

inch of mercury; that at  $70^{\circ}$ , with  $59^{\circ}$  dew point, is 0.515 inch of mercury. It follows that the pressure tending to diffuse the aqueous vapor from the "hydrated" room to the external air, would be 0.365 inch of mercury. The vapor itself, within the room at the same time, possesses but one-forty-eighth the tension of that of the air present, and hence, as it is endeavoring to escape under the pressure of about 25 lbs. per square foot (which corresponds to the 0.365 inch of mercury column), it becomes evident that it would diffuse through cracks, outlets, and even through the passages for supply of fresh air, with great rapidity, and that this ratio of saturation is practically impossible to maintain in any *ventilated* room, or even in any room whatever, as ordinarily enclosed and built.

These estimates and considerations show fairly what would result from the attempt to produce an artificial summer climate in the houses of our Northern states in winter; but while the futility of the effort in its complete accomplishment is made evident by them, it by no means follows that some degree of hydration of warmed air is not the requisite of health or of comfort, and the question recurs, what proportionate hydration is needed for these ends?

[To be continued.]

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## ELEMENTARY SPECTRAL HARMONIES.—II.

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By PLINY E. CHASE, LL. D.

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[Continued from Vol. lxxiv, p. 288.]

The interferences of harmonic undulations, which are supposed to be influential in planetary aggregation and elementary molecular grouping, should be most obvious in the spectral lines which are most prominent. Hence, we can hardly hope to find any more conclusive evidence of such interference than is presented by the figurate harmonies of alternate Fraunhofer lines, the subordinate harmonies of intermediate lines, and the exponential embodiment of the same fundamental series in the solar system.<sup>1</sup>

The multitude of faint and microscopic lines in the solar spectrum is so great that a variety of apparent harmonies might be readily found, of which many would be reasonably open to the suspicion of merely accidental coincidence, and it would be difficult to find any satisfactory criterion for distinguishing the true from the casual. We may, however, fairly presume that the elementary spectra offer a good field for preliminary investigation, and that such observations as give the least number of lines are especially worthy of early study. Such accordances as are found in groups which have been already measured, may become valuable guides in the formation of future groups, and means may, perhaps, be thus devised for co-ordinating the investigations of Clarke, Cooke, Gibbs, Hinrichs, Kopp, Mendelejeff, Wrede and Wurtz, and opening a new world for scientific exploration.

The wave-measurements, in all of the following comparisons, are taken from the paper of Professor Wolcott Gibbs, in the *American Journal of Science*, second series, vol. xlvii, pp. 198, *seq.* Kirchhoff's lines are indicated by K; Huggins's, by H; Gibbs's groupings of corresponding lines, in the observations of both Kirchhoff and Huggins, by K H; the left hand columns containing Kirchhoff's estimates, and the right hand columns those of Huggins:

## MERCURY, K H.

Wave-Lengths.		Quotients.		Theoretical.	
568.47	568.55	1.0000		1.0000	1
546.33	546.13	1.0407	1.0411	1.0406	1 + 6 <i>a</i>
542.80	542.80	1.0473	1.0484	1.0474	1 + 7 <i>a</i>

## LEAD, K H.

Wave-Lengths.		Quotients.		Theoretical.	
561.29	561.46	1.0000		1.0000	1
537.71	537.85	1.0439	1.0439	1.0440	1 + 3 <i>a</i>
439.07	438.93	1.2784	1.2792	1.2784	1 + 19 <i>a</i>

## LITHIUM, H.

Wave-Lengths.		Quotients.		Theoretical.	
610.73		1.0000		1.0000	1
479.48		1.2277		1.2214	1 + 2 <i>a</i>
459.93		1.3279		1.3321	1 + 3 <i>a</i>

## RUTHENIUM AND IRIDIUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
635.45	1.0000	1.0000	1
545.44	1.1650	1.1646	1 + 5 <i>a</i>
530.52	1.1973	1.1975	1 + 6 <i>a</i>

## CHROMIUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
541.35	1.0000	1.0000	1
521.20	1.0387	1.0387	1 + 111 <i>a</i>
520.98	1.0391	1.0391	1 + 112 <i>a</i>
520.83	1.0394	1.0394	1 + 113 <i>a</i>

## COPPER, K.

Wave-Lengths.	Quotients.	Theoretical.	
578.67	1.0000	1.0000	1
529.30	1.0933	1.0914	1 + 6 <i>a</i>
522.24	1.1070	1.1066	1 + 7 <i>a</i>
465.64	1.2428	1.2437	1 + 16 <i>a</i>

## ARSENIC, K H.

Wave-Lengths.	Quotients.	Theoretical.	
617.54 617.67	1.0000	1.0000	1
611.69 611.67	1.0096 1.0098	1.0093	1 + <i>a</i>
578.95 578.73	1.0667 1.0673	1.0650	1 + 7 <i>a</i>
533.55 533.41	1.1566 1.1580	1.1579	1 + 17 <i>a</i>

## MAGNESIUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
518.73	1.0000	1.0000	1
517.64	1.0021	1.0020	1 + 2 <i>a</i>
517.17	1.0030	1.0030	1 + 3 <i>a</i>
459.62	1.1286	1.1285	1 + 9 <i>b</i>
448.57	1.1564	1.1570	1 + 11 <i>b</i>
448.39	1.1569		

## TIN, K H.

Wave-Lengths.	Quotients.	Theoretical.	
645.83 645.27	1.0000	1.0000	1
615.59	1.0491	1.0530	1 + <i>a</i>
556.83	1.1598	1.1590	1 + 3 <i>a</i>
556.59	1.1604	1.1620	1 + 2 <i>b</i>
510.55 510.40	1.2650 1.2642	1.2650	1 + 5 <i>a</i>
459.47	1.4056	1.4050	1 + 5 <i>b</i>
453.41	1.4244	1.4240	1 + 8 <i>a</i>

## POTASSIUM, H.

Wave-Lengths.	Quotients.	Theoretical.	
630.85	1.0000	1.0000	1
624.81	1.0097	1.0097	$1 + \frac{1}{3} a$
613.25	1.0287	1.0291	$1 + a$
583.78	1.0806	1.0802	$1 + c$
581.79	1.0843	1.0843	$1 + b$
580.80	1.0862	1.0872	$1 + 3 a$
551.96	1.1430	1.1454	$1 + 5 a$
483.18	1.3360	1.3371	$1 + 4 b$
438.96	1.4372	1.4362	$1 + 15 a$
431.16	1.4632	1.4653	$1 + 16 a$
426.00	1.4809	1.4810	$1 + 6 c$
418.77	1.5064	1.5057	$1 + 6 b$

## SILVER, K H.

Wave-Lengths.	Quotients.	Theoretical.	
547.55 547.44	1.0000	1.0000	1
546.96 546.63	1.0011 1.0015	1.0013	$1 + a$
521.32 521.34	1.0503 1.0501	1.0502	$1 + 38 a$

This cannot be regarded as a satisfactory accordance.

## ZINC, K H.

Wave-Lengths.	Quotients.	Theoretical.	
636.99 637.37	1.0000	1.0000	1
610.64 610.89	1.0432 1.0442	1.0390	$1 + a$
589.90 589.90	1.0798 1.0805	1.0781	$1 + 2 a$
472.25 471.98	1.3488 1.3504	1.3513	$1 + 9 a$

## CADMIUM, K H.

Wave-Lengths.	Quotients.	Theoretical.	
647.22 647.08	1.0000	1.0000	1
644.59	1.0041	1.0041	$1 + a \div 28$
531.27 531.01	1.2182 1.2186	1.2300	$1 + 2 a$
509.00 508.83	1.2715 1.2717	1.2727	$1 + 5 b$
480.56 480.27	1.3468 1.3473	1.3450	$1 + 3 a$
468.10	1.3826	1.3818	$1 + 7 b$
441.94 441.81	1.4645 1.4646	1.4600	$1 + 4 a$

The quotient of Kirchhoff's sixth wave-length by the seventh (468.10  $\div$  441.94), is equal to the quotient of the fourth by the fifth (509  $\div$

480.56 = 1.0592). The harmonic denominators,  $1 + 7c$ ,  $1 + 11c$ ,  $1 + 15c$ —if  $c = 311.6$ —give 1.2181, 1.3428, 1.4674; but this is not so satisfactory a representation, on the whole, as the one I have adopted.  $(2 + 3 + 4)a = (5 + 2 \times 7)b$ .

## LANTHANUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
538.56	1.0000	1.0000	1
538.43	1.0003	1.0003	$1 + \frac{1}{4}a$
538.00	1.0011	1.0011	$1 + a$
534.48	1.0077	1.0077	$1 + 7a$
520.80	1.0341	1.0340	$1 + 31a$
519.20	1.0373	1.0373	$1 + 34a$
518.69	1.0383	1.0384	$1 + 35a$
481.59	1.1183	1.1183	$1 + 108a$

## SODIUM, H.

Wave-Lengths.	Quotients.	Theoretical.	
616.74	1.0000	1.0000	1
616.56	1.0002		
590.04	1.0452	1.0455	$1 + 6a$ ( $6 = 1 + 5$ )
589.43	1.0462		
569.46	1.0830	1.0835	$1 + 11a$ ( $11 = 1 + 2 \times 5$ )
568.90	1.0840		
515.90	1.1954		
515.37	1.1966	1.1973	$1 + 26a$ ( $26 = 1 + 5 \times 5$ )
498.87	1.2362	1.2362	$1 + 31a$ ( $31 = 1 + 6 \times 5$ )

## ANTIMONY, K H.

Wave-Lengths.	Quotients.	Theoretical.	
630.84 630.49	1.0000	1.0000	1
613.50 613.73	1.0283 1.0273	1.0270	$1 + 2a$
598.41 598.72	1.0542 1.0531	1.0540	$1 + 4a$
591.61 591.45	1.0663 1.0660		
589.76 589.76	1.0697 1.0691	1.0675	$1 + 5a$
564.54 564.41	1.1174 1.1171	1.1165	$1 + 3b$
557.19 557.18	1.1322 1.1316	1.1350	$1 + 10a$
546.61 546.33	1.1554 1.1540	1.1553	$1 + 4b$
471.10 471.03	1.3391 1.3385	1.3375	$1 + 25a$

## ARSENIC, K.

Wave-Lengths.	Quotients.	Theoretical.	
617.54	1.0000	1.0000	1
611.69	1.0096	1.0093	1 + <i>a</i>
603.38	1.0235	1.0244	1 + 2 <i>b</i>
578.95	1.0666	1.0653	1 + 7 <i>a</i>
558.29	1.1063	1.1096	1 + 9 <i>b</i>
550.42	1.1219	1.1217	1 + 10 <i>b</i>
538.75	1.1462	1.1461	1 + 12 <i>b</i>
533.55	1.1574	1.1585	1 + 17 <i>a</i>
521.32	1.1846	1.1826	1 + 15 <i>b</i>

The sixth quotient is also very nearly  $1.1212 = 1 + 13 a$ ; or  $13 a = 10 b$ .

## BARIUM, K H.

Wave-Lengths.	Quotients.	Theoretical.	
650.24 650.44	1.0000	1.0000	1
611.75 612.15	1.0629 1.0625	1.0634	1 + 4 <i>a</i>
603.08 602.70	1.0782 1.0792	1.0792	1 + 5 <i>a</i>
597.05 597.58	1.0891 1.0885	1.0890	1 + 15 <i>c</i>
585.51 585.67	1.1106 1.1106	1.1109	1 + 7 <i>a</i>
582.88 582.77	1.1156 1.1161	1.1159	1 + 2 <i>b</i>
578.51 578.00	1.1240 1.1253	1.1246	1 + 21 <i>c</i>
553.95 554.06	1.1738 1.1740	1.1739	1 + 3 <i>b</i>
552.40 552.06	1.1771 1.1782	1.1780	1 + 30 <i>c</i>
493.78 493.57	1.3168 1.3178	1.3168	1 + 20 <i>a</i>
490.20 490.23	1.3265 1.3268	1.3264	1 + 55 <i>c</i>

The eighth quotient is also very nearly  $1 + 11 a = 1.1742$ ; or  $11 a = 3 b$ .

## STRONTIUM, K H.

Wave-Lengths.	Quotients.	Theoretical.	
641.38 641.39	1.0000	1.0000	
553.90 553.74	1.1579 1.1583	1.1592	1 + <i>d</i>
552.57 552.38	1.1607 1.1614	1.1610	1 + <i>e</i>
550.83 550.61	1.1645 1.1649	1.1647	1 + 3 <i>a</i>
549.11 549.78	1.1680 1.1666	1.1675	1 + 3 <i>b</i>
548.68 548.75	1.1689 1.1686	1.1691	1 + 3 <i>c</i>
525.98 525.95	1.2194 1.2195	1.2195	1 + 4 <i>a</i>
524.18 524.26	1.2236 1.2234	1.2234	1 + 4 <i>b</i>
523.24 523.23	1.2258 1.2258	1.2255	1 + 4 <i>c</i>
522.97 522.83	1.2264 1.2268	1.2266	1 + $\rho d$
522.71 522.60	1.2270 1.2273	1.2272	1 + $\sqrt{2} e$

The ratio between the first and the ninth harmonic increment,  $\rho = 1.4232$ , is my theoretical value for the ratio between heat of constant pressure and heat of constant volume;<sup>1</sup> the ratio between the second and the tenth harmonic increment,  $\sqrt[3]{2}$ , is the ratio between dissociative- or wave-velocity, and stable- or circular-velocity. The geometric mean of 1.1645, 1.1680, 1.1689, is  $1.1671 = 1 + 3 \times 557.16$ ;  $(1.2194 \times 1.2236 \times 1.2258)^{\frac{1}{3}} = 1.2229 = 1 + 4 \times 557.16$ . Huggins's means are not so theoretically exact, but their deviation is far within the limits of probable error, for  $(1.1649 \times 1.1666 \times 1.1688)^{\frac{1}{3}} = 1.1668$ ;  $(1.2195 \times 1.2234 \times 1.2258)^{\frac{1}{3}} = 1.2229$ ;  $1 + 3 \times 556.8 = 1.1670$ ;  $1 + 4 \times 556.8 = 1.2227$ . Kirchhoff gives the following additional lines:

## (2) STRONTIUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
650.68	.9857		
554.52	1.1566		
461.69	1.3892	1.3893	$1 + 4 a'$
461.62	1.3894	1.3898	$1 + 4 b'$
431.38	1.4868	1.4867	$1 + 5 a'$
431.18	1.4875	1.4872	$1 + 5 b'$

## PLATINUM, K H.

Wave-Lengths.	Quotients.	Theoretical.	
598.22 598.14	1.0000	1.0000	
596.86 596.59	1.0023 1.0026	1.0026	$1 + 3 a$
595.62 595.47	1.0044 1.0045	1.0044	$1 + 5 a$
548.07 547.95	1.0915 1.0916	1.0910	$1 + 5 b$
530.70 530.76	1.1272 1.1270	1.1275	$1 + 7 b$
523.10 523.08	1.1436 1.1435	1.1419	$1 + 7 c$
506.43 506.32	1.1812 1.1813	1.1825	$1 + 9 c$
456.19 454.92	1.3113 1.3148	1.3129	$1 + 20 d$
450.77 449.72	1.3271 1.3300	1.3285	$1 + 21 d$
445.65 444.45	1.3424 1.3455	1.3442	$1 + 22 d$

This is not given among the comparisons in Gibbs's Table XI, but it embraces all the lines in which Huggins's measurements (Table IV) and Kirchhoff's (Table IX) differ by less than a unit. The groups may be connected by the equations,  $21 a = b$ ;  $10 b = 9 c$ ;  $6 b = 7 d$ .

<sup>1</sup> *Proc. Soc. Phil. Amer.*, xiv, 651.