab code Exa 8.3.2 Cooling of an ideal gas

```
1 clc
2 pathname=get_absolute_file_path('8_3_2.sce')
3 filename=pathname+filesep()+'832.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook \n ")
6 disp("part 1")
7 function[Cp]=fun1(T)
```

Fifteen kmol/min of air is cooled from 430°C to 100°C. Calculate the required heat removal rate using (1) heat capacity formulas from Table B.2 and (2) specific enthalpies from Table B.8.

Figure 8.3: Evaluation of delta H using Heat Capacities and Tabulated Enthalpies

```
8       Cp=0.02900+ T*0.2199*10^(-5) + T^2 * 0.5723
           *10^(-8) - T^3 * 2.871 * 10^(-12)
9   endfunction
10  [deltaH,err]=intg(T1,T2,fun1) //intg is an inbult
       function used for definite integration
11  Qdot=ndot*deltaH
12  printf("Heat Transferred=%f KJ/min",Qdot)
13  disp("part2")
14  function[CV]=fun2(T)
15      CV=fun1(T)-8.14* 10^(-3)
16  endfunction
17  [deltaU,err]=intg(T3,T4,fun2) //intg is an inbult
       function used for definite integration
18  n=P*V/(R*T)
19  Q=n*deltaU
20  printf("Heat transferred=%f KJ",Q)
```

check Appendix AP 22 for dependency:

833.sci

Scilab code Exa 8.3.3 Evaluation of delta H using Heat Capacities and Tabulated En

```
1  clc
2  pathname=get_absolute_file_path('8_3_3.sce')
3  filename=pathname+filesep()+'833.sci'
4  exec(filename)
```

Calculate the heat required to bring 150 mol/h of a stream containing 60% C_2H_6 and 40% C_3H_8 by volume from 0°C to 400°C. Determine a heat capacity for the mixture as part of the problem solution.

Figure 8.4: Heat Capacity of a mixture

```
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
     from those of Textbook \n ")
6 function[Cp]=fun(T)
7     Cp=0.02894 + T* 0.4147 *10^(-5) + T^2 * 0.3191 *
          10^(-8) - T^3 * 1.965 * 10^(-12)
8 endfunction
9 deltaH=intg(T1,T2,fun)  //intg is an inbult function
     used for definite integration
10 Qdot=ndot*deltaH*10^3 /60
11 printf(" \n Rate of heat removal= %f KW",Qdot)
```

check Appendix AP 21 for dependency:

834.sci

Scilab code Exa 8.3.4 Heat Capacity of a mixture

```
1 clc
2 pathname=get_absolute_file_path('8_3_4.sce')
3 filename=pathname+filesep()+'834.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
     from those of Textbook \n ")
6 function[Cp1]=fun1(T)
7     Cp1=0.04937 + T*13.92*10^(-5) - T^2
        *5.816*10^(-8) + T^3 *7.280 * 10^(-12)
```

A stream containing 10% CH_4 and 90% air by volume is to be heated from 20°C to 300°C. Calculate the required rate of heat input in kilowatts if the flow rate of the gas is 2.00×10^3 liters (STP)/min.

Basis: Given Flow Rate

Assume ideal gas behavior.

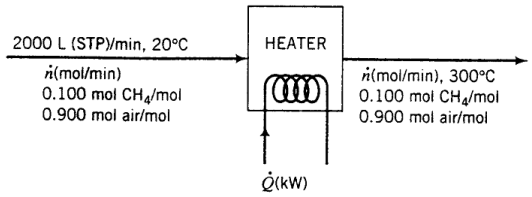


Figure 8.5: Energy Balance on a gas preheater

```
8  endfunction
9  function[Cp2]=fun2(T)
10     Cp2=0.06803 +T*22.59*10^(-5) - T^2
          *13.11*10^(-8) + T^3 *31.71 * 10^(-12)
11 endfunction
12 function[Cp]=fun(T)
13     Cp=x*fun1(T)+ (1-x)*fun2(T)
14 endfunction
15 deltaH=intg(T1,T2,fun) //intg is an inbult function
     used for definite integration
16 printf(" \n Heat capacity of Mixture=%f KJ/mol",
     deltaH)
17 Qdot=ndot*deltaH
18 printf(" \n Heat Required=%f KJ/h",Qdot)
```

check Appendix AP 20 for dependency:

835.sci

Scilab code Exa 8.3.5 Energy Balance on a gas preheater

At what rate in kilowatts must heat be transferred to a liquid stream of methanol at its normal boiling point to generate 1500 g/min of saturated methanol vapor?

Figure 8.6: Heat of Vaporization

```
clc
pathname=get_absolute_file_path('8_3_5.sce')
filename=pathname+filesep()+'835.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook \n ")
ndot=Vdot/22.4
function[Cp]=fun(T)
     Cp=0.03431 + T*5.469*10^(-5) + T^2
        *0.3661*10^(-8) + T^3 *11*10^(-12)
endfunction
H1=intg(T1,T2,fun)  //intg is an inbult function
    used for definite integration
printf("H1=%f Kj/mol",H1)
disp("From Tables H2= -0.15 Kj/mol    ,    H3=8.17 Kj/
    mol")
H2= -0.15
H3=8.17
Qdot=(ndot*x*H1+ ndot*(1-x)*(H3-H2))/60
printf("Heat Input=%f KW",Qdot)
```

check Appendix AP 19 for dependency:

841.sci

Scilab code Exa 8.4.1 Heat of Vaporization

One hundred g-moles per hour of liquid *n*-hexane at 25°C and 7 bar is vaporized and heated to 300°C at constant pressure. Neglecting the effect of pressure on enthalpy, estimate the rate at which heat must be supplied.

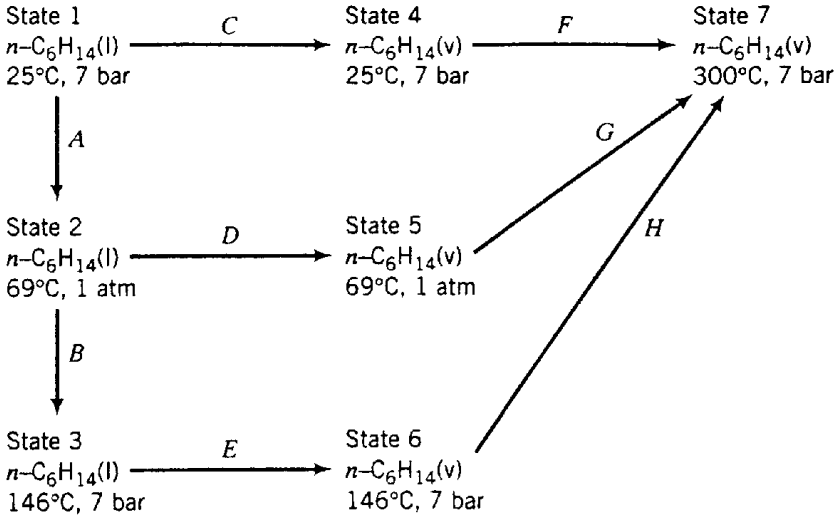


Figure 8.7: Vaporization and Heating

```
clc
pathname=get_absolute_file_path('8_4_1.sce')
filename=pathname+filesep()+'841.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook \n ")
Qdot=mdot*deltaHv/(M*60)
printf("Rate of Heat transfer=%f KW",Qdot)
```

check Appendix AP 18 for dependency:

842.sci

The normal boiling point of methanol is 337.9 K, and the critical temperature of this substance is 513.2 K. Estimate the heat of vaporization of methanol at 200°C.

Figure 8.8: Estimation of a Heat of Vaporization

Scilab code Exa 8.4.2 Vaporization and Heating

```
clc
pathname=get_absolute_file_path('8_4_2.sce')
filename=pathname+filesep()+'842.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("We have deltaHv at 69C hence We follow path
    ADG")
deltaHA=Cp*(T2-T1) + V*(1.013-P)*M/(D*10^4)
printf(" \n deltaHA=%f",deltaHA)
deltaHD=deltaHv
printf(" \n deltaHD=%f",deltaHD)
function[C]=fun1(T)
    C=0.13744 + T*40.85*10^(-5) - T^2 *23.92*10^(-8)
        + T^3 *57.66*10^(-12)
endfunction
deltaHG=intg(T2,T3,fun1)  //intg is an inbult
    function used for definite integration
printf(" \n deltaHG=%f Kj/mol",deltaHG)
Qdot=ndot*(deltaHA+deltaHD+deltaHG)/3600
printf(" \n rate of Heat supply= %f Kj/mol",Qdot)
printf(" \n In this problem we neglected V*deltaP as
    it is negligible ")
```

---

check Appendix AP 17 for dependency:

843.sci

Scilab code Exa 8.4.3 Estimation of a Heat of Vaporization

```
1 clc
2 pathname=get_absolute_file_path('8_4_3.sce')
3 filename=pathname+filesep()+'843.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp("using Trouton rule,")
7 deltaHvT1=0.109*T1
8 disp("In this case, trouton rule gives a better
    estimate")
9 disp("using Watson correction")
10 deltaHvT2=36.8*((Tc-T2)/(Tc-T1))^(0.38)
11 printf("Estimated value using Trouton rule=%f Kj/mol
    ",deltaHvT1)
12 printf(" \n Estimated value using watson correction=
    %f Kj/mol",deltaHvT2)
```

---

check Appendix AP 16 for dependency:

844.sci

Scilab code Exa 8.4.4 Partial Vaporization of a mixture

```
1 clc
2 pathname=get_absolute_file_path('8_4_4.sce')
3 filename=pathname+filesep()+'844.sci'
4 exec(filename)
```

An equimolar liquid mixture of benzene (B) and toluene (T) at 10°C is fed continuously to a vessel in which the mixture is heated to 50°C. The liquid product is 40.0 mole% B, and the vapor product is 68.4 mole% B. How much heat must be transferred to the mixture per g-mole of feed?

Basis: 1 mol Feed

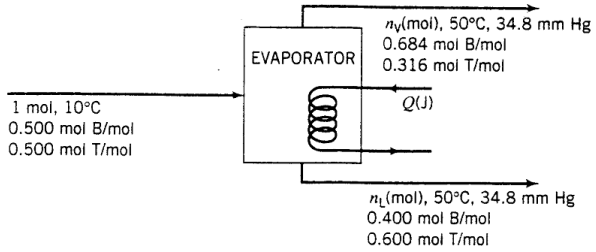


Figure 8.9: Partial Vaporization of a mixture

```
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  A=[1 1;x y]
7  b=[basis;basis/2]
8  C=A\b
9  //Here We solved two linear equations simultaneously
10 nV=C(1,1)
11 nL=C(2,1)
12 H1=5.332
13 H2=6.340
14 H3=37.52
15 H4=42.93
16 Q=nV*x*H1 + nV*(1-x)*H2 + nL*y*H3 + nL*(1-y)*H4
17 printf(" \n Heat transferred= %f Kj",Q)
18 disp("The answer for this problem in Text is wrong")
```

---

check Appendix AP 15 for dependency:

851.sci

Hydrochloric acid is produced by absorbing gaseous HCl (hydrogen chloride) in water. Calculate the heat that must be transferred to or from an absorption unit if HCl(g) at 100°C and $H_2O(l)$ at 25°C are fed to produce 1000 kg/h of 20.0 wt% HCl(aq) at 40°C.

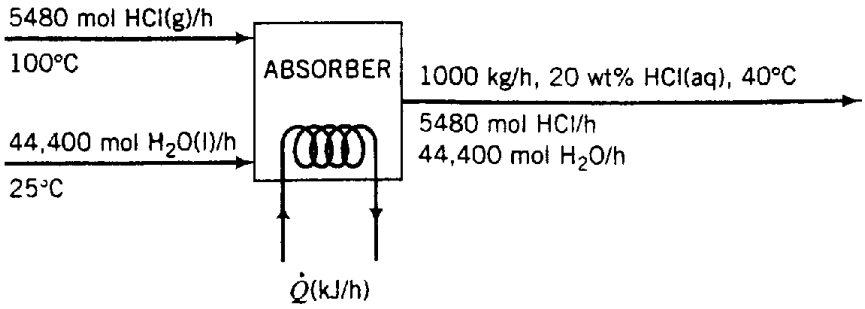


Figure 8.10: Production of Hydrochloric Acid

Scilab code Exa 8.5.1 Production of Hydrochloric Acid

```
clc
pathname=get_absolute_file_path('8_5_1.sce')
filename=pathname+filesep()+'851.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
nHCl=mdot*x*10^3 /M1
nH2O=mdot*(1-x)*10^3 /M2
function[Cp1]=fun(T)
    Cp1=29.13*10^(-3) - T*0.1341*10^(-5) +T^2
       *0.9715*10^(-8) - T^3 *4.335*10^(-12)
endfunction
H1=intg(T1,T2,fun)  //intg is an inbult function
   used for definite integration
disp(H1)
r=nH2O/nHCl
disp("From table B.11, deltaHa= -67.4 Kj/mol HCl")
```

A 5.0 wt% H_2SO_4 solution at 60°F is to be concentrated to 40.0 wt% by evaporation of water. The concentrated solution and water vapor emerge from the evaporator at 180°F and 1 atm. Calculate the rate at which heat must be transferred to the evaporator to process 1000 lb_m/h of the feed solution.

Basis: Given Feed Rate of 5% Solution

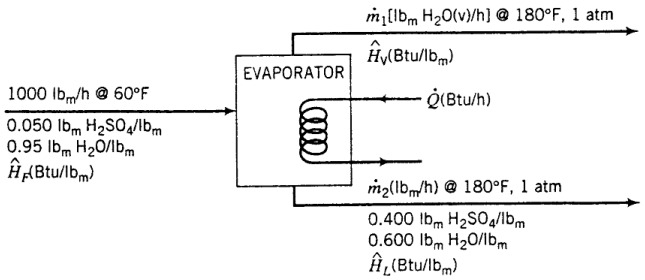


Figure 8.11: Concentration of an aqueous sulphuric acid solution

```
15 deltaHa= -67.4
16 y=nHCl/(nHCl+nH2O)
17 Cp=0.73*mdot*4.184/nHCl
18 deltaHb=Cp*(T3-T1)
19 H2=deltaHa+deltaHb
20 Qdot=nHCl*(H2-H1)
21 printf("Heat =%E kj/h",Qdot)
```

---

check Appendix AP 14 for dependency:

852.sci

Scilab code Exa 8.5.2 Concentration of an aqueous sulphuric acid solution

```
1 clc
2 pathname=get_absolute_file_path('8_5_2.sce')
3 filename=pathname+filesep()+'852.sci'
4 exec(filename)
```

A 30 wt% NH_3 solution at 100 psia is fed at a rate of 100 lb_m/h to a tank in which the pressure is 1 atm. The enthalpy of the feed solution relative to the reference conditions used to construct Figure 8.5-2 is 100 Btu/lb_m. The vapor composition is to be 89 wt% NH_3. Determine the temperature of the stream leaving the tank, the mass fraction of NH_3 in the liquid product, the flow rates of the liquid and vapor product streams, and the rate at which heat must be transferred to the vaporizer.

Basis: 100 lb_m/h Feed

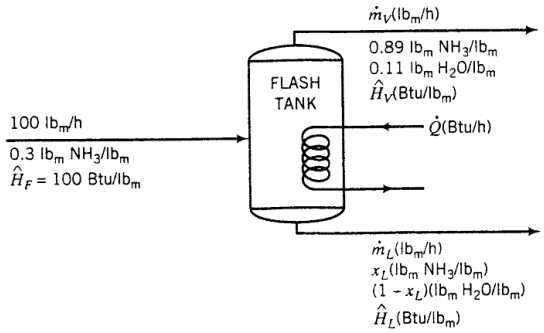


Figure 8.12: Adiabatic Mixing

```
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 disp("sulphuric acid balance")
7 m2=x*mdot/y
8 disp("Total Mass balance")
9 m1=mdot-m2
10 Qdot=m1*Hv+m2*Hl-mdot*Hf
11 printf(" Rate of Heat transfer= %f Btu/h",Qdot)
```

check Appendix AP 13 for dependency:

855.sci

Scilab code Exa 8.5.5 Adiabatic Mixing

```
clc
pathname=get_absolute_file_path('8_5_5.sce')
filename=pathname+filesep()+'855.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
disp("From figure 8.5-2, ")
xL=0.185
xV=0.89
mL=basis*((xV-xF)/(xV-xL))
mV=basis-mL
Qdot=mV*Hv + mL*Hl - basis*HF
printf("Rate of heat transfer=%f Btu/h",Qdot)
```

Chapter 9

Balances On Reactive Processes

check Appendix AP 12 for dependency:

911.sci

Scilab code Exa 9.1.1 Calculation of Heats of Reaction

```
1  clc
2  pathname=get_absolute_file_path('9_1_1.sce')
3  filename=pathname+filesep()+'911.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  disp("Part 1")
7  E1= ndot/4
8  deltaH1=E1*Hr1
9  printf("enthalpy change=%E Kj/s",deltaH1 )
10 disp("part2")
11 Hr2=2*Hr1
12 E2=ndot/8
13 deltaH2=E2*Hr2
```

1. The standard heat of the combustion of *n*-butane vapor is

$$C_4H_{10}(g) + \tfrac{13}{2}O_2(g) \longrightarrow 4\,CO_2(g) + 5\,H_2O(l): \quad \Delta\hat{H}_r^\circ = -2878\ \text{kJ/mol}$$

   Calculate the rate of enthalpy change, $\Delta\dot{H}$(kJ/s), if 2400 mol/s of CO_2 is produced in this reaction and the reactants and products are all at 25°C.
2. What is the standard heat of the reaction

$$2\,C_4H_{10}(g) + 13\,O_2(g) \longrightarrow 8\,CO_2(g) + 10\,H_2O(l)$$

   Calculate $\Delta\dot{H}$ if 2400 mol/s of CO_2 is produced in *this* reaction and the reactants and products are all at 25°C.
3. The heats of vaporization of *n*-butane and water at 25°C are 19.2 kJ/mol and 44.0 kJ/mol, respectively. What is the standard heat of the reaction

$$C_4H_{10}(l) + \tfrac{13}{2}O_2(g) \longrightarrow 4\,CO_2(g) + 5\,H_2O(v)$$

   Calculate $\Delta\dot{H}$ if 2400 mol/s of CO_2 is produced in this reaction and the reactants and products are all at 25°C.

Figure 9.1: Calculation of Heats of Reaction

The standard heat of the reaction

$$C_2H_4(g) + 2\,Cl_2(g) \rightarrow C_2HCl_3(l) + H_2(g) + HCl(g)$$

is $\Delta\hat{H}_r^\circ = -420.8$ kJ/mol. Calculate $\Delta\hat{U}_r^\circ$ for this reaction.

Figure 9.2: Evaluation of Internal Energy

```
14 printf("Enthalpy change=%E kj/s",deltaH2)
15 disp("part 3")
16 Hr3=Hr1+5*HvWater+HvButane
17 deltaH3=E1*Hr3
18 printf("Enthalpy change=%E kj/s",deltaH3)
```

check Appendix AP 11 for dependency:

912.sci

Scilab code Exa 9.1.2 Evaluation of Internal Energy

Determine the standard heat of reaction for the combustion of liquid *n*-pentane, assuming $H_2O(l)$ is a combustion product.

$$C_5H_{12}(l) + 8\,O_2(g) \rightarrow 5\,CO_2(g) + 6\,H_2O(l)$$

Figure 9.3: Determination of a Heat of Reaction from Heat of Formations

```
clc
pathname=get_absolute_file_path('9_1_2.sce')
filename=pathname+filesep()+'912.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("From reaction, only gaseous are counted")
left=1+2
right=1+1
deltaUr=deltaHr-R*T*(right-left)/10^3
printf("deltaUr=%f Kj/mol",deltaUr)
```

check Appendix AP 10 for dependency:

931.sci

Scilab code Exa 9.3.1 Determination of a Heat of Reaction from Heat of Formations

```
clc
pathname=get_absolute_file_path('9_3_1.sce')
filename=pathname+filesep()+'931.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
Hr=5*HCO2+6*HH2O-HC5H12
printf(" \n Heat of the rxn= %f KJ/mol",Hr)
```

Calculate the standard heat of reaction for the dehydrogenation of ethane:

$$C_2H_6 \rightarrow C_2H_4 + H_2$$

Figure 9.4: Calculation of a Heat of Reaction from Heats of Combustion

---

check Appendix AP 9 for dependency:

941.sci

Scilab code Exa 9.4.1 Calculation of a Heat of Reaction from Heats of Combustion

```
1 clc
2 pathname=get_absolute_file_path('9_4_1.sce')
3 filename=pathname+filesep()+'941.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
6 Hr=Hethane-Hethene-Hhydrogen
7 printf(" \n Heat of the rxn= %f Kj/mol",Hr)
```

---

check Appendix AP 8 for dependency:

951.sci

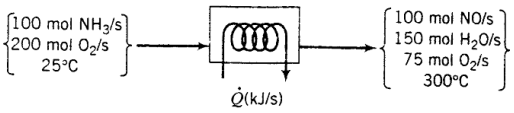
Scilab code Exa 9.5.1 Energy balance about an Ammonia Oxidizer

The standard heat of reaction for the oxidation of ammonia is given below:

$$4\,NH_3(g) + 5\,O_2(g) \longrightarrow 4\,NO(g) + 6\,H_2O(v): \quad \Delta\hat{H}_r^\circ = -904.7\ \text{kJ/mol}$$

One hundred mol NH_3/s and 200 mol O_2/s at 25°C are fed into a reactor in which the ammonia is completely consumed. The product gas emerges at 300°C. Calculate the rate at which heat must be transferred to or from the reactor, assuming operation at approximately 1 atm.

Basis: Given Feed Rates



eferences: $NH_3(g)$, $O_2(g)$, $NO(g)$, $H_2O(v)$ at 25°C and 1 atm

Substance	$\dot{n}_{in}$ (mol/s)	$\hat{H}_{in}$ (kJ/mol)	$\dot{n}_{out}$ (mol/s)	$\hat{H}_{out}$ (kJ/mol)
NH_3	100	0	—	—
O_2	200	0	75	$\hat{H}_1$
NO	—	—	100	$\hat{H}_2$
H_2O	—	—	150	$\hat{H}_3$

Figure 9.5: Energy balance about an Ammonia Oxidizer

```
clc
pathname=get_absolute_file_path('9_5_1.sce')
filename=pathname+filesep()+'951.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
function[Cp]=fun(T)
    Cp=29.50*10^(-3)+ T*0.8188*10^(-5) - T^2 *
       0.2925 *10^(-8) + T^3 * 0.3652 * 10^(-12)
endfunction
H2=intg(T1,T2,fun)  //intg is an inbuilt function
   which can calculate definite integrals
E=nNH3/4
nO2out=nO2in-nNH3*5/4
nNO=nNH3
nH2O=nNH3*6/4
deltaH=E*Hr+(nO2out*H1+nNO*H2+nH2O*H3)
Qdot=deltaH
printf(" \n Heat Transferred= %f kW",Qdot)
```

check Appendix AP 7 for dependency:

952.sci

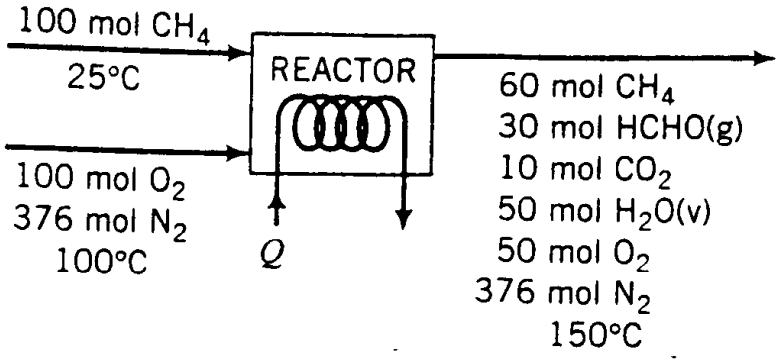
Scilab code Exa 9.5.2 Energy Balance on a Methane Oxidation Reactor

```
clc
pathname=get_absolute_file_path('9_5_2.sce')
filename=pathname+filesep()+'952.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
```

Methane is oxidized with air to produce formaldehyde in a continuous reactor. A competing reaction is the combustion of methane to form CO_2.

1. $CH_4(g) + O_2 \rightarrow HCHO(g) + H_2O(v)$
2. $CH_4(g) + 2\,O_2 \rightarrow CO_2 + 2\,H_2O(v)$

A flowchart of the process for an assumed basis of 100 mol of methane fed to the reactor is shown here.



References: C(s), $O_2(g)$, $H_2(g)$, $N_2(g)$ at 25°C and 1 atm

Substance	n_{in} (mol)	$\hat{H}_{in}$ (kJ/mol)	n_{out} (mol)	$\hat{H}_{out}$ (kJ/mol)
CH_4	100	$\hat{H}_1$	60	$\hat{H}_4$
O_2	100	$\hat{H}_2$	50	$\hat{H}_5$
N_2	376	$\hat{H}_3$	376	$\hat{H}_6$
HCHO	—	—	30	$\hat{H}_7$
CO_2	—	—	10	$\hat{H}_8$
H_2O	—	—	50	$\hat{H}_9$

Figure 9.6: Energy Balance on a Methane Oxidation Reactor

```
function[Cp]=fun1(T)
    Cp=34.31*10^(-3)+ T*5.469*10^(-5) + T^2 * 0.3661
        *10^(-8) - T^3 * 11 * 10^(-12)
endfunction
HoutMethane=intg(T1,T2,fun1)
H4= -74.85 + HoutMethane
function[C]=fun2(T)
    C=34.28*10^(-3)+ T*4.268*10^(-5) - T^3 * 8.694 *
        10^(-12)
endfunction
HoutFormal=intg(T1,T2,fun2) //intg is an inbuilt
   function which can calculate definite integrals
H7= -115.90+ HoutFormal
deltaH=NoutWater*H9+NoutCarbon*H8+NoutFormal*H7+
   NoutNitrogen*H6+NoutOxygen*H5+NoutMethane*H4-
   NinNitrogen*H3-NinOxygen*H2-NinMethane*H1
Q=deltaH
printf(" \n Q=%f Kj",Q)
```

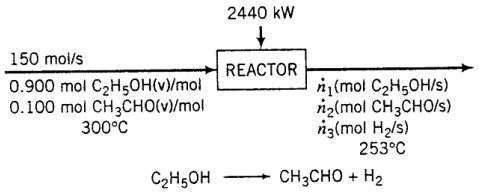
check Appendix AP 6 for dependency:

954.sci

Scilab code Exa 9.5.4 Simultaneous Material and Energy Balance

```
clc
pathname=get_absolute_file_path('9_5_4.sce')
filename=pathname+filesep()+'954.sci'
exec(filename)
printf(" All the values in the textbook are
   Approximated hence the values in this code differ
    from those of Textbook")
disp("Carbon Balance")
```

The ethanol dehydrogenation reaction of Example 9.5-3 is carried out with the feed entering at 300°C. The feed contains 90.0 mole% ethanol and the balance acetaldehyde and enters the reactor at a rate of 150 mol/s. To keep the temperature from dropping too much and thereby decreasing the reaction rate to an unacceptably low level, heat is transferred to the reactor. When the heat addition rate is 2440 kW, the outlet temperature is 253°C. Calculate the fractional conversion of ethanol achieved in the reactor.



References: C(s), $H_2(g)$, $O_2(g)$ at 25°C and 1 atm

Substance	$\dot{n}_{in}$ (mol/s)	$\hat{H}_{in}$ (kJ/mol)	$\dot{n}_{out}$ (mol/s)	$\hat{H}_{out}$ (kJ/mol)
C_2H_5OH	135	−212.19	$\dot{n}_1$	−216.81
CH_3CHO	15	−147.07	$\dot{n}_2$	−150.90
H_2	—	—	$\dot{n}_3$	6.595

Figure 9.7: Simultaneous Material and Energy Balance

1. Calculate $\Delta\hat{H}_r^\circ$ for the reaction

$$H_3PO_4(aq, r = \infty) + 3\,NaOH(aq, r = 50) \rightarrow Na_3PO_4(aq, r = \infty) + 3\,H_2O(l)$$

2. If 5.00 mol of NaOH dissolved in 250 mol of water is neutralized completely at 25°C with dilute phosphoric acid, what is the attendant enthalpy change?

Figure 9.8: Standard Heat of a Neutralization reaction

```
printf("%d * %f *2 + %d * %f *2=2 n1+2 n2",basis,x,
    basis,1-x)
disp("Hydrogen Balance")
printf("%d * %f *6 + %d * %f *4 = 6 n1+4 n2+2 n3",
    basis,x,basis,1-x)
disp("Energy Balance")
printf("%d = %f n1  %f n2 + %f n3 -%d * %f -%d* %f",
    Q,HoutEthanol,HoutEthanone,HoutHydrogen,
    NinEthanol,HinEthanol,NinEthanone,HinEthanone)
A=[1 1 0;3 2 1;216.81 150.9 -6.595]
b=[150;435;28412]
C=A\b
n1=C(1,1)
printf(" \n n1=%f mol Ethanol/s",n1)
n2=C(2,1)
printf(" \n n2=%f mol Ethanone/s",n2)
n3=C(3,1)
printf(" \n n3=%f mol Hydrogen/s",n3)
disp("The solutions in the Text are Wrong")
fraction=(NinEthanol-n1)/NinEthanol
printf("Fractional conversion of Ethanol=%f",
    fraction)
```

---

check Appendix AP 5 for dependency:

955.sci

A 10.0 wt% aqueous solution of H_2SO_4 at 40°C is to be neutralized with a 20.0 wt% aqueous solution of NaOH at 25°C in a continuous reactor. At what rate in kJ/kg H_2SO_4 solution must heat be removed from the reactor if the product solution emerges at 35°C?

Basis: 1 kg H_2SO_4 Solution

$$H_2SO_4(aq, 10\%) + 2\,NaOH(aq, 20\%) \rightarrow Na_2SO_4(aq) + 2\,H_2O(l)$$

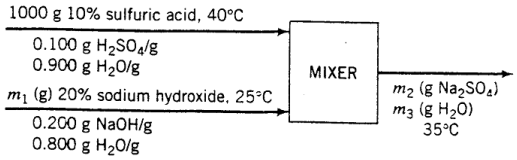


Figure 9.9: Energy Balance on a Neutralization process

Scilab code Exa 9.5.5 `Standard Heat of a Neutralization reaction`

```
1  clc
2  pathname=get_absolute_file_path('9_5_5.sce')
3  filename=pathname+filesep()+'955.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  disp("part 1")
7  Hr=HfSalt+3*HfWater-HfAcid-3*HfBase
8  printf("Hr of the rxn=%f Kj/mol",Hr)
9  disp("part 2")
10 deltaH=Hr*5/3
11 printf("deltaH=%f Kj",deltaH)
```

---

check Appendix AP 4 for dependency:

`956.sci`

Scilab code Exa 9.5.6 Energy Balance on a Neutralization process

```
clc
pathname=get_absolute_file_path('9_5_6.sce')
filename=pathname+filesep()+'956.sci'
exec(filename)
printf(" All the values in the textbook are
    Approximated hence the values in this code differ
     from those of Textbook")
disp("Using S balance, ")
m2=basis*x*MS*MSalt/(MAcid*MS)
printf(" \n m2=%f g Na2SO4",m2)
disp("Using Na balance, ")
m1=2*MNa*m2*MBase/(y*MNa*MSalt)
printf(" \n m1=%f g NaOH",m1)
disp("Total mass balance, ")
m3=basis+m1-m2
printf(" \n m3=%f g H2O",m3)
printf(" \n Mass of product solution =%f",m2+m3)
m=m2+m3
Water=m2*2/MSalt
printf(" \n Water Formed in the reaction=%f mol H2O"
    ,Water)
disp("H2SO4(aq):")
a1=basis*(1-x)/MWater
b1=basis*x/MAcid
rAcid=a1/b1
printf(" \n rAcid=%f mol Water/mol Acid",rAcid)
disp("NaOH(aq):")
a2=m1*(1-y)/MWater
b2=m1*y/MBase
rBase=a2/b2
printf(" \n rBase=%f mol Water/mol Base",rBase)
disp("Na2SO4(aq):")
a3=m3/MWater
b3=m2/MSalt
rSalt=a3/b3
printf(" \n rSalt=%f mol Water/mol Salt",rSalt)
```

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

$$CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(v): \quad \Delta\hat{H}_c^\circ = -802 \text{ kJ/mol}$$
$$C_2H_6(g) + \tfrac{7}{2}O_2(g) \rightarrow 2\,CO_2(v) + 3\,H_2O(v): \quad \Delta\hat{H}_c^\circ = -1428 \text{ kJ/mol}$$

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

Figure 9.10: Calculation of a Heating Value

```
34 E=b1
35 printf(" \n Extent of reaction=%f mol",E)
36 nHAcid=basis*3.85*(T3-T1)/1000
37 nHSalt=m*4.184*(T2-T1)/1000
38 nHBase=0
39 HfSalt= -1384
40 HfAcid= -884.6
41 HfBase= -468.1
42 HfWater= -285.84
43 deltaHr=HfSalt+ 2*HfWater - HfAcid - 2*HfBase
44 printf(" \n Entahlpy change in the rxn=%f Kj/mol",
     deltaHr)
45 Q=E*deltaHr + (nHSalt-nHAcid-nHBase)
46 printf(" \n Q of the rxn=%f Kj",Q)
47 disp("The answer in the Text is wrong.")
```

---

check Appendix AP 3 for dependency:

961.sci

Scilab code Exa 9.6.1 Calculation of a Heating Value

```
1 clc
2 pathname=get_absolute_file_path('9_6_1.sce')
3 filename=pathname+filesep()+'961.sci'
```

```
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  y1=x*16
7  y2=(1-x)*30
8  xCH4=y1/(y1+y2)
9  HHVMethane=(H1+ 2*44.013)/M1
10 HHVEthane=(H2+ 3*44.013)/M2
11 HHV=xCH4*HHVMethane + (1-xCH4)*HHVEthane
12 printf(" \n HHV of Fuel=%f KJ/g",HHV)
```

Chapter 11

Balances on Transient Processes

check Appendix AP 2 for dependency:

```
1112.sci
```

Scilab code Exa 11.1.2 Water Balance on a city reservoir

```
1 clc
2 pathname=get_absolute_file_path('11_1_2.sce')
```

The water level in a municipal reservoir has been decreasing steadily during a dry spell, and there is concern that the drought could continue for another 60 days. The local water company estimates that the consumption rate in the city is approximately 10^7 L/day. The State Conservation Service estimates that rainfall and stream drainage into the reservoir coupled with evaporation from the reservoir should yield a net water input rate of $10^6 \exp(-t/100)$ L/day, where t is the time in days from the beginning of the drought, at which time the reservoir contained an estimated 10^9 liters of water.

1. Write a differential balance on the water in the reservoir.
2. Integrate the balance to calculate the reservoir volume at the end of the 60 days of continued drought.

Figure 11.1: Water Balance on a city reservoir

A well-stirred batch reactor wrapped in an electrical heating mantle is charged with a liquid reaction mixture. The reactants must be heated from an initial temperature of 25°C to 250°C before the reaction can take place at a measurable rate. Use the data given below to determine the time required for this heating to take place.

Reactants:	Mass = 1.50 kg
	C_v = 0.900 cal/(g·°C)
Reactor:	Mass = 3.00 kg
	C_v = 0.120 cal/(g·°C)
Heating rate:	$\dot{Q}$ = 500.0 W

Negligible reaction and no phase changes during heating.
Negligible energy added to the system by the stirrer.

Figure 11.2: Start-up of a Batch Reactor

```
3  filename=pathname+filesep()+'1112.sci'
4  exec(filename)
5  printf(" All the values in the textbook are
       Approximated hence the values in this code differ
        from those of Textbook")
6  function [dv]=fun(t)
7      dv=(10^6)*exp(-t/100) -10^7
8  endfunction
9  [vol,err]=intg(0,60,fun) //intg is an inbuilt
       function which can calculate definite integrals
10 printf(" \n Volume at the end of 60 days=%E",vol+v0)
```

check Appendix AP 1 for dependency:

1131.sci

Scilab code Exa 11.3.1 Start-up of a Batch Reactor

```
1  clc
```

```
2 pathname=get_absolute_file_path('11_3_1.sce')
3 filename=pathname+filesep()+'1131.sci'
4 exec(filename)
5 printf(" All the values in the textbook are
     Approximated hence the values in this code differ
      from those of Textbook")
6 MCv=(m1*Cv1 + m2*Cv2)*1000*4.184
7 disp(MCv)
8 tf=(T1-T2)*MCv/Qdot
9 printf(" \n Time required = %d in sec and %f in min"
     ,tf+1,tf/60)
```

Appendix

Scilab code AP 1 11.3.1.sci

```
1 m1=1.50 //kg
2 m2=3 //kg
3 Cv1=0.9 //cal/g C
4 Cv2=0.12 //cal/g C
5 Qdot=500 //W
6 T1=250 //C
7 T2=25 //C
```

Scilab code AP 2 1112.sci

```
1 v0=10^9
```

Scilab code AP 3 9.6.1.sci

```
1 x=0.85
2 H1= 802 //Kj/mol
3 H2= 1428 //kj/mol
4 M1=16
5 M2=30
```

Scilab code AP 4 9.5.6.sci

```
1 x=0.1
2 y=0.2
3 MAcid=98.1
4 MS=32
```

```
5  MSalt=142
6  MBase=40
7  MWater=18
8  MNa=46
9  basis=1000 //g
10 T2=35
11 T1=25
12 T3=40
```

Scilab code AP 5 9.5.5.sci

```
1 disp("from tables,")
2 HfAcid= -1294 //Kj/mol
3 HfBase= -469.1 //Kj/mol
4 HfSalt= -1974 //Kj/mol
5 HfWater= -285.8 //Kj/mol
```

Scilab code AP 6 9.5.4.sci

```
1  basis=150 //mol/s
2  x=0.9
3  HinEthanol= -212.19
4  HinEthanone= -147.07
5  HoutEthanol= -216.81
6  HoutEthanone= -150.9
7  HoutHydrogen=6.595
8  NinEthanol=135
9  NinEthanone=15
10 Q=2440 //KW
```

Scilab code AP 7 9.5.2.sci

```
1 NinMethane=100 //mol
2 NinOxygen=100 //mol
3 NinNitrogen=376 //mol
4 NoutMethane=60 //mol
5 NoutOxygen=50 //mol
```

```
6  NoutNitrogen=376 //mol
7  NoutFormal=30 //mol
8  NoutCarbon=10 //mol
9  NoutWater=50 //mol
10 H1= -74.85 //Kj/mol
11 H2= 2.235 //Kj/mol
12 H3= 2.187 //Kj/mol
13 H5=3.758//Kj/mol
14 H6=3.655 //Kj/mol
15 H8= -393.5+4.75 //Kj/mol
16 H9= -241.83+4.27 //Kj/mol
17 T1=25 //C
18 T2=150 //C
```

Scilab code AP 8 9.5.1.sci

```
1 nNH3=100 //mol/s
2 nO2in=200 //mol/s
3 H1=8.470 //Kj/mol
4 H3=9.570 //Kj/mol
5 T1=25
6 T2=300
7 Hr= -904.7 //Kj/mol
```

Scilab code AP 9 9.4.1.sci

```
1 Hethane= -1559.9 //Kj/mol
2 Hethene= -1411 //Kj/mol
3 Hhydrogen= -285.84 //Kj/mol
```

Scilab code AP 10 9.3.1.sci

```
1 HCO2= -393.5 //Kj/mol
2 HH2O= -285.84 //Kj/mol
3 HC5H12= -173 //Kj/mol
```

Scilab code AP 11 9.1.2.sci

```
deltaHr= -420.8 //kj/mol
R=8.314
T=298 //K
```

Scilab code AP 12 9.1.1.sci

```
ndot=2400 //mol/s
Hr1= -2878 //Kj/mol
HvWater=44 //Kj/mol
HvButane=19.2 //Kj/mol
```

Scilab code AP 13 8.5.5.sci

```
basis=100 //lbm/h
Hv=728 //Btu/lbm
Hl=45 //Btu/lbm
HF=100 //Btu/lbm
T=120 //F
xF=0.30
```

Scilab code AP 14 8.5.2.sci

```
x=0.05
y=0.4
mdot=1000 //lbm/h
Hf=10 //Btu/lbm
Hl= -17 //Btu/lbm
Hv=1138 //Btu/lbm
```

Scilab code AP 15 8.5.1.sci

```
M1=35.6 //g/mol
M2=18 //g/mol
x=0.2
mdot=1000 //kg/h
T1=25 //C
T2=100 //C
T3=40 //C
```

Scilab code AP 16 8.4.4.sci

```
basis=1 //mol feed
x=0.684 //mole fraction Of B
y=0.4
```

Scilab code AP 17 8.4.3.sci

```
T1=337.9 //K
T2=473 //K
Tc=513.2 //K
```

Scilab code AP 18 8.4.2.sci

```
deltaHv=28.85  //Kj/mol at 69 C
T1=25 //C
T2=69 //C
Cp=0.2163 //Kj/mol C
V=1 //L
P=7 //bar
D=0.659 //KG/L
M=86.17 //Kg
ndot=100 //mol/h
T3=300 //C
```

Scilab code AP 19 8.4.1.sci

```
mdot=1500 //g/min
M=32 //g/mol
deltaHv=35.3 //Kj/mol
```

Scilab code AP 20 8.3.5.sci

```
x=0.1 //CH4
T1=20
T2=300
Vdot=2000 //L/min
```

Scilab code AP 21 8.3.4.sci

```
x=0.6
T1=0
T2=400
ndot=150 //mol/h
```

Scilab code AP 22 8.3.3.sci

```
T1=430 //C
T2=100 //C
ndot=15 //Kmol/min
```

Scilab code AP 23 8.3.2.sci

```
T1=20 //C
T2=100 //C
T3=90 //C
T4=30 //C
P=3 //bar
V=5 //L
R=0.08314 //L.bar/mol.K
T=363 //K
ndot=100 //mol/min
```

Scilab code AP 24 8.3.1.sci

```
mass=200 //kg
Ti=20 //C
Tf=150 //C
```

Scilab code AP 25 7.7.3.sci

```
Ws=10^6 //N.m/s
deltaP= -83*10^3 //N/m^2
g=9.81 //m/s^2
```

```
4 deltaZ= -103 //m
5 D=10^3 //kg/m^3
```

Scilab code AP 26 7.7.2.sci

```
1 deltaZ= -2.5 //ft
2 u1=0
3 D=50 //lbm/ft^3
4 F=0.80 //ft.lbf/lbm
5 V=5 //gal
6 g=32.174 //ft/s^2
7 ID=0.25 //in
```

Scilab code AP 27 771.sci

```
1 Vdot=20 //L/min
2 P2=1.01325*10^5 //atm
3 ID1=0.5 //cm
4 ID2=1 //cm
5 g=9.81 //m/s^2
6 deltaZ=50 //m
```

Scilab code AP 28 7.6.3.sci

```
1 m3=1150 //Kg/h
2 H3=2676 //KJ/Kg
3 H2=3074 //KJ/Kg
4 H1=3278 //KJ/Kg
```

Scilab code AP 29 7.6.2.sci

```
1 basis=1 //Kg/s
2 x=0.6 //ethane
3 T1=150 //K
4 T2=250 //K
5 P=5 //bar
6 Hout1=973.3 //KJ/Kg
```

```
7 Hout2=237.0 //KJ/Kg
8 Hin1=314.3 //KJ/Kg
9 Hin2=30 //KJ/Kg
```

Scilab code AP 30 7.6.1.sci

```
1 m1=120 //kg
2 m2=175 //kg
3 m3=295 //kg
4 ID=6 //cm
5 P=17 //bar
6 H1=125.7 //Kj/Kg
7 H2=271.9 //Kj/Kg
8 H3=2793 //Kj/kg
```

Scilab code AP 31 7.5.3.sci

```
1 mdot=2000 //Kg/h
2 P=10 //bar
```

Scilab code AP 32 7.5.1.sci

```
1 H0=196.23 //Btu/lbm
2 H50=202.28 //Btu/lbm
3 Pfinal=51.99 //psia
4 Pinitial=18.90 //psia
5 Vfinal=1.920 //ft^3/lbm
6 Vinitial=4.969 //ft^3/lbm
```

Scilab code AP 33 7.4.2.sci

```
1 mdot=500/3600 //Kg/s
2 u1=60 //m/s
3 u2=360 //m/s
4 deltaZ=-5 //m
5 g=9.81 //m/s^2
6 Qdot= -10^4 //Kcal/h
7 Ws=70 //KW
```

Scilab code AP 34 7.4.1.sci

```
U=3800 //J/mol
P=1 //atm
Vcap=24.63 //L/mol
ndot=250 //Kmol/h
```

Scilab code AP 35 7.2.2.sci

```
g=9.81 //m/s^2
mdot=15 //Kg/s
z2=20 //m
z1=-220 //m
```

Scilab code AP 36 7.2.1.sci

```
ID=2 //cm
Vdot=2 //m^3/h
```

Scilab code AP 37 6.7.1.sci

```
V=50 //L
P=1 //atm
T=34+273.2 //K
y=0.3
xF=0.001
R=0.08206
Pstar=169 //mm of Hg
Pmm=760 //mm of Hg
```

Scilab code AP 38 6.6.2.sci

```
basis=1000 //Kg of solution
inputxA=0.3 //Wt. fraction of acetone
outputxA1=0.05
outputxM1=0.02
```

```
5 outputxA2=0.1
6 outputxM2=0.87
```

Scilab code AP 39 6.6.1.sci

```
1 V1=200 //CC Acetone
2 x=0.1 //Wt acetone
3 V2=400 //CC chloroform
4 DA=0.792 //g/cc
5 DC=1.489 //g/cc
6 DW=1 //g/cc
```

Scilab code AP 40 6.5.4.sci

```
1 m1=5 //g of solute
2 m2=100 //g of Water
3 P=1 //atm
4 Tf=100.421 //C
5 Ti=25 //C
6 R=8.314 //J/mol.K
```

Scilab code AP 41 6.5.3.sci

```
1 basis=1 //Tonne Epsom salt produced/h
2 inputx=0.301 //Tonne MgSO4/tonne
3 outputx=0.232 //Tonne MgSO4/tonne
4 M=120.4
5 M1=246.4
```

Scilab code AP 42 6.5.2.sci

```
1 inputx=0.6
2 basis=100 //kg Feed
3 S=63 //Kg KNO3/100 Kg H2O
```

Scilab code AP 43 6.5.1.sci

```
basis=150 //kg feed
S100=0.905 //g AgNO3/g
S20=0.689 //g AgNO3/g
inputx=0.095 //kg water/kg
outputx=0.311 //kg water/kg
```

Scilab code AP 44 6.4.2.sci

```
y=0.01
T=30 //C
P=20 //atm
H=2.63*10^4
xB=0.5
```

Scilab code AP 45 6.4.1.sci

```
basis=100 //lb-mole/h
x=0.45
PH2O=31.6 //mm of Hg
PSO2=176 //mm of Hg
P=760 //mm of Hg
y=2
M1=64
M2=18
```

Scilab code AP 46 6.3.3.sci

```
T=75 +273 //K
P75=289 //mm of Hg
hr=0.3
Porig=825 //mm of Hg
PorigBar=1.1 //bar
Vdot=1000 //M^3/h
R=0.0831
```

Scilab code AP 47 6.3.2.sci

```
T=100+273.2 //K
PT=5260 //mm of Hg
y=0.1 //by volume
basis= 100 //mol of feed gas
```

Scilab code AP 48 6.3.1.sci

```
P=760 //mm of Hg
Pstar=289 //mm of Hg
```

Scilab code AP 49 6.1.1.sci

```
T2=15.4+273.2  //K
T1=7.6+273.2  //K
P1=40 //mm of Hg
P2=60 //mm of Hg
T=42.2+273.2 //K
R=8.314 //J/mol.k
```

Scilab code AP 50 5.4.3.sci

```
yN2=0.75
yH2=1-yN2
P=800 //atm
T= -70+273.2 //K
TcH2=33 //K
TcN2=126.2 //K
PcH2=12.8 //atm
PcN2=33.5 //atm
```

Scilab code AP 51 5.4.2.sci

```
n=100 //gm-moles
V=5 //ltr
T= -20.6 + 273.2 //K
Tc=126.2 //K
Pc=33.5 //atm
R=0.08206
```

Scilab code AP 52 5.4.1.sci

```
Vcap=50 //M^3/hr
P=40 //bar
T=300 //K
R=8.314
M=16.04 //kg/kmol
```

Scilab code AP 53 5.3.2.sci

```
V=2.5 //m^3
n=1.00 //Kmol
T= 300 //K
Tc=304.2 //K
Pc=72.9 //atm
w=0.225
R=0.08206
```

Scilab code AP 54 5.3.1.sci

```
T= -150.8 + 273.2  //k
Vcap= 3 /2 //L/mol
Tc=126.2 //k
Pc=33.5 //atm
w=0.040
```

Scilab code AP 55 5.2.5.sci

```
flowinA=400 //L/min
flowinN=419 // m^3   STP /min
Pfinal=6.3 //gauge
Tfinal=325 // C
Pacetone=501 //mm of Hg
Dacetone=791  //g/L
Macetone=58.08  //g
T1=300 //k
P1=1238 //mm Hg original
```

Scilab code AP 56 5.2.4.sci

```
1 //all the calculations are done in R scale
2 T2=285+460 //R
3 T1=32+460 //R
4 P2=1.30 //atm
5 P1=1 //atm
6 V1dot=3.95*10^5 //ft^3/h
```

Scilab code AP 57 5.2.3.sci

```
1 V1=10 //ft^3
2 T1=70+460 //R
3 P1=1 //atm
4 P2=2.5 //atm
5 T2=610+460 //R
```

Scilab code AP 58 5.2.2.sci

```
1 T=360+273 //Kelvin
2 P=3 //atm
3 Vdot=1100 //kg/h
4 M=58.1
```

Scilab code AP 59 5.2.1.sci

```
1 T=23+273 //kelvin
2 P=3+14.7 //psi
3 //conversion of pressure from psig to psi requires
     addition of 14.67 which is 1 atm
4 R=0.08206 //lt-atm
5 MN2=28 //molecular wt.
6 weight=100 //grams
```

Scilab code AP 60 5.1.1.sci

```
wtperct=0.5
Dwater=0.998 //g/cm^3
Dsulfuric=1.834 //g/cm^3
```

Scilab code AP 61 4.9.1.sci

```
feed=59.6 //mol/s
x=0.2
TopFlow1=48.7 //mol/s
outputx1=0.021
BottomFlow1=10.9
TopFlow2=48.3
outputx2=0.063
BottomFlow2=6.4
```

Scilab code AP 62 4.8.4.sci

```
basis=100 //mol pf product gas
xCO=0.015
xCO2=0.060
xO2=0.082
xN2=0.843
```

Scilab code AP 63 4.8.3.sci

```
basis=100 //mol ethane feed
E1=0.9
E2=0.25
excess=0.5
```

Scilab code AP 64 4.8.2.sci

```
basisButane=100 //mol/h butane
basisAir=5000 //mol/h
```

Scilab code AP 65 4.8.1.sci

```
xN2wet=0.6
xCO2wet=0.15
xO2wet=0.1
xH2O=0.15
basis=100 //mol Wet gas
```

Scilab code AP 66 4.7.3.sci

```
x0=0.996
basis=100 //mol combined feed to the reactor
inputxH2=0.7
single_pass=0.6
inputxCO2=0.28
molI=2
Ix=0.004
final=155 //kmol/h
```

Scilab code AP 67 4.7.2.sci

```
E=0.95
basis=100 //mol
```

Scilab code AP 68 4.6.3.sci

```
basis=100 //mol
x=0.850
conv1=0.501
conv2=0.471
```

Scilab code AP 69 4.6.1.sci

```
basis=100 //mol
xP=0.1
xN=0.12
xA=0.78
x=0.3
```

Scilab code AP 70 4.5.2.sci

```
feed=4500 //kg/h
feedx=0.333
m3x=0.494
m5x=0.364
x=0.95
```

Scilab code AP 71 4.5.1.sci

```
x1=0.960
x2=0.977
x3=0.983
basis=100 //mol
```

Scilab code AP 72 4.4.2.sci

```
massin=100 //kg
M1=100 //kg
M2=75 //Kg
massout=43.1 //kg
inputx=0.5
outputxA=0.053
outputxM=0.016
m1xA=0.275
m1xM=0.725
m3xW=0.03
m3xA=0.09
m3xM=0.88
```

Scilab code AP 73 4.4.1.sci

```
inputMass1=100 //kg/h
inputMass2=30 //Kg/h
outputMass1=40 //Kg/h
outputMass2=30 //Kg/h
inputx1=0.5
```

```
6 inputx2=0.3
7 outputx1=0.9
8 outputx2=0.6
```

Scilab code AP 74 4.3.5.sci

```
1 inputx=0.45
2 outputx=0.95
3 basis=2000 //L/h
4 outputBasis=100 //Kmol
5 M1=78.11
6 M2=92.13
7 D=0.872
8 z=0.08
```

Scilab code AP 75 4.3.3.sci

```
1 basis=100 //kg
2 inputx=0.2
3 outputx=0.08
4 D=1 //kg/L
```

Scilab code AP 76 4.3.2.sci

```
1 basis=100 //mol
2 FinalBasis=1250 //lb-moles/h
```

Scilab code AP 77 4.3.1.sci

```
1 Vdot=20 //CC/min
2 x=0.015
3 MH2O=18.02 //g
4 DH2O=1 //g/CC
5 x1=0.2
```

Scilab code AP 78 4.2.4.sci

```
1 rate=0.1 //kmol/min
2 x1=0.1 //mole fraction hexane vapour
3 vol=10 //m^3
4 d=0.659 //kg/L
5 M=86.2 //Kg/kmol
```

Scilab code AP 79 4.2.3.sci

```
1 m1=200 //g
2 m2=150 //g
3 x1=0.4  //methanol/g
4 x2=0.7  //methanol/g
```

Scilab code AP 80 4.2.2.sci

```
1 inputBenzene=500 //kg/h
2 inputToluene=500 //kg/h
3 UpStreamBenzene=450 //kg/h
4 DownStreamToluene=475 //kg/h
```

Scilab code AP 81 4.2.1.sci

```
1 input=50000 //ppl/yr
2 generation=22000 //ppl/yr
3 consumption=19000 //ppl/yr
4 output=75000 //ppl/yr
```

Scilab code AP 82 3.5.2.sci

```
1 T1=20 //F
2 T2=80 //F
```

Scilab code AP 83 3.4.2.sci

```
1 P0=10.4*1.013*10^5 /10.33//m H2O
2 D=1000 //kg/m^3
3 g=9.807 //m/s^2
4 h=30 //m
```

Scilab code AP 84 3.4.1.sci

```
Pressure=2.00*10^5
```

Scilab code AP 85 3.3.5.sci

```
conc=0.5 //molar
rate=1.25 //m^3/min
D=1.03 //no units
M=98
```

Scilab code AP 86 3.3.4.sci

```
yN2=0.79
MN2=28
MO2=32
xN2=0.767
```

Scilab code AP 87 3.3.3.sci

```
//let the total mass be 100
massO2=16
massCO=4
massCO2=17
massN2=63
MO2=32
MCO=28
MCO2=44
MN2=28
```

Scilab code AP 88 3.3.2.sci

```
xA=0.15 //mass fraction
yB=0.20 //mole fraction
mass=175 //kg of solution
flowrate1=53 //lbm/h
```

```
5 flowrate2=1000 //mol/min
6 massofA=300 //lbm
7 molarB=28 //kmolB/s
```

Scilab code AP 89 3.3.1.sci

```
1 mass=100 //g of CO2
2 M=44.01  //molecular weight
```

Scilab code AP 90 3.1.2.sci

```
1 T1=20 //  C
2 T2=100 //  C
3 Vat20=0.560 //ft^3
4 D=0.0208333 //ft
```

Scilab code AP 91 3.1.1.sci

```
1 mass=215 //kg
```

Scilab code AP 92 2.7.2.sci

```
1 T=[10 20 40 80]
2 M=[14.76 20.14 27.73 38.47]
3 sqrtT=sqrt(T);
```

Scilab code AP 93 2.7.1.sci

```
1 x=[10 30 50 70 90]
2 y=[20 52.1 84.6 118.3 151.0]
```

Scilab code AP 94 2.5.2.sci

```
1 //the badbatches per week are taken as elements of a
      vector y
2 y=[17 27 18 18 23 19 18 21 20 19 21 18]
```

Scilab code AP 95 2.4.1.sci

```
1 density=62.4 //lbm/ft^3
2 volume=2 //ft^3
```

Scilab code AP 96 2.3.1.sci

```
1 Initial=23   //lb.ft/min^2
```

Scilab code AP 97 2.2.1.sci

```
1 AcclInitial=1 //cm/s^2
```
