tentiometrically (quinhydrone electrode) or colorimetrically.

Strong Cation Exchange Resin.—A colorless exchanger of polystyrolsulfonic acid[3] was prepared. Commercial, colorless polystyrol was cut in pieces, treated with chlorosulfonic acid for one day at room temperature, then slowly poured into water and allowed to stand overnight. A colorless, or faintly yellow, gelatinous cation exchanger resulted. It was converted to the NaR type with excess sodium acetate solution, washed with water, crushed, and screened in to 30 to 60 mesh size in water. Dry weight was measured after dehydration over calcium chloride. A 5-ml. bed volume of the wet exchanger in water adsorbed 0.05 ml. of 0.1% solution of dimethylaminoazobenzene in 90% alcohol. The neutral NaR resin is yellow but readily changes to red by washing with distilled water because of slight hydrolysis of adsorbed sodium ion. Five ml. of resin and 20 ml. of sodium chloride solution were bottled in a flask. The color was adjusted to the pink orange transition point of the indicator by the use of a minimum amount of 0.1 *N* hydrochloric acid or sodium hydroxide. This adjustment is so delicate that there is no considerable change in either a_{Nas} or a_{Nar}. The stable condition of exchange equilibrium was obtained in a short time by shaking the flask. The $p\text{H}_s$ was then measured. Since the adsorbed indicator was not eluted by washing or by change of $p\text{H}_s$, the above procedure and measurement could be repeated with the resin. The results are summarized in Table I.

TABLE I

EQUILIBRIUM BETWEEN SODIUM–POLYSTYROLSULFONATE[a] AND SODIUM CHLORIDE SOLUTIONS

Concentration of solution, *N* NaCl	pHs	pNas	pHs − pNas	Swelling volume,[c] ml./g.
1.0	3.6	0.2[b]	3.4	9
0.3	3.9	0.6[b]	3.3	11
.1	4.3	1.1[b]	3.2	14
.03	4.7	1.5	3.2	15
.01	5.0	2.0	3.0	17
.003	5.5	2.5	3.0	17
.001	6.2	3.0	3.2	17

[a] The adsorbed amounts of Na^+ in all cases were equal to 4.4 m. eq./g. [b] At higher concentrations of NaCl solution the activity coefficient of single Na^+ (or Cl^-) was used. [c] The change of swelling volume with salt concentration will slightly influence the $p\text{H}_s$–$p\text{Na}_s$.

Analogous experiments were repeated for other cations. Metallic chloride solutions were percolated through the bed of exchanger until saturated with the metallic ion. The exchanger was then mixed with metallic salt solution. For 0.1 *N* solutions of Li^+, Na^+, NH_4^+, K^+, Ag^+ (as nitrate), Ca^{++} and Ba^{++} the measured $p\text{H}_s$ values were, respectively: 4.2, 4.2, 4.1, 4.0, 3.0, 3.6 and 3.0.

Strong Anion Exchange Resin.—Amberlite IRA-400[5,6] (Rohm & Haas Co.) was employed. It was 30 to 50 mesh in size and pale yellow in color. It was treated with 5% sodium hydroxide and washed almost completely with carbon dioxide free distilled water. It was dried in a slow stream of carbon dioxide free air. One-tenth-gram sample of the ROH type resin, 1.5 ml. of 0.1 *N* hydrochloric acid, 0.5 ml. of 0.04% aqueous solution of thymol blue and 20 ml. of sodium chloride solution were mixed in stoppered bottles. Although the indicator did not diffuse in to the centers of the granules, it was completely adsorbed by the resin. For these cases the color adjustments to dark green with hydrochloric acid took a rather long time. Table II presents the results.

Analogous experiments for other anions were performed at concentrations of 0.1 molar using 1 ml. of 0.02% indicator solution per gram of resin. Thymol blue or phenol red were the indicators. The RCl type resin was treated with 0.1 *M* salt solution. For 0.1 *M* solution (or mixture of 0.1 *M* solutions) of potassium fluoride; sodium chloride; potassium bromide; potassium iodide; potassium nitrate; potassium sulfate; sodium acetate and acetic acid; disodium hydrogen phosphate and orthophosphoric acid the measured $p\text{H}_s$ values with thymol blue indicator at a yellowish-green color were, respectively: 7.4, 7.5, 7.6, 8.2, 7.8, 7.5, 7.4 and 7.6. For phenol red indicator at an orange color the $p\text{H}_s$ values were, respectively: 6.4, 6.5, 6.7, 7.0, 6.6, 6.5, 6.0 and 6.2. For this indicator the amount of chloride ion adsorbed was 1.6 m. eq./g.

TABLE II

EQUILIBRIUM BETWEEN AMBERLITE IRA-400 (RCl)[a] AND SODIUM CHLORIDE SOLUTIONS

Concentration of solution, *N* NaCl	pHs	pCls	pHs + pCls
1.0	8.8	0.2	9.0
0.1	7.7	1.1	8.8
.01	6.9	2.0	8.9
.001	6.1	3.0	9.1
.000	4.6	*ca.* 4.3[b]	*ca.* 8.9

[a] The adsorbed amounts of Cl^- were equal to 1.5 m. eq./g. [b] By nephelometry.

Weak Anion Exchange Resin.—Amberlite IR-4B[4] (Rohm & Haas Co.) at 20 to 50 mesh and orange in color was employed. The inherent color of this exchanger made it somewhat difficult to observe the transition point of the indicator. Two-tenths gram of resin in the ROH form was colored with 0.2 ml. of 0.02% aqueous phenol red solution or 0.6 ml. of 0.04% aqueous thymol blue and then treated with 20 ml. of hydrochloric acid and sodium chloride solutions. The results are summarized in Table III.

TABLE III

EQUILIBRIUM BETWEEN AMBERLITE IR-4B (RCl) AND SODIUM CHLORIDE SOLUTION

Concentration of solution, *N* NaCl	pHs	pCls	$p\text{H}_s + p\text{Cl}_s$
With thymol blue indicator (1.2 m. eq./g.)			
1.0	8.1	0.2	8.3
0.1	7.2	1.1	8.3
.01	6.4	2.0	8.4
.001	5.5	3.0	8.5
.000	4.7	*ca.* 4.0[a]	*ca.* 8.7
With phenol red indicator (3.2 m. eq./g.)			
1.0	6.4	0.2	6.6
0.1	5.6	1.1	6.7
.01	4.7	2.0	6.7
.001	3.7	3.0	6.7
.000	3.2	*ca.* 3.5[a]	*ca.* 6.7

[a] By nephelometry.

From these experiments and others[2] it was noticed that the $p\text{H}_r$ was roughly equal to $p\text{H}_s + p\text{Cl}_s$ or $p\text{H}_s - p\text{Na}_s$ for any exchanger in those cases where the adsorbed indicator showed the same pH in the resin as in the aqueous solution. This leads to the possible assumption that the numerical values of $p\text{Cl}_r$ or $p\text{Na}_r$ are almost negligible with regard to the value of the $p\text{H}_r$.

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An Enzymatic Synthesis of *sym*-Bis-(N-carbobenzoxy-L-alanyl)-hydrazine

BY FREDERICK W. HOLLY, JOSEPH J. CAHILL, JR., AND KARL FOLKERS

In an attempt to prepare N-carbobenzoxy-L-alanine hydrazide from N-carbobenzoxy-DL-alanine by application of the method described for an enzymatic synthesis of N-carbobenzoxy-L-glutamic

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(5) R. Kunin and F. X. McGarvey, *Ind. Eng. Chem.*, **41**, 1265 (1949).

(6) The Amberlite resins were obtained through the courtesy of Mr. R. Kunin.

acid anilide,[1] the formation of *sym*-bis-(N-carbobenzoxy-L-alanyl)-hydrazine was observed. Treatment of N-carbobenzoxy-DL-alanine with a tenfold excess of hydrazine in the presence of papain gave a 19% yield, based on N-carbobenzoxy-DL-alanine, of the disubstituted optically active hydrazine. With one molar equivalent of hydrazine a lower yield was obtained. *sym*-Bis-(N-benzoylglycyl)-hydrazine has been obtained[2] by an enzymatic synthesis not involving resolution.

Experimental

Ten grams of carbobenzoxy-DL-alanine[3] was dissolved in 25 ml. of water containing 1.8 g. of sodium hydroxide; 17 g. of hydrazine hydrate (85%), 0.54 g. of L-cysteine hydrochloride in 20 ml. of water and 36 ml. of phosphate buffer (*p*H 4.90) were added. The solution was adjusted to *p*H 5.1 with 1 *N* hydrochloric acid and a solution of 1.5 g. of papain[4] in 37 ml. of water was added. After an hour crystals began to form and the mixture was placed in a constant temperature room at 37° for forty-eight hours. The crystalline product was collected on a filter, washed with water and dried *in vacuo* to give 3.8 g. of *sym*-bis-(N-carbobenzoxy-L-alanyl)-hydrazine, m.p. 237–238°. A sample recrystallized from alcohol melted at 237–238°; $[\alpha]^{23}\text{D}$ $-21.2°$ (*c*, 0.476 in dimethyl formamide).

Anal. Calcd. for $C_{22}H_{26}N_4O_6$: C, 59.72; H, 5.92; N, 12.66. Found: C, 59.90; H, 5.86; N, 13.09.

From a similar reaction in which 1.7 g. of 85% hydrazine hydrate was used 2.4 g. of *sym*-bis-(N-carbobenzoxy-L-alanyl)-hydrazine was obtained.

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[1] J. S. Fruton, G. W. Irving, Jr., and M. Bergmann, *J. Biol. Chem.*, **133**, 703 (1940).

[2] C. Niemann and P. L. Nichols, Jr., *ibid.*, **143**, 191 (1942).

[3] M. Bergmann and L. Zervas, *Ber.*, **65**, 1192 (1932).

[4] Papain Merck was used without purification.

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Preparation and Thermal Stability of Thallous Hypophosphite

BY WILMER A. JENKINS AND DON M. YOST

In the course of studies on the exchange of tritium between tritiated water and hypophosphorous acid, H_3PO_2, it became necessary to prepare thallous hypophosphite, TlH_2PO_2, and study carefully some of its properties. To our knowledge, reference to this rather rare chemical has appeared only twice in the literature[1a,b]; we, therefore, feel it relevant to communicate some new observations regarding this substance.

Preparation of Hypophosphorous Acid.—Hypophosphorous acid of adequate purity can be obtained by either of two methods: (1) Conversion of commercial C.P. sodium hypophosphite to hypophosphorous acid by ion exchange, using Amberlite IR-120, or some similar high capacity resin. (2) Recrystallization of commercial 50% hypophosphorous acid. This procedure, which is somewhat involved, will be described more fully elsewhere. Good results will not be obtained in the preparation of thallous hypophosphite if the commercial acid is used directly. If the first method is used, it is necessary to concentrate the acid by vacuum desiccation before it can be used efficiently to prepare thallous hypophosphite. The acid prepared by the second method is generally purer (0.2 to 0.4 mole per cent. phosphite) than that prepared by the first method (0.6 to 0.8 mole per cent. phosphite). No phosphate was detected in the acid prepared by either method.

Preparation of Thallous Hypophosphite.—In trying out the methods of preparation described by Ferrari and Colla[1a] and by Rammelsberg,[1b] we met with only moderate success. After several other attempts, we found that the following method gave a very pure product and was the most satisfactory for our purposes. It is especially suitable for the preparation of large quantities (200 g. or more) of the salt. Thallous hydroxide solution is prepared by shaking thin slices of thallium metal with an 80% excess of water, while bubbling oxygen through the mixture. The resulting mixture is then filtered and saturated with carbon dioxide; after partial evaporation and cooling, thallous carbonate precipitates out and can be recrystallized from water. To the crystals, an equivalent amount of approximately 10 *f* hypophosphorous acid is added, and the resulting solution is filtered and further concentrated under vacuum. After two days, about 20% of the salt will precipitate out and can be filtered off. To the remainder of the solution, a large excess of *n*-propyl or isopropyl alcohol is then added (about 3 liters of alcohol per 100 ml. of saturated salt solution), and the resulting mixture is refrigerated at 5° for one week. The white, needle-like crystals that form are collected and washed with fresh isopropyl alcohol. The product is then dried in a vacuum desiccator.

Samples of thallous hypophosphite prepared in this manner were analyzed for thallium by the gravimetric chromate method,[2,3] with the following results: (1) crystals obtained directly from water, 75.8 ± 0.04%; (2) salt removed from isopropyl alcohol, 75.8 ± 0.03% (theoretical thallium, 75.89%). In a typical preparation, the overall yield was about 70%, based on thallium.

Melting Point of Thallous Hypophosphite.—The average of four determinations gave 114 ± 0.5° (cor.), thereby confirming the value of Ferrari and Colla (110°), but not that of Rammelsberg (150°). Slight decomposition of the salt was usually observed at and near the melting point.

Stability of Thallous Hypophosphite toward Heat.—Since this matter was of importance to us, and since the existing information on thermal stability is somewhat sketchy, we reinvestigated this point in some detail. The results are presented in Table I.

Series I was run by simply heating a salt sample for successive 24-hour periods in a Fisher "Iso-Temp" electric oven, with poor (±5°) temperature control, and weighing after each 24-hour heating period. Under these conditions, the salt began to liquefy at 90°, liquefaction becoming complete after about 120 hours at 90°. This fact, coupled with the weight increase observed and our inability to detect the odor of phosphine at any time, leads us to suppose that under these conditions, thallous hypophosphite is slowly air-oxidized to thallous phosphite, TlH_2PO_3, which has a reported melting point of 70°.[4] Analysis of the heated product for thallium supported this supposition.

Each member of Series II, III and IV was run as follows: about one gram of the salt in a small, open weighing bottle was freed of most of its adsorbed solvent (isopropyl alcohol in Series II and III, water in Series IV) by vacuum desiccation. It was then weighed and the bottle inserted in a 28 mm. Pyrex tube which was sealed off at one end and fitted at the other with a 34/45 ST joint. The tube and bottle were evacuated at room temperature with a mercury diffusion pump until the salt attained constant weight. At no time in this initial pumping was a weight loss greater than about 0.2 mg. noted. After weighing, the tube and bottle were re-evacuated, and a cylindrical electric heater, at the desired temperature, was placed around the tube. During each heating period, a vacuum of 10^{-5} mm. was maintained. The salt, in its bottle, was removed at the end of each heating period, weighed, pulverized, stirred up well, returned to the tube and heated under vacuum as before. Fresh salt samples were taken for each series. The *net* weight losses are listed in Table I.

Several interesting phenomena were noted during these heating experiments. (a) In all cases, the salt blackened slowly during the course of a heating period. At 95°, about six or seven hours were usually necessary to cause blackening to begin. At the present time, we can offer no explanation for this

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[1] (a) Ferrari and Colla, *Gazz. chim. ital.*, **67**, 88 (1937); (b) Rammelsberg, *Ber.*, **5**, 494 (1872); *Pogg. Ann.*, **146**, 592 (1872); *J. Chem. Soc.*, **26**, 7 (1873).

[2] Browning and Hutchins, *Am. J. Sci.*, **8**, 460 (1899).

[3] Mach and Lepper, *Z. anal. Chem.*, **68**, 36 (1926).

[4] Amat, *Ann. chim. phys.*, **24**, 310 (1891).