LETTERS TO THE EDITOR

TO THE EDITOR

It is worth mentioning a few points concerning the recent article by Timm and Cooper (*5*). The authors state that the nucleation rate is an exponential function of the growth rate

$$J = K_N' \, r^i \, M^j \qquad (1)$$

Although this relationship has been verified experimentally by a number of authors (*1, 2*), the equation distorts the physical picture and, in some cases, does not follow from fundamental analysis.

Nucleation and growth depend on the same operating variables of the crystallizer, but the manner in which these phenomena depend on the variables is not the same. It is an oversimplification of the physical situation to state that the nucleation rate is necessarily a function of the growth rate.

The fundamental analysis leading to a form of Equation (1) was first presented by Randolph and Larson (*3*). The steady state equation for the population density in a continuous, unseeded, nonclassified, well-mixed, isothermal crystallizer is

$$n = n^0 \exp\left(-L/rT\right) \qquad (2)$$

$$n^0 = J/r \qquad (3)$$

The following equation can be used to relate the level of supersaturation to the nucleation rate

$$J = K_N \, s^b \, M^j \qquad (4)$$

It should be noted that Equation (4) is an approximation to Volmer's homogeneous nucleation model only for high values of b ($b \geqq 4$). For the study in point (*5*), $b = .9$, indicating that heterogeneous nucleation might well be controlling the nucleation rate. To continue with the derivation of Equation (1), the growth rate is assumed proportional to an exponential function of supersaturation

$$r = K_g \, s^a \qquad (5)$$

Equation (1) is obtained by combining Equations (4) and (5) where

$$K_N' = K_N/K_g^{\,i}; \quad i = b/a \qquad (6)$$

The analysis breaks down when the nucleation rate is not a function of supersaturation, i.e., $b = 0$. In this case Equations (4) and (5) are not related to each other. Rosen and Hulburt (*4*) found that the vacuum crystallization of potassium sulfate from aqueous solution produced just such an analysis as stated above

$$J = K_N \, M \qquad (7)$$

The nucleation rate was independent of supersaturation.

Although the nucleation rate and growth rate can be related in most cases by eliminating the common independent variable of supersaturation, one must be careful of the interpretation. In the case where nucleation rate is independent of supersaturation, the analysis leading to Equation (1) breaks down entirely.

NOTATION

a = kinetic order for crystal growth
b = kinetic order for crystal nucleation
i = relative kinetic order, $i = b/a$
J = nucleation rate, l/hr.
K_g = growth rate constant
K_N = nucleation rate constant
M = suspension density, g.-crystal/density
n = steady state crystal population density, number/mm.
r = linear crystal growth rate
s = supersaturation

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Howard N. Rosen
North Central Forest
Experiment Station
Forest Sciences Laboratory
Southern Illinois University
Carbondale, Illinois 62901

TO THE EDITOR

The fundamental design equations for the separation of gases by permeation were published by Weller and Steiner (*1, 2*). These authors derived equations for the compositions of the streams (when a binary gas mixture diffuses through a permeable membrane) and also for the area required for a desired rate of operation.

The area depends on the volume of feed to a permeation cell, the permeability, the ratio of permeabilities of the two materials, the pressures, and the final composition. An exact equation is given for this calculation, and a simpler approximate method is also given.

It is likely that those using these articles have merely bypassed the exact equation and gone on to use the approximate method. However, the availability of computers makes the exact equation easier to use so that it is important to note that this equation is printed incorrectly in both articles. The following is a derivation leading to the correct form of this equation.

For a permeation cell, let n_{A0} and n_{B0} be the standard volumes of substances A and B in the feed that is the high pressure part of the cell. The cell operates with pressures P upstream and p downstream. The cell permeability coefficients are Q_A and Q_B in std.cc./(sq.cm.-sec.-cm. Hg). (These are uncorrected for thickness. $Q_A = P_A/t$, where t is the thickness.) It is desired to calculate the required area S.

For the case of laminar flow Weller and Steiner list these differential equations as

$$dS = \frac{-\,dn_B}{Q_B\left(\dfrac{P}{i+1} - \dfrac{p}{f(i)+1}\right)} \qquad (1)$$

$$dn_B = \frac{n_B di}{f(i) - i} = \frac{n_{B0}(n_B/n_{B0})di}{f(i) - i} \qquad (2)$$

where $i = n_A/n_B$ and $f(i) = dn_A/dn_B$ and where n_A and n_B are the volumes of substances A and B in the high pressure part of the cell at any point. The function $f(i)$ is calculated by the following equations:

$$a = Q_A/Q_B \qquad (3)$$

$$A = ((1-a)p/P + a)/2 \qquad (4)$$

$$C = -\,((1-a)p/P - 1)/2 \qquad (5)$$

$$B = -\,AC + a/2 \qquad (6)$$

$$f(i) = Ai - C + (A^2 i^2 + 2Bi + C^2)^{0.5} \qquad (7)$$

Combining Equations (1) and (2)

$$dS = -\frac{n_{B0}}{Q_B} \frac{(n_B/n_{B0})\,di}{(f(i)-i)\left(\frac{P}{i+1}-\frac{p}{f(i)+1}\right)} \tag{8}$$

Integrating from i_0 to i_f, the working equation is obtained

$$S = \frac{n_{B0}}{Q_B}\int_{i_f}^{i_0} \frac{(n_B/n_{B0})\,di}{(f(i)-i)\left(\frac{P}{i+1}-\frac{p}{f(i)+1}\right)} \tag{9}$$

This equation should be used in place of Equation (16) in reference *1*, and of Equation (9) in reference 2.

ACKNOWLEDGMENT

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JAMES O. OSBURN
DEPT. OF CHEMICAL ENGINEERING
UNIVERSITY OF IOWA
IOWA CITY, IOWA 52240

TO THE EDITOR

The *AIChE Journal* should be commended for switching to the metric system. The need for metrication (as the British call it) is particularly appreciated by anyone doing business overseas. Our old system of units is obsolete on an international basis. However, the metric system as practiced abroad is something rather different from what you now demand for the *Journal.* A major justification for going metric is to conform to the practices of other industrial nations. No nation practices the pure SI system of units, and few if any international journals in science or engineering require complete conformity to this system.

I believe the *AIChE Journal* should adopt the metric system in the sense of eliminating inches, pounds, °F, and the like. However, a number of reasonable exceptions to the strict SI system should not only be tolerated but actively encouraged. Our aim should be to enhance communication and commerce; and to this end, we should accept any metric based unit which is commonly used by the international scientific community.

I am not prepared to make an encyclopedic listing of all those non-SI units which should be allowed. However, the following many serve as a general guide:

1. Certain units based on secondary standards: Electron volts, light years, gravities (of acceleration) are examples. In chemical engineering, I feel that the atmosphere should be retained as an alternate unit of pressure and would also accept the torr (or mm of Hg).
2. Certain common CGS units: Examples are poise (centipoise), calorie, watt-hour, and dynes/cm. It seems a disservice to beginning students if we ignore the properties of water. It has a density of about 1 gm/cm^3, a heat capacity of about 1 cal/gm °C, and a viscosity of about 1 centipoise. These close approximations are one important rationale for the student learning the metric system in the first place. Also, CGS units of this type are almost universally used in the physical chemistry literature.
3. Temperature: The BBC is gradually converting the British housewife, but not by telling her to dress the children for 270°K weather. Degrees Celsius are becoming internationally accepted. It is incredibly pedantic for us to insist upon Kelvin and, indeed, presumptuous to expect the rest of the world to subtract 273.15 everytime they see a temperature in the *AIChE Journal.*
4. Times and velocities: Obviously, hours, days, and years must remain acceptable (can you imagine a woman giving her age in gigaseconds?). Certain rates based on these secondary time units must also be accepted. Quoting something like a corrosion rate in picometers per second borders on the absurd.
5. Angles and angular velocities: Angles in degrees (but decimal fractions please) and such standards as RPM should be allowed. A base of 360 may not be the best possible, but at least I can express such simple angles as 30°, 45°, 60°, and 90° with a finite number of digits.

My most recent issue of *Science* (the AAAS publication) contains such SI no-no's as °C, angstroms, electron volts, and circular degrees. *Science* forces its authors to use metric units but does not demand strict adherence to the SI system. I believe their policy is a reasonable one for the *AIChE Journal.* Ours is an engineering journal published by an engineering society. We would be ill advised to become more "scientific" than *Science.*

Perhaps you underestimate the shock of most practicing chemical engineers when forced to abandon such favorites as BTU/ft^2 hr °F. Please let water under one atmosphere boil at 100°C. for the time being.

E. B. NAUMAN
UNION CARBIDE CORP.
CHEMICALS AND PLASTICS
BOUND BROOK, N. J. 08805

[EDITOR'S NOTE: Dr. Nauman's suggestions are eminently reasonable, and the *Journal* will follow his recommendations. However, authors may, if they desire, conform to the stricter SI System outlined in the March issue.]

TO THE EDITOR

I was electrified by your editorial on "Metrology"; I applaud and congratulate you. In one fell swoop you have hurled this aspect of American chemical engineering square into the twentieth century. Unfortunately, I think that the chemical construction business here will be slow in following and may well be the last industry anywhere to go metric; nevertheless your effort is a bold and needed first step.

Still, I will shed a tear for my dear and faithful friends, the BTU and the calorie.

OCTAVE LEVENSPIEL
DEPT. OF CHEMICAL ENGINEERING
OREGON STATE UNIVERSITY
CORVALLIS, OREGON 97331