F.1

An aqueous stream contains 3.25 g A/100 g water, which is to be extracted with one-third the mass of methylene chloride (CH_2Cl_2). The following data are available for the equilibrium of A between water and methylene chloride.

g A/100 g water	g A/100 g CH_2Cl_2
0.125	0.46
0.25	0.83
0.5	1.55
1.0	3.86
1.5	7.0
2.0	10.8

What is the number of equilibrium stages required to recover 98% of A?

F.2

A fermentation broth contains 100 mg/L nisin, which is to be extracted with butyl acetate (BA). An extractor with 6 stages is available for the extraction. The following data are available for the equilibrium of nisin between water and BA.

mg nisin/L water	mg nisin/L BA
10	23.6
20	36.8
30	53.5
50	77.5
70	98.4
90	117

The objective of the extraction is to recover 97.5% of the nisin. What is the minimum S/F ratio necessary to accomplish this extraction in 6 stages?

F.3

You are responsible for testing a new pilot-scale extractor with 75 cm height and 4 cm diameter. You use a solute having a partition coefficient of 3.5 in a feed of 75 mL/min. The solvent has a flowrate of 42 mL/min.

a) If 95% of the solute is extracted, find the HETS of this pilot extractor.
b) You want to scale up to a feed of 3,500 mL/min, and keep the S/F and volumetric throughput the same. If the target is 98% extracted, what is the height and diameter of the extractor needed?

F.4

Extraction experiments are conducted with the hypotension (blood pressure increasing) drug Eitemanic dissolving a known mass of pure Eitemanic into 10 mL of water, extracting with 10 mL of amyl acetate, and measuring the concentration of Eitemanic in both phases. The following results are obtained:

Eitemanic (**water** phase) (mM)	Eitemanic (**amyl acetate** phase) (mM)
1	7.5
2	14
3	20
4	26
5	31
6	35
8	42

The extraction processes is to be scaled-up to the manufacturing scale, which involves 8.0 L/min of an aqueous stream containing an Eitemanic concentration of 8 mM. The target is to extract 95% of the Eitemanic.

a) What is the minimum flowrate of extractant (amyl acetate) that will be needed to accomplish this extraction? Draw and label the corresponding operating line as "MINIMUM". What is the equation of this line?
b) If 1.6 L/min of extractant (amyl acetate) are used, what is the number of theoretical stages required to recover 95% of the Eitemanic?

F.5

Dawgimycin has a constant partition coefficient of 2.5 between 1-octanol and water. An aqueous solution containing 150 mg/L dawgimycin is to be extracted with 1-octanol. Calculate the fraction of the dawgimycin extracted into 1-octanol for each of the following conditions (you should not use a graphical solution):

a) Contact (i.e., bring to equilibrium) 1 liter of 1-octanol with 1 liter of the dawgimycin solution.
b) Contact 0.5 liter of 1-octanol with 1 liter of the dawgimycin solution. After equilibrium and separation, contact the remaining 1 liter raffinate with a second fresh 0.5 liter of 1-octanol.
c) Conduct a countercurrent extraction using 1 liter/min of 1-octanol in contact with 1 liter/min of the dawgimycin solution over 2 equilibrium stages.
d) Conduct a countercurrent extraction using 1 liter/min of 1-octanol in contact with 1 liter/min of the dawgimycin solution over 3 equilibrium stages.

F.6

A countercurrent extractor has four equilibrium stages and is used to separate “A” from “B”. The feed contains 60 mg A/L and 40 mg B/L, and their constant partition coefficients in the solvent are K(A) = 3 and K(B) = 1.

Define R = S/F. Write six equations:

a) The “extraction coefficient equation” for A: x_4(A) as a function of R.
b) The “extraction coefficient equation” for B: x_4(B) as a function of R.
c) A material balance for A over the entire four stage extractor: y_1(A) as a function of x_4(A) and R.
d) A material balance for B over the entire four stage extractor: y_1(B) as a function of x_4(B) and R.
e) An equation for solvent-free purity of A in the exiting extract.
f) An equation for the fraction of the mass of A recovered in the exiting extract. (That is, the mass of A exiting in the extract divided by the mass of A entering the extractor in the feed.)

Construct an excel for R between 0.01 and 1.0 (i.e., spreadsheet column A). Use the equations derived above to calculate in subsequent columns: x_4(A), x_4(B), y_1(A), y_1(B), purity, fraction of mass of A recovered. Make a single plot with R on the x-axis and “purity” and “fraction of mass recovered” on the y-axis.

At what R would you operate the extractor? Explain.