Letters

Equilibrium: A Teaching/Learning Activity

Back in September of 1998, Wilson contributed an excellent exercise on equilibrium (*J. Chem. Educ.* **1998,** *75*, 1176); comments by Sadavoy and by Paiva and Gil (*J. Chem. Educ.* **1999,** *76*, 900) further refined the exercise. I would like to add two points to further improve this excellent classroom activity. Most importantly, readers should note that Wilson's equation for K_{eq} in the instructions for "Activity #1" includes a typo in section 6; the equation should read "number of items P/number of items R", and *not* vice versa.

Second, Paiva and Gil suggested that rounding errors in K_{eq} can be avoided by giving students 10 boxes of 40 matches, instead of just 40 matches. A much simpler solution to the problem of round-off errors would be to simply start with the "correct" number of matches. For example, as stated by Wilson, if the R-to-P transfer fraction (k_{fwd}) is $^3/_4$ and the P-to-R transfer fraction (k_{rev}) is $^1/_8$, then K_{eq} should be 6. If the total number of matches between the two teams is 40, then solving for $(40 - x)/x = 6$, at equilibrium R (= x) must have 5.7 matches and P, 34.3. Clearly, without breaking matches into pieces, an accurate value for K_{eq} is not possible when starting with 40 matches. Starting with 42 matches, however ($x = 6$), will yield an accurate value of $K_{eq} = 36/6 = 6$.

The trick is to choose the total number of matches ($\#m_{tot}$) such that each team, R and P, ends with an integral number of matches at equilibrium and the quotient P/R yields an accurate value for K_{eq}. Solving the algebraic expression for the equilibrium constant, $(\#m_{tot} - x)/x = K_{eq}$, we get $\#m_{tot} = x(1 + K_{eq})$. In this expression, x is the number of matches held by team R at equilibrium. If x is chosen so that the product $x(1 + K_{eq}) = \#m_{tot}$ is an integer, then round-off errors will cancel out, and an accurate value of K_{eq} will be obtained from the exercise.

For example, for Wilson's initial transfer rates of $k_{fwd} = {}^1/_2$ and $k_{rev} = {}^1/_4$, $K_{eq} = 2$; one would have to start with either 39 or 42 matches (x = 13 or 14, respectively) in order to end with an accurate value of K_{eq}. Similarly, for transfer rates of $k_{fwd} = 0.88$ and $k_{rev} = 0.11$, $K_{eq} = 8.0$; starting with either 36 or 45 matches (x = 4 or 5) will yield an accurate value of K_{eq}. Starting with 40 matches would yield $K_{eq} = \text{P/R} = {}^{35}/_5 = 7$ instead of 8. Hence using the algebraic expression $\#m_{tot} = x(1 + K_{eq})$ allows one to judiciously choose the initial number of matches so that for any values of k_{fwd} and k_{rev}, the equilibrium situation will yield an accurate value of K_{eq}.

Todd P. Silverstein
Department of Chemistry
Willamette University
Salem, OR 97301
tsilvers@willamette.edu

The author replies:

Thank you to Todd Silverstein for further input and refinements for this Equilibrium Activity. The formula for calculating the appropriate starting numbers of items for each team to give an integer for K_{eq} is useful, although rounding up during the transfer process will still be necessary.

It is very satisfying to have this interest generated and confirms the benefit of sharing activities we find useful in our teaching.

Audrey Wilson
Department of Chemistry
University of Wollongong
Wollongong, NSW 2522, Australia