therm curve. Exact details of the procedure cannot be enumerated, but many detailed procedures of gas adsorption methods are described in the literature (*1*).

The results of the tests are given in Table 1. It was impossible to obtain exact values for the whole teeth because not a single equilibrium pressure-volume point necessary for the isotherm could be obtained during a continuous 8-hour determination. The most probable reason for the failure to obtain equilibrium points was the unusually large size of the samples.

TABLE 1

| Sample | Approximate particle size | Wt. of sample (grams) | Total surface (sq. cm.) | Specific surface (sq. m./gram) |
|---|---|---|---|---|
| Apatite |  | 0.0098 | 5,002 | 51.1 |
| Dentine | 60 mesh | 0.0192 | 461.7 | 2.4 |
| Enamel | 60 " | 0.0196 | 352.8 | 1.8 |
| Bone ash | 60 " | 0.0089 | 8,835 | 99.3 |
| Tooth #2 |  | 1.2845 | 22,000* | 1.77* |
| Tooth #3 |  | 1.0528 | 16,700* | 1.59* |

* Estimation.

The surface area results on the powders are amazing. For example, bone ash has about 100 sq. m. of surface/gram. The variation of specific surface between bone, apatite, dentine, and enamel is of special interest because these were of the same particle size (*i.e.* 60 mesh). Presumably these variations revealed differences in the sizes of the submicroscopic crystals of hydroxylapatite.

## References

1. Brunauer, S., Emmett, P. H., and Teller, E. *J. Amer. chem. Soc.* 1938, **60**, 309; Emmett, P. H., and DeWitt, T. *Ind. eng. Chem.* (Anal. ed.), 1941, **13**, 28.
2. Crowell, C. D., Hodge, H. C., and Line, W. R. *J. dent. Res.*, 1934, **14**, 251.
3. Hodge, H. C., LeFevre, M. L., and Bale, W. F. *Ind. eng. Chem.* (Anal. ed.), 1938, **10**, 156.
4. Manly, R. S., and Hodge, H. C. *J. dent. Res.*, 1939, **18**, 203.

# Increasing the Spreading Coefficient of Mustard Gas[1]

Walter H. C. Rueggeberg

*Chemical Corps Technical Command,*
*Edgewood Arsenal, Maryland*

It is a well-known fact that small amounts of so-called "capillary active agents," when added to water, greatly reduce the surface tension of that liquid. As a result of this phenomenon, it was assumed that the addition of a low percentage of an appropriate soluble wetting agent to mustard gas (hereafter referred to as H) would reduce its surface tension to such an extent that the interfacial tension between it and water would be reduced sufficiently to increase the spreading coefficient beyond its normal value of 1 to 4.[2] To this end, several of the commercially available wetting agents were tried. Unfortunately, however, most of these, due to their high polarity, were insoluble in H and consequently, in this investigation, Alkaterge-O[3] was used throughout in order to establish the validity of the initial premise. The mustard gas was prepared from thiodiglycol and hydrochloric acid (m.p., 14.25°; purity, 99.5%). Distilled water having a surface tension of 72.0 dynes at 26° was used.

The mathematical reasoning involved in the theory of the spreading of liquids is adequately covered in textbooks on physical chemistry (*1*).

### Procedure

All measurements were made by means of the Du Nuoy interfacial tensiometer. All equipment, including the ring, was carefully cleaned in chromic acid. The ring was heated in a Bunsen flame before insertion into its seat in the apparatus. No attempt was made to control the temperature to an accuracy greater than ±1°, since the aim was to find tension differences far greater than those encountered over a 1° range in temperature. Readings were taken at room temperature of about 24°–26°. The results, averaging from about 6 to 8 separate readings, are compiled in Table 1.

TABLE 1

Surface and Interfacial Tensions of H, the System H-$H_2O$ With and Without Alkaterge-O, and the Spreading Coefficient of H Calculated From These Values*

| System | Alkaterge-O (%) | Surface tension in air, γ (dynes/cm.) | Interfacial tension (γ AB, dynes/cm.)† | Calculated spreading coefficient of H on water (γB-γA-γAB) |
|---|---|---|---|---|
| $H_2O$ | 0 | 72.0 | — | — |
| H | 0 | 40.6 | 23.0‡ | +8.4§ |
| H | ½ | 33.2 | about 6.0 | +32.9 |
| H | 1 | 31.7 | " 1.0 | +39.3 |
| H | 2 | 31.6 | " 1.0 max. | +39.4 |
| H | 5 | 31.4 | " 1.0 max. | +39.6 |

* All values are corrected by means of calibration curve.

† A = surface tension of H; B = surface tension of $H_2O$; AB = interfacial tension of the system H-$H_2O$.

‡ A value of 28.4 dynes/cm. at a lower temperature is on record in an Edgewood Arsenal report.

§ A value of +1.6 has been previously recorded for a lower temperature in an Edgewood Arsenal report.

It is apparent from the data presented that the surface and interfacial tensions of H can be lowered through the addition of 1 per cent of a surface active agent such as Alkaterge-O. The lowering of the tensions is sufficient to increase the spreading coefficient considerably above the value obtained with untreated H.

## Reference

1. Freundlich, H. *Colloid and capillary chemistry.* New York: E. P. Dutton, 1926. Chaps. I and II; Glasstone, S. *Textbook of physical chemistry.* New York: D. Van Nostrand, 1940. Pp. 474–477.

---

[1] Published with the permission of the Chief, Chemical Corps.

[2] Taken from reports on file at Edgewood Arsenal.

[3] An amine of high molecular weight, obtainable from the Commercial Solvents Corporation, New York City. According to the analysis performed in the Edgewood Laboratories, the empirical formula is $C_{22}H_{38}O_2NH_2$.