material and infinitely more so than that which is pinned and dried. The only deterioration possible is that arising from breakage of the containing vessels.

There is one point of caution that should be borne in mind concerning these oils. They are absolutely neutral and non-toxic and it is not impossible that improperly treated material might ultimately develop decay. This could not occur, however, with specimens properly sterilized and completely dehydrated in the beginning, since no bacterial action can continue in the absence of both oxygen and water. It is also well to bear in mind that with all material, except that which is usually or just as easily studied while immersed in liquid, difficulty would be experienced in ridding the specimen of surplus oil. This could of course be easily accomplished by washing with xylene.

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SPECIAL ARTICLES

ARC SPECTRUM REGULARITIES FOR RUTHENIUM

THE arc spectrum of iron having been investigated by Walters[1] and by Laporte,[2] it appeared desirable to study the corresponding element, ruthenium, of the next period.

According to a plan of cooperation which was arrived at with the Institute for Theoretical Physics of the University of Munich, through the courtesy of Professor A. Sommerfeld, the elements Rh and Pd are being investigated for spectral structure by Drs. Catalán and Bechert, while the Ru analysis has been undertaken by ourselves. We are thankful to Dr. Bechert for his kindness in communicating to us some provisional results in Ru.

Although new wave length measurements[3] have been made by Meggers, no other experimental data (temperature classification and Zeeman effect[4]), which have been so important for the analysis of the iron spectrum, were available. As a substitute for absorption or furnace spectrograms we made photographs of the spectrum emitted by a condensed spark under water which showed 85 distinct absorption lines[5] between 2255 and 4709A. From these we recognize the lowest term of ruthenium as being a 5-fold term with the separations 392.2, 621.7, 900.9, 1190.8 cm^{-1}, and the inner quantum numbers 0, 1, 2, 3, 4, which in analogy with iron may be regarded as a quintet-D term. It must be pointed out that many separations which appear to be real (including three of the Δ D) were found by E. Paulson[6] ten years ago. The D term combines with 46 or more higher levels, thus accounting for the majority of strong lines in the ruthenium arc spectrum. The azimuthal quantum numbers of these levels are indicated by the fact that in general only the main lines and not the satellites of a combination appear in absorption. As an example of the combination of the low D term with a higher F term, we give the following multiplet to which we were guided by the strong occurrence of the main lines and the weak occurrence of the first satellites in absorption. The preliminary wave lengths and intensities here given were derived from an arc spectrogram made for this purpose, since

	$^5D_0$	392.2	$^5D_1$	621.7	$^5D_3$	899.6	$^5D_2$	1190.8	$^5D_4$
$^5F_1$	2392.42(15) 41785.9		2370.17(12) 42178.1		2335.74(5) 42799.8				
90.5									
$^5F_2$			2375.27(15) 42087.6		2340.69(15) 42709.3		2292.41(8) 43608.7		
193.1									
$^5F_3$					2351.34(20) 42516.0		2302.60(15) 43415.8		2241.10(10) 44607.0
286.0									
$^5F_4$							2317.85(25) 43130.2		2255.59(20) 44320.6
468.3									
$^5F_5$									2279.67(30) 43852.3

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[1] Walters, Journ. Wash. Acad. Sci., 13, 243; 1923; J. O. S. A. & R. S. I., 8, 245; 1924.

[2] Laporte, Zs. f. Phys. 23, 135; 1924; *ibid.*, 26, 1; 1924.

[3] Meggers, Bur. Stand. Sci. Pap. 20, 20; 1925.

[4] The Zeeman data published by Purvis (Proc. Cambr. Phil. Soc. 13, 344; 1906) are found to be of very little value. New observations are being made in cooperation with Prof. B. E. Moore, of the University of Nebraska.

[5] A paper dealing with the under-water absorption spectra of the six platinum metals is in preparation.

[6] Paulson, Phys. Zs. 16, 81; 1915.

the published values[7] do not cover the range of wave lengths covered by this multiplet.

In agreement with a general rule that the most sensitive lines of a spectrum always involve a quantum jump with $\Delta K = 1$, the *raies ultimes,* 3436.74 and 3498.95A, occur also in a ^5D–^5F combination.

More details of this investigation will appear in the Journal of the Washington Academy of Sciences.

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BUREAU OF STANDARDS
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MANGANESE AS A CURE FOR A CHLOROSIS OF SPINACH*

YELLOW chlorotic foliage and poor growth have been noted in spinach grown for several years on heavily limed soil at the Rhode Island Experiment Station. During the season of 1925, spinach planted on April 3 and grown under low temperature and high moisture conditions began to show chlorosis very soon after the unfolding of the first pair of leaves. Accompanying a very slow growth rate, the first indications of chlorosis were observed in the yellowing of the older leaves which gradually led to a disintegration of the chloroplasts and finally to the appearance of dead transparent areas. Determinations of the soil pH range gave figures from 6.2 to 6.9 and when the lime requirement was determined, the range was from 683 pounds to 233 pounds per acre (modified Jones method).

In an attempt to correct this situation without appreciably changing the soil reaction, solutions of 0.02 per cent. ferrous sulfate, 0.004 per cent. manganous sulfate, 0.08 per cent. ammonium nitrate, 0.1 per cent. potassium sulfate, 0.2 per cent. potassium phosphate, 0.02 per cent. ferric ammonium citrate, 0.02 per cent. citric acid, and manure leachings were sprayed on the rows of chlorotic spinach, 9 liters of solution being added to 30 feet of row. These additions were made on soil which had been treated with a complete chemical fertilizer ration and also moderately manured before the spinach was planted. Of these treatments, the only one which gave any positive or marked result was the manganous sulfate. After a period of four days from treatment, a definite improvement in the color of the leaves could be seen and at the end of a week the change was very marked. The previously afflicted plants developed a bright green color and resumed normal growth. Following this initial result, other spinach plants which were growing under the same range of pH and lime requirement and which had begun to show definite indications of chlorosis were treated with a solution of 8 parts per million. Similar results were obtained as with the weaker treatment, thus confirming the original observations. When harvested a 40 per cent. increase in yield was obtained from the treated plat.

In order to localize more definitely the reacting element, plants were treated with a solution of 5 parts per million of sulfuric acid. This treatment caused no noticeable improvement in the chlorotic plants. From these results there are indications that the active element concerned in the cure of chlorotic plants is manganese.

Other investigators have shown, recently, relationships concerning manganese. Loew and Sawa,[2] McCool[3] and Brenchley[1] used solutions containing 15 and more parts per million of manganese salts and obtained chlorosis (in solution culture), which condition was followed by a definite toxic effect. Other investigators, working with concentrations below 10 parts per million, have obtained definite growth stimulation. McHargue,[4] Brenchley[1] and Skinner and Sullivan[6] observed in this connection a correlation between the soil reaction and this stimulatory effect; the less the acidity, the more marked was the growth response to manganese applications. Finally McHargue[5] obtained chlorosis of spinach in sand cultures from which manganese had been very carefully excluded. To the best of our knowledge, however, no one has reported the correction under practical conditions of a chlorotic disturbance of spinach by the use of manganese salts.

The results obtained wtih manganous sulfate as a cure for chlorotic spinach serve to corroborate the observations of other workers and at the same time seem to point to the use of manganese salts in field

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[7] Kayser, Handbuch der Spektroscopie VI, 371.

* Contribution 320 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

[1] Brenchley, Miss W. E., "Effect of manganese compounds." In "Inorganic Plant Poisons and Stimulants," p. 78–92, 1914.

[2] Loew, O., and Sawa, S., "On the action of manganese compounds on plants," Tokyo Imp. Univ., Coll. Agr. Bul. 5: 161–172, 1902–03.

[3] McCool, M. M., "The action of certain nutrient and non-nutrient bases on plant growth," Cornell Univ., Agr. Exp. Sta. Memoir 2: 113–116, 1913.

[4] McHargue, J. S., "Effect of different concentrations of manganese sulfate on the growth of plants in acid and neutral soils and the necessity of manganese as a plant nutrient," Jour. Agr. Research, XXIV: 781–793, 1923.

[5] McHargue, J. S., "Rôle of manganese in plants," Jour. Amer. Chem. Soc., 44: 1592–1598, 1922.

[6] Skinner, J. J., and Sullivan, M. X., "The action of manganese in soils," U. S. Dept. Agr. Bul. 42: 1–32, 1914.