Introduction to Chemical Engineering

Chapter 06

Spreadsheets
(Calculating the Cost of the Base)

6.1 The calculation scheme

Available NaOH solutions from the XYZ company

Preparation	Concentration	Preparation	Concentration
A	5.0	K	30.0
B	7.5	L	32.5
C	10.0	M	35.0
D	12.5	N	37.5
E	15.0	O	40.0
F	17.5	P	42.5
G	20.0	Q	45.0
H	22.5	R	47.5
I	25.0	S	50.0
J	27.5	T	52.5

Price formula depending on NaOH concentration

$$\$/L = 0.058\left(c_{NaOH}\right)^{1.4} + 0.017$$

c_{NaOH}: concentration of NaOH in units of mM

6.1 The calculation scheme

From chapter 5…

$$c_{HCl} = 14.0\ mM$$

$$\dot{V}_{HCl\ solution} = 11600\ L/hr$$

System

HCl from Manufacturing Process

HCl Tank

NaOH pumping cost

$\$0.173/L \quad$ for $c_{NaOH} < 13\ mM$

$\$0.194/L \quad$ for $c_{NaOH} \geq 13\ mM$

NaOH Tank

$c_{NaOH} = ?$

$\dot{V}_{NaOH\ solution} = ?$

Neutralization Reactor

To Disposal

$$c_{HCl} = c_{NaOH} = 0\ M$$

$$\frac{r_{consumption,HCl}}{r_{consumption,NaOH}} = \frac{1}{1} = 1$$

$$HCl + NaOH \rightarrow H_2O + NaCl$$

Steady-State Mole Balance for HCl

$$\sum_{\substack{input \\ streams}} \left(c_{HCl} \dot{V}_{HCl\ solution} \right)_{in} + r_{formation,HCl} = \sum_{\substack{output \\ streams}} \left(c_{HCl} \dot{V}_{HCl\ solution} \right)_{out} + r_{consumption,HCl}$$

$$\underset{0}{} \qquad \underset{0}{}$$

$$r_{consumption,HCl} = r_{consumption,NaOH}$$

$$c_{NaOH} \dot{V}_{NaOH\ solution} = c_{HCl} \dot{V}_{HCl\ solution}$$

Steady-State Mole Balance for NaOH

$$\sum_{\substack{input \\ streams}} \left(c_{NaOH} \dot{V}_{NaOH\ solution} \right)_{in} + r_{formation,NaOH} = \sum_{\substack{output \\ streams}} \left(c_{NaOH} \dot{V}_{NaOH\ solution} \right)_{out} + r_{consumption,NaOH}$$

$$\underset{0}{} \qquad \underset{0}{}$$

$$\dot{V}_{NaOH\ solution} = \frac{c_{HCl} \dot{V}_{HCl\ solution}}{c_{NaOH}}$$

6.1 The calculation scheme

Several possible strategies for calculations

- ➤ Hand-written calculation sheet

- ➤ Algebraic cost function

- ➤ Computer program

- ➤ Spreadsheet

6.2 Setting up a spreadsheet

Formatting and headings

➢ In cell C1, enter an overall title "NaOH Costs" and change it to Bold style.

➢ In cells A2 through F2, put the headings for the columns.

	A	B	C	D	E	F
1			**NaOH Costs**			
2	Conc.	Flow	Price	Cost	Pmp Cost	Tot Cost
3	(mM)	(L/hr)	($/L)	($/hr)	($/hr)	($/hr)
4						
5						

➢ In cells A3 through F3, enter the appropriate units.

➢ Use the center-justify tool.

➢ Adjust some column widths.

column	width	column	width
A	4	G	1
B	6	H	12
C	6	I	5
D	7	J	3
E	7	K	1
F	7	L	4

➢ Choose the font and its size (10-point Calibri)

6.2 Setting up a spreadsheet

6.2.1 Setting up the spreadsheet for the acid-neutralization problem

➢ **NaOH concentrations (Column A):**

1. In cell A5, enter the lowest concentration (5.0).

2. Set the number format to display one digit to the right of the decimal point.

3. Select A6 and type the formula "=A5+2.5".

4. Drag the handle from A6 through A24.

5. Put the given information.

	A	B	C	D	E	F	G	H	I	J	K	L
1			NaOH Costs									
2	Conc.	Flow	Price	Cost	Pmp Cost	Tot Cost		HCl flow (L/hr) =	11600			
3	(mM)	(L/hr)	($/L)	($/hr)	($/hr)	($/hr)		HCl conc (mM) =	14			
4												
5	5.0							NaOH cost ($/L) =				
6	7.5								0.0058 *C^	1.4	+	0.017
7	10.0											
8	12.5							Pumping cost ($/L) =				
9	15.0							C<13 mM	0.173			
10	17.5							C>=13 mM	0.194			
11	20.0											

➢ **NaOH Flow rate (Column B):**

1. Select B5 and type the formula "=I3*I2/A5" (see equation 6.2).

2. Drag the handle from B5 through B24.

$$\dot{V}_{NaOH\ solution} = \frac{c_{HCl} \dot{V}_{HCl\ solution}}{c_{NaOH}} \quad (6.2)$$

3. Select B5 and type a dollar sign ($) in front of the number "=I$3*I$2/A5"

4. Drag the handle from B5 through B24 again.

5. Set comma style and remove decimal points.

6.2 Setting up a spreadsheet

6.2.1 Setting up the spreadsheet for the acid-neutralization problem

➢ **NaOH Price (Column C):**

1. Select C5 and type the formula "=H$6*A5^J$6+L$6" (see equation 6.1). $\$/L = 0.058(c_{NaOH})^{1.4} + 0.017$

2. Drag the handle from C5 through C24.

3. Set the number format to display three digits to the right of the decimal point.

4. Set dollar sign ($) in front of the number.

➢ **NaOH Purchase Cost (Column D):**

1. Select D5 and type the formula "=B5*C5".

2. Drag the handle from D5 through D24.

3. Set comma style and remove decimal points.

4. Set dollar sign ($) in front of the number.

6.2 Setting up a spreadsheet

6.2.1 Setting up the spreadsheet for the acid-neutralization problem

➢ **NaOH Pumping Cost (Column E):**

1. Select E5 and type the formula "=IF(A5<13,I$9*B5,I$10*5)".

2. Drag the handle from E5 through E24.

3. Set comma style and remove decimal points.

4. Set dollar sign ($) in front of the number.

➢ **Total Cost (Column F):**

1. Select F5 and type the formula "=D5+E5".

Given NaOH pumping cost

$$\$0.173 / L \quad for\ c_{NaOH} < 13\,mM$$

$$\$0.194 / L \quad for\ c_{NaOH} \geq 13\,mM$$

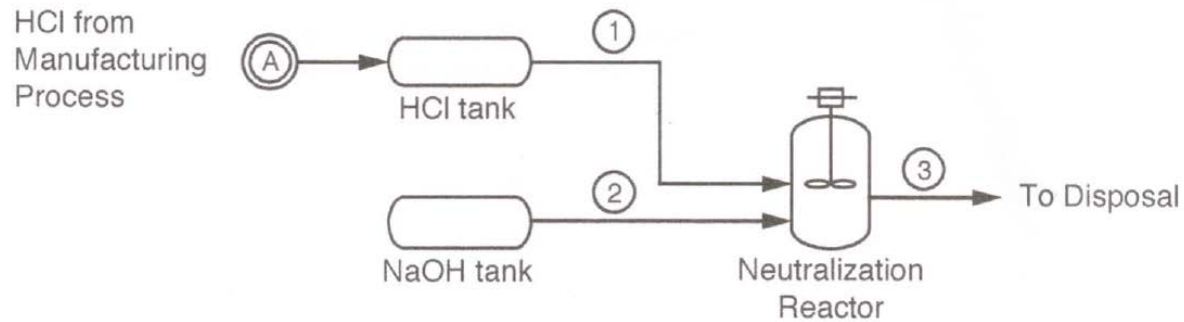|	A	B	C	D	E	F	G	H	I	J	K	L
1			NaOH Costs									
2	Conc.	Flow	Price	Cost	Pmp Cost	Tot Cost		HCl flow (L/hr) =	11600			
3	(mM)	(L/hr)	($/L)	($/hr)	($/hr)	($/hr)		HCl conc (mM) =	14			
4												
5	5.0	32,480	$0.072	$2,345	$5,619	$7,964		NaOH cost ($/L) =				
6	7.5	21,653	$0.114	$2,477	$3,746	$6,223			0.0058	*C^	1.4 + 0.017	
7	10.0	16,240	$0.163	$2,642	$2,810	$5,452						
8	12.5	12,992	$0.216	$2,808	$2,248	$5,055		Pumping cost ($/L) =				
9	15.0	10,827	$0.274	$2,967	$2,100	$5,067		C<13 mM	0.173			
10	17.5	9,280	$0.336	$3,117	$1,800	$4,918		C>=13 mM	0.194			
11	20.0	8,120	$0.401	$3,260	$1,575	$4,835						
12	22.5	7,218	$0.470	$3,395	$1,400	$4,796						
13	25.0	6,496	$0.542	$3,524	$1,260	$4,784		Changeable				
14	27.5	5,905	$0.617	$3,646	$1,146	$4,792						
15	30.0	5,413	$0.695	$3,764	$1,050	$4,814						
16	32.5	4,997	$0.776	$3,876	$969	$4,845						
17	35.0	4,640	$0.859	$3,984	$900	$4,884						
18	37.5	4,331	$0.944	$4,088	$840	$4,928						
19	40.0	4,060	$1.032	$4,188	$788	$4,976						
20	42.5	3,821	$1.122	$4,286	$741	$5,027						
21	45.0	3,609	$1.214	$4,380	$700	$5,080						
22	47.5	3,419	$1.308	$4,471	$663	$5,134						
23	50.0	3,248	$1.404	$4,559	$630	$5,189						
24	52.5	3,093	$1.502	$4,645	$600	$5,245						

6.3 Graphing

Chart of total cost versus NaOH concentration
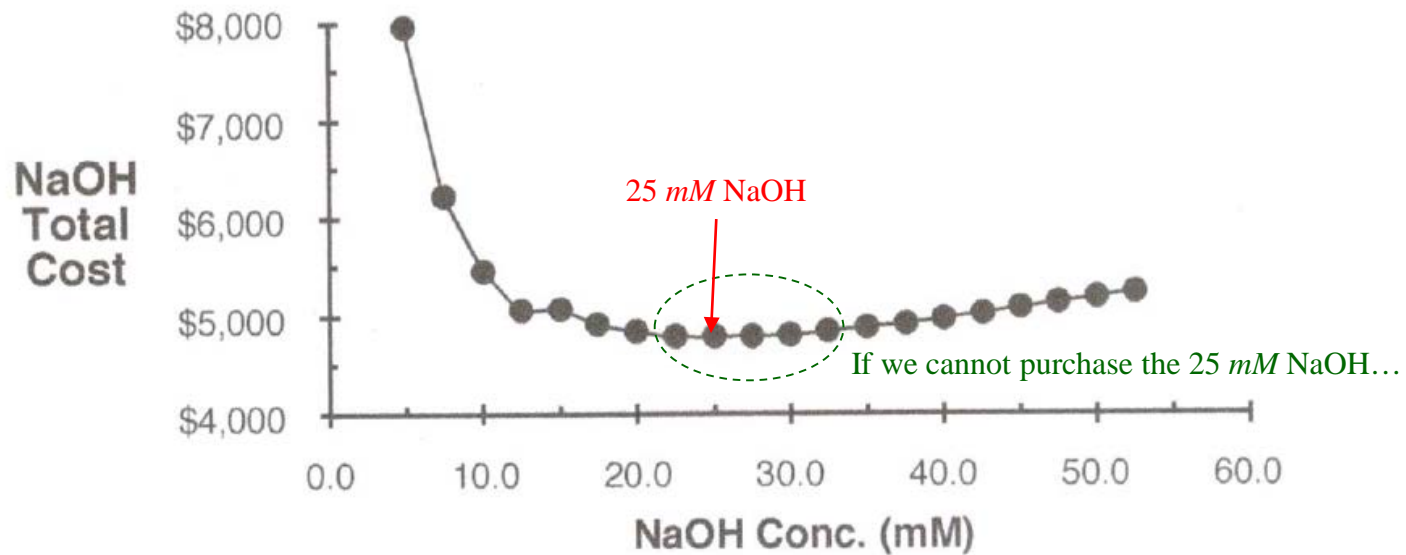
6.3 Graphing

Process flow diagram with stream table

Flows kg/h

Line no.	1	2	3	ABC Chemical Co.	
Stream Component	Acid feed	Base feed	Reactor outlet		
HCl	6	—	—	Acid neutralization	
NaOH	—	6	—	1×10^8 L/yr	
H₂O	11594	6490	18096	Sheet no. 1	
Total	11600	6496	18096	Dwg by	Date
				Checked	1 Sep.2010