ides and iodides of lithium, sodium and potassium has been determined over a range of concentration and of temperature.

A method for carrying out these measurements is described.

CHICAGO, ILLINOIS RECEIVED OCTOBER 21, 1935

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, SMITH COLLEGE]

Effect of Heat Treatment on Hydrous Chromic Oxide Sols

BY GILBERT H. AYRES

The influence of heat treatment on certain properties of ferric oxide sols has been studied previously by the author, with special attention to particle size,[1] stability[2] and viscosity.[3] In the study of ferric oxide sols, several samples of the colloid were prepared by hydrolysis of ferric chloride, at temperatures above the boiling point of water, in an autoclave. Although these sols showed a decrease in viscosity and in flocculation value with increasing temperature of hydrolysis, more pronounced effects were observed on sols prepared by hydrolysis of ferric chloride in boiling water, dialyzed free from chloride, and then heated to higher temperatures in the autoclave. The purpose of the present investigation is to apply similar methods to chromic oxide sols. However, this study is limited to sols prepared by the use of chromic chloride and ammonium hydroxide, purified by hot dialysis, and then heat treated.

Experimental Methods and Results

Preparation of Sols.—Sols were prepared by the method of Neidle and Barab.[4] The chromic chloride used was a Baker and Adamson product marked "Chromium Chloride, Reagent, Green Crystals, $CrCl_3 \cdot 6H_2O$." This sample analyzed for approximately 30% chromium, whereas the theoretical percentage in the hexahydrate is 19.5.

Purification.—The sols were purified by dialysis through parchment, using essentially the method described by Neidle,[5] except that dialysis was carried out at a temperature of approximately 90°, and continued until a small amount of the colloid began to gel in the dialyzer; this required usually from one hundred and ten to one hundred and sixty hours. The hot sol was filtered through cotton and stored in Pyrex bottles until used for the heat treatment described later. At the end of the dialysis period the dialysate gave negative tests for chromic-ion and chloride-ion; however, the colloid always contained considerable chloride. This system is considered by some to be chromic oxychloride hydrosol,[6] but as the present investigation is not concerned primarily with the chemical composition of the dispersed phase, the colloid will be referred to as "hydrous chromic oxide sol."

Attempts to dialyze the mixture by the use of collodion bags—a procedure which is entirely satisfactory for ferric oxide sols—resulted in passage of most of the chromium compounds through the membrane. Neidle and Barab observed a similar effect, using parchment and intermittent dialysis[7] and using parchment of different weights.[4]

During dialysis, the viscosity of the system increased considerably; in fact, continuing the dialysis sufficiently long resulted in gelation of the sample. Similar results were obtained by Chakravarti and Dhar[8] for oxide sols of vanadium, cerium and chromium, and by Mittra and Dhar[9] for concentrated sols of iron, aluminum and chromium hydroxides. Figure 1 shows a typical curve of viscosity plotted against time of dialysis. Table I shows that within the first ten hours of

TABLE I

SOL NO. B-5

Hours dialysis	Relative viscosity	Cr, g. per liter
0	1.07	10.81
10	1.06	6.81
26	1.12	6.42
36	1.19	6.95
48	1.36	..
58	1.43	6.13
72	1.60	6.15
84	2.05	6.36
96	4.13	6.20

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[1] Ayres and Sorum, *J. Phys. Chem.*, **34**, 875 (1930).

[2] Ayres and Sorum, *ibid.*, **34**, 2629 (1930).

[3] Ayres and Sorum, *ibid.*, **34**, 2826 (1930).

[4] Neidle and Barab, THIS JOURNAL, **39**, 71 (1917).

[5] Neidle, *ibid.*, **38**, 1270 (1916).

[6] Thomas and von Wicklen, *ibid.*, **56**, 794 (1934).

[7] Neidle and Barab, *ibid.*, **38**, 1961 (1916).

[8] Chakravarti and Dhar, *J. Phys. Chem.*, **30**, 1646 (1926).

[9] Mittra and Dhar, *J. Indian Chem. Soc.*, **9**, 315 (1932).

dialysis the amount of total chromium in the sample did not vary to a great extent; the slight variations are due probably to the fact that the volume of the sol could not be held exactly constant during dialysis.

For use in heat treatment experiments, several 800 ml. quantities of colloid were prepared and dialyzed; four such samples were characterized as shown in Table II. As samples B-6 and B-7 were quite similar in viscosity and in chromium content, but quite different in these respects from samples B-8 and B-9, samples B-6 and B-7 were combined to give a larger stock sol for use later; this stock is designated hereafter as sample B-67. Likewise, samples B-8 and B-9 were combined and the stock designated as sample B-89.

TABLE II

Sol no.	Hours dialysis	Cr, g. per liter	Relative viscosity	
			End of dial.	After 90 days
B-6	100	6.173	2.96	3.04
B-7	124	5.852	2.09	2.49
B-8	161	8.254	4.08	13.00
B-9	109	9.704	5.64	19.14

Analysis for Chromium Content.—Pipetted samples were dissolved in warm, dilute sulfuric acid, and oxidized to dichromate by means of ammonium persulfate (silver nitrate catalyst). The dichromate was determined by titration with standard ferrous ammonium sulfate, using diphenylamine indicator. Results were calculated to grams of chromium per liter of sol.

Heat Treatment.—Samples of the stock B-67 were diluted to give sols containing 1, 2, 3, 4 and 6 g. of chromium per liter, respectively. Likewise, stock B-89 was diluted to give sols containing 1, 2, 3, 4, 6 and 8 g. of chromium per liter, respectively. Samples (about 40 ml.) of the various concentrations were sealed in Pyrex tubes and heated to various temperatures in an electrically-heated steel bomb. The tubes containing the colloid were supported in a metal rack, and were surrounded by water in order to reduce breakage of the tubes during the heating process. As far as possible, all dilutions of the same stock were heated simultaneously so as to ensure identical treatment. The bomb was heated as rapidly as possible to the desired temperature, then removed from the heating jacket and allowed to cool to room temperature. The tubes containing the colloid were opened and the contents stored in Pyrex flasks for use later.

The following general observations may be made regarding the effect of heat treatment: the concentrated samples were caused to gel by heating, and the more concentrated the sample, the lower the temperature required to cause gelation. Although it is almost impossible to determine an exact temperature which causes gelation (*e. g.*, to distinguish between very viscous liquid and a gel; and to obtain identical conditions, such as rate of heating), an inspection of the results showed that the temperature required to cause the colloid to gel, by the treatment described above, was very nearly a linear function of the concentration of colloid. The dilute samples, on heating to temperatures around 230–240°, became somewhat opaque, occasionally throwing down a trace of precipitate, and changing in color from clear, emerald green to brown-green. At temperatures of 250–260°, the dilute samples were precipitated, yielding a brown-green gelatinous precipitate and a clear, colorless supernatant liquid. Although the author has not made a detailed study of this point, it is apparent from preliminary experiments that the same general results can be accomplished by a longer period of heating at a lower temperature.

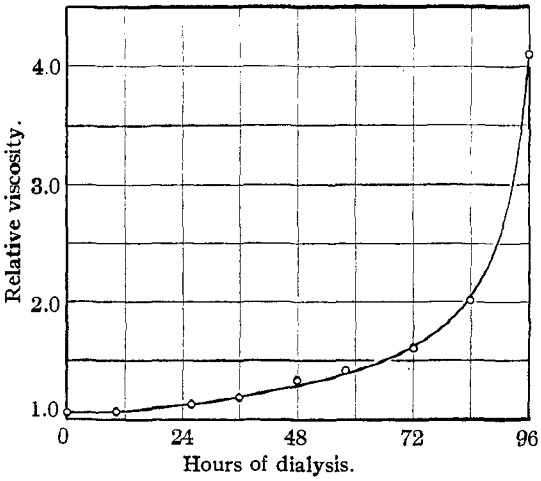

Fig. 1.

Viscosity.—All measurements of viscosity were made by means of Ostwald viscometers in a thermostat at 25 ± 0.02°. For the purpose of calculating relative viscosities, the densities of the samples were determined, at the same temperature, by means of a 25 ml. vacuum-jacketed pycnometer. (The density was found to be a linear function of the concentration; in this respect the hydrous chromic oxide sol is similar to hydrous ferric oxide sol.[10]) As the viscosity of the samples

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(10) Ayres and Sorum, *J. Phys. Chem.*, **35**, 412 (1931).

changed slowly on standing after heat treatment, all measurements of viscosity were made after the same time interval—six days—following the heat treatment.

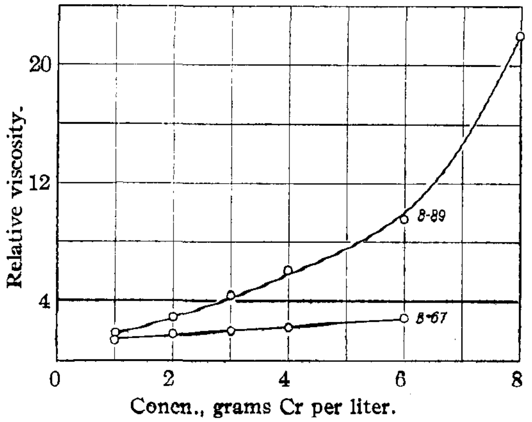

Fig. 2.

Figure 2 shows a plot of relative viscosity against sol concentration, for samples which have not been subjected to heat treatment. The results with the chromic oxide sols are similar to those obtained with ferric oxide sols,[10] and show that no generalization may be made as to the shape of the viscosity–concentration curve; the curve for sol B-67 shows a linear relation up to a concentration of 6 g. of chromium per liter, while the curve for sol B-89 at the same concentration is becoming convex toward the concentration axis, the convexity increasing quite sharply above that concentration.

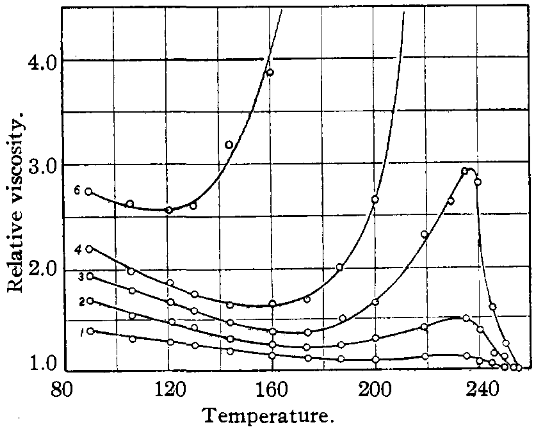

Fig. 3.—Effect of heat treatment on viscosity, sample B-67 of various concentrations.

Figure 3 shows the effect of heat treatment on the viscosity of the various dilutions of sol B-67. Similar results for sol B-89 are shown in Figs. 4 and 5. Particular attention is called to the shape of the curve in the cases of samples B-67-2, B-67-3 and B-89-2; with increasing temperature to which the samples had been heated, the viscosity at first diminished, passed through a minimum, then increased to a maximum corresponding to a treatment temperature of 240–250°, then decreased sharply, the samples being completely precipitated by heating to temperatures of 250–260°. (These results were somewhat similar to those previously reported for zirconium oxide sols.[11]) The more concentrated samples were made less viscous by heat treating at the lower temperatures, and after going through a minimum

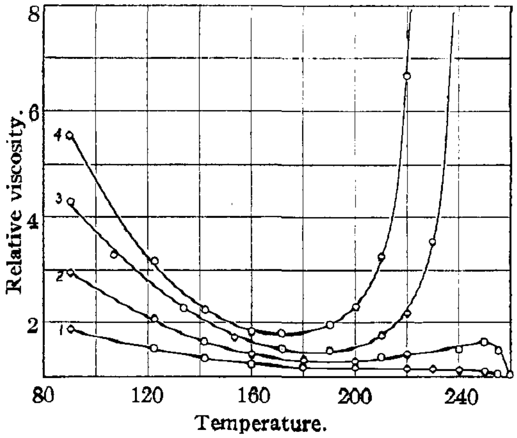

Fig. 4.—Effect of heat treatment on viscosity, sample B-89 of various concentrations (see also Fig. 5).

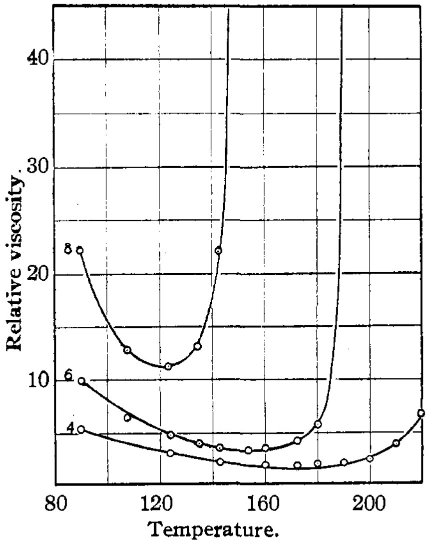

Fig. 5.—Effect of heat treatment on viscosity, sample B-89 of various concentrations (see also Fig. 4).

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[11] Robinson and Ayres, This Journal, 55, 2288 (1933).

the viscosity increased very sharply with increasing temperature, and finally gave rigid gels. The temperature of minimum viscosity, for a given stock sol, was found to be a linear function of the sol concentration, as shown in Fig. 6.

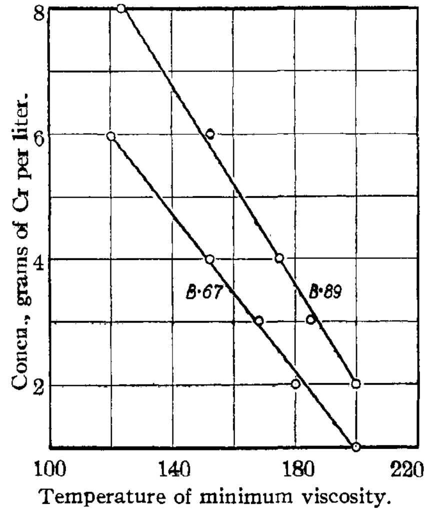

Fig. 6.

From the general shape of the viscosity-temperature curves, it is obvious that at least two factors, or two sets of factors, are involved in causing the observed results.

(1) The decrease in viscosity might be ascribed to one or more of the following factors: (a) partial dehydration of the dispersed phase;[12] (b) desorption of stabilizing ions;[3] (c) decrease in rigidity as particles grow by coagulation;[13] (d) olation and/or oxolation, as postulated by Thomas and von Wicklen.[6] Robinson and Ayres[11] found for zirconium oxide sols that heating decreased the *p*H and the viscosity.

(2) The increase in viscosity might be ascribed to one or both of the following factors: (a) hydrolysis of intermicellar chromic chloride, as indicated by Rabinerson[14] for ferric hydroxide sols; (b) increase in particle size.[13]

In the lower temperature range, factors of the first class evidently have a predominating influence, whereas the effect of factors of the second class predominates in the higher temperature range.

Flocculation Value.—Precipitations were carried out in 125 × 15-mm. Pyrex test-tubes, using in all cases 2 ml. of sol and 3 ml. of potassium sulfate solution of varying concentration. A uniform procedure of mixing colloid and electrolyte was used; the stoppered tubes were allowed to stand undisturbed for twenty-four hours, and were then centrifuged for five minutes at 800 r. p. m. and observed for completeness of precipitation. A sample was considered to be completely precipitated when, after centrifuging, there was present above the precipitated chromic oxide a layer of liquid which showed no green color. Results were calculated to millimoles of potassium sulfate required for complete precipitation, in twenty-four hours, of the chromic oxide in one liter of sol plus electrolyte mixture.

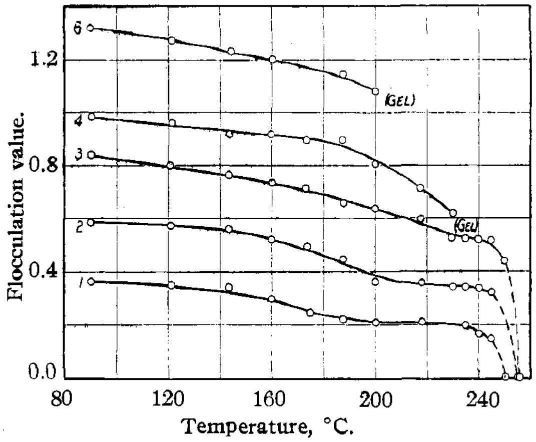

Fig. 7.—Effect of heat treatment on stability, sample B-67 of various concentrations.

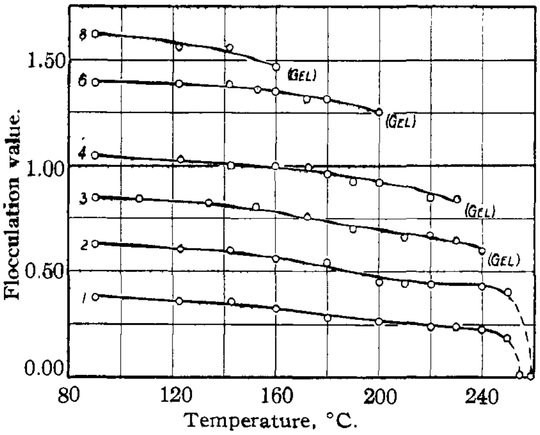

Fig. 8.—Effect of heat treatment on stability, sample B-89 of various concentrations.

Figures 7 and 8 show the results obtained. It will be noted that heat treatment caused, in all cases, a decrease in the stability of the colloid; this decrease in stability may be attributed to

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(12) Fernau and Pauli, *Kolloid-Z.*, **20**, 20 (1917); Kruyt, *ibid.*, **31**, 338 (1922); Rabinovich, THIS JOURNAL, **44**, 954 (1922); Kuhn, *Kolloid-Z.*, **35**, 275 (1924); Thomas and Hamburger, THIS JOURNAL, **52**, 456 (1930); Ayres and Sorum, *J. Phys. Chem.*, **34**, 2826 (1930); Klanfer and Pavelka, *Kolloid-Z.*, **57**, 324 (1931); Gallay, *Can. J. Research*, **7**, 662 (1932).

(13) Murty, *Kolloid-Z.*, **64**, 319 (1933).

(14) Rabinerson, *ibid.*, **66**, 303 (1934).

dehydration and/or to desorption of stabilizing ions.[3] It is interesting to note also the form of the flocculation curves for samples B-67-2, B-67-3 and B-89-2; in the temperature region of 210-250° the curves flatten out considerably, becoming almost parallel to the temperature axis. This temperature range is the region in which the viscosity curves for these samples are rising toward maxima, prior to precipitation by heat treatment alone. A somewhat similar effect has been reported for zirconium oxide sols,[11] and is also in agreement with the results obtained by Thomas and co-workers,[6,15] who found that "aging" at elevated temperature made aluminum oxyhalide and chromium oxychloride sols less responsive to the action of chloride and sulfate.

The author takes pleasure in acknowledging many valuable suggestions made by Dr. H. E. Wells during the course of this investigation.

Summary

1. Hydrous chromic oxide sols have been prepared, and samples of various concentrations heated to temperatures up to 260°.

2. Viscosity measurements have been made on the samples which were heat treated. In the lower temperature range, heating was found to decrease the viscosity, whereas at still higher temperatures the viscosity was increased. Concentrated sols were caused to set to rigid gels, whereas dilute samples were finally precipitated by heat treatment to temperatures around 250-260°.

3. Heating caused, in all cases, a decrease in the stability of the colloid, as measured by flocculation values with potassium sulfate.

4. Various means of accounting for the observed effects have been suggested.

NORTHAMPTON, MASS. RECEIVED SEPTEMBER 6, 1935

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(15) Thomas and Tai, THIS JOURNAL, **54**, 841 (1932).

[CONTRIBUTION FROM THE LABORATORY FOR PURE RESEARCH, MERCK & CO., INC.]

The Preparation and Properties of Beta-*n*-Alkylcholine Chlorides and their Acetyl Esters[1]

BY RANDOLPH T. MAJOR AND HOWARD T. BONNETT

Recent investigations have shown that acetyl-β-methylcholine is a powerful drug with many of the physiological properties of muscarine without the nicotine-like action of the related acetylcholine.[2]

When the present work was begun none of the esters of the higher homologs of β-methylcholine had been prepared and only one of the higher homologs of β-methylcholine itself was known namely, β-amylcholine iodide,[3] and apparently this had not been studied pharmacologically. Due to the interest in β-methylcholine and its esters as medicinals it became necessary, specifically due to the request of Dr. A. Simonart, to prepare some of these homologs and their acetyl esters.

These compounds were prepared as follows. The appropriate chlorohydrin[4] was treated with dimethylamine. The resulting dimethylaminoalkanol yielded a methiodide from which the acetyl ester of the β-*n*-alkylcholine chloride was prepared by standard procedures. Some of the lower homologs, namely, β-ethyl, β-*n*-propyl, and β-*n*-butylcholine chlorides, were prepared by treating the appropriate chlorohydrin with trimethylamine. Because of the rapid increase in hygroscopicity with size of the alkyl group it was found more convenient to proceed by means of the reaction of methyl iodide on dimethylaminoalkanol so that the necessary purification could be effected.

During the course of the work a number of intermediate compounds were prepared which have not been reported previously. These are 1-chlorononanol-2, 1-dimethylaminobutanol-2, 1-dimethylamino-hexanol-2, 1-dimethylaminooctanol-2 and 1-dimethylaminononanol-2.

We are indebted to Doctor Hans Molitor, Director of the Merck Institute of Therapeutic Research, for the following report of the pharmacological action of this series of compounds.

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(1) Presented before the Division of Medicinal Chemistry at the Cleveland Meeting of the American Chemical Society, September, 1934.

(2) Simonart, *J. Pharmacol.*, **46**, 157 (1932); Comroe and Starr, *ibid.*, **49**, 283 (1933); Starr, Elsom and Reisinger, *Am. J. Med. Sci.*, **186**, 313 (1933); Abbott, *ibid.*, **186**, 323 (1933); Starr, *ibid.*, **186**, 330 (1933).

(3) Von Braun and Schirmacher, *Ber.*, **56B**, 1845-1850 (1923).

(4) Levene and Haller, *J. Biol. Chem.*, **77**, 560 (1928).