

RHEOLOGY BULLETIN



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Publication
of the
SOCIETY OF RHEOLOGY

Vol. XV No. 3

August, 1944

RHEOLOGY BULLETIN

Published Quarterly by

THE SOCIETY OF RHEOLOGY

Dedicated to the Development of the Science of the
Deformation and Flow of Matter

57 East 55th Street
New York 22, New York

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Non-member Subscriptions: \$2.00 Annually

Single Copies: 75c

Address All Communications to the Editor

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PROGRAM

ANNUAL MEETING OF THE SOCIETY OF RHEOLOGY

November 17 and 18, 1944

at the

Hotel Pennsylvania, New York City

Friday Morning

- 9:00-9:30 Registration
1. 9:35-10:05 The Fluidity of Protein Solutions, E. C. Bingham, Lafayette College, Easton, Pa.
 2. 10:10-10:40 The Vismeter, C. D. Miller, North Andover, Mass.
 3. 10:45-11:15 An Automatic Recorder for a Rotational Viscosimeter, Ruth N. Weltmann, Interchemical Corporation, New York, N. Y.
 4. 11:20-11:50 A Theoretical Discussion of the Creep of Amorphous Polymers, T. Alfrey, Monsanto Chemical Company, Springfield, Mass.
 5. 11:55-12:25 The Fluidity of Normal Horse Serum and Immune Horse Serums, Albert Glaubiger, Department of Health, City of New York.

Luncheon

Friday Afternoon

6. 2:00-2:30 Viscosity of Solutions of Branched Polymers, I. Valyi and H. Mark, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
7. 2:35-3:05 The Rigidities of Solutions of Gelatins of Varying Degrees of Degradation, J. D. Ferry, Harvard Medical School, Boston, Mass.
8. 3:10-3:30 The Viscosity of Denatured Egg Albumin, C. C. F. MacPherson and Michael Heidelberger, College of Physicians and Surgeons, Columbia University, New York, N. Y.

9. 3:35-3:50 Discussion: The Viscosity of Water,
E. C. Bingham, Lafayette College, Easton,
Pa.

10. 3:55-5:00 Annual Business Meeting

Saturday Morning

11. 9:00-9:30 On The Relation Between Intrinsic Viscosity, Molecular Weight and Dimensions of High Polymers, R. Simha, Howard University, Washington, D. C., and H. Mark Polytechnic Institute of Brooklyn, N. Y.

12. 9:35-10:05 Anomalous Flow of Isotropic Fluids, Arnold Bondi, International Lubricant Corporation, New Orleans, La.

13. 10:10-10:40 Deformation and Heterogeneity, F. O. Anderegg, John B. Pierce Foundation, New Haven, Conn.

14. 10:45-11:15 A High-Temperature, High-Pressure Rheometer for Plastics, H. K. Nason, Monsanto Chemical Company, Dayton, Ohio.

15. 11:20-11:50 Resistance to Translation of Dispersed Colloidal Particles, M. A. Lauffer, University of Pittsburgh, Pittsburgh, Pa.

16. 11:55-12:25 Retraction of Stressed Rubber, (Rubber Research Laboratory, Department of Physics, University of Notre Dame).

THE FLUIDITY OF PROTEIN SOLUTIONS

Eugene C. Bingham

That there is a sharp line of demarcation between the so-called "true" and seeming, i.e. colloidal, solution has not been generally realized. But just as the liquid and solid states may be best differentiated rheologically, so the rheological differences of particles in solution most naturally make themselves felt in phenomena involving motion of the particles or flow, e.g. in Brownian movement, settling, electrical conductivity, endosmose, etc.

The viscosity of colloidal solutions has so long been carrying the sign "Verboten" that it is strange to find it a simple and inviting subject instead of one filled with fog. Let us review the elements of the subject for a few moments.

The simplest true solution mixture follows the formula

$$\Phi = a \Phi_1 + b \Phi_2 \dots\dots\dots(1)$$

where a is the volume fraction of the component A whose fluidity is Φ_1 and b is the volume fraction of the component B whose fluidity is Φ_2 . This may also be written as

$$\Phi = \Phi_1 + (\Phi_1 - \Phi_2) b \dots\dots\dots (2)$$

Many colloidal solutions, which we may also regard as the simplest, follow a somewhat different formula

$$\Phi = (1 - b/b') \Phi_1 \dots\dots\dots (3)$$

where b' is the volume fraction of the component B when the fluidity of the mixture becomes zero. If, however, the value of b' reaches unity, then $\Phi = (1-b) \Phi_1$ and since $1 - b = a$ we may write for this case

$$\Phi = a \Phi_1 \dots\dots\dots (4)$$

which is the analog of Raoult's Law, the simplest rheological formula for solutions, and marking the demarcation between the true and colloidal solutions.

Treffers first showed that many types of proteins followed the formula (3) suggested by Bingham and Durham. Nageli's data for human blood serum at 20° follows the equation

$$\Phi_{20^\circ} = 89.8 - 3.99 b.$$

We give this example, because the fluidity of water at 20°

is not 89.8 but 100 rhes and this difference cannot be explained by the dissolved salts. This is quite unexplained. Since Bingham and Durham observed that b' in their suspensions was independent of the temperature and moreover the fluidity of water over a limited range is nearly linear, we have the approximate relation

$$\frac{\bar{\Phi} t_1 c_0}{\bar{\Phi} t_2 c_0} = \frac{\bar{\Phi} t_2 c_1}{\bar{\Phi} t_2 c_1}$$

Put in words, this says that the ratio of the fluidities at two temperatures is independent of the concentration. It was because of this approximate relation that W. R. Hess was able to conclude that the relative fluidity of blood is independent of the temperature, the standard always having the temperature of the substance measured.

Such a relation will not hold even approximately for a hydrated colloid like gelatin, but the data from 35° to 60° are reproduced very well at all concentrations up to at least four per cent by the formula

$$\frac{\bar{\Phi} + c}{\bar{\Phi}_1 + c} = 1 - 0.0659 b$$

where $c = 73.9$ rhes.

Rewriting equation (3) for simplicity as

$\bar{\Phi} = \alpha - \beta b$, the fluidity of a mixture of proteins being additive, may be written as

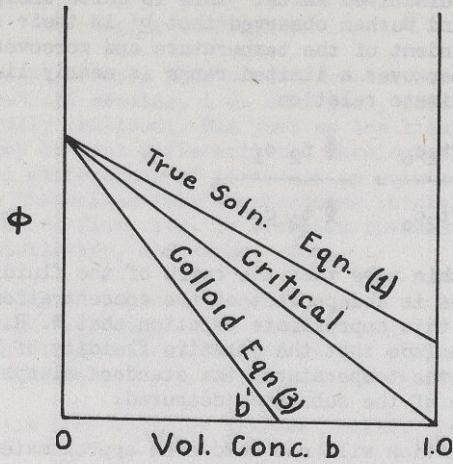
$$\bar{\Phi} = \bar{\Phi}_1 - \beta_1 b_1 - \beta_2 b_2 - \beta_3 b_3 - \dots (5)$$

where β_1 , β_2 , and β_3 are the fluidity lowering constants of different proteins present.

	b Vol. %	βb
Salts		1.3
Albumin	4.01	24.4
Globulin	2.83	31.8
Fibrinogen	0.42	16.2
		73.7 rhes

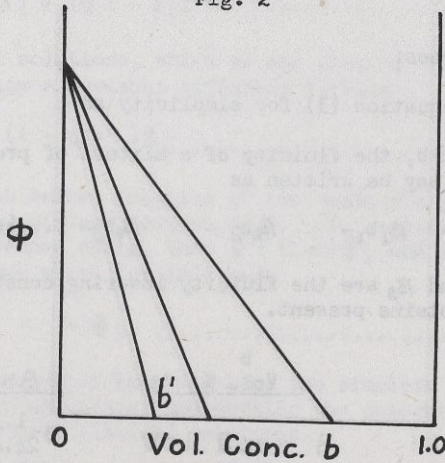
The fluidity of blood plasma is therefore $144 - 73.7$ rhes = 70.3 rhes.

Fig. 1



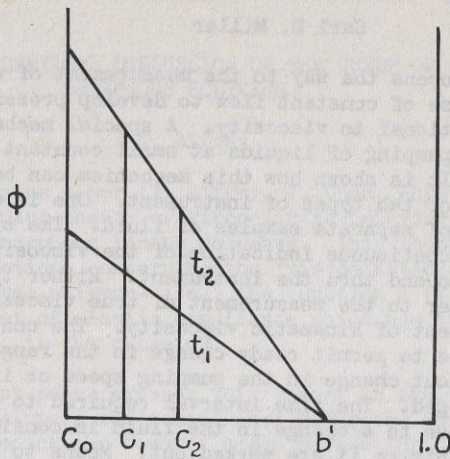
Relation of "True" to Colloidal Solution.

Fig. 2



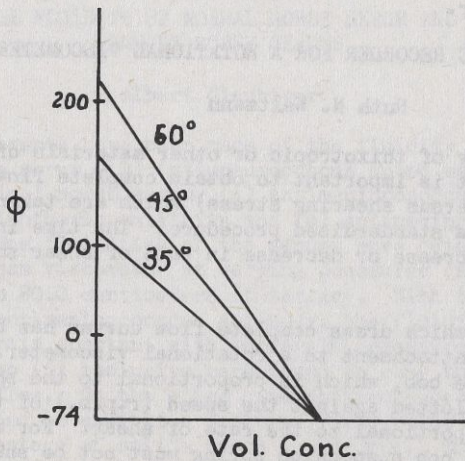
Comparison of Different Proteins At a Given Temperature in Aq. Soln.

Fig. 3



Relation of Fluidity
to Concentration and Temperature
For Protein Soln.

Fig. 4



Fluidity of Gelatin
at Various Temps.

$$\frac{\phi - c}{\phi_0 - c} = 1 - 0.0659b$$

$$c = 74$$

THE VISMETER

Carl D. Miller

The paper opens the way to the measurement of viscosity thru the use of constant flow to develop pressure which is proportional to viscosity. A special mechanism adapted to the pumping of liquids at small constant rates is described. It is shown how this mechanism can be utilized in either of two types of instrument. One is adapted to the testing of separate samples of fluid. The other is adapted to the continuous indication of the viscosity of fluid flowing to and thru the instrument. Either type can be adapted either to the measurement of true viscosity, or to the measurement of kinematic viscosity. The continuous type can be made to permit ready change in the range of the instrument without change in the pumping speed or in the pressure developed. The time interval required to get a complete response to a change in the fluid is considered, and means to minimize it are worked out. Means to bring the fluid to the required temperature within the instrument is developed. Mathematical formulas are given to assist in the explanation and to give definite relationships and magnitudes. Dimensions and other quantitative data for instruments of different viscosity ranges are given. Mathematical development of the formulas is given in the latter part of the paper.

AN AUTOMATIC RECORDER FOR A ROTATIONAL VISCOMETER

Ruth N. Weltmann

In the study of thixotropic or other materials of anomalous behavior, it is important to obtain complete flow curves (rate of shear versus shearing stress) which are taken in accordance with a standardized procedure. The time interval for any given increase or decrease in rate of shear should remain constant.

A recorder which draws complete flow curves has been developed as an attachment to a rotational viscometer. The deflection of the bob, which is proportional to the shearing stress, is plotted against the speed (r.p.m.) of the cup which is proportional to the rate of shear. For accurate measurements the bob suspension spring must not be subjected to any friction load; therefore the recorder uses sparks generated by high voltage to puncture the recording paper. The sparking electrode is moved by the bob deflection spring while the paper is moved perpendicular to the electrode motion by the transmission handle, the position of which controls the cup speed.

A number of measurements have been made with the recorder.

The flow curves obtained permit immediate interpretation and calculation of the consistency data without any replotting.

A THEORETICAL DISCUSSION OF THE CREEP OF AMORPHOUS POLYMERS

T. Alfrey

In a previous paper (T. Alfrey, J. Chem. Phys. Sept. 1944), a molecular theory of viscoelastic behavior was advanced for amorphous linear polymers. This theory gives definite predictions concerning the "viscoelastic spectrum" of a monodisperse polymer--i.e., the function $J(\tau)d\tau$ which gives the amount of elastic compliance which has the retardation time τ , in the range $d\tau$.

The present paper extends this theory to the cases of polydisperse polymers and crosslinked polymers, and then proceeds to predict the form of creep curves for both linear and cross-linked amorphous polymers. The effects of molecular weight, molecular weight distribution curve, and temperature, are discussed.

The theoretical predictions are compared with available experimental data.

THE FLUIDITY OF NORMAL HORSE SERUM AND IMMUNE HORSE SERUMS

Albert Glaubiger

Measurements have been made of the fluidity of (1) Normal horse serum, (2) Antipneumococcus horse serum, (3) Antiscarlatinal horse serum, (4) Antimeningococcus horse serum, (5) Diphtheria antitoxin and (6) Antimeningococcus antibody. The fluidities of the serums were determined with a Bingham viscometer at varying pressures ranging from 13.0 to 80.0 centimeters of mercury. With the exception of antimeningococcus antibody, the fluidities were found to remain constant with increasing pressure, i.e. serums (1) to (5) inclusive were found to obey the laws of viscous flow. On the other hand antimeningococcus antibody was found to exhibit a positive yield value as soon as the percentage of solids reach 4 per cent. The yield value increases rapidly but not linearly with the concentration of solids. In the case of antimeningococcus antibody a mobility has been determined corresponding to a plastic fluidity.

VISCOSITY OF SOLUTIONS OF BRANCHED POLYMERS

I. Valyi and H. Mark

p-p'-divinyl diphenyl and p-p'-di-isopropenyl diphenyl were prepared and have been used as comonomers together with styrene. Depending upon the amount of the divinyl derivative, one obtains soluble or insoluble materials.

Copolymers with 10, 25, 50, 100 and 200 parts per million divinyl monomer have been prepared and the soluble polymers have been fractionated by gradual precipitation of the methyl ethyl ketone solution with methanol. The intrinsic viscosities and osmotic pressure of the various fractions were determined and the constants of the equation

$$[\eta] = K.M^a$$

established. Both K and a vary with the degree of branching.

THE RIGIDITIES OF SOLUTIONS OF GELATINS OF VARYING DEGREES OF DEGRADATION

John D. Ferry

The rigidities of solutions of various gelatin samples were measured by following the propagation of transverse vibrations, and the dependence of rigidity upon concentration and temperature was studied.

The samples were from three different sources (ossein, calfskin, and porkskin), and had undergone degradation to different extents. Scatchard, Oncley, Williams, and Brown have, on the basis of a simple degradation mechanism, calculated the distribution of molecular weights in these samples, which may be considered to cover a range from single amino acids to chains of about 1200 units. The results were confirmed by measurements of osmotic pressure, viscosity, and sedimentation.

The maximum rigidity attainable at low temperatures was found to be proportional to the square of the concentration. On the basis of the assumed distribution function, it is proportional to

$$\left(\sum_i i c_i \right)^2$$

where $i + 1$ is the number of amino acid units in a molecule of the i 'th class and c_i is the weight concentration of that class.

From the variation of rigidity with temperature, the heat of gelation and entropy of gelation can be calculated. These quantities are approximately proportional to the total number of molecules per unit weight.

THE VISCOSITY OF DENATURED EGG ALBUMIN

C. C. F. MacPherson and Michael Heidelberger

Peculiarities of the fluidities of solutions of egg albumin denatured by acid, alkali, or heat, are described and discussed. Axial ratios of the products are calculated and approximate particle weights deduced from these and compared with corresponding values from sedimentation and diffusion.

ON THE RELATION BETWEEN INTRINSIC VISCOSITY, MOLECULAR WEIGHT AND DIMENSIONS OF HIGH POLYMERS

R. Simha and H. Mark

Empirical relations have been previously developed between the molecular weight M of a fractionated high polymer solute and the intrinsic viscosity $[\eta]$. On the other hand, theory gives an expression for $[\eta]$ as a function of geometrical dimensions, in particular of the axis ratio f , if the molecule is approximated by an ellipsoid of revolution.

A semi-empirical method of analysis is suggested, which combines both approaches and establishes a relation between molecular weight and molecular "dimensions", or more correctly, the dimensions of the ellipsoid, which produces the same viscosity increment as the actual molecule. The statistical theory of the shape of long chain molecules suggests the existence of a relation of the type:

$$F = C.M^p \quad (1)$$

where C is a constant characteristic for the monomer. The exponent p should assume values between zero and one, the two limits for an ideal statistical coil and a completely straight chain. Furthermore, it has been found that for well defined fractions of compounds such as polyisobutylene, polystyrene or cellulose acetate, the relation between $[\eta]$ and the osmotic molecular weight is of the form

$$[\eta] = K.M^a \quad (2)$$

The exponent a is found to vary between zero and an upper limit larger than one. The above mentioned viscosity-axis ratio function, which has been previously applied to protein solutions, together with (1), gives an interpretation of the empirical result (2).

The validity of equation (1) for three series of polystyrenes and one series of cellulose acetate in various solvent and solvent mixtures is demonstrated. f -values are computed from the measured intrinsic viscosities and are related to the osmotic molecular weights of the respective fractions. It is shown that in a thermodynamically good solvent, as measured by the slope of the curve of reduced osmotic pressure, p assumes values nearer to one than in a less good solvent. This indicates that the chains seek preferentially more curled up configurations in media in which they are less soluble. Finally the direction of further work is briefly indicated.

ANOMALOUS FLOW OF ISOTROPIC FLUIDS

Arnold Bondi

The application of high shear stresses to liquids in engineering practice as well as in analytical rheology either by the use of high rates of shear or the handling of extremely viscous materials has led to the observation of serious deviations from "ideal" flow conditions even in the case of isotropic liquids. The observed deviations can be attributed to three independent but superimposed factors: 1. Existence of a temperature gradient normal to the direction of flow. 2. Reduction of the height of the potential energy barrier to viscous flow by the amount of the applied shearing force. 3. The orientation of rod-shaped molecules with their axes parallel to the direction of flow. The first two factors have already received fairly complete mathematical treatment by other authors to permit of quantitative evaluation. A theory of the third - orientation - is developed here on the basis of statistical mechanics.

The application of the derived concepts to the critical evaluation of viscosity data presented in the literature and the reformulation of the premises of a revised theory of journal bearing lubrication is also discussed.

DEFORMATION AND HETEROGENEITY

F. O. Anderegg

Portland cement concrete, like most inorganic systems, is hard, rigid and brittle. It is capable of only comparatively small plastic deformation; but when certain bitumens are added in the proper amounts, the concrete can be deformed fairly readily. Its modulus of elasticity is lower; its ability to absorb the energy of impacts is greater; and hence it is much easier to walk and stand on it. This is an obviously heterogeneous system, and the analysis of the deformation mechanism might well be helpful in orienting our ideas about deformation in general. This leads to the

suggestion of the presence in any system capable of deformation of a series of bonds of different magnitude. A statistical expression for such a distribution, in combination with an expression for the distribution of thermal energies for all bonds should be of value in the quantitative understanding of deformation.

A HIGH-TEMPERATURE, HIGH-PRESSURE RHEOMETER FOR PLASTICS

H. K. Nason

A modified Bingham-type rheometer, designed for operation at temperatures up to 500°F. and at pressures up to 2000 psi., is described. Interchangeable orifice plates permit wide variation of shear conditions. With this instrument flow properties may be studied under conditions approximately those encountered in the actual processing of plastics, e.g., by molding or extrusion. Typical results are presented for cellulose acetate, polystyrene and polyvinyl resin plastics, and correlation with practical experience is pointed out. The instrument is slow. This limits its use for other than research investigations.

RESISTANCE TO TRANSLATION OF DISPERSED COLLOIDAL PARTICLES

Max A. Lauffer

Stokes' law for spherical particles and comparable treatments for ellipsoids relates the resistance to translation of a colloidal particle in an infinitely dilute suspension to the dimensions of the particle and the viscosity of the medium. In dealing with colloidal solutions of finite concentration, most investigators regard the resistance to translation of the dispersed particles as being a function of the solvent viscosity. However, a study of the rate of sedimentation of tobacco mosaic virus particles in solutions of low but finite concentration showed that the rate was approximately inversely proportional to the solution viscosity and not to the solvent viscosity. A re-examination of many data available in the literature on other colloidal and macro molecular systems tended to support this observation. These results encouraged the author to propose that, at least as a matter of practical expediency, the resistance to translation of suspended or dissolved particles be considered as being a function of solution viscosity rather than of solvent viscosity.

ANNUAL MEETING OF THE BRITISH RHEOLOGISTS' CLUB
at Oxford, July 6-9, 1944

The following cablegrams were exchanged between Prof. G. W. Scott-Blair and Prof. H. Mark:

"BRITISH RHEOLOGISTS' CLUB FIRST CONFERENCE AT OXFORD SEND HEARTIEST CONGRATULATIONS TO AMERICAN COLLEAGUES AND LOOK FORWARD TO CLOSE COOPERATION IN NEAR FUTURE WHEN WAR IS WON." Scott-Blair.

"MANY THANKS FOR CABLE. AMERICAN RHEOLOGISTS WISH YOUR CONFERENCE BEST SUCCESS AND SHARE FULLY YOUR HOPE FOR SPEEDY VICTORY AND SUCCESSFUL COOPERATION IN POSTWAR PERIOD." H. Mark.

Over 120 people registered at the Oxford Meeting which was held at St. Hilda's College. The conference began on Thursday evening with a social and musical program to which Dr. Harrison and Dr. Kosterlitz contributed. Friday morning was devoted to a discussion on "The Rheology of Large Deformations and Plastic Flow", introduced by three papers:-

1. Plasticity of Metals, by Dr. E. Orowan.
2. Polymers, by Dr. R. F. Tuckett.
3. The Liquid State, by Mr. A. G. Ward

Two papers were presented on Friday afternoon:-

4. Relationships between Tension, Compression and Shear and Complex Bodies, by Mr. R. L. Brown.
5. Some Rheological Applications to Medical Science, by Mr. C. F. Clift, F.R.C.S.

On Friday evening Dr. S. Whitehead lead an informal discussion on "Relaxation". On Saturday morning, Dr. Hugh O'Neill of the L.M.S. Railway Co., introduced a discussion on "Rheological Nomenclature of Symbols, Metallurgical and Non-Metallurgical" in which a number of metallurgists joined in debate with other rheologists on the vexed question of nomenclature.

In the afternoon, a visit was paid to the very fine new Physical Chemical Laboratories at the University, under the guidance of Mr. E. J. Bowen, F.R.S.

In the evening a short business session was followed by a very topical debate on "Future Organizations of Rheology". Many points of view were expressed but there was unanimity in the desire for very close cooperation with The Society of Rheology in America and for establishing friendly contacts with rheologists in other countries.

It was also felt that the rapid increase in membership of the Club, which now numbers about 270, showed that it was fulfilling a useful function.

Negotiations are in progress toward the publication of the "Proceedings" of the meeting in book form.

Mr. D. G. Broome acted as Chairman of the Conference.

We are indebted to Prof. Scott-Blair for these notes which have been somewhat abbreviated by the Editor.

Abstractors in this Issue

The following are the names of our Good Friends who have cooperated in making this August 1944 Rheology Bulletin a success:

T. Alfrey
Bull. Institute of Paper Chemistry (B.I.P.C.)
A. Bondi
T. Boyd
C. K. Bump
T. S. Lawton
R. M. Levy
H. Mark
D. Telfair
R. N. Weltmann
S. Zerfoss

RHEOLOGY PROGRESS ABSTRACTS

Apparatus and Methods

THE EFFECT OF THIXOTROPY ON PLASTICITY MEASUREMENTS.—
Henry Green and Ruth N. Weltmann, J. Applied Phys. 15, 414-
20 (1944).

The present paper is devoted to laboratory procedures whereby plastic viscosity and yield value can be recorded at a known thixotropic level and the coefficients of thixotropic breakdown calculated. The rheological measurement of a thixotropic system presents two outstanding problems: (1) how to measure the magnitude of the thixotropic phenomenon, and (2) how to designate the particular state of structural breakdown in which the material exists at the time of measurement. In actual practice, this state is far more likely to be partial than complete. The ideal method for conditioning the thixotropic material would be to allow it to remain undisturbed in the viscometer cup with bob inserted until it attained its maximum structural growth; this would tie up the viscometer for a day or even longer. The next best method is to age the material in its own container and transfer it to the cup; some damage to the thixotropic structure is unavoidable during this process. Tabulated data of measurements made by different operators using different viscometers indicate that the checks are close in spite of the fact that each used his own judgment in handling and transferring.

B. I. P. C.

THE OSMOTIC BALANCE.—Ingvar Jullander and The Svedberg, Nature 153, No. 3887, 523-4 (April 29, 1944).

The methods used thus far for determining the osmotic pressure of solutions of high polymers aim at determining the position of a liquid meniscus in a capillary, either by measuring the height of a volume at equilibrium, or by applying a visible counter-pressure against the meniscus and measuring its rate of migration at different values of the counterpressure. For determining lower osmotic pressures than can be ascertained by the previous methods, an osmometer has been constructed, in which the liquid passing through the membrane is weighed. In an analytical balance, one of the scales is removed and replaced by an arrangement consisting essentially of a glass cylinder for the solvent and an osmotic cell. Experiments with the apparatus—which is described in detail—have been carried out on nitrocellulose (12.28% nitrogen content) dissolved in butyl acetate at 25°C. The osmotic measurements gave results which correspond to an average "number" molecular weight of 148,000 and are said to show an increase in accuracy of a power of ten when compared with earlier procedures.

B. I. P. C.

BASIC SOLUTIONS FOR FLOW MEASUREMENTS.—H. Ziebolz, Rev. Sci. Insts., 15, 80 (1944).

The problem of translating fluid flow rates into flow indicator movements, i.e., the design of flow meters, is analyzed from the standpoint of the physics involved. In the light of this analysis, the advantages and disadvantages of a number of common types of flow meters are discussed.

D. TELFAIR

EXPERIMENTAL STRESS ANALYSIS, Brit. Plast. 16, 199 (May, 1944).

The present trend towards high power/weight ratios in aircraft and automobile engines has brought with it a greater need for reliable methods of stress analysis. Of the various approaches to this problem, photoelasticity is the most important.

In the analysis of two-dimensional stresses, the photoelastic technique is quite simple, and frequently yields valuable information. However, it does not always give sections of maximum stress. Three dimensional methods have been developed which will do this, but they are comparatively difficult and time consuming.

Except for special cases, such as centrifugal stresses, dynamic stresses cannot be studied with assurance, but considerable progress is being made.

In spite of its disadvantages, the photoelastic approach to stress analysis is of great importance, and photoelastic methods have been and are being used with considerable success in industry.

D. TELFAIR

MINERAL POWDER SUSPENSIONS IN BITUMENS AND RELATED MATERIALS, II.--H. Walther, Kolloid-Z. 103, 233 (1943).

The author has studied various methods of evaluating particles in suspension. He has come to the conclusion that the most important research methods for mineral powders are the microscopic examination of particle size, particle distribution and particle shape, the establishment of volume discharges and the direct determination of the specific surface by permeability measurements on powder sediments. The determination of particle distribution thru the sedimentation analysis and especially the calculation of the specific area from their results are only limited because of question-al validity of Stokes Law for their abnormal particles, because of the necessary disregard for the smallest particles, particle shape and surface irregularity for the surface area calculation, and are not suited for the comparison of different mineral powders and their stabilizing action on bitumens.

T. BOYD

DIELECTRIC MEASUREMENT OF THE PLASTICIZATION OF POLY-VINYL CHLORIDE.--F. Wurstlin, Kolloid-Z. 105, 9 (1943).

A study was made to determine the softening of polyvinyl chloride and similar high molecular weight substances using electrical test methods instead of the usual mechanical methods. Wurstlin has shown that the two methods of measurement are related and that differences found can be explained easily.

T. BOYD

FLOW PROPERTIES OF CELLULOSE ESTERS.--C. J. Frosch, Bell Laboratories Record 22, 269 (Feb. 1944).

The flow properties of cellulose esters, polystyrene and a laminated phenol-formaldehyde plastic materials have been measured by means of a parallel plate plastometer and compared with Rockwell penetration data. The Rockwell test is less accurate but is more rapid and simpler to carry out.

Both methods give useful information in comparing the plasticizing effect of water on the flow of various materials considered for applications in telephone apparatus.

C. K. BUMP

MEASUREMENT OF DYNAMIC STRESS AND STRAIN IN TENSILE TEST SPECIMENS.--R. O. Fehr, E. R. Parker, and J. J. de Michael, J. Applied Mechanics 11, A-65 (1944).

The tensile strength, yield strength, elongation, and breakage energy of test specimens (cold rolled steel, and dural) were measured by breaking the specimens by a force applied at high velocities in a commercial impact testing machine. The four material characteristics mentioned were found to increase with increasing striking velocity (limit of experimental arrangement: 100 feet per second). At this maximum striking velocity the increase of dynamic over static values ranged between 10 and 100%. Measurements were performed with resistance type strain gages, the resistance change of which was recorded on photographic film by means of a cathode ray oscillograph and a high speed camera.

A. BONDI

HEAT EFFECTS IN LUBRICATING FILMS.--A. C. Hagg, J. Applied Mechanics 11, A-72 (1944).

Temperature gradients in lubricating films are analysed on the basis of simple shear of the lubricant, Reynolds' viscosity-temperature function, and a first order differential heat balance across the film. The analysis presented gives the dependence of film temperature on velocity, and the resulting velocity distribution profile. Formulae for shear stress and shear rate containing the exponential temperature coefficient of viscosity as second material constant are also derived. Experiments carried out with a model high speed bearing support the analytical results.

A. BONDI

MEASUREMENT OF THE DAMPING OF ENGINEERING MATERIALS DURING FLEXURAL VIBRATIONS AT ELEVATED TEMPERATURES.--C. Schabtach and O. Fehr, J. Applied Mechanics 11, A-86 (1944).

A tuning fork specimen is set into vibration by jerking a spreader from the gap between the ends. The logarithmic decrement of the decaying vibration is measured and recorded by means of a magnetic oscillograph and resistance type strain gages cemented to the specimen.

Measurements were performed on 8 different alloys at ca. 1000 Hz, a maximum bending stress of 40,000 psi. and temperature up to 1400 F. The log decrement was found with some materials to increase monotonically with temp. and appl. bending stress, while a number of material temp. curve goes through a flat maximum. The modulus of elasticity decreases monotonically with increasing temperature.

A. BONDI

SURVEY OF THE LITERATURE ON PLASTICITY, VISCOSITY, AND ALLIED PROPERTIES.--Paul G. Herold and S. J. Smothers, Bull. Am. Ceram. Soc. 23, No. 5, 184-8 (May, 1944).

A search of the literature and a grouping of the methods used in various industries for measuring plasticity, consistency, and viscosity show that most of the industries have standardized on the measurement of viscosity. Industries such as the ceramic, paint, rubber, and cellulose industries are still attacking the problem of plasticity. Characteristic apparatus used in each industry for measuring rheological properties is described. 85 references.

B. I. P. C.

Cellulose

THE STATE OF SOLUTION IN VISCOSE.--J. J. Stockly, Kolloid-Z. 105, 190-9 (1943).

A hypothesis is suggested to eliminate the controversy of freely moving macromolecules versus micelles in commercial viscose (cellulose xanthate solution). This hypothesis is based upon the assumption that cellulose xanthate is present in solution in the form of mixed bodies composed of xanthated and solvated chain molecules and that these mixed bodies retain the original parallel orientation of the cellulose chain molecules.

B. I. P. C.

THE STATE OF SOLUTION OF HIGH POLYMERS. III. VISCOSITY MEASUREMENTS ON VISCOSE.--M. Takel, Kolloid-Z. 106, 30-5 (1944).

True solvation of the cellulose xanthate particles increases and the particle size decreases with increasing time of aging of the alkali cellulose. The essential phenomenon during the aging of alkali cellulose consists of partial disorientation of the crystalline regions. Whereas viscose from unaged alkali cellulose possesses a

primary structure, viscose from an aged solution develops a secondary structure. True solvation decreases with increasing ripening degree of the viscose, and the rate of decreased solvation is more rapid, the longer the alkali cellulose has been aged. On the other hand, the particle size shows no or only little change. Both solvation and micelle size change less during ripening, the more carbon disulfide was used in the preparation of the viscose. The state of solution is not changed by adding varying amounts of carbon disulfide, provided a certain quantity of it had been taken up previously by the alkali cellulose. The solvation of the xanthate in 4 and 7% sodium hydroxide solutions shows no essential difference, although the particle size is influenced to a certain extent by the caustic soda concentration. On the other hand, the xanthate undergoes considerable hydration if it is dissolved in water, and in this solution, the micelle particles possess the largest size. It is suggested that the viscose particles in commercial viscose are arranged in a lattice of fringed micelles.

B. I. P. C.

MOLECULAR WEIGHT OF CELLULOSE; MEASUREMENT OF AVERAGE DEGREE OF POLYMERIZATION.--O. A. Battista, Ind. Eng. Chem., Anal. Ed. 16, 351-4 (1944).

Viscosity-concentration data are given for five samples of purified cellulose representing the degree of polymerization range from 300 to 3000. On plotting the data on semilogarithmic paper, linear relationships were found to exist, in each case, between (1) the viscosity function (η_{sp}/c) and concentration, and (2) the relative viscosity function measured at 0.5% concentration and the degrees of polymerization corresponding to values calculated from viscosity-concentration data extrapolated to infinite dilution. The data have been used to derive a mathematical expression by means of which the value of the viscosity function at the standard concentration of 0.5% may be converted to degree of polymerization data equivalent to values obtained by extrapolation of viscosity-concentration data to infinite dilution. 14 references.

B. I. P. C.

RELATIONSHIP BETWEEN CELLULOSE VISCOSITIES MEASURED BY THE TAPPI STANDARD AND THE CUPRIETHYLENE DIAMINE METHODS.-- Alfred J. Corey, Paper Trade J. 118, 51 (1944).

Viscosities of a series of bleached sulfite pulps covering a range of high and low viscosities have been measured by the TAPPI standard and the cupriethylene diamine methods.

The results obtained by the two methods are compared on the basis of 1% cellulose solutions, and the relationship is shown graphically.

R. M. LEVY

THE CUPRIETHYLENE DIAMINE VISCOSITY METHOD AS A CONTROL IN THE MANUFACTURE OF PULP OF SPECIFIED VISCOSITY.—E. P. Wood, Paper Trade J. 118, 37 (1944).

It was found that the cuprammonium viscosity test was not adequate for mill control, however, it was found that through the use of cupriethylene diamine as a viscosity solvent for pulp, plant operation can be controlled within very narrow limits. No details are given.

R. M. LEVY

RELATIONSHIP BETWEEN SOLUTION VISCOSITY AND MOLECULAR WEIGHT IN THE AMYLOSE SERIES.—Joseph F. Foster and R. M. Hixon, J. Am. Chem. Soc. 66, 557 (1944).

Osmotic pressure and dilute solution viscosity measurements were made on a series of amyloses prepared from various starch derivatives. All measurements were made at 25°C. Osmotic pressure values for corn and tapioca amylose are given. From the results of other investigations, molecular weights of other members of this series are estimated.

From the rigidity of the Fischer-Hirschfelder models of amylose, α in the equation $ni = KM^\alpha$ would be expected to be greater than unity. The value of α from this work is 1.5, confirming the Fischer-Hirschfelder models.

The rigidity of acetylated amylose molecules in chloroform has been shown to be the same as that of amylose in ethylenediamine.

T. S. LAWTON

THE ACTION OF ULTRAVIOLET LIGHT UPON CELLULOSE.
I. Irradiation Effects. II. Post-Irradiation Effects.—
R. A. Stillings and R. J. Van Nostrand, J. Am. Chem. Soc. 66, 753 (1944).

The effect of oxygen and nitrogen on the photolysis of cellulose was studied. Cellulose, glucose, and cellobiose were irradiated with ultraviolet light in a specially designed apparatus which allows irradiation of powders in various atmospheres and which provides for evacuation prior to exposure, continuous mixing and continuous analysis of

gaseous products. The degradation of these materials was determined by the change in degree of polymerization, x-cellulose content, copper number, and liberation of carbon monoxide and carbon dioxide.

The effect of oxygen was to degrade the material, as evidenced by a drop in the degree of polymerization and x-cellulose content, an increase in copper number, and liberation of gases. The rate of degradation increased with increasing amounts of oxygen.

The effect of nitrogen was to degrade the material, although the rate of degradation was greater than the rate calculated on the assumption that the reaction was of the first-order type. Also, the degradation in nitrogen could not be explained by oxygen in the nitrogen or that retained the cellulose at the start of exposure. The rate of degradation was considerably slower for glucose and cellobiose than for cellulose.

The post-irradiation effect on cellulose was studied. This effect was increased by raising the temperature and by replacing the air with oxygen. Some of the increased post-irradiation effect was due to the rise in temperature. This effect could be changed by varying the exposure atmosphere, and a long storage time in oxygen caused the post-irradiation effect to end. Cellulose irradiated in oxygen showed the post-irradiation reaction; however, the effect became smaller as the oxygen exposure time increased.

These results appear to confirm the previously advanced hypothesis that, in the absence of oxygen, two reactions take place during the action of ultraviolet light on cellulose, one which ruptures the glycosidic linkages and the other which leaves these linkages unstable to oxygen. The mechanism of this reaction is still obscure.

T. W. LAWTON

CLAY

FUNDAMENTAL STUDY OF CLAY: VI. Flow Properties of Kaolinite-Water Suspensions.—F. H. Norton, A. L. Johnson and W. G. Lawrence, *J. Am. Ceram. Soc.* 27, 149-64 (1944).

The flow properties of six monodisperse kaolinite fractions were studied over a large range of concentration. From these results, it has been possible to set up an equation relating viscosity to concentration which holds over a very wide range. Equations relating concentration to thixotropy and to yield point which have general application could also be established. The viscosity of a

suspension is obtained from the sum of three quantities--namely, those contributed by the liquid, the individual particle, and the collision of the particles. Thixotropy is found to be due to the sum of two quantities--namely, the contribution of the individual particle and the interference of the particles. The yield point in these fractions was found to be proportional to the cube of the concentration. With these relations, it is possible to calculate the viscosity of a slip for any change in specific gravity. Diagrams and tabulated data are included. 15 references.

B. I. P. C.

DISPERSIONS

EFFECT OF SURFACE-ACTIVE AGENTS UPON DISPERSIONS OF CALCIUM CARBONATE IN XYLENE.--Vivian Richard Damerell and Raymond Mattson, *J. Phys. Chem.* 48, 134-41 (1944).

Dispersions of calcium carbonate in xylene were studied in the presence of a number of surface-active agents. These dispersions were analyzed for particle-size distribution by use of a sedimentation balance and a slit ultramicroscope. The most effective surface-active agents in this system were the zinc, barium, and sodium salts of dioctyl sulfosuccinate, sodium dihexyl sulfosuccinate, lecithin, and magnesium oleate. The calcium carbonate organosols had a milky white, opalescent appearance and were coagulated by water, 95% ethyl alcohol, and ethyl ether. Heat partially coagulated them, but cooling (to 0° C.) did not. The colloidal particles were positively charged in these systems, except when lecithin was used as a dispersing agent in which case both positively and negatively charged particles were present.

B. I. P. C.

A STUDY OF THE COLLOIDAL SYSTEM CARBON DISPERSED IN XYLENE.--V. R. Damerell and A. Urbanic, *J. Phys. Chem.* 48, 125-33 (1944).

In the present investigation, the effect of 24 surface-active agents upon various carbon-xylene systems was studied by sedimentation and ultra-microscopic analysis. In addition, adsorption measurements, cataphoresis measurements, and studies of high dried carbon-xylene systems were carried out. Certain surface-active chemicals were found to increase greatly the degree of dispersion of carbon in xylene. Lecithin, copper oleate, cobalt naphthenate, and sodium dioctyl sulfosuccinate were most effective, in the order named. The surface-active agents became more

effective as the water content of the system was lowered by extensive drying. Carbon dispersed in xylene under the conditions described is negatively charged; copper oleate and cobalt naphthenate are positively adsorbed by the carbon, whereas the ineffective oleic acid was not adsorbed. The dispersed carbon phase could be partially or completely thrown down by the addition of alcohol or water, by heat, or in an electrical field. A low temperature, down to -0.5°C ., had no effect.

B. I. P. C.

NOTE

Abstracts covering Foam, Plastics, Polymers, Proteins, Solutions and Theory have been omitted due to lack of space but shall appear in the next issue.

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