

## 7d. Persistent Lines of the Elements

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Table 7d-1 gives the strongest lines of each element and is useful for the spectroscopic identification of small traces of elements and spectrochemical analysis in general, when the elements in question occur in rather small concentrations. For the procedure of routine quantitative analysis with larger concentrations, see the special literature.

A selection of strong lines is given both from the spectrum of the neutral atom and from the spectrum of the singly ionized atom. The former are most prominent with mild excitation (d-c arc at atmospheric pressure, glow discharge in a gas at moderate pressure, microwave discharge). The lines of the ionized atoms appear with stronger excitation (condensed spark, discharge in a gas at very low pressure, etc.). The relative intensities even in the same spectrum may depend very pronouncedly on the discharge conditions so that what is indicated as the strongest line may be relatively weak at a particular condition. The data are taken from W. F. Meggers, C. H. Corliss, and B. F. Scribner, "Tables of Spectral-line Intensities," 2 parts, National Bureau of Standards Monograph 32, Government Printing Office, Washington, D.C., 1961. These tables list the relative intensities, obtained in a 10-Å direct-current arc, of the lines of 70 elements mixed in a concentration of 0.1 atomic percent with copper. The lines of gaseous and unstable elements are from older sources.

In general, wavelengths in Table 7d-1 and other tables of this section are wavelengths in standard air for  $\lambda > 2,000 \text{ \AA}$  and in vacuum for  $\lambda < 2,000 \text{ \AA}$ .

PERSISTENT LINES OF THE ELEMENTS

TABLE 7d-1. PERSISTENT LINES OF THE ELEMENTS

Z	Symbol	Neutral atoms				Singly ionized			
		Strong-est line	Other strong lines			Strong-est line	Other strong lines		
1	H	1,215.66	6,562.85	4,861.33					
2	He	584.33	5,875.62	3,888.65	303.78				
3	Li	6,707.85	6,103.64		199.26				
4	Be	2,348.61	2,650.47	3,321.34	3,130.42	3,131.07			
5	B	2,497.73	2,496.78		1,362.46	3,451.41			
6	C	1,657.01	2,478.57		1,335.71	4,267.27	2,836.71		
7	N	1,134.98	4,109.98	4,099.94	1,085.74	5,079.50	5,000.04		
8	O	1,302.19	7,771.93	7,774.14	7,775.43	834.47			
9	F	954.80	6,856.02	6,902.46	606.81				
10	Ne	735.89	5,852.49	6,402.25	5,400.56	460.73			
11	Na	5,880.05	5,805.02	8,104.81	3,302.32	372.04			
12	Mg	2,852.13	3,838.26	5,183.62	3,832.31	2,795.53	2,802.70		
13	Al	3,961.53	3,092.78	3,944.03	3,082.16	1,670.81	2,669.17	2,816.18	
14	Si	2,516.11	2,881.60	2,524.11	2,528.51	1,817.0			
15	P	1,774.94	2,535.65	2,553.28		1,542.32			
16	S	1,807.31	9,212.91	9,228.11	4,694.13	1,259.53			
17	Cl	1,347.2				1,071.05	4,794.54	4,810.06	4,819.46
18	A	1,048.22	8,115.31	7,067.22	6,965.43	919.78			
19	K	7,664.01	7,698.98	4,044.14	4,047.20	600.77			
20	Ca	4,226.73	4,454.78	6,162.17	4,434.96	3,933.67	3,968.47	3,179.33	8,542.09
21	Sc	3,911.81	3,907.49	4,020.40	5,081.56	3,613.84	3,630.74	4,246.83	3,572.53
22	Ti	3,998.64	3,653.50	3,642.68	4,981.73	3,349.41	3,234.52	3,372.80	3,383.76
23	V	4,379.24	3,183.98	4,111.78	4,384.72	3,093.11	3,102.30	3,110.71	2,908.82
24	Cr	3,578.69	3,593.49	4,254.35	3,605.33	2,835.63	2,677.16	3,843.25	2,849.84
25	Mn	4,030.76	4,033.07	2,794.82	4,034.49	2,576.10	2,593.73	2,605.69	2,949.20
26	Fe	3,734.87	3,581.20	3,719.94	4,045.82	2,599.40	2,611.87	2,598.37	2,404.88
27	Co	3,453.50	2,405.12	3,502.28	3,569.98	2,388.92	2,528.02		
28	Ni	3,414.76	3,524.34	3,515.05	3,619.39	2,394.52	2,216.47		
29	Cu	3,247.54	3,273.96	5,218.20	5,105.54	2,135.98	2,700.96	2,192.26	
30	Zn	2,138.56	3,345.02	4,810.53	4,722.16	2,061.91	2,025.51		
31	Ca	4,172.06	4,032.08	2,943.64	2,874.24	1,414.44			
32	Ge	2,651.18	2,709.63	3,039.06	2,754.59	1,649.26			
33	As	1,890.43	2,780.22	2,860.44	2,349.84	1,266.36			
34	Se	1,960.91	2,039.85	2,062.79	8,918.80	1,192.29			
35	Br	1,488.4				1,015.42	4,704.80	4,785.50	4,810.71
36	Kr	1,235.82	5,870.92	5,570.29		917.43			
37	Rb	7,800.23	7,947.60	4,201.85	4,215.56	741.4			
38	Sr	4,607.33	6,408.47	4,962.26	5,480.84	4,077.71	4,215.52	3,464.46	
39	Y	4,102.38	4,077.38	3,620.94	4,643.70	3,710.30	3,000.73	3,774.33	4,374.94
40	Zr	3,601.19	3,519.60	3,835.96	4,687.80	3,391.98	3,438.23	3,496.21	3,572.47
41	Nb	4,058.94	4,079.73	4,100.92	3,580.27	3,094.18	3,130.79	2,927.81	2,950.88
42	Mo	3,798.25	3,864.11	3,132.59	3,902.96	2,775.40	2,816.15	2,848.23	2,871.51
43	Tc	3,636.10	4,297.06	4,262.26		2,543.24	2,610.00	3,237.02(?)‡	
44	Ru	3,728.13	3,498.94	3,726.93	4,080.60	2,678.76	2,402.72	2,456.57	
45	Rh	3,692.36	3,528.02	3,434.89	3,657.99	2,520.53	2,490.77	2,715.31	
46	Pd	3,404.58	3,609.55	3,634.70	3,421.24	2,488.92			
47	Ag	3,280.68	3,382.89	5,209.07	5,465.49	2,413.18	2,437.79	2,246.41	
48	Cd	2,288.02	3,610.51	5,085.82	3,466.20	2,265.02	2,144.38		
49	In	4,511.32	4,101.77	3,256.09	3,039.36	1,586.4			
50	Sn	2,839.99	2,863.33	3,034.12	2,706.41	2,152.22			
51	Sb	2,598.05	2,528.52	2,877.92	3,232.52	1,606.98			
52	Te	2,385.76	2,383.25	2,142.75		1,161.52			
53	I	1,830.4				1,233.97	2,062.38	5,464.61	
54	Xe	1,469.62	4,671.23	4,624.28		1,100.42			

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TABLE 7d-1. PERSISTENT LINES OF THE ELEMENTS (Continued)

Z	Symbol	Neutral atoms				Singly ionized			
		Strongest line	Other strong lines			Strongest line	Other strong lines		
55	Cs	8,521.10	8,943.50	4,555.36	6,723.28	926.75			
56	Ba	5,535.55	6,110.78	6,498.76	7,059.94	4,554.03	4,934.09	6,141.72	6,498.90
57	La	6,249.93	5,177.31	5,234.27	5,501.34	3,949.10	4,086.72	3,794.78	4,333.74
58	Ce	5,699.23	5,159.69	5,161.48	5,245.92	4,186.60	3,952.54	3,801.53	3,999.24
59	Pr	4,951.36	4,939.74	5,045.53	4,695.77	4,179.42	4,222.98	4,225.33	3,908.43
60	Nd	4,924.53	4,883.81	4,634.24	5,620.54	4,303.58	4,061.00	3,803.30	4,012.25
61	Pm					3,892.16	3,910.26	3,998.96†	
62	Sm	4,296.74	5,071.20	5,175.42	4,336.14	3,568.27	3,592.60	3,885.29	4,424.34
63	Eu	4,205.05	3,819.67	3,930.48	3,907.10	4,594.03	4,627.22	4,661.88	3,212.81
64	Gd	4,225.85	3,783.05	4,078.70	4,053.64	3,768.39	3,422.47	3,640.19	3,340.47
65	Tb	4,326.47	4,318.85	3,765.14	4,338.45	3,509.17	3,702.85	3,568.51	3,324.40
66	Dy	4,211.72	4,045.99	4,186.78	4,194.85	3,531.70	3,968.42	3,645.41	3,944.70
67	Ho	3,796.75	3,810.73	4,103.84	4,053.93	3,456.00	3,891.02	3,398.98	3,484.84
68	Er	4,007.97	3,862.82	4,151.10	3,892.69	3,906.34	3,372.76	3,692.04	3,499.11
69	Tm	4,094.19	4,105.84	3,717.92	4,187.62	3,462.20	3,848.02	3,131.26	3,425.08
70	Yb	3,987.98	3,464.36	5,556.48	7,699.49	3,694.19	3,289.37	2,891.38	2,970.56
71	Lu	3,281.74	3,359.56	3,312.11	3,376.50	2,615.42	2,911.39	3,077.60	3,507.39
72	Hf	2,866.37	3,072.88	2,916.48	2,940.77	3,309.80	3,661.66	2,820.22	3,505.23
73	Ta	2,653.27	2,714.67	2,647.47	2,656.61	3,012.54	2,685.17	2,400.63	2,635.58
74	W	4,008.75	4,074.36	4,294.61	2,724.35	2,555.09	2,571.44	2,658.04	2,764.27
75	Re	3,460.46	3,464.73	3,424.62	2,999.60	3,580.15	2,461.84	2,608.50	2,733.04
76	Os	2,909.06	3,058.66	3,301.56	4,260.85		2,538.00	2,486.24	
77	Ir	3,220.78	2,543.97	3,133.32	3,800.12		3,731.36	2,242.68	
78	Pt	3,064.71	2,659.45	2,702.40	2,733.96	1,777.09	2,488.74		
79	Au	2,675.95	2,427.95	3,122.78	2,748.26	1,740.47	2,802.19		
80	Hg	1,849.68	2,536.52	4,358.35	5,460.74	1,649.96			
81	Tl	3,519.24	5,350.46	3,775.72	3,429.43	1,908.64			
82	Pb	4,057.83	3,683.48	2,801.99	2,833.06	1,726.75	2,203.51	5,508.8	
83	Bi	3,067.72	3,897.98	2,938.30	2,989.03	1,902.41			
84	Po	2,449.99							
85	At								
86	Rn	1,786.07	7,450.00	7,055.42					
87	Fr								
88	Ra	4,825.91				3,814.42	4,682.28	3,649.55	4,340.64
89	Ac					4,168.40	4,088.40	3,863.12	
90	Th	3,719.44	3,803.07	3,304.24	3,967.39	4,019.13	2,837.30	3,469.92	3,392.03
91	Pa		2,743				2,743.9	3,054.6	3,957.8†
92	U	3,812.00	3,854.88	3,871.04	3,566.60	3,859.58	3,854.66	3,670.07	3,890.36
93	Np						2,956.6	3,829.2	4,290.9†
94	Pu						2,835.5	3,907.1	3,989.7†
95	Am						2,832.3	3,926.2	4,188.2†
96	Cm								
97	Bk								
98	Cf								
99	Es								
100	Fm								
102	No								
103	Lw								

† Scribner, Bozman, Meggers, *J. Research Natl. Bur. Standards* 46, 85 (1951) (Pm).  
 ‡ Scribner, Bozman, Meggers, *J. Research Natl. Bur. Standards* 45, 476 (1950).  
 ¶ Fred. Tomkins, *J. Opt. Soc. Am.* 39, 357 (1949).