3. The end point can be obtained in a clear solution instead of in an opalescent solution by supplementing the starch present with 10 cc. of a 1% soluble starch solution just before titration.

4. The original method and the method as applied with the use of additional starch both give satisfactory results.

RICHMOND, VA.

[CONTRIBUTION FROM THE ARKANSAS AGRICULTURAL EXPERIMENT STATION.]

THE DETERMINATION OF PHYTIN PHOSPHORUS IN PLANT PRODUCTS.[1]

BY J. B. RATHER.

Received August 13, 1917.

No satisfactory method for the direct determination of phytin phosphorus in plant products exists. The amount of phytin phosphorus in such materials has been estimated by Posternak[2] by separating the crude acids in a state more or less free from bases, by Suzuki and Yoshimura[3] by precipitating the acid extract of the plant with absolute alcohol and determining the phosphorus in this product, and by Funatsu[4] by determining the phosphorus in the acid extract of the plant. The exclusion of inorganic phosphorus, organic forms of phosphorus other than phytin, and enzymatic hydrolysis was, apparently, not considered by these workers.

Heubner and Stadler[5] determine phytin phosphorus in pharmaceutical products by titrating with ferric chloride under certain definite conditions. These workers show that inorganic phosphorus and glycerophosphates do not interfere with the titration. Briefly the method is as follows: The volume of the solution to be titrated is, at the beginning of the titration, 100 cc. and contains 0.6% hydrochloric acid and 0.03% ammonium sulfocyanate. It is titrated with standard ferric chloride solution in 0.6% hydrochloric acid, the solution containing from 0.05 to 0.2% Fe, until the supernatant liquor above the whitish iron precipitate develops a pale red color persisting for 5 minutes. One mg. Fe corresponds to 1.19 mg. phytin P. The factor was derived from experiments on a sample of commercial phytin.

On account of its simplicity the method of Heubner and Stadler was made the basis of work by the present writer.

Experimental.

In testing the applicability of the ferric chloride titration method for

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[1] Full details of this work will be published as a Bulletin of the Arkansas Experiment Station.

[2] *Compt. rend.*, 137, 202 (1903).

[3] *Bull. Coll. Agr. Tokyo*, 7, 495–502 (1907).

[4] *Ibid.*, 7, 457.

[5] *Biochem. Z.*, 64, 422–437 (1914).

the determination of phytin to plant products, the following factors were considered: (1) the time required for complete extraction of the phytin from plant products, (2) the influence of phytin-splitting enzymes, (3) the possible interference of other phosphorus compounds in the plant extract, (4) the possible interference of non-phosphorized substances in the plant extract, and (5) the ratio of iron to phosphorus under the conditions of the method as ascertained by examination of purified phytin products obtained from the plant products under examination.

Influence of Enzymes.—According to Forbes[1] phenol inhibits the activity of the enzyme phytase, and Boutwell[2] and Anderson[3] have shown that by increasing the strength of the hydrochloric acid used as a solvent above the usual 0.2%, the activity of the enzyme can probably be prevented. The effect of these reagents was tested as follows: Ten-gram portions of the finely divided sample were digested for 3 hours with frequent shaking with (*a*) 300 cc. 0.2% hydrochloric acid, (*b*) 300 cc. 0.2% hydrochloric acid containing 50 g. phenol per liter, and (*c*) 300 cc. 1.2% hydrochloric acid. Aliquot portions of 50 cc. of the filtered solutions were taken for titration in duplicate. To (*a*) and (*b*) extracts, 8.3 cc. of 6.0% hydrochloric acid, 10 cc. 0.3% ammonium sulfocyanate solution, and 33.7 cc. water were added. To (*c*) extracts, 10 cc. ammonium sulfocyanate solution and 40 cc. water were added. The volume of the solutions and concentration of indicator and acid were thus in accordance with the directions of Heubner and Stadler. The solutions were then titrated with standard ferric chloride solution containing 0.6% hydrochloric acid, and concentration of the Fe being within the limits set by the above workers. Since the results were intended for comparative purposes only the factor 1.19 of Heubner and Stadler was employed. The results follow:

TABLE I.—EFFECT OF REAGENTS ON ENZYMATIC HYDROLYSIS OF PHYTIN.

Sample No.	Material.	Phytin phosphorus in % of sample. 0.2%. HCl.	 0.2%. HCl and phenol	 0.2%. HCl.
2234	Wheat bran	0.89	0.87	1.18
2217	Kafir	0.16	0.12	0.23
2347	Rice polish	1.00	0.97	1.18
2333	Rice bran	0.94	0.83	1.18
2311	Corn	0.10	0.10	0.21
	Mean	0.61	0.58	0.80

The averages of the results with 0.2% hydrochloric acid with and without phenol are practically the same. The results with 1.2% hydrochloric acid average somewhat higher. The higher results with this solvent may

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[1] Forbes, *et al.*, Ohio Experiment Sta., *Bull.* **215** (1910).

[2] THIS JOURNAL, **39**, 491–503 (1917).

[3] *J. Biol Chem.*, **20**, 483–491 (1915).

be due both to prevention of enzyme activity and to a superior solvent power for the phytin phosphorus. It is possible that the addition of a foreign substance like phenol, not contemplated in the method of Heubner and Stadler depresses the titration figures. For this reason, and because the strength of the 1.2% acid lends itself readily to dilution to 0.6%, and because of the probable superior solvent power of the acid, the more concentrated hydrochloric acid was used in the method as finally adopted.

Time Required for Complete Extraction of Phytin Phosphorus.—Ten grams of the samples were digested for 3 hours, 6 hours and 24 hours with 300 cc. of 1.2% hydrochloric acid with shaking during the working day. Aliquots of the filtered extracts were titrated as described above. All samples of the same number were titrated at the same time so as to make results strictly comparable. The results follow:

TABLE II.—EFFECT OF TIME ON THE EXTRACTION OF PHYTIN PHOSPHORUS.

		Phytin phosphorus in % of sample.		
Sample No.	Material.	3 hrs.	6 hrs.	24 hrs.
2234	Wheat bran	1.18	1.17	1.18
2217	Kafir	0.23	0.24	0.24
2347	Rice polish	1.18	1.20	1.20
2333	Rice bran	1.18	1.15	1.11
2311	Corn (maize)	0.21	0.20	0.21
2195	Wheat shorts	0.61	0.61	0.60
	Mean	0.77	0.76	0.76

Maximum extraction of phytin phosphorus is reached with 1.2% hydrochloric acid with 3 hours' digestion.

The Ratio of Iron to Phosphorus.—In order to determine the ratio of iron to phosphorus in the determination of phytin phosphorus by the ferric chloride titration method, purified salts of the principal inosite phosphoric acid of cottonseed meal, wheat bran, corn rice bran, kafir corn and rice polish were titrated with ferric chloride under the same conditions as prescribed for the determination as devised by Heubner and Stadler.

Previous work by the writer on cottonseed meal[1] and on wheat bran, kafir corn and corn (maize)[2] has shown that the principal inosite-phosphoric acid of these materials is probably inosite pentaphosphoric acid, $C_6H_6(OH)(H_2PO_4)_5$. The method of separation of the substances used in this work was the same as described in the above papers. The method consists in freeing the crude acids from bases and separation and purification of the fractions by means of the strychnin salts. The purity and identity of the substances were demonstrated by the analysis of different fractions which had been subjected to fractional recrystallization. Sodium

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[1] Rather, THIS JOURNAL, 39, 777 (1917); Ark. Agr. Exp. Sta., *Bull.* 131 (1917).

[2] Paper read at the Kansas City Meeting of the American Chemical Society, April, 1917 (unpublished). Abstract in *Science*, N. S., 46, 97 (1917).

salts of the acid were made as follows: Portions of the purified strychnin salts were dissolved in warm water and a slight excess of sodium hydroxide solution added. The cooled mixture was filtered to remove the strychnin and made neutral with dilute hydrochloric acid solution. Phosphorus was determined in aliquots taken from these solutions by the Official Volumetric Method after ignition with magnesium nitrate. Aliquots were also titrated with ferric chloride solution under the conditions described for the titration of phytin phosphorus mentioned above. The freedom of the materials from inorganic phosphates had previously been demonstrated. It having been found that strychnin did not influence the results of titrations, strychnin salts were also titrated under the same conditions as to volume of solution, concentration of acid and indicator, etc., as already described. The results follow:

TABLE III.—THE RATIO OF IRON TO PHOSPHORUS IN TITRATIONS WITH PURE PHYTIN PRODUCTS.

Sample No.	Substance and source.	Fe consumed. Mg.	Phosphorus. Mg.	P/Fe ratio.
2355-1	Sodium salt, from kafir	12.04	14.66	1.217
2285-1	Sodium salt, Wheat bran	6.170	7.47	1.211
2219-1	Sodium salt, Cottonseed meal	6.536	7.79	1.192
2284-1	Sodium salt, Cottonseed meal	6.830	7.89	1.155
2288-1	Sodium salt, Corn (maize)	6.683	8.22	1.230
2370-1	Sodium salt, Rice bran	10.54	12.89	1.223
2387-1	Sodium salt, Rice polish	10.13	12.63	1.243
2219-2	Strychnin salt, Cottonseed meal	9.548	11.73	1.228
2284-1	Strychnin salt, Cottonseed meal	9.841	11.74	1.193
2284-2	Strychnin salt, Cottonseed meal	10.43	12.28	1.177
2285-1	Strychnin salt, Wheat bran	9.328	11.51	1.234
2288-1	Strychnin salt, Corn (maize)	9.915	12.15	1.225
2370-1	Strychnin salt, Rice bran	10.54	12.66	1.202
2387-1	Strychnin salt, Rich polish	10.13	11.95	1.180
	Mean	...	...	1.207
	Calc. for $((C_6H_6)(OH)H_3(PO_4)_5)_3Fe_7$	...	...	1.191
	Ratio as found by Heubner and Stadler	...	...	1.19

The organic phosphorus compounds used in the above titrations have, as stated above, been shown probably to be salts of inosite pentaphosphoric acid. The data on rice bran and rice polish, however, have not been published. The hepta-ferric salt of inosite pentaphosphoric acid would have the phosphorus-iron ratio of 1.191, the mean of the experimentally determined ratios is 1.207, and the result obtained by Heubner and Stadler, 1.19. The small individual differences in the ratios obtained by the writer are attributed to errors in titration, as the end point of the titration is not very sharp. Larger quantities of the products were not used on account of the greater difficulty of obtaining a permanent end point when large quantities of phytin phosphorus are titrated. On account of the evidence that the present writer has brought out that the principal inosite phosphoric acid of plant products is inosite pentaphosphoric acid, the factor 1.191 was adopted for making the calculations of the analytical results in the method as finally adopted, instead of the experimentally determined figure 1.207.

Interference of Non-phosphorized Substances in the Plant Extract on the Titration of Phytin Phosphorus.—Samples of corn chops and of rice bran were digested with acid as already described for the determination of phytin phosphorus and aliquots taken for titration. Different volumes of solutions of a purified sodium salt of inosite pentaphosphoric acid, of known phosphorus content, were added to the aliquots as indicated below. The titration was conducted as already described. The results follow:

TABLE IV.—RECOVERY OF PHYTIN PHOSPHORUS ADDED TO PLANT EXTRACTS.

Addition.	$FeCl_3$ sol. consumed. Cc.	Calc. $FeCl_3$ sol. consumed. Cc.	Difference. Cc.	P added. Mg.	P recovered. Mg.
To Corn Chops:					
None	1.8	...	...	...	...
2 cc. (*a*)	2.7	2.6	0.1	0.73	0.84
4 cc. (*a*)	3.5	3.4	0.1	1.47	1.60
8 cc. (*a*)	5.1	5.0	0.1	2.93	3.10
12 cc. (*a*)	6.6	6.5	0.1	4.40	4.50
16 cc. (*a*)	8.1	8.1	0.0	5.86	5.91
24 cc. (*a*)	11.2	11.3	0.1	8.80	8.82
To Rice Bran:					
None	28.0	...	...	...	...
5 cc. (*b*)	30.2	30.4	0.2	2.15	1.92
10 cc. (*b*)	33.0	32.8	0.2	4.30	4.37
20 cc. (*b*)	37.5	37.6	0.1	8.60	8.30
40 cc. (*c*)	46.0	45.9	0.1	16.80	15.64

The calculated amount of ferric chloride solution required was ascertained by adding titration figures obtained with the salt solutions to those obtained by titrating the plant extracts alone. The results actually obtained do not differ from the calculated figures by more than 0.2 cc., and in most cases only 0.1 cc. The amount of phosphorus added was calculated from the total phosphorus contents of the salt solutions, and the phosphorus recovered was calculated from the results of the ferric chloride titrations. In every case but one (see last line in table) the difference in the amount of phosphorus added and that recovered is 0.3 mg. or less. The larger the amount of phytin phosphorus to be titrated the greater the difficulty of the titration. This is due to the larger amount of the white iron precipitate and the greater length of time required to secure an end point persisting for 5 minutes. No difficulty with the end point was met with when the number of mg. of phytin phosphorus to be titrated did not greatly exceed 10.

It is concluded from this work that non-phosphorized substances in the plant extract do not affect the titration of phytin phosphorus with ferric chloride, and that added phytin phosphorus can be recovered quantitatively from plant extracts.

Influence of Phosphorus-Containing Substances Other than Phytin on Accuracy of Results.—The copper acetate used to precipitate the phosphorus compounds in the preparation of inosite pentaphosphoric acid from plant products, removes the phosphorus from solution almost completely. The amounts remaining in solution, as determined by quantitative tests varied from 0.03 to 0.08% of the sample. A considerable part of this soluble material must consist of copper salts of orthophosphoric acid and of inosite pentaphosphoric acid, since these salts are appreciably soluble in weak acid solutions. The copper precipitate, then, probably represents almost the entire acid-soluble phosphorus. In the subsequent processes of purification and fractionation, none of the phosphorus is lost, so that a study of the effect of ferric chloride on the different fractions, under the conditions of the method for the determination of phytin phosphorus, should indicate the effect of phosphorus compounds other than inosite pentaphosphoric acid on the results.

The precipitated acids, after being freed from bases as already described, were fractionated by means of their strychnin salts into two principal fractions, (*a*) that portion of the strychnin salts which was relatively insoluble in cold water and having a melting point of 220–222°, and which the present writer believes to be a pure salt of inosite pentaphosphoric acid, and (*b*) that portion of the strychnin salts which was quite soluble in cold water. Fraction (*b*) is phosphorus containing and has been met with in all the materials examined. It has been obtained in crystallin form and its nature will be reported upon at a later date. The phosphorus in this material makes up only a relatively small part of the acid-soluble phosphorus. It consists in part of a strychnin salt of orthophosphoric acid.

Samples of these products were titrated with ferric chloride as already described and the total phosphorus determined in the samples after titration. The results are given below; the figures should be regarded as comparative only.

It can be seen from the figures below that the only fraction which consumed an appreciable amount of ferric chloride solution in the titration is the fraction (*a*) which has been identified by the writer as being probably a salt of inosite pentaphosphoric acid. No fraction which had been completely freed from this compound consumed any ferric chloride solution at all. The writer concludes that inosite pentaphosphoric acid is the only constituent of the plant extracts examined that consumes appreciable amounts of ferric chloride in the titration of phytin phosphorus by the method under investigation.

TABLE V.—FERRIC CHLORIDE CONSUMED BY DIFFERENT FRACTIONS OF ACID-SOLUBLE PHOSPHORUS COMPOUNDS.

Sample No.	Source of substance.	$FeCl_3$ sol. consumed. Cc.	Total P. Mg.
2355(*a*)	Kafir Corn	13.0	12.41
2355(*b*)	Kafir Corn	0.0	13.39
2285(*a*)	Wheat Bran	12.5	11.52
2285(*b*)	Wheat Bran	0.0	11.41
2285[1]	Wheat Bran	0.7	10.44
2369(*a*)	Oats	10.3	10.34
2369(*b*)	Oats	0.2	5.81
2288(*a*)	Corn (maize)	13.2	12.15
2288[1]	Corn	1.1	10.09
2288[2]	Corn	0.0	9.63
2288(*b*)	Corn	0.0	3.08

Since it has been impossible to find inosite triphosphoric acid[3] or inosite hexaphosphoric acid[4] in the materials examined by the present writer it cannot be stated what effect these substances will have on the results. Inosite triphosphoric acid by enzyme action, and, if this is the case, is not to be looked for in extracts where enzyme action has been inhibited. The inosite hexaphosphoric acid of Anderson is no doubt the same substance believed by the present writer to be inosite pentaphosphoric acid. Since the experimentally determined factor for the calculation of iron to phosphorus is essentially the same as the theoretical factor adopted in the method it is evident that if further evidence should justify the conclusion of Anderson, the proof of the accuracy of the method will not have been impaired.

The Amount of Phytin Phosphorus in Plant Products.—The method finally adopted for the determination of phytin phosphorus in plant products was as follows: Extract 8 g. of the finely ground sample with 200 cc. 1.2% hydrochloric acid for 3 hours with frequent shaking. Filter through a dry filter into a dry flask and take aliquots of 50 cc. for titration. Put aliquots in slender conical form beakers of about 150 cc. capacity and add 10 cc. of 0.3% NH_4CNS solution and 40 cc. water. Prepare a blank by adding 10 cc. 6.0% hydrochloric acid and 10 cc. of the NH_4CNS solu-

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[1] Identified as strychnin orthophosphate mixed with a little strychnin inosite pentaphosphate.

[2] Probably strychnin orthophosphate.

[3] This compound was separated from wheat bran by Anderson, *J. Biol. Chem.*, 20, 463 (1915); and from cottonseed meal by the present writer, THIS JOURNAL, **39**, 777 (1917); but it could not be obtained from wheat bran, cottonseed meal, or any of the other plant products examined by the writer in Arkansas.

[4] This compound is believed by Anderson to be the principal inosite phosphoric acid of plant products. The present writer has been unable to obtain the substance, using Anderson's method, from any of the materials examined. Boutwell, THIS JOURNAL, **39**, 491 (1917) could not obtain the substance from wheat bran.

tion to 80 cc. water in a beaker similar to the above and add 0.1 to 0.2 cc. standard ferric chloride solution. Titrate aliquots in duplicate with a standard ferric chloride solution in 0.6% hydrochloric acid containing 0.7344 g. Fe per liter. The end point of the titration is reached when the supernatant liquor above the whitish iron precipitate maintains a coloration equal to that of the blank when viewed by reflected light and persisting for 5 minutes. Deduct the amount of the blank from the titration figure. One cc. of the iron solution corresponds to 2 mg. phytin P_2O_5 (0.10% phytin P_2O_5) or 0.8739 mg. phytin phosphorus. For samples containing a large amount of phytin phosphorus, such as rice bran and rice polish, 4 g. of the sample should be used instead of 8 g.

The concentration of the iron in the above solution is within the limits prescribed by Heubner and Stadler. Experience has led the present writer to believe that these limits should be adhered to. The end point of the titration is most readily observed when the amount of phytin phosphorus in the solution to be titrated is 10 mg. or less.

Results on some plant products with this method, together with results of determinations of total phosphorus and 1.2% hydrochloric acid soluble phosphorus in the same products are given in the table below.

TABLE VI.—PHOSPHORUS IN DIFFERENT FORMS IN PLANT PRODUCTS.

					Phytin P in % of	
Sample.	Material.	Total P, %.	Acid-soluble P, %.	Phytin P, %.	Total P.	Acid-soluble P.
2175	Corn (maize)	0.27	0.24	0.19	67	75
2176	Cottonseed meal	1.05	0.80	0.76	72	95
2195	Wheat shorts	0.92	0.73	0.61	66	84
2217	Kafir	0.34	0.31	0.23	68	74
2234	Wheat bran	1.41	1.39	1.24	88	89
2290	Oats	0.39	0.32	0.26	67	81
2311	Corn (maize)	0.26	0.24	0.20	77	83
2332	Cottonseed meal	1.22	0.89	0.86	71	97
2333	Rice bran	1.39	1.35	1.18	85	87
2347	Rice polish	1.42	1.35	1.26	89	93
2405	Soy bean	0.53	0.42	0.36	68	86
2366	Clover seed	0.56	0.34	0.29	52	85
	Mean				73	86

The amount of phosphorus extracted from the plant products by 1.2% hydrochloric acid varied from 73% of the total phosphorus, with cottonseed meal No. 2332, to 99% of the total phosphorus with wheat bran. Acid of this strength seems to exert a greater solvent power than 0.2% hydrochloric acid.

The minimum amount of phytin phosphorus found was 0.18% with corn No. 2175 and the maximum amount was 1.26 with rice polish. Wheat bran, rice bran and rice polish contained over one per cent. of phytin phosphorus; corn, kafir, oats, soy beans and clover seed contained the smallest amounts, while cottonseed meal and wheat shorts occupied an intermediate position as regards percentage of this form of phosphorus. In every case a high total phosphorus was accompanied by a high phytin phosphorus content.

The checking of duplicates in the determination of phytin phosphorus in the method, as finally adopted was satisfactory in every case. The greatest difference between duplicates, all run on different solutions and on different days, was 0.07% P (in per cent. of sample) and the average variation from the mean, 0.018%.

The percentage of phytin phosphorus in the acid-soluble phosphorus varied from 74% with kafir to 97% with cottonseed meal No. 2332, and averaged 86% of the acid-soluble phosphorus. It is probable that inorganic phosphorus makes up a considerable portion of the remaining amount of the acid-soluble phosphorus. Data concerning the amount of inorganic phosphorus in these samples, as determined by the Forbes method, indicates that this is the case, but in view of evidence casting doubt on the accuracy of the method it is thought best to withhold it at the present time. The percentage of phytin phosphorus in terms of total phosphorus varied from 52% with clover seed to 89% with rice polish, and averaged 73%.

It is evident from these results that phytin phosphorus constitutes the principal source of phosphorus in the plant products examined.

Attempts were made to determine phytin phosphorus in plant parts other than seed (hays) by the method outlined above. Soy bean, cow pea, velvet bean, and alfalfa were used. On account of the deep color of the plant extracts it was found impossible to titrate the solutions, as the end point was completely obscured. The method for the determination of phytin phosphorus as described in this article does not, therefore, appear to be applicable to such materials. In this connection it might be stated that Hart and Tottingham[1] could find no phytin phosphorus in dried forage plants.

Acknowledgment: The author is indebted to former Assistant E. G. Will, and to Assistant R. H. Ridgell for much of the analytical work reported in this article.

Summary.

1. The ferric chloride titration method for the determination of phytin phosphorus in pharmaceutical products is applicable to plant products, with such modifications as the difference in the nature of the materials demands. The accuracy of the method is not affected by non-phosphorized substances or by phosphorized substances other than phytin in the plant extract. Duplicate determinations check closely and added phytin phosphorus can be quantitatively recovered from plant extracts. The

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[1] *J. Biol. Chem.*, **6**, 431–444 (1909).

method does not appear to give satisfactory results with dried forage plants.

2. The ratio of iron to phosphorus in determinations of phytin phosphorus as ascertained by titrations of purified salts of inosite pentaphosphoric acid obtained from kafir, cottonseed meal, wheat bran, rice bran, corn, and rice polish, was found to average 1.207. Heptaferric inosite pentaphosphate would have the ratio 1.191.

3. Of the plant products examined, the largest amounts of phytin phosphorus were found in wheat bran, cottonseed meal, wheat shorts, rice bran, rice polish, and the smallest amounts on corn, oats, soy bean, clover seed and kafir. The phytin phosphorus in the plant products examined constituted on an average 73% of the total phosphorus and 86% of the 1.2% hydrochloric acid-soluble phosphorus.

FAYETTEVILLE, ARK.

NEW BOOKS.

Laboratory Manual of General Chemistry (with Exercises in the Preparation of Inorganic Substances). By ARTHUR B. LAMB. First Edition. Cambridge: Harvard University Press. 1916.

In the first part of this volume (about 100 pages) the author presents the more advanced experiments of General Chemistry. This presentation is replete with many new experiments which cannot fail to impress the student with the fundamental principles of the science. The experiments upon the effect of dissolved substances in solution deserve especial mention for clearness of discussion. In fact the outstanding feature of the manual is this attempt to give the student some idea of each experiment before the experiment itself is begun. These discussions are condensed, to the point, and exceedingly clear. Manuals which eliminate this feature encourage all too easily the mechanical process and rarely open the mind of the student to larger interpretations.

In the second part (about 50 pages) the author considers a number of inorganic preparations, all of which are interpreted from modern standpoints. The study of equilibrium constants, in particular, is so well brought out that the attention of all advanced students in General Chemistry might well be called to this presentation in connection with whatsoever laboratory courses they may be following.

There are a number of small errors which it is hoped will be eliminated in the future edition. The use of the hybrids "divalent," "tetravalent," etc., is not in keeping with proper word formation. Latin stems demand Latin prefixes, and thus bivalent, quadrivalent, etc., constitute the correctly formed adjectives. In the best usage the Greek prefixes have found distinct positions in the nouns, "diad," "tetrad," etc. It is well to keep the two ideas apart. Again the indiscriminate use of "chlorine"