curve 2 of Fig. 2. The neutrons striking the scatterer are presumably faster than if no cadmium had been present. It will be seen from the curve that the scattering from iron is less for these neutrons than for those which have not passed through cadmium. The cross section, calculated from the curve, is 8.1×10^{-24} cm^2.

We are indebted to Mr. Lawrence M. Langer for help in taking some of the readings and to Dr. C. B. Braestrup of the Physical Laboratory of the Department of Hospitals of the City of New York for many favors. We also wish to acknowledge our indebtedness to the American Association for the Advancement of Science for a grant to one of us (A. C. G. M.) with the aid of which apparatus has been purchased.

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The Spectrum of the Zinc Arc in Vacuum

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Sixty lines in the spectrum of the vacuum zinc arc have been observed in the wave-length range 2178A to 7799A. All known solar zinc lines, including two not hitherto listed, are included. A suitable source for obtaining weak lines in vacuum is described. The stronger lines of the following elements were observed: Pb, Cu, Cd, Ag, Sn, Na, K, Rb, Cs, Sr, Be. The observations were made by means of the F and P interferometer, and by various gratings and prisms.

THE spectrum of the zinc arc was observed with a view to obtaining accurate vacuum wave-lengths of all those lines which are now, or might soon be, of astrophysical importance. This object has perhaps been attained, since precise values have been measured for the lines which have been identified as zinc in the *Rowland Revision*.[1] Two additional solar lines, both weak, are probably due at least in part to zinc. These are λ4292A and λ7799A.

The derivation of precise values of the atomic levels of an element usually makes it possible to compute accurate wave-lengths of lines which cannot be easily observed, either because the lines are faint, or because they lie in an inaccessible region of the spectrum. In the case of our work on zinc, only two such lines can be computed; λ1404A and λ1457A. The combinations of the low singlet S with the odd triplet P terms give rise to lines in the Schuman region; these are undoubtedly quite faint. Other possible combinations give lines in the far infrared.

The source of the zinc spectrum of wave-length less than 3700A was an arc in vacuum between brass electrodes, operated at 4 amperes. In the longer region, special brasses containing up to 80 percent zinc[2] were used in addition to commercial brass. Whatever the initial percentage of zinc, after the arc had run five minutes the tips of the electrodes were reduced to that alloy which remains stable at the operating temperature, and this is very low in zinc.

The strong lines of zinc can be observed in sharp condition and with reasonable exposure times by using carbon electrodes which have been soaked in a solution of a zinc salt. To obtain satisfactory sharpness, the amperage must be low. Zinc sulphate packed into a thin-walled copper or silver tube proved to be a fairly satisfactory source. For the weak lines, requiring long exposure at high current, the most satisfactory source was a pool of molten zinc held in a large brass cup, and an upper electrode of sterling silver. The use of copper as an upper electrode caused the zinc to oxidize more rapidly than was the case when silver was used; this made it

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[1] St. John, Moore, Ware, Adams, and Babcock, *Revision of Rowland's Preliminary Table of Solar Spectrum Wave-lengths* (1928).

[2] Kindly alloyed for us by Federated Metals Corporation.

TABLE I. *Wave-lengths in the zinc arc in vacuum.*

λ (Air)	ν (Vacuum)	Terms	Int.	p.e.	Instrument
1404.118*	71219.077	$4^1S_0-7^1P_1^0$			
1457.572*	68607.256	$4^1S_0-6^1P_1^0$			
2138.56 –	46745.6 –	$4^1S_0-4^1P_1^0$	100R	D	P
2312.72 –	43225.8 –	Zinc II	3	D	P
2502.001	39955.97	Zinc II	4	A	G3, P
2515.807**	39736.72	$4^3P_2^0-7^3D_3$	1	D	I
2557.958	39081.97	Zinc II	20	D	I
2569.871	38900.81	$4^3P_0^0-6^3D_1$	8	B	I
2582.440	38711.49	$4^3P_1^0-6^3D_2$	7	C	G3
2582.487	38710.79	$4^3P_1^0-6^3D_1$	1	D	G3
2608.558	38323.92	$4^3P_2^0-6^3D_3$	30	B	G3, I
2608.640	38322.72	$4^3P_2^0-6^3D_2$	5	D	G3
2670.530	37434.64	$4^3P_0^0-7^3S_1$	2	C	G2, I
2684.161	37244.55	$4^3P_1^0-7^3S_1$	6	C	I
2712.488	36855.62	$4^3P_2^0-7^3S_1$	10	B	I
2756.452	36267.82	$4^3P_0^0-5^3D_1$	60	A	I
2770.865	36079.18	$4^3P_1^0-5^3D_2$	80	A	I
2770.984	36077.63	$4^3P_1^0-5^3D_1$	25	C	G2
2800.869	35692.71	$4^3P_2^0-5^3D_3$	80	C	G2
2801.056	35690.33	$4^3P_2^0-5^3D_2$	15	B	G2
2801.167	35688.91	$4^3P_2^0-5^3D_1$	2	D	G2
3018.352	33121.04	$4^3P_0^0-6^3S_1$	30	B	I
3035.781	32930.87	$4^3P_1^0-6^3S_1$	35	B	G2, I
3072.062	32542.00	$4^3P_2^0-6^3S_1$	70	B	I
3075.901	32501.39	$4^1S_0-4^3P_1^0$	90	B	I
3282.333	30457.39	$4^3P_0^0-4^3D_1$	100	B	G2, I
3302.588	30270.60	$4^3P_1^0-4^3D_2$	150	C	G2
3302.941	30267.36	$4^3P_1^0-4^3D_1$	125	C	G2
3345.020	29886.63	$4^3P_2^0-4^3D_3$	150	D	G2
3345.572	29881.69	$4^3P_2^0-4^3D_2$	100	D	G2
3345.934	29878.46	$4^3P_2^0-4^3D_1$	30	B	G2
3799.002	26315.26	$4^1P_1^0-9^1S_0$	3	D	G1
3883.340	25743.76	$4^1P_1^0-7^1D_2$	3	D	G1
3965.432	25210.83	$4^1P_1^0-8^1S_0$	15	D	G1
4101.665	24373.49	Indium?	3	D	G1
4113.210	24305.08	$4^1P_1^0-6^1D_2$	12	D	G1
4292.885	23287.83	$4^3P_1^0-5^1S_0$	8	A	I
4298.327	23258.35	$4^1P_1^0-7^1S_0$	6	B	I
4629.814	21593.113	$4^1P_1^0-5^1D_2$	12	A	I
4680.138	21360.933	$4^3P_0^0-5^3S_1$	45	A	I
4722.159	21170.851	$4^3P_1^0-5^3S_1$	75	A	I
4810.534	20781.924	$4^3P_2^0-5^3S_1$	65	A	I
4911.664	20354.03	Zinc II	6	C	G1, I
4924.043	20302.86	Zinc II	6	D	I
5068.655	19723.62	$5^3S_1-9^3P_2^0$	2	D	G1
5069.577	19720.31	$5^3S_1-9^3P_1^0$	1	D	G1
5181.995	19292.231	$4^1P_1^0-6^1S_0$	30	A	I
5308.648	18831.96	$5^3S_1-8^3P_2^0$	3	D	G1
5310.241	18826.32	$5^3S_1-8^3P_1^0$	2	D	G1
5311.02 –	18823.6 –	$5^3S_1-8^3P_0^0$	1	D	G1
5772.102	17319.92	$5^3S_1-7^3P_2^0$	10	D	I
5775.501	17309.73	$5^3S_1-7^3P_1^0$	6	D	I
5777.112	17304.90	$5^3S_1-7^3P_0^0$	3	D	G1
5894.351	16960.71	Zinc II	2	D	I
6237.891	16026.64	$4^1P_1^0-4^3D_2$	5	B	I
6239.182	16023.32	$4^1P_1^0-4^3D_1$	1	C	I
6362.347	15713.136	$4^1P_1^0-4^1D_2$	100	A	I
6479.155	15429.86	$5^1S_0-7^1P_1^0$	10	B	I
6928.319	14429.543	$5^3S_1-6^3P_2^0$	10	A	I
6938.472	14408.428	$5^3S_1-6^3P_1^0$	6	C	I
6943.202	14398.613	$5^3S_1-6^3P_0^0$	2	A	I
7799.365	12818.036	$5^1S_0-6^1P_1^0$	1	B	I

* Reciprocal of the wave number.

** Classification doubtful.

necessary to open the lamp house frequently to clear away the oxide which forms around the arc. The silver electrode was scarcely consumed at all. The lines were quite sharp in the silver-zinc source.

Some of the lines were measured by means of a prism spectrograph only, others by means of a grating; these are indicated by P or G in the last column of each table. The number following the G indicates the order. The symbol I in the last column means that the measurement was made by means of an interferometer. For wave-lengths shorter than 3570A a separation of 3.75 mm was used; from 3572A to 4200A, separations of 3.75 mm and 8.00 mm were used. From 4292A to 7800A, separations of 3 to 20 mm were used; some lines would not stand the highest resolving power under the conditions of operation.

In the shorter region, the copper lines, and some iron lines occurring as impurities, were used to determine the thickness of the interferometer. In the region longer than 4200A the lines were compared with neon by simultaneous exposure.

The term system of zinc is quite simple. The active electrons are but two in number, and in every case one of these is $4s$. The terms are numbered in such a manner that the electron configuration is found by adding to $4s$ an electron of the same number and letter as those of the term. Thus 5^1S_0 and 5^3S_1 have the electron configuration $4s5s$: $4^1P_1^0$ and $4^3P^0_{0,\,1,\,2}$ have the configuration $4s4p$.

The strong lines of zinc, and many of the weak ones, are as nearly sharp as can be estimated under the observing conditions. Although the

TABLE II. *Relative term values in the spectrum of zinc I.*
(Derived from wave-lengths in Table I.)

4^1S_0	0.000	4^1D_2	62458.51	5^3D_1	68579.13
5^1S_0	55789.220	5^1D_2	68338.48	5^3D_2	68580.60
6^1S_0	66037.60	6^1D_2	71050.45	5^3D_3	68583.03
7^1S_0	70003.72	7^1D_2	72489.13		
8^1S_0	71956.20			6^3D_1	71212.13
9^1S_0	73060.63	4^3D_1	62768.75	6^3D_2	71212.90
		4^3D_2	62772.00	6^3D_3	71214.24
5^3S_1	53672.241	4^3D_3	62776.95		
6^3S_1	65432.32				
7^3S_1	69745.94				
$4^1P_1^0$	46745.37	$4^3P_0^0$	32311.308	$8^3P_0^0$	72495.8 –
$6^1P_1^0$	68607.26	$4^3P_1^0$	32501.390	$8^3P_1^0$	72498.56
$7^1P_1^0$	71219.08	$4^3P_2^0$	32890.317	$8^3P_2^0$	72504.20
		$6^3P_0^0$	68070.854	$9^3P_1^0$	73392.27
		$6^3P_1^0$	68080.669	$9^3P_2^0$	73395.86
		$6^3P_2^0$	68101.784		
		$7^3P_0^0$	70977.14		
		$7^3P_1^0$	70981.97		
		$7^3P_2^0$	70992.16		

TABLE III. *Wave-lengths of various elements, vacuum arc.*

λ (air)	(vac.)	Int.	p.e.	Instrument	
A. LEAD					
2169.994	46068.57	2	B	P	
2203.528	45367.56	15	B	P	
2237.421	44680.40	3	C	P	
2332.43 –	42860.6 –	5	D	P	
2388.78 –	41849.6 –	3	D	P	
2393.795	41761.93	30	A	G3, I	
2399.58 –	41661.3 –	4	D	P	
2401.945	41620.25	25	A	I	
2411.735	41451.31	15	C	G3	
2443.830	40906.97	8	A	I	
2446.184	40867.61	20	B	I	
2476.381	40369.32	60	A	G3, I	
2577.266	38789.20	30	B	G3, I	
2613.657	38249.16	40	B	G3, I	
2614.178	38241.54	80	B	G3, I	
2628.263	38036.61	4	C	I	
2663.158	37538.26	90	A	I	
2802.000	35678.30	60	B	I	
2823.189	35410.54	30	A	I	
2833.067	35287.08	50	A	G2, I	
2873.316	34792.81	70	A	I	
3572.734	27981.81	60	A	I	
3639.568	27467.99	90	A	I	
3671.494	27229.14	20	A	I	
3683.469	27140.62	90	A	I	
3739.940	26730.82	50	A	I	
4019.636	24870.87	6	A	I	
4057.812	24636.89	100	A	I	
4062.138	24610.65	20	A	I	
4168.035	23985.38	4	C	I	
5005.427	19972.76	4	C	I	
5201.444	19220.09	1	C	I	
6001.884	16656.83	2	D	I	
B. COPPER					
3654.243*	27357.68	2	B	I	
3860.472*	25896.25	3	B	I	
4480.354	22313.424	6	A	I	
4509.377	22169.814	4	A	I	
4530.787	22065.054	6	A	I	
4651.160	21494.160	8	A	I	
4697.522	21281.88	4	D	I	
4704.606	21249.836	6	B	I	
5016.613	19928.227	3	A	I	
5105.541	19581.121	8	B	I	
5111.918	19556.695	2	A	I	
5153.233	19399.906	8	B	I	
5212.780*	19178.30	1	D	I	
5218.204	19158.362	10	A	I	
5220.073	19151.502	6	B	I	
5292.518	18889.357	4	A	I	
5352.666*	18677.10	2	D	I	
5360.030*	18651.439	1	B	I	
5463.094*	18299.57	2	D	I	
5554.935*	17997.03	3	C	I	
5631.670*	17751.81	1	D	I	
5700.244	17538.254	6	B	I	
5732.325*	17440.10	1	C	I	
5782.133	17289.873	8	A	I	
7933.130	12601.904	10	B	I	
8092.639	12353.517	10	A	I	
C. CADMIUM					
2144.382	46618.74	15	D	P	
2265.017	44136.09	70	D	G3	
2288.018	43692.44	80	D	G3	
2312.57 –	43228.6 –	5	D	G3	
2775.047	36024.81	1	D	G2	
3261.050	30656.16	10	B	G2, I	
4678.160	21369.964	40	B	I	
4799.918	20827.885	50	B	I	
5085.824	19657.025	8	B	I	
6438.472	15527.354	5	B	I	
D. SILVER					
3280.682	30472.72	20	A	I	
3383.890	29552.07	50	A	I	
4476.048	22334.890	12	B	I	
4668.479	21414.276	10	B	I	
5209.080	19191.919	12	B	I	
5465.497	18291.528	10	A	I	
5471.554	18271.279	6	A	I	
7687.779	13004.085	20	B	I	
8273.519	12083.439	5	B	I	
E. TIN					
2706.505	36937.08	1	D	I	
2839.980	35201.19	4	D	I	
2863.321	34914.26	3	B	I	
3009.146	33222.37	3	D	G2	
3175.044	31486.55	5	D	G2	
3262.330	30644.13	6	B	I, G2	
3800.996	26301.45	1	D	G2	
4524.735	22094.567	2	A	I	
F. SODIUM					
4978.585	20080.442	3	D	I	
4982.845	20063.275	4	B	I	
5682.657	17592.532	6	B	I	
5688.224	17575.315	7	B	I	
5889.953	16973.371	50	A	I	
5895.923	16956.185	35	A	I	
6154.229	16244.503	3	B	I	
6160.760	16227.282	4	B	I	
8183.270	12216.699	3	D	I	
8194.811	12199.494	3	D	I	
G. VARIOUS ELEMENTS					
6911.286	14465.104	1	D	I	K
6938.975	14407.383	2	D	I	"
7664.907	13042.888	5	B	I	"
7698.979	12985.167	5	A	I	"
6103.642	16379.137	4	D	I	Li
6707.844	14903.813	10	D	I	Li
7800.227	12816.618	2	D	I	Rb
7947.60 –	12578.96	1	D	G1	"
4555.421	21945.737	7	B	I	Cs
4593.195	21765.259	4	D	I	"
4607.331	21698.482	4	A	I	Sr
4572.671	21862.949	5	D	I	Be

* These lines have not been measured previously by interference. One of the levels involved in each case appears to be multiple.

triplet $5^3S-6^3P^0$ at wave-length 6928A consists of sharp lines, the triplets $5^3S-7^3P^0$ and $5^3S-8^3P^0$, at 5772A and 5308A are diffuse or multiple in a source of sufficient intensity to register them in a few hours observing time. This lack of sharpness may be associated with an electric effect, since the current was raised to 8 amperes in order to photograph the weakest lines. The wave-lengths reported for these diffuse lines are center of gravity values. The line $5^1S-8^1P^0$ at 5937A proved to be too unstable for measurement at the intensity necessary to register it in a reasonable exposure time. The line $5^1S-6^1P^0$ is also somewhat unstable, yet the wave-length reported for it is probably reproducible to a part in a million, even at high intensities of source.

The use of brass electrodes permitted the measurement of several lines of lead and tin. Copper lines occur in the long wave portion of the spectrum because of the use of copper, brass or sterling silver as one electrode. All the lines of copper measured in this region are published, since they were compared directly with neon, and not used to reduce the plates, as in the shorter region. For the lines common to both, the mean wave-lengths of the copper lines is a part in two million greater than in the table of Burns and Walters.[3] This may be due in part to the greater intensity of source used in the present work.

Silver showed as an impurity in the brass used for electrodes in the shorter region; and those observations made by means of a sterling silver electrode showed the stronger lines of silver in a beautifully sharp condition. The silver lines reported in this paper with probable error "A" may well be considered as standards.

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[3] Burns and Walters, *Wave-lengths in the Spectra of the Vacuum Copper Arc*, Publ. Allegheny Obs., Vol. 8, No. 3.

Cadmium was present in nearly every zinc and brass sample. The lines of cadmium which have been well observed previously have somewhat greater wave-length in the present table. The red line is only slightly increased in wave-length by the powerful source, but the effect on the blue lines, which are multiple, was considerably greater.

The beryllium line lacks sharpness; this may be due to electric effect or to the presence of hyperfine structure.

The wave-lengths of the alkalies are center of gravity values excepting in the case of rubidium 7800A. The reported wave-length of this complex line probably refers to one component. The line is very easily self-reversed, it shows a wide hyperfine structure, and no doubt the isotope separation is measurable. The line occurred as a weak impurity because of the previous use of the lamp house in observing rubidium. The most suitable interferometer separations for resolving 7800A were not sought as the line was not on the present program.

Rods of German silver were used as electrodes in making a few exposures; these exposures showed several lines of nickel. The nickel lines agree well with the solar wave-lengths of St. John and others,[1] and there seems to be no need to report these values which for the most part rest on a single observation of each line.

In the column headed "p. e." an A means that an accuracy of a part in two million has been obtained; B indicates a part in a million; C shows that the error may be greater than a part in a million; and D indicates that the value is unreliable. In the short wave region, the prism and grating measurements are by Burns; the interferometer measurements are by Boreman, who also observed the beryllium line. The longer region was observed and measured by Hetzler. We are indebted to the Carnegie Institute of Technology and to Dr. F. M. Walters, Jr., for the use of a Hilger E-1 spectroscope, and for assistance in observing. The short wave grating plates were taken at the U. S. Bureau of Standards, by courtesy of Dr. W. F. Meggers, and the late Director G. K. Burgess, Allegheny Observatory, April, 1935.

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Deepest Terms in Ions of the Isoelectronic Sequence A I-Mn VIII

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Radiations corresponding to the energy differences between the terms $3p^6\,{}^1S_0-3p^5\,4s\,{}^3P_1{}^0$, ${}^1P_1{}^0$ in Ti V, V VI, Cr VII, Mn VIII and $3p^6\,{}^1S_0-3p^5\,5s\,{}^3P_1{}^0$, ${}^1P_1{}^0$ in V VI and Cr VII have been observed. These radiations connect the upper states with the deepest terms in each ion and therefore enable the calculation of the ionization potentials. The identification of the lines was facilitated by the use of constant second difference displaced frequency diagrams. The limits of the $3p^6\,{}^1S_0-3p^5$ ms ${}^3P_1{}^0$, ${}^1P_1{}^0$ series have been calculated for V VI and Cr VII, and have an estimated error in the value of the deepest terms of 0.5 percent. The values of the deepest terms of V VI and Cr VII, calculated from series limits, make possible the calculation of the absolute value of the deepest terms of Sc IV, Ti V and Mn VIII from a Moseley diagram.

In a previous report[1] an estimate was given of the absolute value of the ground term $3p^6\,{}^1S_0$ of the argon-like ions Sc IV, Ti V, V VI, Cr VII and Mn VIII. The estimate was based on an almost linear extrapolation of the Moseley diagram for the $3p^5\,4s\,{}^1P_1{}^0$ terms of A I, K II and Ca III.[2] It was made by adding the radiation corresponding to the transition ${}^1S_0-{}^1P_1{}^0$ to the extrapolated value of the ${}^1P_1{}^0$ term which was obtained from the Moseley diagram. Since then, radiations corresponding to the transitions $3p^6\,{}^1S_0-3p^5\,5s\,{}^1P_1{}^0$ and $3p^6\,{}^1S_0-3p^5\,5s\,{}^3P_1{}^0$ have been observed in V VI and Cr VII. The discovery of

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[1] P. G. Kruger and S. G. Weissberg, Phys. Rev. **46**, 336 (1934).

[2] Data from Bacher and Goudsmit, *Atomic Energy States.*