NAME KRESTA Solution

CME 265 Process Analysis Midterm 1
February 9, 2011

The exam is 50 minutes long.
Approved programmable calculators, textbooks and one 8.5x11" crib sheet permitted.
Do ALL questions and provide all answers on the question sheet.
Observe standard notation and problem solving methods for all solutions.

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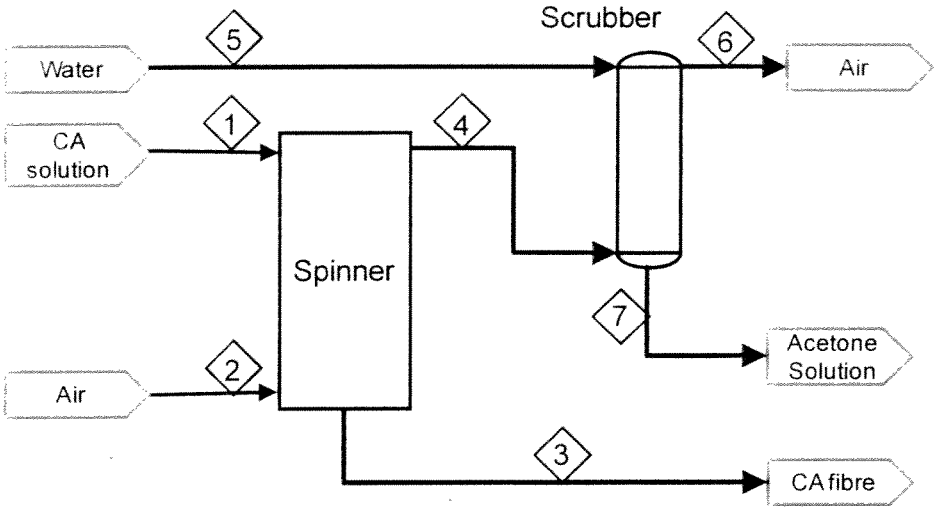
1. In the steady state spinning process shown below, cellulose acetate fibres (CA, stream 3) are spun from a solution of CA and acetone (stream 1). The liquid fibres are dried with warm air (stream 2), and all of the acetone leaves with the air (stream 4). The majority of the acetone is absorbed into water (stream 5) in a scrubber, and recycled back to the process for acetone recovery (stream 7). The exiting air contains a small percentage of acetone (stream 6) which is neglected for the moment.



Air: M=29; SG is unknown
Acetone (C_3H_6O): M=58; SG=0.791
Cellulose Acetate: molar mass and SG are unknown

Material Balance Table: Mass Basis SS, no rxn: **IN=OUT**

Component	1	2	3	4	5	6	7
Cellulose acetate (CA)	0.20	-	1.0	-	-	-	-
Acetone (S)	0.80	-	-	x_{S4}= 0.333	-	-	x_{S7}
Air (A)	-	1.0	-	x_{A4}= 0.667	-	1.0	-
Water	-	-	-		1.0	-	x_{W7}
Flow (T/day)	50	F_2	F_3	F_4	2	F_6	F_7

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a) (10 points) Stream 4 is 20 mole percent acetone. Convert this composition to a mass basis, and enter the result in the material balance table.

For 100 mol Stream 4

	gmol	M	mass (g)	mass fraction
Acetone	20	58	1160	0.333
Air	80	29	2320	0.667
	100		3480 g	

b) (10 points) Now that you have solved for the stream 4 composition, complete a degrees of freedom analysis on the process. *If you were not able to solve part (a), use x_{S4}=0.20 and x_{A4}=0.80.*

Process step	**Spin**	**Scrubber**	**Overall**
Streams	1,2,3,4	4,5,6,7	**1,2,3,5,6,7**
Unknowns	3	5	**6**
Material Balances	3	3	**4**
Σx_i	—	1	**1**
Process Spec	—	—	**0**
Basis	—	—	**0**
Degrees of freedom	0	1	**1**

c) (5 points) What vessel(s) or process step(s) should be chosen as the starting point for the material balance solution? Why?

The spinner because degrees of freedom = 0
so # equations = # unknowns.

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d) (10 points) Write the material balances and other equations which apply to the spinner, and solve as many as possible.

CA: $0.20(50\,T/day) = \boxed{F_3 = 10\,T/day}$ ✱3

S: $0.80(50\,T/day) = x_{S4} F_4 = 0.33 F_4$ ✱

A: $F_2 = x_{A4} F_4 = 0.67 F_4$ ✱

$= 0.67\left[\frac{0.80}{0.33}\left(50\frac{T}{day}\right)\right]$

$\boxed{F_2 = 80\frac{T}{day}}$ 3 $\quad\therefore\quad \boxed{F_4 = 120\frac{T}{day}}$ 3

$F_3 = 10\,T/day$

* $F_2 = 160\,T/day$

* $F_4 = 200\,T/day$

units missing -2
units T -1

$F_1 + F_2 = F_5 + F_4$

1 for all correct

e) (15 points) Complete the material balances for the rest of the process, solving for all remaining unknowns.

Scrubber

S: $0.33(120\,T/day) = x_{S7} F_7 = 40\,T/day$ ✱

A: $0.67(120\,T/day) = \boxed{F_6 = 80\,T/day}$ 5 ✱

W: $2\,T/day = x_{W7} F_7 = 2\,T/day$ ✱

$\therefore\ \boxed{F_7 = 42\,T/day}$ 5

$40\,T/day$

* $F_6 = 160\,T/day$

$F_7 = 42\,T/day$

$x_{W7} = \frac{2}{42} = 0.0476$

$x_{S7} = \frac{40}{42} = 1 - 0.0476 = 0.9524$

or $\boxed{\begin{aligned} x_{W7} &= 0.05 \\ x_{S7} &= 0.95 \end{aligned}}$ 5

$x_{W7} = 0.05$

$x_{S7} = 0.95$

$\Sigma x \neq 1$ -1

F_6 incorrect due to ECF -1
(must have correct for full marks)

$F_4 + F_5 = F_6 + F_7$

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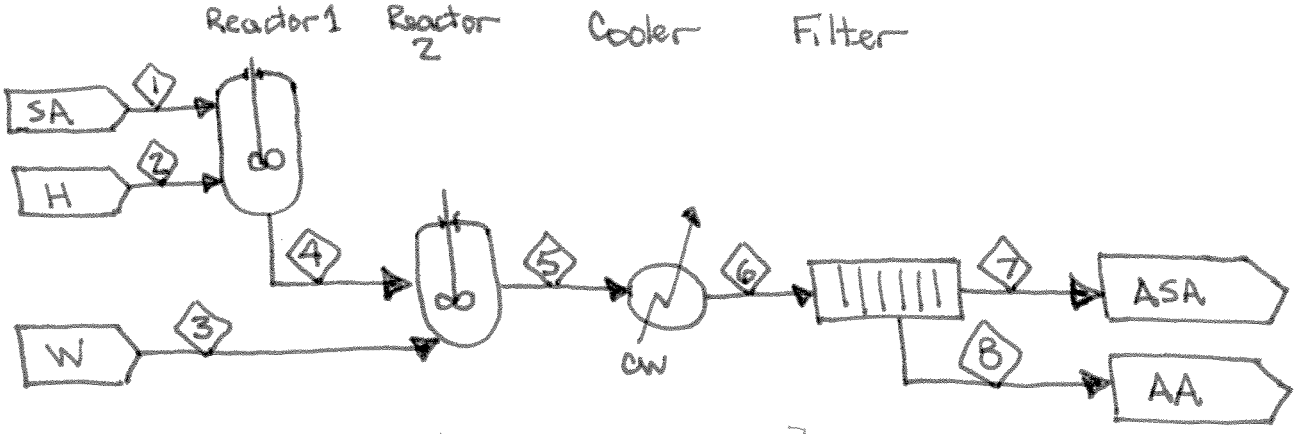
2. The production of acetylsalicylic acid involves two reaction stages, cooling, and a final filtration step. In the first stirred tank reactor, two feed streams (crystalline salicylic acid (SA), and pure acetic anhydride (H)) are combined at 70°C. The product stream from the first reactor contains some unreacted H and the products acetylsalicylic acid (ASA) and acetic acid (AA). This stream is fed to a second stirred tank reactor, where fresh water (W) is added and the remaining H reacts to completion, giving a liquid product stream of ASA and AA. The product stream from the second reactor is cooled in a heat exchanger to crystalize the ASA out of solution, and then filtered to separate the wet ASA crystals from the liquid AA byproduct.

a) (15 points) Draw a flowsheet of the process using best practices and equipment icons.



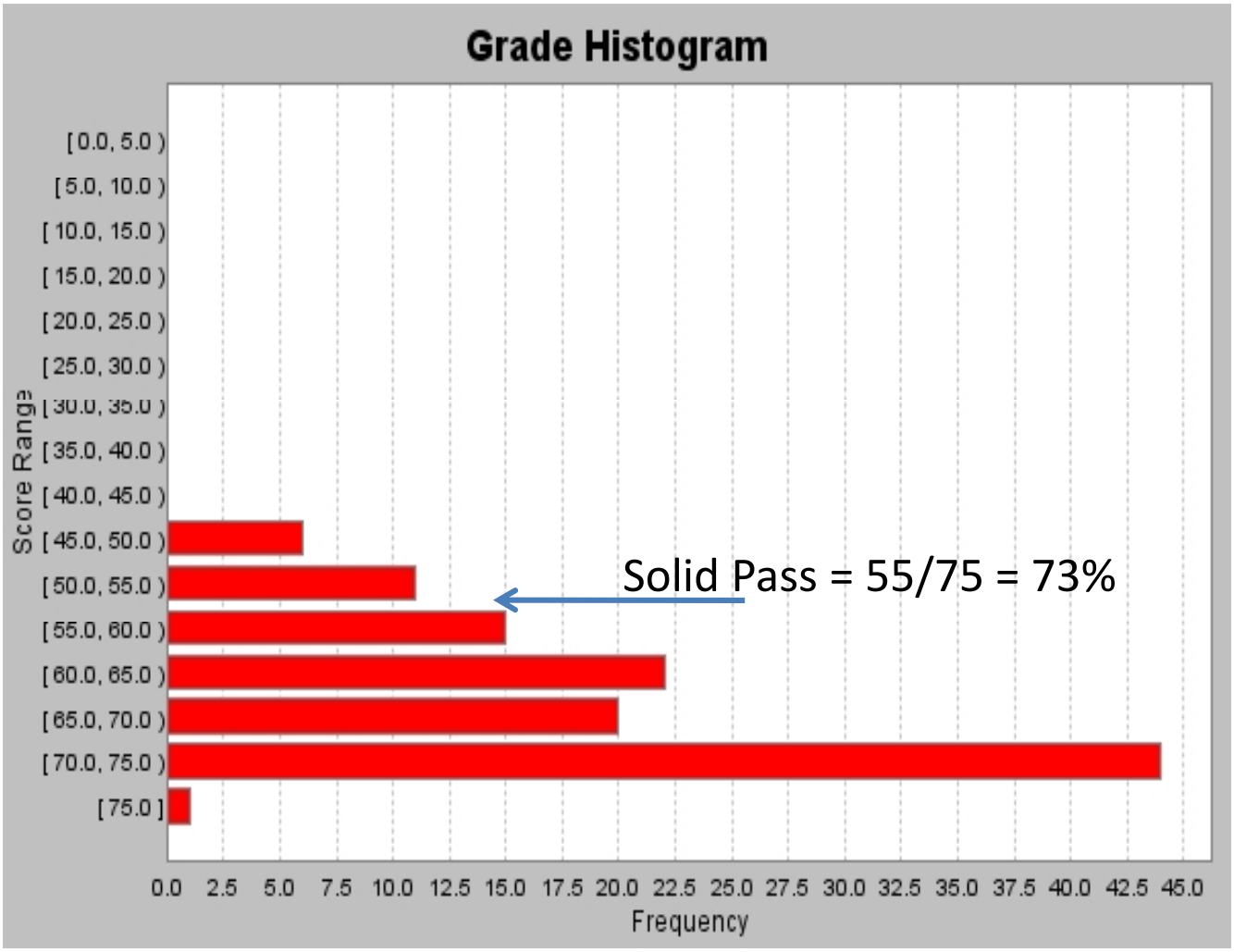
vessels 4 (icon + label)
feeds + products 5 (position + label)
streams 6 (connections, arrows, labels)
} -½ each error
-1 if composition on stream.
And -1 for arrows not touching vessels, stream labels not touching

b) (10 points) Complete the material balance table below, following the notation in the first two streams. If a component is present, insert the appropriate x_{ij} variable. Otherwise, insert a dash (-). The stream numbers must match your flowsheet above: add or delete columns if necessary.

Component	1	2	3	4	5	6	7	8	9
SA	$x_{SA,1}$	-	—	—	—	—	—	—	
H	-	$x_{H,2}$	—	x_{H4}	—	—	—	—	
W	-	-	x_{W3}	—	x_{W5} *	x_{W6} *	x_{W7} *	x_{W8} *	
ASA	-	-	—	x_{ASA4}	x_{ASA5}	x_{ASA6}	x_{ASA7}	—	
AA	-	-	—	x_{AA4}	x_{AA5}	x_{AA5}	x_{AA7}	x_{AA8}	
Flow	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9

* If water is fed in excess, x_{W5} to x_{W8} are non-zero. Since one of the products is acetic acid, this is the most likely outcome.

* The water does not leave as a pure stream from any of the vessels.



Average: **64**

Median: **67**

Max: **75** Min: **46**

Count: **119** Std Dev: **8**

Clear Pass: 55/75

(no D's in this course! – MT1<50/75=F*0.15)

A range >70/75 (45/120 students!)