must be fed to the first bath. Some of the effluent from the first bath can be used as the feed water to the second, but the water flow through the second bath is an order of magnitude less (about 12 lb_m/min), so most of the dilute effluent from the first bath must be sent to the separation process.

One can recover solvent from the combined bath effluents at sufficiently high purity (less than 1 weight percent water) to permit reuse with a single modest column (five stages and reflux ratio of 2). Water recovery to permit reuse in the first bath is more problematic. Large columns with high reflux ratios are required to increase water purity above 99%, the maximum allowed concentration of the effluent from the first bath; use of multiple columns is undesirable since water (the highest concentration component) goes overhead in each column. Therefore, most designs send some water to waste treatment and replace it with fresh water. The trade-offs between the cost of water disposal, cost of solvent lost in the wastewater, and column energy and capital costs dictate the final design. Instructors may use cost information from standard design texts (*e.g.,* Turton, *et al.*[6]) to evaluate the trade-off. Other configurations that students have considered include sending the effluent from each bath to separate columns and sending only the effluent from the second bath (with the highest solvent concentration) to a column. In the latter configuration, all of the effluent from the first bath is sent to waste treatment.

CONCLUSIONS

Three design problems that illustrate hollow fiber membrane manufacturing processes and use of membranes in separation processes are described. The problems have been used in classes that range from the freshman/sophomore to senior years in the curriculum. These problems are unique in their emphasis on membrane manufacture. Upon request, detailed problem statements and sample solutions can be provided.

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ChE stirred pots

After reading David Lindley's book *Boltzmann's Atom,* Professor Robert R. Hudgins (University of Waterloo) was inspired to pen his thoughts on two subjects very familiar to chemical engineers. He shares those thoughts here...

Ludwig Boltzmann's Disorder

Herr Doktor Boltzmann has a vision rare
Of gases as a flight of tiny balls
In random 3-D motion that would dare
Allow him to explain their force on walls.

Ernst Mach insists that physics must be strict
And not be mocked, since atoms are not real.
Observables alone cannot be tricked;
Thereby, vague theories shall be brought to heel.

But Boltzmann's disarray achieves a feat—
Bold inf'rences drawn from how atoms fly.
He reinterprets what is meant by heat,
And temp'rature and pressure by the bye.

At length, chaotic motion proves its worth,
As entropy's conceived and has its birth.

Gibbs' Phase Rule

J. Willard Gibbs, the pedant in this tale,
Reflecting on an elemental state
Of matter at his alma mater, Yale,
Took to his books and never sought a mate.

In love with equilibrium he stayed
(No doubt both metaphorical and real).
When do P phases coexist? He played
With arguments with consecrated zeal.

As countrymen pursued uncivil war
'Round F degrees of freedom for their slaves,
Gibbs solved, with C components of savoir,
A theorem that, when understood, draws raves.

Robust and brief ('twould make a fine tatoo),
Proclaims **F equals C less P plus two.**