

potassium fluoride were compared with a standard solution of titanium in the colorimeter. The following results were obtained:

	Volume of solution c.c.	TiO <sub>2</sub> present gms.	HFl present gms.	Colorimeter reading obtained by comparing solution with (1) as standard.
1	250	0.010	0.000	100.0
2	250	0.010	0.00039	93.3
3	250	0.010	0.00194	80.2
4	250	0.010	0.0039	67.6

Similarly, the change in color caused by adding different amounts of phosphoric acid to a titanium solution of the same concentration was determined. The phosphoric acid used was prepared by Kahlbaum. The titanium solution contained 5 per cent. sulphuric acid and 2 cc. of 3 per cent. hydrogen peroxide in every 250 cc.

	Volume of solution c.c.	TiO <sub>2</sub> present gms.	P <sub>2</sub> O <sub>5</sub> present gms.	Colorimeter reading obtained by comparing solution with (1) as standard.
1	250	0.010	0.00	100.
2	250	0.010	0.13	90.
3	250	0.010	0.26	83.
4	250	0.010	0.52	74.
5	250	0.010	0.78	69.
6	250	0.010	1.04	66.
7	250	0.010	1.30	64.

That the change in color was not due to an impurity in the phosphoric acid used was proved by the fact that on repeating the experiment with solution (3) and using in 250 cc. of solution 0.638 g. of pure K<sub>2</sub>HPO<sub>4</sub> (containing 0.26 g. P<sub>2</sub>O<sub>5</sub>) instead of phosphoric acid a reading of 82.5 was obtained, which agrees with the value obtained when phosphoric acid was used. Moreover, an experiment in which phosphoric acid obtained from another source was used gave results agreeing with the above.

The influence of the phosphoric acid on the titanium color is of importance in the colorimetric determination of titanium in substances containing any considerable amount of phosphates. The results obtained will be low unless enough phosphoric acid is added to the standard to compensate the effect of that in the sample.

## A STUDY OF THE ATOMIC WEIGHT OF INDIUM.<sup>1</sup>

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Received January 25, 1907.

### Historical.

The first determinations of the atomic weight of indium were made by Reich and Richter<sup>2</sup>, who obtained values that varied from 110 to 112.

<sup>1</sup>NOTE.—The following investigation by Mr. Mathers upon the Atomic Weight of Indium is a continuation of the work that was first taken up in the Cornell Laboratory by Mr. W. C. Geer.

L. M. DENNIS.

<sup>2</sup>Reich and Richter, J. pr. Chem., 92, 480 (1864).

They oxidized metallic indium with nitric acid and determined the ratio of indium to indium oxide. The same authors determined the ratio of indium sulphide to indium oxide and barium sulphate. They made only a few experiments and the methods that they followed have since been shown to be very inaccurate. Richards has demonstrated that it is impossible to free precipitated barium sulphate from occluded salts<sup>1</sup> and that metallic oxides that are prepared by the ignition of the nitrates always retain some occluded gases<sup>2</sup>. To further complicate the work, indium oxide is appreciably volatile at 1000°<sup>3</sup>, and is also hygroscopic. From the ratio of indium to gold, Winkler<sup>4</sup> obtained the value, 114. This method should have given correct results, if the material had been pure. A similar ratio, copper to silver, was determined by Richards<sup>5</sup> and excellent results were obtained. Winkler made only two determinations; consequently, the result cannot be given great weight. The same author<sup>6</sup> also obtained the values 107.8 and 113.8 from the ratio of indium to indium oxide. Bunsen<sup>7</sup> incidentally made two determinations of the atomic weight of indium in connection with his work upon the specific heats of the elements and upon calorimeters. He ascertained the ratio of indium to indium oxide and obtained the value 113.8. The only recent work upon the atomic weight of indium is that performed by Thiel<sup>8</sup>. Eight determinations by him of the ratio of indium to indium oxide gave values that vary from 113.4 to 115.6. Since this ratio is subject to the inaccuracies mentioned above, the results obtained are of slight importance. From the ratio of indium to indium trichloride and of indium to indium triiodide, Thiel obtained values that approximate 115.4. It is quite probable that this figure is too high owing to errors caused by loss from volatilization during drying, by the presence of basic compounds in the trichloride or triiodide, or by the presence of moisture or foreign salts in the spongy metallic indium that had been only lightly pressed. Thiel also determined the ratios of indium trichloride to silver chloride and of indium tribromide to silver bromide. His procedure was as follows:—To weighed portions of indium trichloride or tribromide there was added a slight excess of a standard solution of silver nitrate. After filtration, the amount of this excess was determined by precipitating the silver in the filtrate with hydrochloric acid and weighing this precipitate of silver chloride. The weight of the chlorine that was in combination with the indium was ascertained by subtracting the weight of

<sup>1</sup> Richards, *Z. anorg. Chem.*, **8**, 413 (1895).

<sup>2</sup> Richards, *Proc. Amer. Acad. Arts and Sci.*, **26**, 281 (1890-1891).

<sup>3</sup> Meyer, *Z. anorg. Chem.*, **47**, 281 (1905).

<sup>4</sup> Winkler, *J. pr. Chem.*, **102**, 273 (1867).

<sup>5</sup> Richards, *Am. Ch. J.*, **10**, 182 (1888).

<sup>6</sup> *J. pr. Chem.* **94**, 1 (1865).

<sup>7</sup> *Pogg. Ann.*, **141**, 28 (1870).

<sup>8</sup> *Z. anorg. Chem.*, **40**, 280 (1904).

the silver of the silver chloride from the total silver that had been added as silver nitrate. No correction was made for the solubility of silver chloride. The average of four results obtained from the ratio of indium trichloride to silver chloride is 115.05. Three results from the ratio of indium tribromide to silver bromide, give an average of 114.81. Brauner<sup>1</sup> recalculated Thiel's results obtained from the ratio of indium trichloride to silver chloride, and, by using a "somewhat arbitrary" correction for the solubility of silver chloride, obtained the value 114.9. The International Committee on Atomic Weights has adopted the value 115.

Below is a tabulated list<sup>2</sup> of the various determinations.

Name.	Year.	Ratio.	Atomic Weight In.
Reich and Richter	1864	2In : In <sub>2</sub> O <sub>3</sub>	111.2
		In <sub>2</sub> S <sub>3</sub> : In <sub>2</sub> O <sub>3</sub> : 3BaSO <sub>4</sub>	112.
Winkler .....	1865	2In : In <sub>2</sub> O <sub>3</sub>	107.8
	1867	In : Au	114.03
		2In : In <sub>2</sub> O <sub>3</sub>	113.58
Bunsen .....	1870	2In : In <sub>2</sub> O <sub>3</sub>	113.84
Thiel .....	1904	2In : In <sub>2</sub> O <sub>3</sub>	113.4-115.6
		In : InCl <sub>3</sub>	115.4
		In : InI <sub>3</sub>	115.3
		InCl <sub>3</sub> : 3AgCl	115.01
		InBr <sub>3</sub> : 3AgCl : 3AgBr	114.83

The standards used in the table are : silver, 107.92; chlorine, 35.47; and bromine, 79.955.

### Experimental.

The wide variations in the earlier results upon the atomic weight of indium led Dennis and Geer to take up the study of the subject in this laboratory in 1903. While that investigation was still in hand Thiel<sup>3</sup> published a preliminary note in which he announced the provisional atomic weight of 115.08. This called forth a preliminary note<sup>4</sup> by Dennis and Geer in which they describe new methods for the purification of indium and the preparation of the metal. Thiel<sup>5</sup> subsequently published full results upon the ratios, InCl<sub>3</sub> to 3AgCl and InBr<sub>3</sub> to 3AgBr. By the first ratio the atomic weight of indium was 115.05; by the second, 114.81. Although his work was undoubtedly more accurate than any that had preceded it, the averages of the results obtained by the two ratios differed by 0.24. Consequently the study of the subject was continued in this laboratory with the results detailed below.

*Balance and Weights.* The balance used in this work was manufactured by A. Rüprecht. One milligram shifted the zero point ten divisions. This sensitiveness could be increased to such an extent that 0.1 milligram would shift the zero point eight spaces, but this degree of sensitiveness was not

<sup>1</sup> Brauner, Abegg's Handbuch, 3, Part I.

<sup>2</sup> Ibid.

<sup>3</sup> Ber. 37, 175 (1904).

<sup>4</sup> Dennis and Geer, this Journal, 26, 437 (1904).

<sup>5</sup> Z. anorg. Chem., 40, 280 (1904).

required for the work. All weighings were made by the method of substitution and were reduced to vacuum. The weights were standardized by comparison with quartz weights, which, within the past year, had been standardized by the Bureau of Standards at Washington. The balance was kept in a "constant temperature room" where the total variation in temperature during the entire period of work amounted to only a few degrees. The table that supported the balance rested upon the solid concrete floor. Vessels containing concentrated sulphuric acid were used to keep the room dry. Calcium chloride was used inside of the balance case.

*Purification of Materials. Indium.* Commercial metallic indium was dissolved in less than the required amount of hydrochloric acid, and the solution was filtered from the residue of indium and such metals as copper, mercury, silver, etc. An excess of hydrochloric acid was added and the solution was treated with hydrogen sulphide. The insoluble sulphides were filtered out and the hydrogen sulphide was removed by boiling. Ammonium chloride and ammonium hydroxide were added and the solution was warmed. Indium hydroxide was precipitated, together with the hydroxides of iron, aluminum and probably a small amount of zinc. The greater part of the zinc remains in solution. After washing with water, the precipitate was dissolved in hydrochloric acid and reprecipitated with ammonium hydroxide and ammonium chloride and again washed with water. This solution in acid and reprecipitation with ammonium hydroxide was repeated four times. These steps should remove zinc. For the removal of the greater part of the iron that was still present, the precipitate was dissolved in hydrochloric acid and the solution was evaporated almost to a syrup. This was transferred to a separatory funnel, an excess of potassium sulphocyanate was added and the red ferric sulphocyanate was removed by extraction with successive 50 cc. portions of ether<sup>1</sup>. The indium was then precipitated as the hydroxide with ammonium hydroxide and this was washed with water. The indium hydroxide was next dissolved in hydrochloric acid and the solution was evaporated until almost all of the free acid was removed. This solution was placed in a beaker and the metallic indium was deposited by electrolysis with a current of 0.5 ampere. The platinum anode was placed in a porous cup and the platinum wire cathode extended only 0.25 cm. into the liquid. The beaker was kept covered with a bell jar and the chlorine was removed by suction through a glass tube, which reached under the cover glass of the beaker. This very high current density at the cathode lasts for only a very short time because the metallic indium soon grows down into the electrolyte and increases the cathode surface. If a larger platinum cathode were used, much of the indium deposit could not be mechanically removed, since it adheres very tightly to the platinum surface. Under the conditions above described the indium is deposited in a crystalline form and is soft and

<sup>1</sup> Dennis and Geer, this Journal, 26, 437 (1904).

malleable. The compactness of the metal bears a direct ratio to the amount of acid present. The metal was washed with water and compressed, if it was very crystalline and soft. After washing it with alcohol and drying at  $120^{\circ}$ , the metal was fused in a charcoal crucible in an atmosphere of hydrogen. The temperature required was not high, as indium melts at  $155^{\circ}$ . The metal thus purified should be free from aluminum, chromium, manganese and such metals as are not electrolytically precipitated from an aqueous solution. Since indium is electro-negative to zinc and cadmium, these metals also should not be deposited with the indium during electrolysis. Nevertheless, the indium was found to contain traces of iron and, consequently, it was further purified by fractional electrolysis from a solution of indium sulphate acidified with sulphuric acid.

The electrolysis was carried on in a large test tube through the bottom of which was fused a platinum wire. The metallic indium to be purified was placed in the tube directly in contact with the platinum wire which was made the anode. The indium was covered to a depth of about four centimeters with dilute sulphuric acid (1:4 by volume) and a platinum wire cathode was immersed in the liquid to a depth of about three millimeters. The indium is deposited on the cathode in the form above described. A considerable quantity of fine anode slime is produced, but this remains at the anode and does not contaminate the indium that separates upon the cathode. The fractionation was carried on twice to effect the complete removal of the iron. The metallic indium was removed from the cathode, was washed with water and with alcohol and was dried. It was then fused in a charcoal crucible in a current of hydrogen to remove occluded salts and water. It was repeatedly observed that the metallic indium obtained by electrolysis gave off upon fusion appreciable amounts of water even when it had previously been dried for some time in an air-bath. The fused metal was cleaned with dilute hydrochloric acid and was rubbed with filter paper. To ascertain whether the metal was free from iron, a portion of it was converted into anhydrous indium bromide. 3.2323 grams of this salt was dissolved in 15 cc. of water and placed in a Nessler tube of 25 cc. capacity. Ten cubic centimeters of normal ammonium sulphocyanate was then added. The solution showed no appreciable color. Upon adding to this solution 0.0002 gram of ferric chloride, a distinct red color appeared. Consequently, if the indium bromide contained iron, the amount of the latter was less than 0.006 per cent. This metallic indium thus purified was used in the preparation of the different compounds employed in the determination of the atomic weight of the element.

*Bromine.* "Pure" bromine, purchased of Kahlbaum, was shaken with about one-fourth of its weight of calcium bromide and a few grams of zinc oxide<sup>1</sup> and was allowed to stand in contact with these materials for

<sup>1</sup>Stas, Mem. de l'academie royal des sciences, des lettres, et des beaux-arts de Belgique, 43, Note 3 (1882).

several days. By this treatment iodine is converted to zinc iodate<sup>1</sup> and chlorine to calcium chloride. The bromine was distilled off and the distillate was then subjected to fractional distillation. The middle fractions were employed.

*Chlorine.* "Pure," concentrated hydrochloric acid was diluted with an equal volume of water, was then heated to about 85° and was treated with successive small portions of potassium permanganate. The liquid was then heated to boiling and any bromine or iodine set free by the potassium permanganate distilled over in the first fractions. The middle fraction was collected separately and was then again subjected to fractional distillation. The middle fraction of this second distillate was reserved for use. The distillation was carried on in an apparatus made entirely of glass. Chlorine was generated by heating this acid with manganese dioxide that had previously been treated with hot dilute sulphuric acid and had been washed free from that acid.

*Silver.* Metallic silver was dissolved in nitric acid and was precipitated from a very dilute solution with hydrochloric acid. The silver chloride was washed thoroughly with water, then with strong hydrochloric acid, and again with water. It was next treated with strong nitric acid and was freed from this acid by further washing with water. This precipitated silver chloride was then transferred to a platinum dish and was covered to a depth of about 2 cm. with very dilute sulphuric acid. This was then electrolyzed, with the dish as cathode and a platinum disc as anode, the passage of the current being maintained until all of the silver chloride had been reduced. The resultant spongy silver was fused in a charcoal crucible with the blast lamp. It was next cleaned with sand and nitric acid. The silver was then further purified by placing it in a porous cup, covering it with a solution of silver nitrate, and immersing the cup in a beaker containing more of the solution of silver nitrate. This was then subjected to electrolysis, the silver to be purified serving as anode, and a piece of platinum foil that was inserted in the solution in the beaker serving as cathode. Connection between the metallic silver and the circuit was made by means of a platinum rod. With a current of about one ampere per 100 sq. cm. of cathode surface the silver is precipitated in loose crystals that can easily be separated from the cathode. Adhering silver salts were removed by washing the crystalline silver with dilute ammonium hydroxide and then with water. When wanted for use about one-forty-seventh more than the amount of silver required for precipitation was weighed out and was fused with the blast lamp in a charcoal crucible. The silver button was cleaned with sand and with dilute nitric acid and the weight was reduced to about one-fiftieth excess by means of a file.

<sup>1</sup> Richards and Merigold, *Z. anorg. Chem.*, **31**, 261 (1902).

*Nitric Acid.* The purest nitric acid of commerce was distilled from a flask of Jena glass against the side of a platinum dish which contained ice water and which acted as a condenser<sup>1</sup>. The condensed nitric acid was collected and preserved for use in a platinum dish.

*Carbon Dioxide.* Carbon dioxide was generated in a Kipp apparatus from marble and nitric acid. The gas was passed through a solution of sodium bicarbonate to remove any acid that might mechanically be carried along with the carbon dioxide. Any oxygen in the carbon dioxide was removed by passing the gas over red hot copper shot contained in a porcelain tube.

*Distilled Water.* The distilled water of the laboratory was redistilled after the addition to it of a small amount of potassium permanganate to destroy organic matter. The middle portion of this distillate was again redistilled and the middle fraction of this last distillate was used. Glass stoppered distilling flasks were employed, and the condenser used in the last distillation was of block tin.

*Drying Apparatus.* The drying train for each gas consisted of two gas wash bottles filled with concentrated sulphuric acid, a drying tower containing pumice stone saturated with sulphuric acid, and a tube containing phosphorus pentoxide. The pumice stone, before using, was digested with dilute sulphuric acid, washed with water and dried. The drying efficiency of the sulphuric acid was shown by the fact that the phosphorus pentoxide would remain perfectly dry even after a current of gas had been passed over it for from two to three days.

#### METHOD OF ANALYSIS.

The solution to be precipitated was placed in a 1.1 liter Jena glass flask, 4 to 5 cc. of nitric acid was added, and the solution was diluted with distilled water to about 400 cc. About 1/50 excess of an approximately 1 per cent. silver nitrate solution was added drop-wise with constant shaking. This silver nitrate solution was made by dissolving the silver in nitric acid and evaporating this solution until the excess of nitric acid was removed. The flasks were allowed to stand for from twenty-four to forty-eight hours until the mother liquor became clear. The precipitate was filtered upon a Gooch crucible and was washed by decantation until the filtrate was no longer acid. It was then transferred to the crucible by a stream of water from the wash bottle. That portion of the silver precipitate which adhered to the sides of the flask was removed without difficulty by vigorously shaking it with small quantities of pure water. From 1200 to 2000 cc. of wash water was used. All of the above steps were carried out in a photographic dark room to prevent the action of light upon the silver precipitate. The filtrate and wash water were passed through a filter paper to catch shreds of asbestos or any of the precipi-

<sup>1</sup>Morse and Burton, *Am. Ch. J.*, 10, 311 (1888).

tate. In the case of silver chloride, the wash water was evaporated and the silver chloride that was in solution was collected upon a filter paper. After ignition of the paper and the precipitate, the silver was dissolved in nitric acid and was titrated with a standard solution of potassium sulphocyanate. The solubility of the silver bromide is so small that it was neglected. The silver chloride or silver bromide was dried at  $135^{\circ}$ , for a few hours and then at  $150^{\circ}$  for from fifteen to twenty hours, and was weighed. It was then transferred to a porcelain crucible and was fused. Any loss of weight on fusion was subtracted from the original weight of crucible and precipitate.

#### THE RATIO OF INDIUM TO INDIUM SULPHATE.

Metallic indium was placed in a platinum dish, dissolved in redistilled sulphuric acid, and concentrated on a water bath until crystals appeared. The platinum dish was then placed in a porcelain dish which was covered by an inverted porcelain dish as a protection from dust. A thermometer was inserted between the dishes in such a position that its bulb was in contact with the platinum dish. The heating was carried on upon a hot plate. A temperature of  $400^{\circ}$  was maintained for forty-two hours, but even after that length of heating it was found that the weight was still decreasing. The temperature was then raised to  $450^{\circ}$  for fifteen hours, whereupon the weight apparently became constant. The indium sulphate is, however, so very hygroscopic that accurate weighing is very difficult of accomplishment. The results obtained have no real value, but are as follows:

Grams of Indium.	Grams of $\text{In}_2(\text{SO}_4)_3$ .	Atomic Weight Indium.
1.3045	2.9675	113.03
1.0842	2.4659	113.08

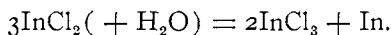
The incomplete removal of sulphuric acid would cause the results to be too low. If heated with a free flame to a dull red heat, some of the indium sulphate is decomposed with the formation of indium oxide as shown by the yellow color. This oxide volatilizes slightly on continual heating.

#### THE RATIO OF INDIUM DICHLORIDE TO SILVER CHLORIDE.

Pure metallic indium was placed in one end of a Jena glass tube that was about 90 cm. long. This tube had previously been constricted so as to form four compartments. After displacing the air with hydrochloric acid gas, the tube was heated with a Bunsen flame. The hydrochloric acid began to attack the metal at a temperature just below the melting point of indium ( $155^{\circ}$ ). The temperature was maintained at such a point that the metal and the chlorides that were formed remained liquid. As long as metallic indium was present, the product was dark brown, almost black, indium monochloride ( $\text{InCl}$ ). Further action of the hydrochloric acid changed this into the light yellow, nearly transparent, indium di-



chloride ( $\text{InCl}_2$ ). This indium dichloride was distilled into the second compartment in a current of hydrochloric acid gas. After displacing all of the hydrochloric acid gas with carbon dioxide, the indium dichloride was distilled in a current of the latter gas into the last two compartments. The tube was then cooled and the carbon dioxide was displaced with dry air. The two samples were sealed off with a blast lamp, and the tubes were dried and weighed. The ends of the tubes, which had been scratched with a file before weighing, were then broken off, the tubes were placed in beakers, and the indium dichloride was dissolved in dilute nitric acid. Indium dichloride reacts with water according to the following equation:



This explains the use of nitric acid in bringing the salt into solution. Even under this treatment, however, the resultant solution was never perfectly clear. This is probably due to the action, even at a low red heat, of indium dichloride upon the glass of the tube. No quantitative determinations were made with solutions that showed this turbidity. To prevent the corrosion of the glass, the later portions of the indium dichloride were not distilled from one compartment of the tube into another, but were simply sealed off in that portion of the tube where they were formed after the hydrochloric acid gas had been completely displaced by carbon dioxide. All of these samples gave clear solutions when the substance was treated with dilute nitric acid. Upon precipitating the chlorine by silver nitrate in the manner previously described, varying results for the atomic weight of indium were obtained. Some of the resulting values are the following:

Grams of Indium.	Grams of AgCl.	Atomic weight of Indium.
3.5354	5.54176	112.03
3.8492	6.03475	111.99
4.6482	7.2359	113.2

Low values would be caused by the incomplete removal of the hydrochloric acid gas or by the formation of some indium trichloride. The ratio was abandoned because of the inaccuracies inhering in the method.

#### THE RATIO OF INDIUM TRICHLORIDE TO SILVER CHLORIDE.

Pure metallic indium was heated in a current of chlorine gas in a constricted tube such as described above. Indium monochloride is first formed; this slowly changes to indium dichloride. The latter halide is then gradually converted into indium trichloride by the continued action of the chlorine. Indium trichloride is a white substance which sublimes easily at a temperature just below a red heat. The indium trichloride was sublimed twice in chlorine and twice in carbon dioxide. The tube was then filled with dry air and the samples were sealed off. The indium trichloride thus prepared gave a perfectly clear solution only when some

nitric acid was added to the water in which the substance was dissolved. This is probably to be explained by the fact that not all of the indium dichloride was converted into the trichloride and that, as a consequence, some metallic indium was set free when the substance was treated with water. It is also possible, however, that the change into indium trichloride was complete, but that this compound was dissociated to some extent into indium dichloride and chlorine<sup>1</sup>. It is presumable that this dissociation of the indium trichloride would take place when the substance is heated in the current of pure carbon dioxide because of the ready removal of the chlorine from the tube and because crystals of the substance filling as they did the entire cross section of the tube would act to some extent as a porous diaphragm. To prevent such dissociation, later sublimations were carried on in a current of carbon dioxide that contained some chlorine gas. After the sublimation had been effected, the temperature was lowered below the sublimation point, and pure carbon dioxide containing no chlorine gas was then passed through the tube. This was continued for half an hour and the tube was then allowed to cool, the passage of the carbon dioxide through the tube being continued through the cooling and for from eighteen to twenty hours after the tube had reached room temperature. The carbon dioxide was then displaced by air and the tube was sealed off at its constrictions. The ends of these tubes containing the samples were scratched with a file, and the tubes were then dried and weighed. The ends were then broken off and the indium trichloride was dissolved in pure water. The solution was perfectly clear in every case, but it sometimes contained small particles of glass. This glass was removed by filtration and was weighed, its weight being added to that of the empty tube and the broken off ends of the tube. Thiel<sup>2</sup> states that filtration of the solution of the trichloride at this point was frequently necessary to remove ferric oxide that was present. During this investigation, however, the presence of ferric oxide in the sublimed indium trichloride was not observed in any case.

	Grams InCl <sub>3</sub>	Grams AgCl	Atomic Weight of Indium.
1	2.1156	4.11421	114.80
2	4.95920	9.64176	114.85
3	1.98175	3.85125	114.95
4	5.54540	10.77904	114.90
5	1.46561	2.84557	114.86
6	4.08602	7.94054	114.96
			Average, 114.88

The chlorine of the indium trichloride was precipitated by means of the solution of silver nitrate in the manner previously described and the ratio of indium trichloride to silver chloride was thus obtained. In the calcula-

<sup>1</sup> Nilson and Pettersson, *J. Chem. Soc. (London) Trans.*, 53, 814 (1888).

<sup>2</sup> *Z. anorg. Chem.* 40, 310 (1904).

tions, the atomic weight of silver was taken as 107.93, and of chlorine as 35.473<sup>1</sup>.

THE RATIO OF INDIUM TRIBROMIDE TO SILVER BROMIDE.

The indium tribromide was made by heating metallic indium in a current of carbon dioxide gas containing bromine. The carbon dioxide was passed through a gas wash bottle that contained bromine and the indium was converted into the tribromide in the apparatus already described under the preparation of the trichloride. Indium tribromide is a white substance that sublimes easily. The ratio of indium tribromide to silver bromide was ascertained in the manner directly analogous to that described under the ratio of indium trichloride to silver chloride. In the calculation of results, the atomic weight of bromine was taken as 79.953<sup>2</sup>.

	Grams InBr. <sub>3</sub>	Grams AgBr.	Atomic Weight of Indium.
7	2.73494	4.34550	114.89
8	7.69880	12.23341	114.86
9	6.27450	9.96917	114.89
10	5.36642	8.52741	114.85
11	5.16112	8.20128	114.85
12	4.98336	7.92009	114.81
			Average, 114.86

SUMMARY.

Because of the unavoidable errors in the precipitation and weighing of the silver chloride due to the solubility of that substance<sup>3</sup>, the results obtained for the ratio of indium tribromide to silver bromide were probably more accurate than those from the ratio of indium trichloride to silver chloride. The averages of the two ratios, however, give closely agreeing values, 114.88 and 114.86. On the basis of these results the author would recommend as the atomic weight of indium the value

114.9.

In conclusion, the author takes this opportunity to express his thanks to Professor L. M. Dennis, who suggested the subject, and to Dr. A. W. Browne and Dr. W. C. Geer, for valuable assistance during the course of the investigation.

CORNELL UNIVERSITY, JANUARY, 1907.

## A NEW METHOD FOR THE SEPARATION OF THE YTTRIUM EARTHS.

BY C. JAMES.

Received January 21, 1907.

In working up a specimen of gadolinite for the rare earths, the remarkable fact was noted that the filtrate, after the beryllium separation

<sup>1</sup> This Journal, 28, 7, (1906).

<sup>2</sup> Baxter, this Journal, 28, 1335 (1906).

<sup>3</sup> Richards, Proc. Am. Acad. Arts and Sci., 29, 71 (1893); and Richards and Wells, Carnegie Institution Public. (Washington) April (1905).