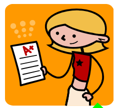
Class 7
More DOF and Balances



Conference Weekend

- Exam #1 coming
  - Sept. 27-Oct. 2 (Wednesday thru Monday)
    - Due in class on Monday morning
    - Take home
    - 2 hr time limit
  - 2 more classes on multiple processes (after today)
  - Exam review (Wed., Sept. 27)
  - No class on Friday, Sept. 29
- DOF required on all remaining problems in Chapter 4 (even after Exam 1)
- Homework key now posted on Learning Suite
- Homework grades posted on web page by alias name
- Homework hints posted for 4.27

Outline

- DOF Review/Questions
- Practice Problem 4.32 (4.22 3rd Ed.)
- Practice DOF for 4.33 (4.23), 4.36 (4.26)
- In-Class Assignment/Quiz

Notes on DOF Analysis

- My method is slightly different than in the book or on the web
  - The authors like to write out more equations and unknowns (like S.G. to convert mass to volume)
- The important thing is to get the DOF correct
  - TA's will be understanding on grades
  - I will be understanding on exams

Questions?

Problem 4.32 (4.22 in 3rd Edition)

*4.22. Gas streams containing hydrogen and nitrogen in different proportions are produced on request by blending gases from two feed tanks: Tank A (hydrogen mole fraction = x_A) and Tank B (hydrogen mole fraction = x_B). The requests specify the desired hydrogen mole fraction, x_P, and *mass* flow rate of the product stream, $\dot{m}_P$(kg/h).

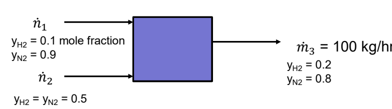
(a) Suppose the feed tank compositions are x_A = 0.10 mol H_2/mol and x_B = 0.50 mol H_2/mol, and the desired blend–stream mole fraction and mass flow rate are x_P = 0.20 mol H_2/mol and $\dot{m}_P$ = 100 kg/h. Draw and label a flowchart and calculate the required *molar* flow rates of the feed mixtures, $\dot{n}_A$(kmol/h) and $\dot{n}_B$(kmol/h).

(b) Derive a series of formulas for $\dot{n}_A$ and $\dot{n}_B$ in terms of x_A, x_B, x_P, and $\dot{m}_P$. Test them using the values in part (a).

(c) Write a spreadsheet that has column headings x_A, x_B, x_P, $\dot{m}_P$, $\dot{n}_A$, and $\dot{n}_B$. The spreadsheet should calculate entries in the last two columns corresponding to data in the first four. In the first six data rows of the spreadsheet, do the calculations for x_A = 0.10, x_B = 0.50, and x_P = 0.10, 0.20, 0.30, 0.40, 0.50, and 0.60, all for $\dot{m}_P$ = 100 kg/h. Then in the next six rows repeat the calculations for the same values of x_A, x_B, and x_P for $\dot{m}_P$ = 250 kg/h. *Explain any of your results that appear strange or impossible.*

(d) Enter the formulas of part (b) into an equation-solving program. Run the program to determine $\dot{n}_A$ and $\dot{n}_B$ for the 12 sets of input variable values given in part (c) and explain any physically impossible results.

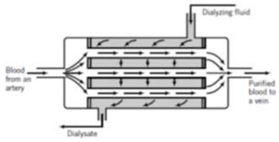
Problem 4.22



DOF
U = 2 ($\dot{n}_1, \dot{n}_2$)
BE = 2
OE = 0
DOF = 0

4.33 in 4th Edition

4.23. An **artificial kidney** is a device that removes water and waste metabolites from blood. In one such device, the **hollow fiber hemodialyzer,** blood flows from an artery through the insides of a bundle of hollow cellulose acetate fibers, and *dialyzing fluid,* which consists of water and various dissolved salts, flows on the outside of the fibers. Water and waste metabolites—principally urea, creatinine, uric acid, and phosphate ions—pass through the fiber walls into the dialyzing fluid, and the purified blood is returned to a vein.



At some time during a dialysis the arterial and venous blood conditions are as follows:

	Arterial (entering) Blood	Venous (exiting) Blood
Flow Rate	200.0 mL/min	195.0 mL/min
Urea (H_2NCONH_2) Concentration	1.90 mg/mL	1.75 mg/mL

(a) Calculate the rates at which urea and water are being removed from the blood.
(b) If the dialyzing fluid enters at a rate of 1500 mL/min and the exiting solution (*dialysate*) leaves at approximately the same rate, calculate the concentration of urea in the dialysate.
(c) Suppose we want to reduce the patient's urea level from an initial value of 2.7 mg/mL to a final value of 1.1 mg/mL. If the total blood volume is 5.0 liters and the average rate of urea removal is that calculated in part (a), how long must the patient be dialyzed? (Neglect the loss in total blood volume due to the removal of water in the dialyzer.)

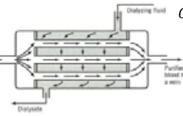
DOF Practice

4.33 in 4th Edition

- Problem 4.23 – Dialysis

$\dot{V}_3 = 1500\ mL/min$
$C_{U,3} = 0.0\ mg/mL$

$\dot{V}_1 = 200\ mL/min$



$\dot{V}_2 = 195\ mL/min$
$C_{U,2} = 1.75\ mg/mL$

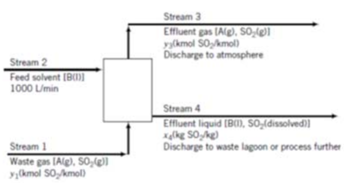
$C_{U,1} = 1.90\ mg/mL$

$\dot{V}_4 = \sim 1500\ mL/\min = ??$
$C_{U,4} = ?\ mg/mL$

4.36 in 4th Edition

4.26. *Gas absorption* or *gas scrubbing* is a commonly used method for removing environmentally undesirable species from waste gases in chemical manufacturing and combustion processes. The waste gas is contacted with a liquid solvent in which the potential pollutants are highly soluble and the other species in the waste gas are relatively insoluble. Most of the pollutants go into solution and emerge with the liquid effluent from the scrubber, and the cleaned gas is discharged to the atmosphere. The liquid effluent may be discharged to a waste lagoon or subjected to further treatment to recover the solvent and/or to convert the pollutant to a species that can be released safely to the environment.

A waste gas containing SO_2 (a precursor of acid rain) and several other species (collectively designated as A) is fed to a scrubbing tower where it contacts a solvent (B) that absorbs SO_2. The solvent feed rate to the tower is 1000 L/min. The specific gravity of the solvent is 1.30. Absorption of A and evaporation of B in the scrubber may be neglected.



The gas in the scrubber rises through a series of *trays* (metal plates perforated with many small holes), and the solvent flows over the trays and through *downcomers* to the trays below. Gas bubbles emerge from the holes in each tray and rise through the covering liquid, and SO_2 diffuses out of the bubbles and into solution.

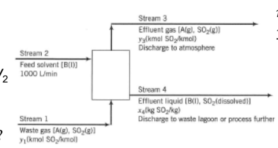
DOF Practice

4.36 in 4th Edition

- Problem 4.26 – Gas Absorption

$\dot{m}_2 = \rho_2 \dot{V}_2$
$\dot{n}_2 = \dot{m}_2/MW_2$

$\dot{n}_1 = ?$
$y_{S1} = ?$

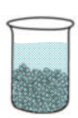


$\dot{n}_3 = ?$
$y_{S3} = ?$

$\dot{m}_4 = ?$
$x_{S4} = ?$

- Perform the DOF analysis

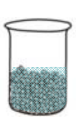
Thought Questions



Beaker of sand + salt water
- 5 g sand
- 9.5 g water
- 0.5 g salt

Pour off 2 g of liquid

What is the mass fraction of salt in the liquid you poured out?

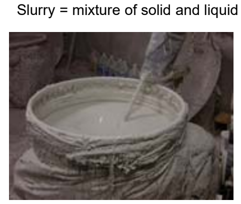


What is the mass fraction of salt in the liquid still in the beaker?

What is the mass fraction of salt in the beaker, including the sand?

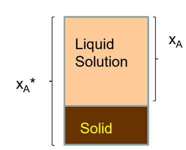
In-Class Problem

Slurry = mixture of solid and liquid



Solids loading = $mass_{solid}$/total mass

Note: Composition may be given of slurry (x_A^*) or just the liquid solution (x_A)



Caution: In a mass balance on species A, we can either use $m_{soln} \cdot x_A$ or $m_{slurry} \cdot x_A^*$ (both give the mass of species A, or m_A).

Answer: $x_{A,soln}$ = 0.23 g NaOH/g soln

In-Class Problem