```
clear
% U5.4
% A is n-butane
% B is air
% C is some oil

% the absorption column properties
Nactual = 8;
efficiency = 0.5;
N = Nactual*efficiency % the number of theoretical (ideal) stages
```

```
N = 4
```

```
p = 101.3e3; % Pa
t = 15+273; % K

% the gas phase
yield = 0.9; % 90% of A should be removed from the air
yin = 0.03; % mol-A/mol-gas
Yin = yin/(1-yin) % mol-A/mol-B
```

```
Yin = 0.0309
```

```
Yout = Yin*(1-yield) % mol-A/mol-B
```

```
Yout = 0.0031
```

```
% base of calculation: 1 mole of A absorbed
% nAabsorbed = 1;  % mol-A
% nAin = nAabsorbed/yield % mol-A
% nB = nAin/Yin    % mol-B
nB = 1/(Yin*yield) % mol-B
```

```
nB = 35.9259
```

```

% the liquid phase
Xin = 0; % mol-A/mol-C (just assuming a clean oil is used)
```

Equilibrium

```
% Raoult's law
% yA = psatA/p * xA = psi * xA
% saturated vapour pressure of 1-butane at 15 deg C
psat = 175970; % Pa
psi = psat/p
```

```
psi = 1.7371
```

```

```

Let us decide, if linear equilibrium assumption can be used

Because for relative mole fraction, the coefficient PHI is not constant: Y = phi(X) * X

```
phi = @(X) psi./(1+X*(1-psi));
```

however, if X is small, then: phi = psi = constant value

Plot equilibrium line for both cases to see the difference. Include also the working line for the minimum solvent consumption.

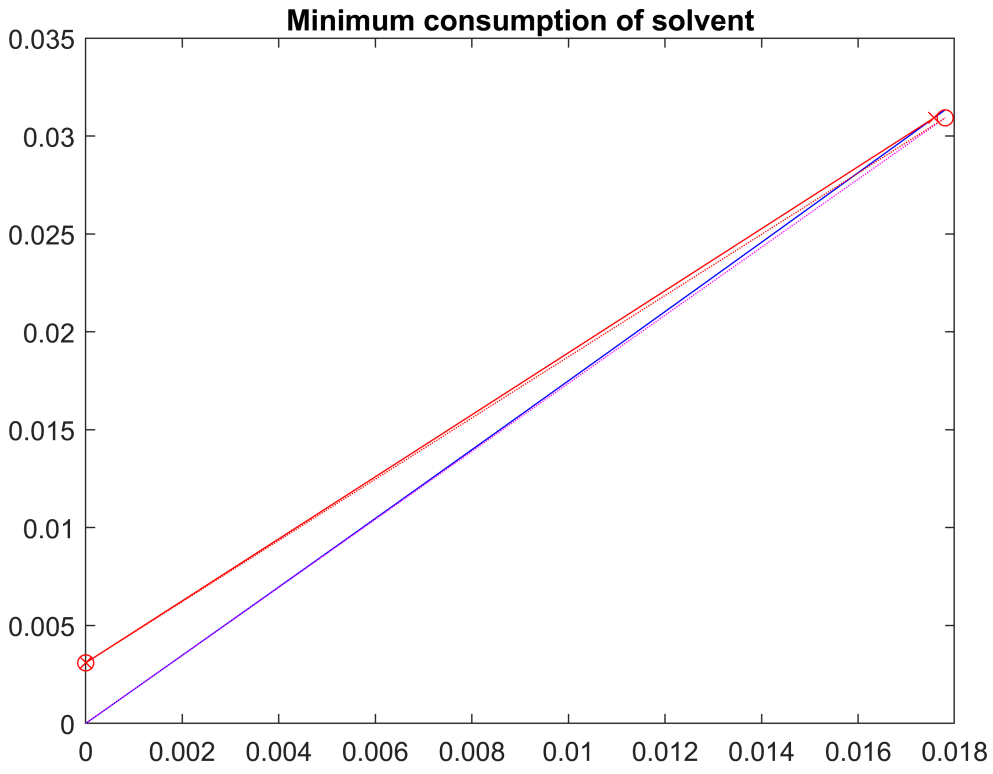
```
Xeq = linspace(0,Yin/psi,100);
Yeq1 = phi(Xeq).*Xeq; % rigorous (blue curve)
Yeq2 = psi*Xeq;       % linearized (magenta curve)

syms X real
assumeAlso(X>0)
MXout1 = eval(solve(Yin/phi(X)==X)) % touching rigorous eq.line
```

```
MXout1 = 0.0176
```

```
MXout2 = Yin/psi                    % touching linear eq.line
```

```
MXout2 = 0.0178
```

```
plot(Xeq,Yeq1,'b-', Xeq,Yeq2,'m:', ...    % equilibria
     [Xin MXout2], [Yout, Yin], 'r:o',... % w.l. linear
     [Xin MXout1], [Yout, Yin], 'r-x')    % w.l. rigorous
title('Minimum consumption of solvent')
```




```
% now the minimum consumption nCmin is calculated from mole balance
```

```
nCmin1 = nB*(Yin-Yout)/(MXout1-Xin) % mol-C
```

```
nCmin1 = 56.9039
```

```
nCmin2 = nB*(Yin-Yout)/(MXout2-Xin) % mol-C (linearized eq.)
```

```
nCmin2 = 56.1668
```

Number of theoretical stages

Assumming the linear equilibrium (see above plot, that this assumption is reasonable)

Need to solve two equations for two unknowns: Xout, nC

Degenerative case (to estimate on which side the actual solution is)

But first, let us look at the degenerative case (DC), where absorption factor equals one (xi==1)

```
nC_DC = psi*nB % for this nC, "xi" will be one
```

```
nC_DC = 62.4076
```

```
% calculate number of theoretical stages for this situation
Xout_DC = Xin + nB*(Yin-Yout)/nC_DC
```

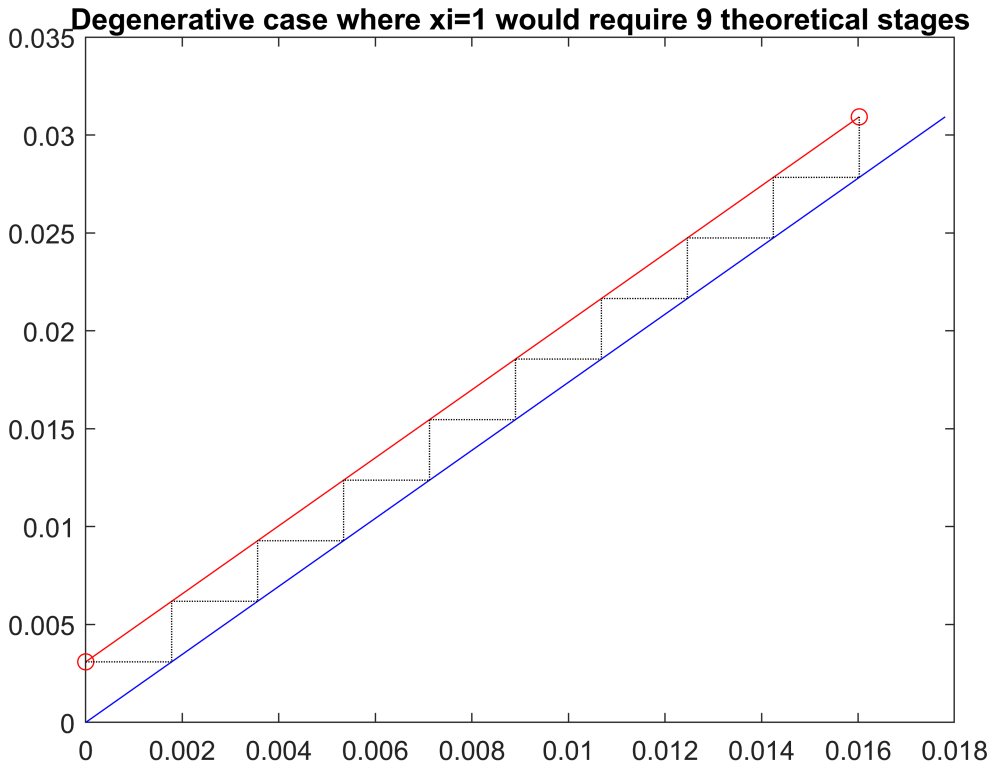
```
Xout_DC = 0.0160
```

```
N_DC = (Xout_DC-Xin)/(Yin/psi-Xout_DC)
```

```
N_DC = 9.0000
```

For illustration, let us also plot the working line and the calculated number of steps for this degenerative case.

```
% YOU CAN SKIP FOLLOWING LINES...
plot(Xeq,Yeq2,'b-',[Xin Xout_DC],[Yout Yin],'r-o')

X = Xout_DC;
Y = Yout + nC_DC/nB*(X-Xin);
XX = [X];
YY = [Y];
for i=1:round(N_DC)
    % go down to the equilibrium
    XX = [XX, XX(end)];
    YY = [YY, XX(end)*psi];
    % go left to the working line
    XX = [XX, Xin+nB/nC_DC*(YY(end)-Yout)];
    YY = [YY, YY(end)];
end
hold on
plot (XX, YY, ['k:'])
hold off
title("Degenerative case where xi=1 would require 9 theoretical stages")
```




```
% ...END OF LINES FOR THE PLOT
```

Because the number of calculated theoretical plates is higher (9) than the given amount (4), in our case, the "nC" must be more than "nC_DC" and "Xout" must be less than "Xout_DC".

The actual case (N=4)

Now let us find "nC" for the given case of (4) theoretical stages

```
syms nC Xout real
assumeAlso(Xout>0);
assumeAlso(Xout<Xout_DC-eps);

eq1 = (nC/(psi*nB))^N == (Yin/psi-Xout)/(Yout/psi-Xin);
eq2 = nC*(Xout-Xin)==nB*(Yin-Yout);
sol=vpasolve([eq1 eq2],[Xout nC])
```

```
sol = struct with fields:
    Xout: [1×1 sym]
      nC: [1×1 sym]
```

```
Xout_solved = eval(sol.Xout) % mol-A/mol-C
```

```
Xout_solved = 0.0118
```

```
nC_solved = eval(sol.nC)     % mol-C [expected 83.3 mol]
```

```
nC_solved = 84.3997
```

```
% ... and also ratio of the nC/nCmin [expected 1.5]
ratio1 = nC_solved/nCmin1 % nCmin from actual eq.
```

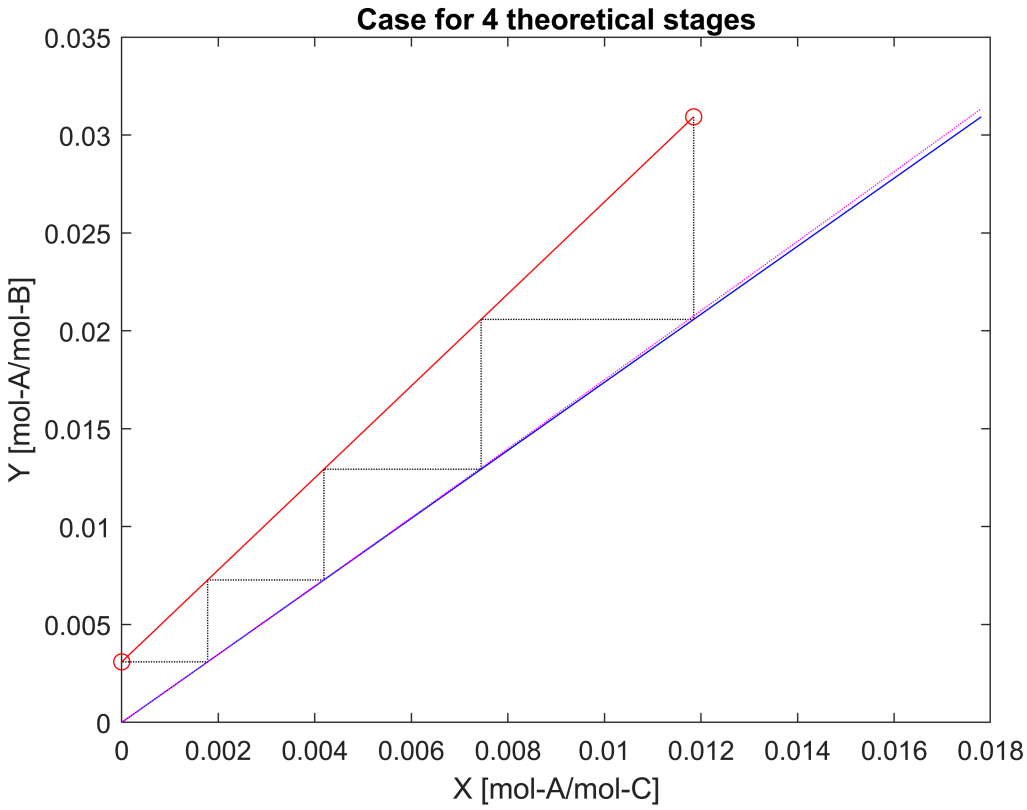
```
ratio1 = 1.4832
```

```
ratio2 = nC_solved/nCmin2 % nCmin from linearized eq.
```

```
ratio2 = 1.5027
```

We can also plot the graphical solution

```
% YOU CAN SKIP FOLLOWING LINES...
plot(Xeq,Yeq2,'b-',[Xin Xout_solved],[Yout Yin],'r-o')

X = Xout_solved;
Y = Yout + nC_solved/nB*(X-Xin);
XX = [X];
YY = [Y];
for i=1:round(N)
    % go down to the equilibrium
    XX = [XX, XX(end)];
    YY = [YY, XX(end)*psi];
    % go left to the working line
    XX = [XX, Xin+nB/nC_solved*(YY(end)-Yout)];
    YY = [YY, YY(end)];
end
hold on
plot (XX, YY, ['k:'])
% add also rigorous eq. line to see extent of
% errors made (you must zoom-in to see the difference)
plot(Xeq, Yeq1, ':m')
hold off
title("Case for 4 theoretical stages")
xlabel('X [mol-A/mol-C]')
ylabel('Y [mol-A/mol-B]')
```




```
% ...END OF LINES FOR THE PLOT
```

Results:

nC / nB ratio is 84.4 (reported 83.3)

nC / nCmin ratio is 1.48 or 1.5 (with linear equilibrium). (reported 1.5)