A Kinetic Study Using Evaporation of Different Types of Hand-Rub Sanitizers

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Because they are more effective than traditional soap and water as antibacterial agents, alcohol-based hand-rubs have become a common sanitizer for a health care worker before and after contact with a patient. Alcohol-based hand-rub sanitizers typically consist of 60% to 75% ethanol, 20% to 35% water, and small quantities of isopropanol, fragrances, thickeners, and moisturizers. Though the quantity of thickener is a trade secret, some brands must have a small quantity of thickener because, even though they appear more viscous than water or ethanol, they are liquids. Other brands must have a slightly larger quantity of thickener because they are gels *(1–5)*. As anyone who has ever used one of these products knows, upon contact with the skin, the sanitizer evaporates.

Kinetics

Kinetics experiments are discussed in general chemistry courses because these experiments teach students about changes in a compound, either physical or chemical, as a function of time. Thus, many times kinetics experiments are done to determine the mechanism of a reaction. Unfortunately, most nursing students and other allied health students taking a general–organic–biochemistry (GOB) course are not interested in reaction mechanisms. However, they do care about how much of a drug or poison a patient retains at some period of time after it is administered.

In an effort to create a laboratory experiment that is relevant to these GOB students, the rate of mass loss due to evaporation of alcohol-based hand-rub sanitizers has been developed into a kinetics experiment. It was found that the gel has a slower rate of evaporation than the liquid. When the data are plotted using first-order kinetics, a straight line is obtained for each type of sanitizer. In contrast, when the data are plotted using zeroth-order or second-order kinetics, a curve is obtained for each type of sanitizer.

Hazards

The hand-rub sanitizers are used daily in hospitals and other medical facilities, and so, except for ingestion, there are no hazards. In addition, because of the water solubility of the sanitizers, the glass or metal plate may be cleaned in a sink with water.

Results and Discussion

By using a balance to monitor the mass of a thin film (on a glass or metal plate) of either a liquid or a gel alcohol-based hand-rub sanitizer, the mass lost due to evaporation was determined. (Sample data may be found in the supporting information.) After the mass data are collected, they may be plotted as zeroth-order ($mass_0 - mass_t$ vs time), first-order ($\ln(mass_0/mass_t)$ vs time), or second-order ($1/mass_t - 1/mass_0$ vs time) kinetics *(6–8)*. Sample zeroth-, first-, and second-order expressions are plotted in Figures 1, 2, and 3, respectively.

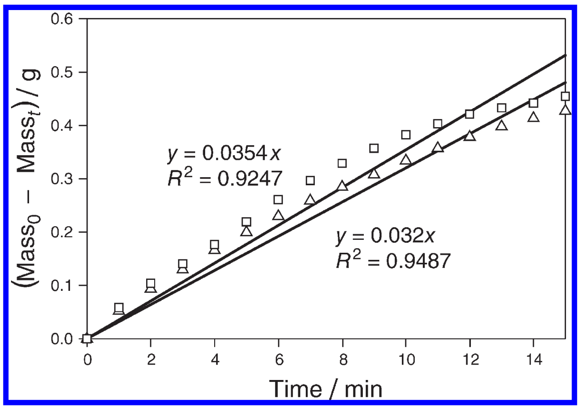

Figure 1. Plot of the mass loss for the gel (triangle) and for the liquid (square) as a function of time. The best-fit lines for the gel and for the liquid are shown.

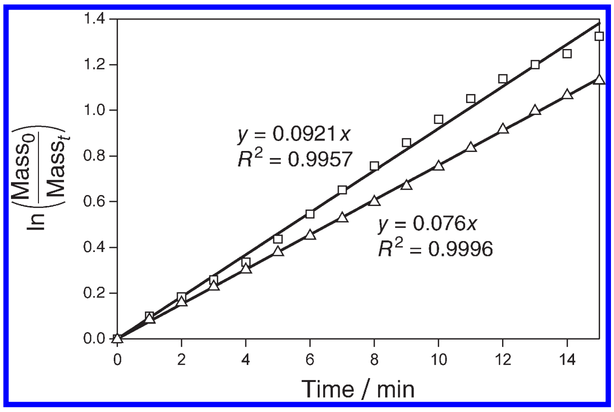

Figure 2. Plot of ln of the mass loss for the gel (triangle) and for the liquid (square) as a function of time. The best-fit lines for the gel and for the liquid are shown.

As can be seen qualitatively from any of these plots, the liquid loses mass more quickly than the gel. The best-fit line was found for each of the six sets of data. Based on the R^2 values, the best-fit lines for the gel and for the liquid are obtained in the first-order plots.

The slope of a first-order plot of $\ln(mass_0/mass_t)$ versus time is equal to the rate constant k. As can be seen in Figure 2, for the gel, slope = k = 0.076 min^{-1} and for the liquid, slope = k = 0.092 min^{-1}. At the half-life of the first-order reaction, half of the original mass has been lost. This is calculated using the

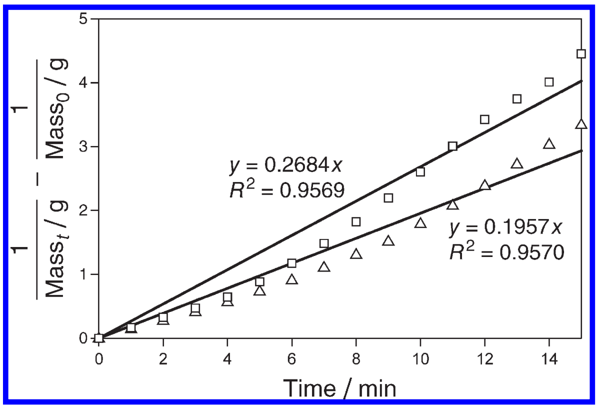

Figure 3. Plot of inverse of the mass loss for the gel (triangle) and for the liquid (square) as a function of time. The best-fit lines for the gel and for the liquid are shown.

expression $t_{1/2} = (\ln 2)/k$. For the gel, $t_{1/2}$ = 9.1 min, and for the liquid, $t_{1/2}$ = 7.5 min.

In this *Journal,* it has been shown that evaporation usually follows zeroth-order kinetics because the concentration does not change *(9, 10)*. However, the evaporation of about a 50/50 ethanol/water mixture from a silane gel does not follow zeroth-order kinetics, but rather follows first-order kinetics *(11)*. In fact, the rate constants obtained from that study (0.018 to 0.146 min^{-1}, depending on how porous the silane gel is) are close to those obtained here. In the previous study, it was found that the more porous the silane gel, the faster the rate of evaporation. Thus, it should not be surprising that, in this study, the water and ethanol mixture should evaporate more slowly from the gel than from the liquid.

Conclusion

The study of the rate of evaporation of alcohol-based hand-rub sanitizers that nurses and other health care professionals use daily nicely leads to a kinetics experiment relevant to students taking a GOB chemistry course. The students who have done this experiment say they find it straightforward and interesting. Because most drugs are metabolized at a first-order rate, a correlation may be drawn between what is learned from this sanitizer evaporation experiment and the metabolism of a drug by a patient.

Acknowledgment

The author thanks the University Research Council of the University of Cincinnati for financial support for this research and the faculty and students of the Department of Chemistry and the Department of Pharmacology of the University of Louisville for their hospitality during a sabbatical leave, when this article was written. In addition, the author thanks the reviewers for many valuable suggestions.

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Supporting Information Available

A full experimental section; a table of results; instructor notes. This material is available via the Internet at http://pubs.acs.org.

