SOLUTIONS MANUAL

Basic Principles and Calculations in Chemical Engineering

Eighth Edition

David M. Himmelblau
James B. Riggs

PRENTICE HALL

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We want to thank Christine Bailor for preparing this Solutions Manual,
and for the many students and graders who have contributed to
the solutions it contains.

David M. Himmelblau
James B. Riggs

TABLE OF CONTENTS

To the Instructor

This *Solutions Manual* accompanies the book *Basic Principles and Calculations in Chemical Engineering, Eighth Edition*, published by Prentice Hall. In addition to the detailed, worked-out solutions for all the problems that follow each chapter in the textbook and answers to the thought problems, you will find in what follows a number of useful components of a syllabus for students, information that usually are handed out during the first day of class:

1. Class grading policies, homework and reading assignments, and examination information.
2. Class objectives.
3. Schedule of topics covered.
4. Suggestions for taking examinations.
5. Format standards for submitting homework.

Suggested Content for the Introductory Course in Chemical Engineering

The introductory course in chemical engineering is usually taught over an interval of one or two semesters, or one or three quarters. The textbook contains more material than can be successfully presented in one quarter and probably in one semester (depending on the background and previous coursework of students). Although an instructor would like to assume that a student has learned all of the material covered in earlier courses in chemistry and physics, it takes just one time in teaching the introductory course to abandon that expectation. The textbook is organized into four parts comprised of 11 chapters plus 6 additional chapters on the accompanying CD that treat material usually not included in a one semester course. The following list suggests the chapters to include in courses of various duration:

One quarter	1–6, 8, 9–10
One semester	1–11
Two quarters	1–7 followed by 8 and 11
Two semesters	1–11 followed by 12–17

Example Course Syllabus

Information for ChE 317
Introduction to Chemical Engineering

Instructor: D.M. Himmelblau Office: CPE 5.410
Office hours: M-F 10-11 a.m.

1. GENERAL

   a. The prerequisites for ChE 317 are Ch 302 and Math 808. If you have not completed these two courses, you will have to drop ChE 317 and should do so at once.

   b. Class conduct is informal. Feel free to raise your hand at any time to ask a question or for an explanation.

2. EXAMINATIONS

   a. Five two-hour examinations plus a final exam will be held at specified announced dates as shown on the assignment sheets. The last examination will be scheduled during the final exam period (refer to the course schedule for details). The lowest exam of the first 5 (excluding the final exam) will be omitted in calculating your final grade. You must take the final. If you will miss an exam, notify me prior to the exam, not afterwards, to arrange for a makeup exam.

3. GRADING

   a. The grading is based on scores on the examinations, each of which is weighted equally (90%), plus class discussion and homework (10%). The grades are assigned on an **absolute basis**, not a curve:

A	> 82
B	71-82
C	61-70
D	51-60
F	< 51

   hence there is no penalty for working together and helping each other.

   b. You will have a grader assigned to this course whose name is ___________, office number is Room ______, and office hours are __________.

   c. The recitation session assistant is ___________________, office number is Room _____, and office hours are __________.

   d. If you disagree with the grader's method of grading and with the total points he has given you on a particular problem, discuss it with the grader first, but if you cannot reach a decision, I will be the referee. Bring exam grade questions to me.

   e. Prepare a grade sheet on which you can keep account of your homework and exam grades so that you will be able to compute your status at any time you wish.

f. A grade of at least a C is required in this course for subsequent courses in chemical engineering.

4. HOMEWORK PROBLEMS

a. CHEMICAL ENGINEERING STANDARDS WILL BE REQUIRED AND ENFORCED. (Capital letters intended.)

b. Problems are due at the beginning of each class according to the assignment. No late problems can be accepted.

c. Turn in a much of a problem as you can get. It is better to get a low grade than a "miss."

d. Working together is an important part of professional practice. After the second week of class, students will be assigned to work on homework (not exams!) in pairs. During the first two weeks of class look for a possible compatible partner. You will receive a list of all of the class members with their phone numbers to help in the selection. Exceptions can be made for individuals who insist on working alone.

e. After each scheduled homework assignment has been turned in, the solution(s) will be placed in a file located in the ChE stockroom that may be checked out for 2 hours at a time.

5. If you have difficulty in the early part of the course, confer with me **before you get into trouble.**

Course Objectives

The objectives for Chemical Engineering 317 are as follows:

1. To introduce you to the principles and calculation techniques used in the field of chemical engineering.

2. To acquaint you with the fundamentals of material and energy balances as applied to chemical engineering.

3. To acquaint you with efficient methods of problem solving so that you can effectively solve problems you will encounter after leaving school.

4. To offer practice in defining problems, collecting data, analyzing the data, and breaking it down into basic patterns, and selection of pertinent information for application.

5. To review certain principles of applied physical chemistry.

6. To help you decide you have chosen the right field.

Contributions to Program Outcomes

By graduation a chemical engineering student should have achieved certain knowledge, skills, and abilities known as Program Outcomes. ChE 317 contributes to five significant outcomes, namely an ability to:

1. Apply knowledge of mathematics, chemistry, physics computing, safety, ethical practice, and technology to solve engineering problems.

2. Apply and integrate elements of chemical engineering to solve problems in design, operation, and control of processes.

3. Participate in team activity effectively and demonstrate leadership.

4. Communicate effectively via oral, written, and graphic means.

5. Appreciate the societal and economic impact of engineering decisions locally and globally.

Fall Semester Exam Schedule

The first 5 exams are evening exams on Thursday, open book, of 2 hours duration, specific times to be arranged (such as 5-7, 6-8, 7-9, etc.):

Exam 1	September 14
Exam 2	October 1
Exam 3	October 16
Exam 4	November 1
Exam 5	November 15

The final exam is listed in the University final exam schedule (that will appear about December 1).

Fall Semester Schedule for the Recitation Section

The recitation section will meet on Thursday, 2–3:30 p.m. in CPE 2.220. The objective of the recitation section is to let you ask questions and provide assistance in problem solving for old or new ChE 317 homework and exam problems on a one-to-one basis.

Attendance is not required, *but* you will miss the unique opportunity to get personal attention if you want it. You will also miss questions asked by other students that you have not considered. You will also have the chance to meet other students in the class, and discuss anything (!) with them.

No assignments are made, no grades given, no lectures presented, and no formal structure exists for the recitation section. It's up to you to make use of it.

Suggestions for Taking Exams

1. Bring what you want to the exams—they are open book. Be sure to have adequate pencils, batteries, etc.

2. Read the entire examination through quickly before starting to work any one problem. Then work first on those problems which seem the simplest or about which you are most confident in solving.

3. Be sure to allot your working times to the questions roughly according to the grade value of each. If a problem is not completed in the time allotted, it is usually better to discontinue work on it and spend time on the other problems. Be sure to spend at least some time on each problem. Partial solutions to all problems usually result in a higher overall grade than complete solutions to only a small portion of the problems (provided you do enough work on a problem to indicate that the correct method of attack is being used).

4. When starting work on a problem read it through carefully and be certain you understand it. Spend a short time thinking about the method of solution instead of writing down what first comes to mind.

5. When writing down the solution, organize your work in a neat and logical manner in spite of the time constraints. This step not only impresses the grader but also permits him or her to follow the work closely enough so that if a mistake is made he or she can still evaluate the succeeding work. Neatness and organization also permit you to check your work more easily and to find quickly information needed later in the problem.

6. In answering a question write enough so that the grader does not have to guess what you had in mind. For example, when using equations, write down the equation first and then substitute numbers. A group of numbers alone may confer little information to the grader, especially if they are the wrong numbers. When using data obtained from tables or charts, state the source—and in some cases the method of using the source. Draw pictures, and separate subproblems from each other.

7. If it is obvious that you are not going to finish a problem, carefully outline the remainder of the solution by numbered steps, and include sufficient details, such as pertinent equations and methods of solving them, sources for remaining necessary data, etc.

8. If you start to get rattled, slow down a bit— perhaps even think of something besides the examination for a minute or two. Remember that this one examination is not going to make or break you whatever success you have on it. View the problem bothering you as you would a bridge hand, crossword puzzle, or other game that involves solving a problem based on a given set of facts with available information.

9. Sample old exams are located in the ChE Stockroom, and can be taken out and copied. Practice solving old exams two or three days in advance of each exam to isolate your weaknesses in subject material and exam taking skills.

What you should know about this course at the beginning that will be clear by final exam time

1. You no longer are a freshman so that the material covered proceeds at a rapid pace.

2. Your notions of teaching and learning will require substantial adjustment. Our goal is <u>not</u> for you to reproduce what was told to you in the classroom or you read in the text. Your study habits probably must change.

3. Lecture time is at a premium and must be used efficiently. Listening is not learning any more than lecturing is teaching. <u>You</u> are responsible for learning the material, a phase that will occur primarily outside the classroom. The instructor cannot "teach" all the skills you need in the short time of a class. It will take you two or three hours on the average per hour of class time to become proficient.

4. The instructor's job is to provide a framework of the topic along with demonstrations to guide you in your learning of concepts, methods, and efficient problem solving skills. It is not to imprint you with isolated facts and problem types.

5. If you read the material in the assigned section for the next period before coming to class, the lecture will make more sense, and you can ask questions to clarify any uncertain issues.

Standards for Chemical Engineering Homework Assignments

1. Engineering paper must be used (paper ruled on the back with a grid).

2. Use the unruled side of the sheet for the calculations, and the back side for drawings (rarely required).

3. Use the sheet with the holes to the left.

4. Turn in your work with the paper folded vertically.

5. Write neatly. Make the text in your calculations in letters 0.20 inches high—these match the horizontal grid spacing on the back of the paper. Leave 0.20 inches (one grid interval) between lines. The idea is to be professional in presenting your work.

6. Use engineering/scientific notation for numbers such as 0.341 and 1.453×10^5. Use judgment as to how many zeros you put after the decimal point or before the first significant figure. Note: always put a zero before the decimal point for a number less than unity.

7. Indicate multiplication and division using units as seen below. (Note: Use vertical and horizontal rules as necessary.)

$$\frac{3.45 \text{ lb NaCl}}{1 \text{ ft}^3 \text{ soln}}\left|\frac{4 \text{ gal soln}}{}\right|\frac{1 \text{ ft}^3}{7.48 \text{ gal}} =$$

   As you gain experience, you can suppress the units for simple problems and show multiplication and division thus (use parenthesis rather than centered dots as the dots get confused with periods, dust specks, etc.)

$$(3.45)(4)\left(\frac{1}{7.48}\right) =$$

8. Use a solid line across the page between the vertical rules on the engineering paper to demark the end of a part of a problem with multiple parts. Denote the end of the entire problem by a line across the page from the left hand rule to the far right edge of the paper.

9. Always show the units of your answer, underline the numbers and units, and draw an arrow from the right edge of the paper to the answer so that the answer is easy to pick out on the page thus

$$\frac{8.5 \text{ lbH}_2}{\text{lb F}}\left|\frac{1 \text{ lb mol H}_2}{2.02 \text{ lb H}}\right|\frac{1 \text{ lb mol Zn}}{1 \text{ lb mol H}_2} = \underline{\frac{4.21 \text{ lb mol Zn}}{\text{lb F}}} \quad \longleftarrow \text{part (a) of the problem}$$

10. Indicate a new problem by placing the problem number in the left hand margin.

11. Always show the basis of your calculations thus

   Basis: 100 lb feed

12. On each submission place your class number, the date, the assignment number, your name, and the page numbering at the top of each and every page, even if you staple the pages together, thus

317	Sept. 10, 2003	Assignment No. 5	Jones, Robert	2/3
↑	↑	↑	↑	↑
Class	Date	Assignment Identification	Your name	Page 2 of 3 pages submitted

TYPICAL ASSIGNMENTS FOR ONE SEMESTER

	Topic and Problem Assignments Due	All assignments are in the 8th edition. Study:
1.	First Class meeting. No assignments due	
2.	UNITS, DIMENSIONS, UNIT CONVERSION 2.1.1, 2.2.2, 2.2.6	Chapter 2
3.	DIMENSIONAL CONSISTENCY, SIGNIFICANT FIGURES, VALIDATION, MOLES 2.3.1, 2.3.3, 2.3.8	Chapter 2
4.	METHODS OF ANALYSIS AND MEASUREMENT 2.6.1a, 2.6.4a, 2.9.1	Chapter 2
5.	BASIS, TEMPERATURE, PRESSURE 2.7.1a,b,c; 2.11.2, 2.11.5	Chapter 2
6.	PRESSURE MEASUREMENT 2.11.9	Chapter 2
7.	INTRODUCTION TO MATERIAL BALANCES 3.1.11, 3.1.19, 3.1.16, 3.1.7, 3.1.8	Chapter 3
8.	STRATEGY FOR SOLVING MATERIAL BALANCES 3.2.2, 3.2.4, 3.2.5, 3.2.9, 3.2.14	Chapter 3
9.	No class meeting. Exam No. 1 in the evening.	
10.	MATERIAL BALANCES WITHOUT REACTION—SINGLE UNITS 4.1.7, 4.1.8, 4.1.10, 4.1.12	Chapter 4
11.	MATERIAL BALANCES (CONTINUED) 4.1.18, 4.1.20, 4.1.23, 4.1.25	Chapter 4
12.	STOICHIOMETRY 5.1.2a,e; 5.1.5; 5.2.14; 5.2.15	Chapter 5
13.	MATERIAL BALANCES WITH REACTION—SINGLE UNITS 5.3.1, 5.3.2, 5.3.6, 5.3.7	Chapter 5
14.	MATERIAL BALANCES WITH REACTION—SINGLE UNITS (CONTINUED) 5.5.5, 5.5.7, 5.5.10, 5.5.13	Chapter 5

	Topic and Problem Assignments Due	All assignments are in the 8th edition. Study:
15.	Review for Exam No. 2.	Chapters 4–5
16.	No class meeting. Exam No. 2 in the evening.	
17.	MATERIAL BALANCE PROBLEMS WITH MULTIPLE UNITS 6.1.2, 6.1.5, 6.2.1, 6.2.7	Chapter 6
18.	MATERIAL BALANCE PROBLEMS WITH RECYCLE (NO REACTION) 6.3.1b,d; 6.3.2; 6.3.16, 6.3.17	Chapter 6
19.	MATERIAL BALANCE PROBLEMS WITH RECYCLE (WITH REACTION) 6.3.8, 6.3.13, 6.3.21	Chapter 6
20.	IDEAL GAS AND PARTIAL PRESSURE 7.1.1, 7.1.5, 7.1.12c, 7.1.22, 7.1.31	Chapter 7
21.	MATERIAL BALANCES WITH IDEAL GASES 7.1.52, 7.1.44, 7.1.55	Chapter 7
22.	REAL GASES—COMPRESSIBILITY 7.3.1, 7.3.3, 7.3.13	Chapter 7
23.	REAL GASES—EQUATIONS OF STATE 7.2.8, 7.2.5, 7.2.17, 7.2.13	Chapter 7
24.	Review for Exam No. 3.	Chapters 6–7
25.	No class meeting. Exam No. 3 in the evening.	
26.	SINGLE COMPONENT-TWO PHASE SYSTEMS (VAPOR PRESSURE) 8.2.1, 8.2.9, 8.3.2 a to e, 8.3.4, 8.3.5b, 8.3.19, 8.3.20	Chapter 8
27.	TWO PHASE GAS-LIQUID SYSTEMS 8.3.17, 8.3.22a, 8.4.2, 8.4.4, 8.4.7	Chapter 8
28.	TWO PHASE GAS-LIQUID SYSTEMS (CONTINUED) 8.4.14, 8.4.16, 8.4.18, 8.4.27	Chapter 8

	Topic and Problem Assignments Due	All assignments are in the 8th edition. Study:
29.	VAPOR-LIQUID EQUILIBRIA AND THE PHASE RULE 8.2.4, 8.2.5, 8.5.3, 8.5.6, 8.5.14, 8.5.18	Chapter 8
30.	Review for Exam No. 4	Chapter 8
31.	No class meeting. Exam No. 3 in the evening.	
32.	ENERGY: TERMINOLOGY, CONCEPTS, AND UNITS 9.1.1, 9.1.5, 9.1.7, 9.1.11, 9.2.4, 9.2.21, 9.2.22	Chapter 9
33.	ENERGY BALANCES—CLOSED SYSTEMS 9.3.31a,b; 9.3.9; 9.3.25; 9.3.45	Chapter 9
34.	ENERGY BALANCES—OPEN SYSTEM 9.3.31, 9.3.32, 9.3.17a, 9.3.33	Chapter 9
35.	CALCULATING ENTHALPY CHANGES 9.2.26, 9.2.37, 9.2.46	Chapter 9
36.	APPLICATIONS OF ENERGY BALANCES WITHOUT REACTION-CLOSED SYSTEMS 9.3.19, 9.3.39, 9.3.40	Chapter 9
37.	APPLICATIONS OF ENERGY BALANCES WITHOUT REACTION-OPEN SYSTEMS 9.3.21, 9.3.41	Chapter 9
38.	Review for Exam No. 5	Chapter 9
39.	No class meeting. Exam No. 5 in the evening.	
40.	ENERGY BALANCES WITH REACTION 10.1.6; 10.1.8a,b; 10.2.1a; 10.2.3; 10.2.4	Chapter 10
41.	CONTINUED 10.2.17, 10.2.6, 10.2.10, 10.4.6	Chapter 10
42.	PARTIAL SATURATION AND HUMIDITY 11.1.1	Chapter 11
43.	HUMIDITY CHARTS 11.2.1, 11.3.1, 11.3.7	Chapter 11
44.	Exam No. 6 is the final exam held on the scheduled final exam period (3 hours).	

TYPICAL EXAMS FOR A ONE SEMESTER COURSE

(scheduled in the evening to avoid time constraints on students

Exam No. 1
(Open Book, 1 1/2 hours)

PROBLEM 1 (5%)

Hydrogen can be separated from natural gas by diffusion through a round tube. The rate of separation is given by

$$N = 2\pi D\rho R$$

where

N	=	rate of transport of H_2 from the tube, g moles/(sec)(cm of length of tube)
D	=	diffusion coefficient
ρ	=	molar density of H_2, g moles/cm^3
R	=	log mean radius of tube, $r2 - r_1 / l\,n\left(\frac{r_2}{r_1}\right)$, with r in cm.

What are the units of D?

PROBLEM 2 (10%)

A pallet of boxes weighing 10 tons is dropped from a lift truck from a height of 10 feet. The maximum velocity the pallet attains before hitting the ground is 6 ft/sec. How much kinetic energy does the pallet have in (ft)(lb_f) at this velocity?

PROBLEM 3 (5%)

The specific gravity of a fuel oil is 0.82. What is the density of the oil in lb/ft^3? Show all units.

PROBLEM 4 (10%)

Sulfur trioxide (SO_3) can be absorbed in sulfuric acid solution to form more concentrated sulfuric acid. If the gas to be absorbed contains 55% SO_3, 41% N_2, 3% SO_2, and 1% O_2, how many parts per million of O_2 are there in the gas? (b) What is the composition of the gas on a N_2 free basis?

PROBLEM 5 (15%)

You have 100 kilograms of gas of the following composition:

CH_4	30%
H_2	10%
N_2	60%

What is the average molecular weight of this gas?

PROBLEM 6 (15%)

If the heat capacity of a substance is 5.32 J/(g)(°C) and its molecular weight is 37.4, what is its heat capacity in

(a) J/(g)(°F)
(b) J/(lb)(°R)
(c) J/(gmol)(K)

PROBLEM 7 (20%)

A rock containing 100% $BaSO_4$ is burned with coke (94%C, 6% ash) and the composition of the product is $BaSO_4$ (11.1%) BaS (72.9%), C (13.9%, ash (2.2%). The reaction is

$$BaSO_4 + 4C \rightarrow BaS + 4CO$$

Calculate the percent excess reactant, and the degree of completion of the reaction.

PROBLEM 8 (20%)

A gas cylinder to which is attached a Bourden gauge appears to be at a pressure of 27.38 in. Hg at 70°F. the barometer needs 101.8 kPa. A student claims that the pressure in the tank is 1.3 psia, but another student points out that this is impossible—the pressure is really 28.2 psia. Can 1.3 psia be correct? Explain and show calculations to back up your explanation.

EXAM NO. 2
(Open Book, 2 hours)

PROBLEM 1 (25%)

A chemist attempts to prepare some very pure crystals of Na_2SO_4-$10H_2O$ by dissolving 200 g of Na_2SO_4 (MolWt=142.05) in 400 g of boiling water. He then carefully cools the solution slowly until some $Na_2S0_4 \cdot 10H_20$ crystallizes out. Calculate the g of $Na_2SO_4 \cdot 10H_2O$ recovered in the crystals per 100 g of initial solution, if the residual solution after the crystals are removed contains 28% Na_2SO_4.

	Right answer but:	–10 if answer is in g of Na2SO4 and not g of $Na_2SO_4 \cdot 10H_2O$		–10 if answer not per 100 g of initial soln

PROBLEM 2 (25%)

Water pollution in the Hudson River has claimed considerable recent attention, especially pollution from sewage outlets and industrial wastes. To determine accurately how much effluent enters the river is quite difficult because to catch and weigh the material is impossible, weirs are hard to construct, etc. One suggestion which had been offered is to add a trace Br^- ion to a given sewage stream, let it mix well, and sample the sewage stream after it mixes well.

On one test of the proposal you add ten pounds of NaBr per hour for 24 hours to a sewage stream with essentially no Br^- in it. Somewhat downstream of the introduction point a sampling of the sewage stream shows 0.012% NaBr. The sewage density is 60.3 lb/ft^3 and river water density is 62.4 lb/ft^3.

What is the flow rate of the sewage in lb/min?

		–10 if answer based on 0.012 fractin and not 0.00012.		–15 if 24 hr basis was used and then not converted back to per hour basis.

PROBLEM 3 (25%)

In preparing 5.00 moles of a mixture of three gases (SO_2, H_2S, and CS_2), gases from three tanks are combined into a fourth tank. The tanks have the following compositions (mole fractions):

	Gas	Tank 1	Tank2	Tank3	Tank 4
	SO_2	0.10	0.20	0.25	0.20
	H_2S	0.40	0.20	0.25	0.26
	CS_2	0.50	0.60	0.50	0.54

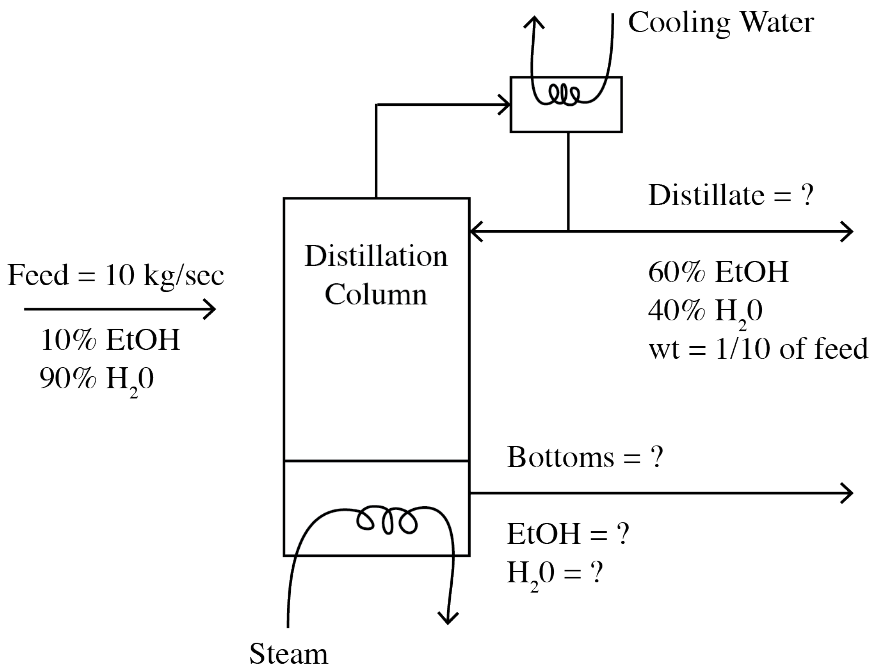
How much of Tanks 1, 2, and 3 must be mixed to give a product with composition of Tank4?

	–10 for correct answer but wrong basis		–15 A lot of people said no soln. They used wrong basis, etc. No soln but correct mat'l balance

PROBLEM 4 (25%)

10% a) For the given distillation process, calculate the composition of the bottoms stream.

15% b) If steam leaked into the column at 1000 mole/sec and all else was constant, what would the new bottoms composition be? –5 (should be g-mole), if assumed to k-mole and not stated.



Exam No. 3
(Open Book Exam, 2 hours)

PROBLEM 1 (35%)

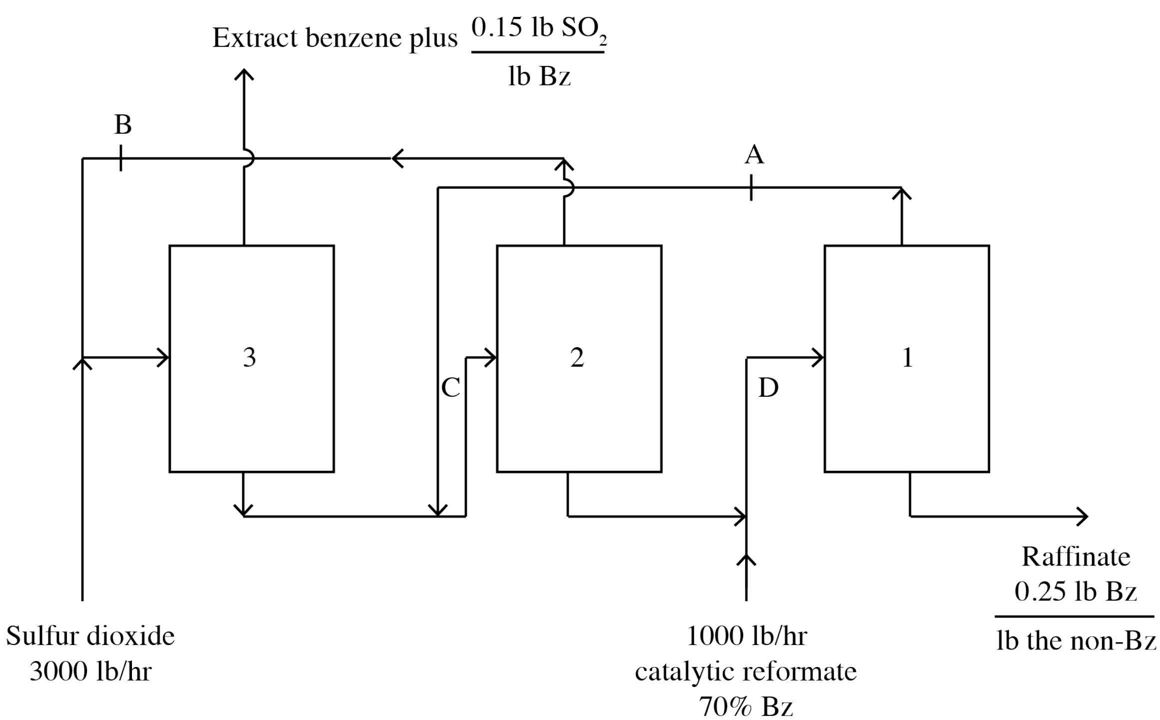
A company burns an intermediate product gas having the composition 4.3% CO_2, 27% CO, 10% H_2, 1.0% CH_4, and the residual N_2 together with a waste oil having the composition 87% C, 13% H_2. Analysis of the stack gas gives an Orsat analysis of 14.6% CO_2, 0.76% CO, and 7.65 O_2 and the rest N_2. Calculate the fraction of the total carbon burned that comes from the product gas.

PROBLEM 2 (35%)

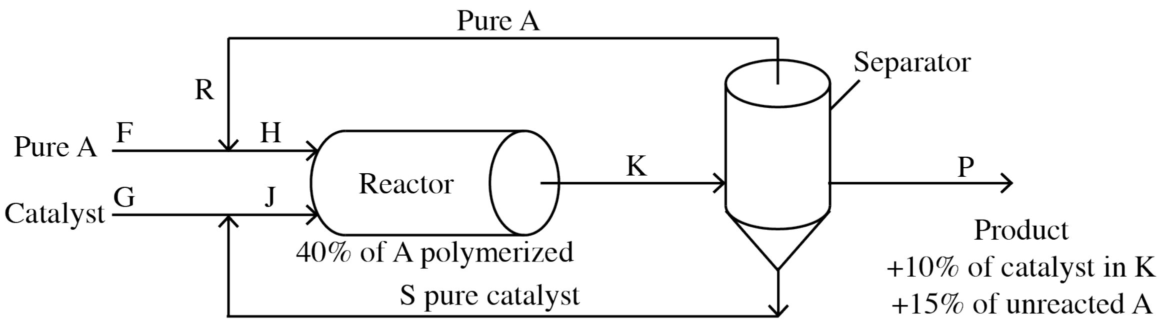
Benzene, toluene and other aromatic compounds can be recovered by solvent extraction with sulfur dioxide. As an example, a catalytic reformate stream containing 70% by weight benzene and 30% non-benzene material is passed through the counter-current extractive recovery scheme shown in the diagram below. One thousand pounds of the reformate stream and 3000 pounds of sulfur dioxide are fed to the system per hour. The benzene product stream (the extract) contains 0.15 pound of sulfur dioxide per pound of benzene. The raffinate stream contains all the initially charged non-benzene material as well as 0.25 pound of benzene per pound of the non-benzene material. The remaining component in the raffinate stream is the sulfur dioxide.

(a) How many pounds of benzene are extracted per hour, i.e. are in the extract?

(b) If 800 pounds of benzene containing in addition 0.25 pound of the non-benzene material per pound of benzene are flowing per hour at point A and 700 pounds of benzene containing 0.07 pound of the non-benzene material per pound of benzene are flowing at point B, how many pounds (exclusive of the sulfur dioxide) are flowing at points C and D?



PROBLEM 3 (30%)



Reactant A is polymerized as shown in the figure. It is mixed with fresh catalyst and recycled catalyst. Conversion of A is 40% on one pass through the reactor. Fresh catalyst (G) enters at the rate of 0.40 lb G per lb of A in stream H. The separator removes 90% of the catalyst and recycles it as well as recycling unreacted A. Nevertheless, the product stream P constraints 15% of the unreacted A and 10% of the catalyst exiting in stream K as well as the polymer product. Determine the ratio of stream R to G.

Note: catalyst does not react in the process!

Exam No. 4
(Open Book, 2 hours)

PROBLEM 1 (25%)

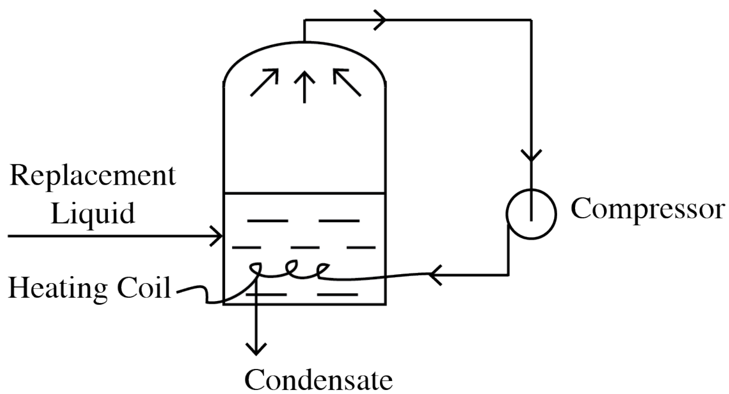
In the vapor-recompression evaporator (not insulated) shown in the figure below, the vapors produced on evaporation are compressed to a higher pressure and passed through the heating coil to provide the energy for evaporation. The steam entering the compressor is 98% quality at 10 psia, the steam leaving the compressor is at 50 psia and 400°F, and 6 Btu of heat are lost from the compressor per pound of steam throughput. The condensate leaving the heating coil is at 50 psia, 200°F. The replacement liquid is at the temperature of the liquid inside the evaporator.

Computer:

(a) the work in Btu needed for compression per pound of H_2O going through the compressor.

(b) the Btu of heat transferred from the heating coil to the liquid in the evaporator per pound of H_2O through the coil.

(c) Bonus of 5 points for correct answer to the question: What is the total heat gained or lost by the entire system?



PROBLEM 2 (25%)

An insulated, sealed tank that is 2 ft^3 in volume holds 8 lb of water at 100°F. A 1/4 hp stirrer mixes the water for 1 hour. What is the fraction vapor at the end of the hour? Assume all the energy from the motor enters the tank.

For this problem you do not have to get a numerical solution. Instead list the following in this order:

1. State what the system you select is.
2. Specify open or closed.
3. Draw a picture.
4. Put all the known or calculated data on the picture in the proper place.
5. Write down the energy balance (use the symbols in the text) and simplify it as much as possible. List each assumption in so doing.
6. Calculate W.

7. Lists the equations with data introduced that you would use to solve the problem.
8. Explain step by step how to solve the problem (but do not do so).

PROBLEM 3 (15%)

What is the enthalpy change in Btu when 1 pound mole of air is cooled from 600°F to 100°F at atmospheric pressure.

Compute your answer by two ways:
1) Use the tables of the combustion gases.
2) Use the heat capacity equation for air.

PROBLEM 4 (10%)

Answer the following questions by placing T fro true and F for false on your answer page. Grading: +2 if correct, 0 if blank, -1 if wrong.

(a) Heat and thermal energy are synonymous terms used to express one type of energy.

(b) You can find the enthalpy change at constant pressure of a Substance such as CO_2 from the solid to the gaseous state by integrating

	$\int_{T_1}^{T_2} C_p dT$	from T_1 (solid temperature) to T_2 (gas temperature) for a constant pressure path.

(c) The enthalpy change of a substance can never be negative.

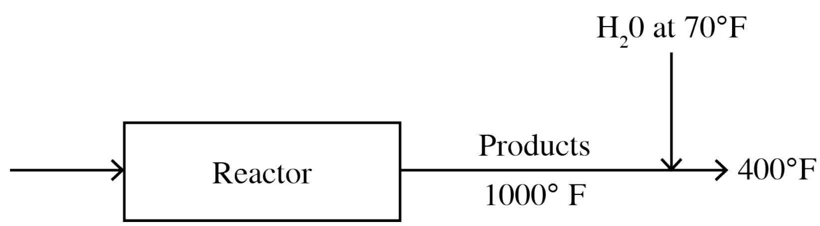
(d Heat and work are the only methods of energy transfer in a non-flow process.

(e) Both Q and ΔH can be classed as state functions (variables)

PROBLEM 5 (25%)

Hot reaction products (assume they have the same properties as air) at 1000°F leave a reactor. In order to prevent further reaction, the process is designed to reduce the temperature of the products to 400°F by immediately spraying liquid water into the gas stream.

How many lb of water at 70°F are required per 100 lb of products leaving at 400°F?



For this problem you do not have to get a numerical solution. Instead list the following in this order.

1. State what the system you select is.
2. Specify open or closed.
3. Draw a picture.
4. Put all the known or calculated data on the picture in the proper places.
5. Write down the material and energy balances (use the symbols in the text) and simplify them as much as possible, list each assumption in so doing.
6. Insert the known data into the simplified equation(s) you would use to solve the problem.