corresponding to barrier heights of 1,300 and 3,400 cal./mole. The latter were calculated by using the vibrational assignment recommended by Herzberg⁵, the bond-lengths and angles given by Crawford¹, and the tables of Pitzer and Gwinn⁶. They are unlikely to be in error by more than 0.15 cal. The results obtained above 120° C. by de Vries and Collins² have been corrected by the Berthelot equation and are also included in the diagram.

The experimental results favour the lower (spectroscopic) value for the barrier height. This would indicate that the entropy discrepancy of 1.0 ± 0.25 E.U. is real. Pauling⁷ showed that a similar discrepancy of 0.8 E.U. for ice could be accounted for by assuming a 'residual entropy' at low temperatures due to a completely random orientation of hydrogen bonds. Methanol may be similar. Unfortunately, the crystal structure is not known; but an infinite lattice with every oxygen atom tetrahedrally coordinated to one methyl group (covalency) and three other oxygen atoms (H-bonded) would allow each molecule to arrange its OH bond in three equivalent directions. The chance that its neighbours would permit any given orientation is 2/3. In complete disorder, such a lattice would have a residual entropy of $k \ln 2^3 = 1.37$ E.U., which is adequate to account for the observed discrepancy. The lattice assumed is in agreement with the X-ray diffraction data for the liquid at -75°C .⁸

It is interesting that there is a disagreement about the barrier height for methylamine⁹, which might have a similarly disordered solid structure, but not for trimethylamine¹⁰, where hydrogen bonding is impossible.

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¹ Crawford, jun., B. L., *J. Chem. Phys.*, **8**, 744 (1940).

² de Vries, T., and Collins, B. T., *J. Amer. Chem. Soc.*, **63**, 1343 (1941).

³ Alexander, E. A., and Lambert, J. D., *Proc. Roy. Soc., A*, **179**, 499 (1942).

⁴ Telfair, D., *J. Chem. Phys.*, **10**, 167 (1942).

⁵ Herzberg, G., "Infra-Red and Raman Spectra of Polyatomic Molecules" (van Nostrand Inc., New York, 1945).

⁶ Pitzer, K. S., and Gwinn, W. D., *J. Chem. Phys.*, **10**, 428 (1942).

⁷ Pauling, L., *J. Amer. Chem. Soc.*, **57**, 2680 (1935).

⁸ Harvey, G. G., *J. Chem. Phys.*, **6**, 111 (1938).

⁹ Aston, J. G., and Doty, P. M., *J. Chem. Phys.*, **8**, 743 (1940).

¹⁰ Aston, J. G., Sagenkahn, M. L., Szasz, G. J., Moessen, G. W., and Zuhre, H. F., *J. Amer. Chem. Soc.*, **63**, 1171 (1941).

Factorial Analysis of Rheological Measurements on Cheese

IN psychology, the meaning of tests of intelligence and mental abilities has been clarified by factorial analyses of the correlation coefficients between the different tests¹. In industrial physics there are occasions when empirical tests are employed the exact meaning of which is not fully understood, and where the interrelationships between the tests could profitably be studied by similar means. Subjective judgments of quality as assessed by experts and others may be included. In view of the elusive nature of such subjective judgments in cheese-grading, it has been thought desirable to develop a number of related mechanical measurements.

We have carried out an analysis of six separate mechanical tests directed towards measuring essentially different 'properties' on some 250 Cheddar cheese. The tests were as follows: (1) total penetration of a sphere under standard load into the surface after 30 sec.; (2) percentage of this penetration

remaining unrecovered 30 sec. after removing the load; (3) penetration of a cylindrical borer under standard load after 10 sec.; (4) ratio of the 10-sec. reading to the 60-sec. reading of the borer (taken negatively); (5) total penetration of a sphere following a series of increments of load (Meyer analysis); (6) slope of the log deformation/log load curve derived from test 5.

The 58 measurements which were correlated were the means from four samples taken from the same batch of cheese. The correlation matrices from these tests were analysed by Thurstone's Simplified Centroid Method² without adjustments to the entries in the diagonal cells in the second stage of approximation. The 'factor axes' may, if desired, be rotated according to specified rules; but in the present analysis of data from experiments not specifically designed for a factorial study, little appeared to be gained by rotation. The correlation and factor matrices are given in the accompanying table.

Correlation matrix: ripe cheese						
Test	1	2	3	4	5	6
1	1.000					
2	0.559	1.000				
3	0.853	0.674	1.000			
4	0.636	0.255	0.538	1.000		
5	0.850	0.544	0.765	0.556	1.000	
6	0.583	0.094	0.434	0.525	0.390	1.000

Factor matrix			
Test	I	II	III
1	+ 0.957	+ 0.026	- 0.026
2	+ 0.602	- 0.499	+ 0.116
3	+ 0.907	- 0.210	+ 0.164
4	+ 0.677	+ 0.301	- 0.083
5	+ 0.861	- 0.123	- 0.297
6	+ 0.574	+ 0.525	+ 0.101

An analysis of the pattern of factor loadings in relation to the qualitative nature of the tests suggests that factors I, II and III may be termed 'hardness', 'springiness' and 'hardening' respectively. It cannot at present be stated how complex these individual 'factors' are or whether, when additional tests are included, further categories will be necessary. The present analysis agrees with Burt's description of factors as "principles of classification"³.

It is of interest to note that both the borer test and the ball compressor test, each of which has a high saturation with the first 'factor', have been designed to simulate the actions of the skilled grader, the first when plunging a steel skewer into the cheese and the second when 'thumbing' it⁴. By means of these operations, the grader is able to make useful judgments of the rheological properties of unripe cheese, from which he foretells the development of quality.

We conclude from this preliminary survey that the technique of factorial analysis shows promise of giving valuable information where mechanical properties of complex materials are to be compared and studied.

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¹ Thomson, G. H., "The Factorial Analysis of Human Abilities" (Univ. London Press, 1939).

² Thurstone, L. L., "A Simplified Multiple Factor Method" (University of Chicago Press, 1933).

³ Burt, C., "The Factors of the Mind", 95 *et seq.* (Univ. London Press, 1940).

⁴ Caffyn, J. E., and Baron, M., *Dairyman*, **64**, 345 (1947).