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Atomic Absorption Spectrum of Praseodymium (Pr I)

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Absorption lines of Pr I were observed using a King furnace. A list of 3532 lines in the region from 1741 to 5839 Å is presented.

An absorption spectrum is of great help in the analysis of a complex and line-rich spectrum. Therefore arrangements were made to obtain the absorption spectra of some rare earths at the Imperial College of Science and Technology in London. Absorption spectrograms of praseodymium, cerium, and erbium have been obtained. The plates were taken with a 3-m normal incidence vacuum spectrograph [1].[1] This instrument has a Bausch and Lomb aluminized replica grating of 30,000 lines per inch, blazed at 1500 Å in the first order. The plate factor is 2.7 Å/mm. Ilford Q2 and Astr. III plates were used. For the region above 2400 Å the spectrograph was not evacuated.

The absorption vessel used was a large King furnace [1] with the following modification: the praseodymium was vaporized in a 6 in. long, ½-in. bore tantalum tube clamped between the ends of the conventional graphite tubes. With a 40 KVA power supply feeding a current transformer capable of delivering 1300 A at 30 V, it was possible to heat the tantalum tube to any temperature up to its melting point at around 3000 °C. The advantage of the tantalum tube over graphite is that carbide formation is inhibited, thus enabling the vaporization of many materials which would otherwise react with hot graphite.

A constant flow of purified helium was maintained at about 8 mm Hg pressure to ensure clean conditions in the King furnace. The temperature was measured with an optical pyrometer suitably calibrated to allow for the difference in emissivity between the tube and a blackbody.

The following three sources for the production of continuum radiation were used: (1) a pointolite lamp (i.e., an incandescent strip of tungsten); (2) a 16 A xenon arc in a quartz envelope; and (3) a H_2 positive column discharge observed end-on. Quartz and quartz-lithium fluoride optical elements were employed in the system.

Absorption spectra at two different temperatures close to 1700 and 2000 °C, respectively, were photographed in each spectral region to assist in the classification of lines arising from the lower energy levels. An iron arc was superposed for standards in the region above 3000 Å while a copper hollow cathode was used in the region below 3000 Å.

These plates have been measured by Zalubas as part of the work on the description and analysis of Pr I being done at the National Bureau of Standards. A scanning comparator built at NBS [2] served for measuring the plates. The measurements were reduced by an electronic computer. In the region 1741 to 3000 Å the superposed standards were used for calculation of wavelengths of absorption lines. In the region above 3000 Å the superposed iron standards were used only for identification of those praseodymium absorption lines that had previously been observed in emission at NBS [3]. The wavelengths of absorption lines were then calculated using the accurately known Pr I emission wavelengths as internal standards. In the region 3000 to 5839 Å all absorption lines are easily identifiable with Pr I emission lines. In the shorter wavelength region absorption lines are more numerous than emission lines. Resonance lines of Er, Cr, Ca, Dy, Ho, Cu, Mg, Na, and Fe were found as impurities and eliminated.

The wavelengths are tabulated in table 1. The first column gives the wavelength in angstrom units. The second column contains intensities of lines estimated by eye on the absorption plates. The letter symbols are used to describe the character of the lines; c—complex, d—double, h—hazy, l—shaded to longer wavelength, s—shaded to shorter wavelength, w—wide, and bl—blended lines.

The wavelengths given in table 1 were obtained from one measurement of each line in absorption, at the 2000 °C furnace temperature. Their values have been rounded off to two decimal places; in general they agree within ±0.02 Å with the values obtained from measurements of emission lines in the region above 3000 Å. Below 3000 Å, however, the wavelength accuracy is not exactly known, since shifts may occur when the copper standards are superposed; although an unlikely occurrence, this possibility could not be ruled out by a comparison with emission line wavelengths in the same region.

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[1] Figures in brackets indicate the literature references at the end of this paper.

Since iron and copper standards were superposed on absorption spectrograms, there are some regions where the lines were partly masked by iron and xenon emission lines or molecular bands, thus causing apparent wavelength shifts. Also, some lines which we observed in emission as self-reversed were completely masked on the absorption plates by superposed standards.

The above wavelength accuracy is sufficient for identification purposes in astronomical or spectrochemical analysis. For spectrum analysis, the emission line wavelengths derived from the plates taken with higher dispersion instruments are used. Using the absorption data, regularities in the spectrum of Pr I have already been discovered, and analysis of the Pr I spectrum is being continued at the National Bureau of Standards.

It is our pleasure to express our appreciation to C. H. Corliss for the generous assistance he has provided. We are indebted to W. R. S. Garton for suggesting the tantalum tube modification to the King furnace. We also thank Mrs. R. L. Peterson for her assistance in preparing table 1.

References

[1] W. R. S. Garton and K. Codling, Proc. Phys. Soc. (London) **75**, 87 (1960).

[2] M. L. Kuder, J. Res. NBS **65C** (Eng. and Instr.) No. 1, 1 (1961).

[3] R. Zalubas, unpublished data (1964).

TABLE 1. — *Wavelengths and intensities of absorption lines of* Pr

λ_{vac}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
1741.63	3	2005.10	5	2086.21	1	2141.41	2	2205.64	2	2277.97	3
1747.84	2	2024.03	1	2086.68	1	2142.40	2	2206.25	2	2278.23	2
1762.95	5	2024.39	3	2087.10	2	2142.77	1	2206.55	2 h	2278.41	3
1765.68	4	2025.87	5	2087.63	3	2143.99	3 wh	2207.01	2	2279.28	3
1766.44	8	2026.19	1	2090.71	1 s	2144.62	1	2207.42	1	2279.70	2
1769.19	5	2027.27	2 sh	2091.38	2	2144.92	2	2208.04	2	2280.27	1
1774.88	5	2038.37	4	2091.88	2	2147.83	1	2208.55	1	2280.56	8 s
1825.36	1	2039.08	5 s	2092.23	2	2150.78	3	2209.17	2	2282.44	2
1827.95	4	2039.86	3 d	2092.42	2	2152.02	2	2209.43	2	2282.89	2
1841.48	2	2039.86	3 d	2092.85	2	2155.77	1	2210.96	2	2283.26	1
1842.61	2	2040.90	2	2093.02	1	2156.56	3	2211.65	1	2283.87	2
1847.49	2	2042.80	2	2093.21	1	2157.20	1	2212.87	1	2284.14	3
1848.16	1	2043.07	2	2094.10	1	2157.86	1	2213.52	2	2284.62	3
1850.70	2	2045.37	5	2094.40	1	2158.59	1	2214.18	2	2284.93	8 s
1851.16	2	2046.60	3	2094.88	2	2159.49	1	2216.72	2	2285.51	1
1852.33	1	2047.27	2	2095.64	1 d	2160.08	2	2216.96	1	2285.90	2
1853.83	1	2047.89	1	2096.49	2 wh	2161.64	1	2218.97	1	2285.51	1
1854.37	1	2048.12	1	2099.62	1	2162.03	1	2219.28	3	2285.62	1
1855.29	1	2048.84	3 wd	2100.11	1	2162.44	1	2219.67	2	2285.90	2
1855.59	1	2049.25	3	2101.75	1	2163.20	2	2220.08	2 wh	2286.06	1
1856.39	1	2049.58	1	2102.40	1	2164.34	2	2220.67	3	2286.36	1
1857.36	1	2050.32	1	2102.62	1	2165.17	2 sh	2222.02	2	2286.86	2 wd
1857.84	2	2050.54	5	2103.12	3	2165.50	2	2223.97	1	2287.31	8
1865.33	1	2051.31	3	2103.12	2	2165.92	1	2225.09	2 wh	2287.91	5
1866.10	1	2052.96	6	2103.72	1	2166.68	1	2231.85	2 wh	2288.15	3
1869.26	1	2054.07	2 sh	2104.18	2	2168.09	1	2233.23	2	2289.40	1
1880.10	1	2056.57	1	2105.48	3	2168.61	2	2234.20	1	2289.59	5
1880.43	1	2057.29	2	2106.45	2	2168.89	2	2234.39	1	2290.35	4
1881.00	1	2057.63	4	2106.91	2	2170.05	2	2234.87	2	2291.72	4
1883.79	1	2058.33	3	2107.13	3	2172.49	1	2235.27	3	2291.98	1
1885.99	1	2059.50	2	2107.44	1	2173.14	2	2236.37	2	2292.48	4
1887.79	1	2060.29	3	2108.67	1	2173.45	2	2237.48	1	2294.39	1
1888.35	1	2060.61	1	2109.02	1	2173.65	2	2238.05	2	2295.13	1
1890.39	1	2061.60	4 d	2110.64	2	2174.13	3	2239.60	3	2295.59	2
1894.67	1 wh	2062.96	2	2111.51	3 sh	2174.63	2	2239.74	2	2295.78	5
1896.94	1	2064.21	3	2112.37	3	2179.03	3	2240.33	1	2296.70	4
1898.59	1	2064.58	2	2112.75	1	2181.80	2 sh	2240.85	2	2296.91	3
1900.96	1	2065.57	2	2113.54	3	2182.42	1	2241.09	2	2297.21	3
1901.44	1	2068.89	3	2113.98	2 lw	2182.62	1	2243.24	2	2297.43	2
1904.80	2	2069.42	2	2115.03	1	2184.19	2	2243.44	2	2300.15	3
1905.82	2 h	2071.24	1	2118.30	2	1991.22	1	2246.11	2	2300.60	3
1906.57	1	2071.49	5	2118.79	3	2185.07	1	2247.78	3	2301.11	1
1908.35	1	2072.35	3	2119.18	1	2185.54	2	2248.48	1	2301.22	4
1934.58	2	2072.65	2	2120.72	1	2185.90	1	2250.32	2 wh	2301.48	4
1935.83	1	2073.30	1	2121.07	3	2186.55	2 sh	2251.26	2 h	2302.10	2
1937.31	2	2073.48	3	2122.17	2 wh	2187.25	3	2253.37	3 hw	2302.34	4
1947.02	2	2074.13	2	2123.43	2	2187.99	3	2263.51	2	2302.53	3
1950.29	1	2074.63	2	2123.88	1	2188.81	2	2269.15	3	2302.67	3
1957.89	3	2075.41	1	2124.12	1	2190.26	1	2266.86	3 w	2303.48	3
1958.65	1	2075.50	2	2124.71	2	2191.14	2	2269.16	8	2303.59	2
1959.68	1	2075.78	2	2126.37	2	2193.00	3	2269.89	3	2303.83	4
1960.20	3	2076.00	3	2129.42	2	2194.17	1	2270.61	4	2304.25	1
1961.29	1	2076.19	1	2129.73	1 bl	2194.86	1	2270.98	4	2304.25	2
1962.17	2	2076.44	2	2130.68	1 bl	2196.89	2 w	2272.12	3 s	2304.53	1
1962.95	1	2077.51	3	2131.64	2	2197.72	2	2272.80	3	2304.80	2
1964.12	1	2078.11	3 s	2132.07	1	2198.81	1	2273.11	5	2305.02	2
1972.32	1	2078.87	2	2132.55	1	2199.05	1	2274.04	3	2305.10	3
1977.57	2 w	2079.56	3	2133.34	1	2200.05	1	2274.68	8	2305.30	3
1983.28	1	2080.80	1	2134.77	2 d	2200.20	1	2275.19	5	2305.48	3
1991.06	2 h	2081.36	3	2135.27	2	2200.78	2	2275.52	2	2305.82	3
1986.05	1 w	2082.24	2	2137.70	2	2202.96	1	2277.04	3	2306.17	4
1993.11	1	2082.47	1	2138.35	2 sh	2203.59	2	2277.31	1	2306.66	2
1993.64	1	2082.83	3	2139.20	2 h	2204.06	2	2277.65	1	2306.91	1
		2083.42	3	2139.76	1	2204.72	3	2277.97	3	2307.13	4
		2085.81	1	2140.95	2	2205.07	1	2277.64	2	2307.91	3

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
2308.07	2	2333.86	1	2358.91	3	2382.60	1	2405.08	3	2432.13	2
2308.21	2	2334.14	8	2359.17	3	2382.83	1	2405.22	3	2432.44	2 d
2308.72	2	2336.79	3	2359.69	1	2383.62	3	2405.40	1	2433.06	2
2309.12	3	2338.27	2	2360.73	3	2383.83	2	2405.72	3	2433.44	2
2309.79	2	2338.46	2	2360.88	2	2384.34	3	2407.23	2	2433.71	2
2310.14	3 h	2339.02	4	2361.85	2	2384.51	2	2407.34	2	2434.20	2
2309.98	3	2339.14	1	2362.11	2	2384.73	5	2407.59	4	2434.34	2
2310.72	5	2339.51	1	2362.32	3	2385.26	2 lc	2408.00	3	2434.83	2
2311.01	3	2340.01	3	2362.62	8	2385.73	2 lc	2408.37	3	2435.20	5
2311.01	3 w	2340.23	4	2362.78	2	2386.50	3	2408.84	3	2435.68	2
2311.81	8	2341.11	2	2363.05	2	2386.65	2	2409.27	3	2435.86	1
2312.52	3	2341.12	2	2363.24	2	2386.91	3	2409.83	8	2436.09	4
2313.17	3	2341.39	1	2363.98	2	2387.05	2	2409.99	2	2436.33	3
2313.39	2	2343.03	2	2364.28	3	2387.14	2	2411.22	3	2436.81	3
2313.54	1	2343.36	5 sh	2364.42	1	2387.63	4	2411.57	2	2439.19	3 s
2313.71	1	2344.10	4	2364.55	2	2387.74	3	2412.13	2	2439.56	3
2314.06	1	2344.34	2	2364.92	1	2388.39	2	2412.29	2	2439.74	1
2314.24	3	2344.83	2	2365.00	1	2388.54	3	2412.55	2	2440.57	3
2314.67	1	2345.02	3	2365.13	4	2388.86	3	2412.90	1 d	2440.88	2
2315.05	2	2345.34	4	2365.71	3	2389.39	2	2413.22	2	2441.96	8
2315.38	5	2345.61	1	2365.94	3	2389.51	2	2413.76	2	2442.62	2
2315.80	3	2346.12	2	2366.65	3	2389.68	3	2413.88	2	2442.89	1
2316.44	2	2346.33	2	2366.93	8	2390.02	3	2414.75	2	2443.12	1
2316.89	2	2346.54	8	2367.11	5	2390.37	2	2414.92	2	2443.60	2
2317.29	3	2347.01	5	2368.56	1	2390.89	2	2415.07	2	2443.81	2
2317.84	3	2347.30	6	2368.75	3	2391.04	4	2415.48	2	2444.63	2
2318.38	3	2347.58	1	2368.98	3	2391.43	4	2415.75	2	2444.78	2
2318.86	3	2347.98	3	2369.22	3	2391.60	2	2416.24	2	2444.95	2
2319.11	5	2348.46	2	2369.61	3	2391.97	2	2416.81	8	2445.38	2
2319.96	1	2348.67	2	2370.41	2	2392.50	4	2416.99	4	2445.48	4
2320.08	2	2349.03	3	2370.86	3	2392.81	2	2417.07	5	2446.27	3
2320.32	2 l	2349.37	3	2371.15	3	2393.15	3	2419.74	3 d	2446.37	2
2320.79	4	2349.72	8	2371.28	3	2393.26	4	2420.04	3	2446.53	3
2321.18	6	2350.19	3	2372.15	8	2393.57	4	2420.41	2	2446.70	2
2321.34	2	2350.35	3	2372.42	1	2393.71	3	2420.78	1	2446.93	2
2321.78	1	2350.48	5	2372.83	2	2393.96	2	2421.05	8	2447.02	5
2322.28	2	2351.18	4	2372.95	2	2394.02	2	2421.42	2	2447.09	2
2322.50	2	2351.50	2	2373.19	3	2394.36	3	2421.88	3	2447.61	2
2322.71	3	2351.75	5 l	2373.32	2	2394.82	2	2422.26	2	2448.45	1
2323.70	3	2352.15	5	2373.42	2	2394.95	1	2422.38	2	2448.78	1
2324.33	4	2352.56	3	2373.88	2	2395.20	3	2422.60	4	2449.70	3
2324.50		2353.00	1	2374.16	5	2395.35	3	2423.24	8	2449.83	2
2324.81	3	2353.12	2	2374.43	2	2395.73	2	2423.84	3	2450.33	2
2325.04	1	2353.24	2	2374.97	1	2396.26	4	2424.25	2	2450.48	3
2325.16	1	2353.42	1	2375.07	5 h	2396.84	3	2425.00	1	2450.60	2
2325.40	3	2353.79	2	2375.50	2	2397.08	2	2425.29	1	2451.09	1
2325.58	2 w	2354.24	3	2375.64	4	2397.28	2	2425.45	3	2451.35	1
2325.85	2	2354.33	2	2376.00	3	2397.40	1	2425.75	1	2451.79	3
2325.92	2	2354.59	2	2376.20	2	2398.02	3	2426.04	3	2452.00	3
2326.07	4	2354.79	4	2376.66	4 s	2398.21	4	2426.26	2	2452.12	3
2326.86	3	2355.25	2	2377.17	4	2398.57	3	2426.44	1	2452.77	3
2327.43	3	2355.26	2	2377.51	3	2398.98	2	2426.73	2	2453.21	3
2327.97	2	2355.47	3	2378.08	1	2399.33	1	2427.46	3	2453.28	3
2328.13	3	2355.47	3	2378.47	8	2399.42	2	2427.72	1	2453.52	3
2328.59	3	2355.90	2	2378.90	2 d	2400.51	2	2428.27	1	2453.82	2
2328.76	2	2356.04	2	2379.34	3	2401.36	3	2428.46	2 h	2454.11	1
2329.02	3	2356.20	3	2379.58	2	2401.54	3	2428.81	2	2454.40	3
2329.87	3 w	2356.54	3	2379.88	2	2401.71	2	2428.98	2	2454.60	2
2330.34	1	2356.85	8	2380.11	3	2401.94	2	2429.11	1	2454.87	2
2330.79	4	2357.13	2	2380.50	2	2402.52	2	2429.72	2	2455.18	3
2332.01	5	2357.58	1	2380.57	2	2402.64	1	2429.84	3	2455.26	2
2332.40	3	2357.97	2	2380.89	2	2403.89	3	2430.40	2	2455.50	2
2332.52	4	2358.24	1	2381.07	2 d	2404.14	5	2430.57	3	2455.98	1
2333.04	1	2358.69	2	2381.44	2	2404.30	1	2430.76	2	2456.36	2
2333.36	2	2358.77	1	2381.72	2	2404.50	1	2431.35	5	2456.85	2

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
2457.06	2	2478.87	3	2523.25	2	2552.15	8	2578.37	4	2598.08	4
2457.27	2	2479.41	2	2523.78	3	2552.93	2	2578.96	2	2598.17	1
2457.37	2	2480.07	2	2524.40	2	2553.21	2	2579.68	2 b l	2599.10	3
2457.76	3	2480.35	3	2525.24	1	2553.75	3	2580.28	2	2599.61	3
2457.85	3	2480.64	2	2525.49	1	2553.86	2	2580.36	4	2599.74	4
2458.21	4	2481.26	4	2525.72	1	2554.08	2	2580.47	2	2599.85	8
2458.69	2	2481.41	3	2525.83	1	2554.42	1	2580.78	1	2599.85	8
2458.98	2	2482.45	3	2526.66	1 b l	2554.83	1	2581.05	2	2600.72	8
2459.12	2	2482.79	3	2526.99	8	2555.01	1	2581.42	3	2600.86	4
2459.49	3	2484.01	2	2527.20	2	2555.18	1	2581.58	3	2601.65	1
2459.73	2	2484.72	2	2527.65	1	2555.26	3	2581.86	1	2602.24	1
2460.29	5	2485.16	3	2528.41	5	2555.50	1	2581.95	1	2602.32	1
2460.69	3	2485.43	1 b l	2528.92	2	2555.76	1	2583.16	2	2602.68	3
2460.77	2	2485.52	1	2529.39	5	2556.47	2	2583.36	5	2602.84	3
2461.21	5	2485.73	2	2529.71	3	2556.97	1	2583.61	3	2602.94	1
2461.63	3	2487.37	3	2530.06	1	2557.05	2	2584.00	3	2603.44	8
2462.07	3	2489.99	3 b l	2530.17	1	2557.30	2	2584.35	3	2603.67	2
2462.37	5	2491.04	3	2530.98	5	2557.54	3	2585.62	2	2603.89	1
2462.37	3	2491.42	1	2531.12	2	2558.77	1	2586.16	1	2604.09	2
2463.05	3	2491.64	2	2531.48	2	2558.98	2	2586.66	1	2604.91	5
2463.77	2	2491.87	1	2531.82	5	2559.35	1	2586.79	1	2605.93	3
2463.87	4	2492.49	8	2532.28	2	2559.53	2	2586.86	1	2606.05	1
2463.97	1	2492.83	4	2532.38	1	2560.21	3	2586.96	1	2606.90	8
2464.79	4	2494.53	3	2532.49	2	2560.48	3	2587.43	3	2607.22	2
2465.40	4	2495.07	2	2533.33	2	2560.61	2	2587.55	1	2607.33	2
2465.57	1	2496.12	5	2534.17	1	2561.20	3	2587.76	3	2607.59	3
2465.77	8	2496.29	1	2534.47	3	2561.86	2	2587.88	3	2607.90	4
2466.06	4	2496.52	1	2534.73	2	2562.94	2	2588.04	3	2608.18	2
2466.72	8	2496.92	1	2535.51	2	2563.09	2	2588.43	2	2608.34	1
2466.91	1	2497.08	6	2536.18	1	2563.51	1	2588.81	3	2609.12	3 s
2467.17	8	2497.92	2 b l	2536.29	2	2563.93	1	2589.00	1	2609.66	3
2467.51	1	2497.99	2 b l	2536.39	1	2564.06	1	2589.08	3	2609.76	1
2467.74	1	2499.70	3	2539.09	3	2564.18	1	2589.22	1	2610.93	2
2467.87	2	2499.97	2	2540.10	3	2564.30	3	2589.93	1	2611.68	3 b l
2467.98	3	2501.00	2	2540.63	3	2564.52	2	2590.31	2	2613.74	4
2468.29	4	2501.24	3	2541.14	3	2564.63	5	2590.45	3	2613.91	4
2468.46	3	2502.59	1	2541.80	2	2565.12	1	2590.56	5	2614.73	2
2468.81	3	2502.90	1	2541.94	1	2566.15	2	2590.96	2	2615.40	2
2468.94	2	2503.13	1	2542.16	1	2566.44	2	2591.20	2	2616.01	1
2469.17	3	2505.77	3	2542.28	1	2566.61	1	2591.30	3	2616.10	1
2469.60	6	2505.96	2	2542.71	1	2567.21	1	2591.58	3	2616.22	1
2469.73	8	2506.72	1	2543.01	1	2567.76	2	2591.93	2	2616.60	1
2470.04	1	2507.24	1	2543.44	2	2567.99	1	2592.11	2	2616.90	1
2470.13	2	2509.32	1	2543.83	2	2568.11	1	2592.46	2	2617.43	1
2470.74	2	2509.59	3	2544.09	3	2568.62	4	2593.12	2 b l	2618.72	8
2470.82	2	2510.83	3 tr	2545.30	2	2568.89	4	2593.23	8	2619.79	2
2471.50	2	2512.10	1	2545.65	1	2569.05	1	2593.45	5	2623.16	1
2471.69	5	2512.46	1	2545.83	3	2569.32	1	2593.82	2	2623.48	1
2472.13	2	2513.57	1	2546.22	1	2569.76	2	2594.05	1	2625.07	2
2472.28	4	2513.77	1	2546.47	1	2569.92	2	2594.48	2	2625.33	3 s
2472.44	2	2513.93	1	2547.20	1	2570.11	2	2594.58	1	2626.60	2
2472.70	1	2514.81	1	2547.48	2	2570.84	5	2594.87	1	2626.94	4
2472.95	2	2515.09	1	2548.40	1	2571.40	2	2595.03	1	2627.55	4
2473.10	2	2517.21	1	2548.86	1	2572.47	1	2595.25	2	2627.72	1
2473.48	5 sh	2517.96	4	2549.03	3	2572.63	2	2595.41	1	2628.66	1
2474.01	5	2518.03	1 b l	2549.18	1	2573.16	1	2595.76	2	2629.00	1
2474.39	1	2518.41	1	2549.35	1	2573.39	1	2595.85	3	2629.16	1
2474.72	3	2518.66	1	2549.79	1	2573.70	2	2596.16	3	2629.46	1
2475.19	3	2518.82	2	2550.00	3	2574.10	2	2596.30	4	2630.09	1
2475.49	2	2519.91	1	2550.15	1	2574.19	2	2596.47	1	2630.45	3
2475.84	1	2519.99	1	2550.28	1	2574.55	5	2596.57	2	2631.10	5
2476.03	4	2521.13	1	2550.54	1	2574.81	4	2596.82	1	2631.20	4
2477.18	2	2521.37	2	2550.82	1	2576.89	2	2597.09	2	2631.39	2 b l
2478.18	2	2522.44	1 b l	2551.32	1	2577.19	2	2597.59	5	2631.82	3
2478.68	3	2522.94	1	2551.81	1	2577.65	2	2597.78	1	2631.93	1

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
2632.44	5	2674.22	3 b l	2719.96	2	2765.37	3	2795.69	5	2826.90	2
2632.74	6	2677.22	1	2720.18	1	2765.81	1	2796.13	3	2827.01	1
2633.09	12	2677.56	1	2720.49	1	2765.92	3	2796.83	5	2827.09	5
2633.80	1	2677.95	1	2720.60	1	2766.13	1	2797.27	2	2827.87	1
2634.05	1	2678.48	3	2721.05	3	2766.27	3	2797.79	1	2828.03	3
2634.70	1 b l	2678.67	3	2721.54	3	2766.27	2	2797.91	5	2828.55	1
2634.78	1 b l	2679.36	1	2721.82	2	2767.32	3	2798.13	8	2829.84	8
2634.91	2	2679.96	1	2722.42	1	2767.73	1	2798.32	1	2830.31	3
2635.12	3	2682.55	1	2725.39	2	2768.09	5	2798.94	2	2831.50	8
2636.24	2	2683.04	2	2725.63	2	2768.43	8	2799.52	3	2831.98	3
2636.33	3	2683.60	1	2727.02	1	2769.85	5	2800.10	3	2832.62	5
2636.54	8	2684.54	1	2727.95	2	2770.02	5	2800.56	2	2833.17	5
2637.04	1	2684.80	2	2728.58	5	2770.38	2	2800.93	3	2833.82	2
2737.32	3	2685.31	1	2728.76	1	2771.01	5	2802.09	8	2833.98	1
2637.40	1	2685.43	1	2729.39	1	2772.56	3	2802.50	5	2834.25	4
2637.75	2	2685.68	1	2729.74	2	2772.90	2	2802.88	2	2834.60	2
2639.63	1	2686.19	1	2729.86	1	2773.61	1	2803.65	1	2835.38	8
2640.36	2	2687.54	1	2730.01	1	2773.76	1	2804.18	8	2835.48	6
2640.82	1	2687.69	2	2730.35	2	2774.78	3	2804.92	3	2835.97	8
2641.23	5	2688.38	1	2730.59	2	2775.27	3	2805.24	5	2836.12	2
2641.55	1	2688.51	1	2731.01	1	2775.73	3	2805.37	2	2837.06	8
2641.98	1	2688.82	2	2731.91	1	2776.48	1	2805.63	8	2837.23	3
2642.16	5	2690.46	1	2733.19	5	2776.91	3	2806.02	4	2837.64	8
2642.69	2	2692.42	1	2736.67	1	2777.53	1	2806.76	4	2838.60	2
2643.63	5	2695.04	1	2736.84	1	2777.73	3	2807.61	1	2838.71	3
2644.05	1	2696.09	1	2737.27	1	2777.84	1 b l	2808.23	3	2839.37	8
2644.43	1	2696.35	2	2737.90	2	2778.31	1	2809.04	3	2840.29	8
2646.25	1	2698.04	1	2738.76	5	2778.67	8	2809.50	1	2840.78	1
2646.39	2	2698.53	3	2739.22	3	2779.42	2	2809.66	1 b l	2841.07	2
2648.15	3	2699.18	1	2740.62	1	2779.88	2	2809.74	2 b l	2841.83	8
2648.55	3	2699.44	1	2741.29	1	2780.10	3	2810.09	3	2842.26	2
2648.82	1	2700.11	1	2741.50	2	2780.38	2	2810.64	2	2842.47	2
2650.01	2	2700.21	1	2741.95	3	2780.55	1	2810.98	1	2843.02	8
2650.54	1	2701.26	1	2742.81	3	2780.66	3	2813.94	10 l	2843.28	8
2652.62	3	2702.07	3	2746.06	2	2780.94	1	2814.14	1	2843.88	4
2653.60	3	2702.28	3	2746.05	2 b l	2781.32	2	2814.44	8	2844.07	8
2653.96	1	2704.49	5	2746.38	1	2782.05	2	2814.51	4 b l	2844.50	2
2654.33	1	2706.04	2	2747.75	1	2782.29	1	2814.96	5	2845.29	8
2654.86	1	2706.37	1	2748.23	2	2782.56	3 b l	2815.47	8	2845.58	6
2655.08	2	2707.14	1	2748.58	3	2782.63	2 b l	2816.35	3	2847.13	3
2655.24	2	2707.84	1	2748.81	1	2783.03	1	2816.88	3	2847.48	8
2655.37	3	2708.54	1	2749.69	1	2783.14	3	2817.13	2	2847.93	5
2655.54	1	2708.92	5	2750.81	8	2783.56	8	2817.30	8	2848.97	3
2656.15	3	2709.11	8	2751.22	2	2783.74	2	2817.93	2	2849.16	4
2656.64	1	2709.98	3	2751.41	1	2784.84	8	2818.23	3	2849.98	1
2657.23	2	2710.95	1	2751.53	5	2785.18	1	2818.77	2	2850.36	4 s
2658.29	1	2711.06	1	2752.46	1	2785.50	2	2819.33	8	2850.68	5
2658.88	1	2711.16	3	2753.12	2	2785.78	8	2819.68	8	2851.87	2
2661.10	2	2711.34	8	2753.72	3	2786.46	5	2819.78	3	2852.79	2
2661.71	1	2712.73	1	2754.64	2	2786.89	5	2819.93	1	2852.97	1
2661.89	1	2713.09	1	2754.96	1 b l	2787.99	2	2820.68	3	2853.15	2
2663.04	2	2714.04	3	2755.02	2	2788.60	3	2820.98	3	2853.23	1
2663.36	5	2714.36	1	2755.63	8	2789.79	1	2821.16	3	2855.45	1
2663.64	1	2714.50	4	2758.45	1	2789.95	2	2821.26	3	2856.48	3
2664.60	2	2714.75	1	2758.92	1	2790.16	8	2821.68	6	2857.17	8
2667.57	1	2714.94	1	2760.42	2	2791.13	3	2821.83	8	2858.05	3
2668.50	5	2715.17	1	2760.82	2	2792.36	2	2822.00	8	2858.74	2
2669.27	1	2715.62	1	2761.70	3	2792.63	3	2823.41	1	2858.83	3
2669.66	1	2715.77	2	2762.16	5	2792.76	3	2823.78	1	2859.06	5
2669.93	1	2716.25	2	2762.29	5 l	2793.07	1	2824.01	4	2859.41	4
2670.51	1	2716.38	1	2764.22	1	2793.30	1	2824.24	5 b l	2859.91	5
2671.09	1	2717.89	1	2764.38	1	2794.00	4 b l	2824.78	8	2860.76	5 l
2671.35	1	2718.32	2	2764.73	2	2794.88	1	2825.87	4	2860.91	3
2672.17	1	2718.42	8	2764.73	3	2795.20	5	2826.20	5	2861.65	4
2673.09	2	2719.15	2	2765.01	1	2795.47	4	2826.67	5	2862.00	1

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
2862.27	5	2902.09	1	2955.99	1	3132.25	8	3228.41	3	3340.45	4
2862.43	5	2902.51	8	2956.67	1	3133.23	3	3228.62	4	3343.91	4
2863.24	3	2903.40	1	2957.03	2	3134.79	4	3228.90	2	3346.58	1
2863.59	1	2903.61	2	2959.12	2	3136.09	2	3231.28	2	3347.41	5
2864.20	8	2904.03	1	2962.65	2	3142.06	4	3231.51	1	3348.24	5
2864.93	8	2904.33	2	2963.64	10	3142.88	1 b l	3231.70	1	3349.58	2
2865.72	4	2905.11	3	2964.92	1	3144.03	1 b l	3232.58	3	3351.34	2
2866.15	4	2905.21	1	2967.03	2	3146.92	4 b l	3233.25	4	3353.44	3
2866.45	8	2906.09	2	2974.16	3	3147.92	2 b l	3235.02	4	3357.40	2
2867.23	2	2906.16	1	2975.54	2	3148.35	3	3235.25	1	3358.51	2
2868.30	1	2907.23	1	2985.43	1 b l	3150.86	1	3235.84	1	3358.94	1
2868.68	2	2907.39	5	2985.54	5	3151.53	1 b l	3238.52	3 h	3359.13	1
2869.43	8	2907.85	2	2986.79	2	3155.90	3	3240.60	3	3363.96	8
2869.88	3	2908.02	1	2987.42	2	3157.20	2 b l	3242.41	2	3365.27	4
2871.02	3	2909.29	2	2992.38	2	3158.33	1 b l	3244.29	8	3366.06	1
2872.76	4	2910.03	4	2994.71	1	3158.88	3 b l	3244.61	3	3366.37	2
2873.63	2	2910.58	5	2997.63	1	3159.75	3 b l	3245.49	2	3369.12	5
2873.93	8	2911.65	12	3000.70	1	3160.02	2	3246.08	2	3372.86	1
2874.23	6	2912.35	1	3001.42	1	3160.34	1 b l	3246.49	4	3373.33	1
2874.47	1	2912.80	1	3006.28	2 w	3161.65	1	3248.72	4	3374.99	3
2874.87	1	2913.89	2	3008.30	3	3163.79	2	3253.15	8	3375.20	2
2875.11	2	2914.55	5	3008.92	1	3167.15	2	3254.62	2	3375.52	1
2875.52	5	2914.70	3	3011.90	1	3167.64	1	3257.18	1	3378.34	8
2877.07	8	2915.01	10	3013.04	4	3169.78	2 b l	3258.02	2	3379.25	1
2877.41	2	2915.63	1	3014.12	2	3170.57	3	3258.97	3	3380.06	4
2877.67	2 b l	2916.03	10	3014.75	1 w	3170.92	1	3259.41	1	3381.42	8
2878.82	3	2916.58	3	3014.83	1 b l	3171.42	1	3259.80	1	3386.04	10
2879.52	8	2916.81	2	3014.96	2	3171.73	1	3260.08	1	3386.63	3
2879.71	10 l	2918.78	3	3017.14	3	3173.09	5	3260.87	4	3391.48	1
2880.36	3	2919.83	1	3017.67	1	3174.05	1	3261.24	4	3393.67	2
2880.95	3	2920.35	2	3018.63	4	3174.39	3	3262.22	3	3393.95	2
2881.27	5	2920.54	1	3019.79	1	3175.61	2	3262.40	2	3394.24	2
2881.56	2	2920.61	3	3021.87	1	3176.21	1	3263.91	2	3395.02	1
2882.35	1	2920.89	1	3022.19	1	3178.85	2	3264.32	8	3395.45	3
2882.63	1	2921.32	1	3022.81	1	3179.97	2	3265.87	1	3395.89	2
2883.67	4	2921.72	1	3026.00	3 b l	3181.02	4	3276.29	1	3396.36	2
2883.94	8	2922.26	3	3027.39	1	3184.13	8	3277.10	1	3393.52	1
2885.87	10	2923.34	8	3028.24	1	3187.03	6	3283.05	2	3393.67	2
2886.83	4	2923.89	3	3033.32	2	3188.41	4	3283.41	5	3393.95	2
2887.36	4	2925.92	2	3034.78	2	3188.88	2	3289.03	1	3394.24	2
2887.56	2	2927.11	2	3035.24	2	3190.70	3	3289.63	3	3395.00	1
2888.41	2	2928.77	1	3047.14	1	3198.60	4	3293.59	3	3395.45	4
2888.56	3	2929.00	1	3047.53	2	3198.74	3	3297.10	2	3395.91	3
2888.82	2	2930.80	2	3052.59	1	3199.26	2	3297.50	3	3396.32	2
2890.54	3	2930.99	1	3054.75	2	3199.64	3	3298.41	1	3397.20	1
2890.73	3	2931.68	2	3055.65	1	3199.95	1	3299.38	1	3397.48	1
2891.27	4	2932.47	1	3056.17	2	3200.35	1	3303.01	3	3398.91	1
2891.62	4	2933.47	2	3056.70	2	3201.14	1	3303.24	2	3399.77	1
2891.99	12	2935.22	2	3059.81	3	3201.60	1	3303.44	3	3400.14	1
2893.44	10	2936.34	1	3063.61	3 b l	3203.12	3	3306.76	5	3402.87	2
2894.21	8	2938.53	2	3066.03	1	3206.04	1	3308.39	3	3402.95	4
2894.64	6	2939.38	1	3071.57	2	3206.33	2	3314.86	3	3403.76	5
2895.47	2	2940.05	2	3101.95	2 b l	3206.61	1	3316.45	3	3404.60	3
2895.91	8	2940.71	5	3102.65	2 b l	3207.16	2	3317.42	2	3404.99	3
2896.54	1	2941.14	1	3103.80	3	3212.49	5	3319.62	3	3405.70	3
2896.65	3	2942.72	1	3105.11	3 b l	3216.24	5	3327.08	2	3406.70	1
2896.73	2	2944.93	5	3113.63	1	3216.80	2	3328.89	2	3408.74	3
2896.92	3	2945.78	2	3118.03	3	3218.26	5	3330.05	2	3409.25	5
2897.65	4	2947.24	2	3119.36	8	3219.91	2	3331.61	3	3409.69	2
2898.22	8	2948.11	2	3122.96	8	3221.83	5	3332.77	1	3410.13	3
2899.24	3	2948.11	2	3124.28	1	3222.47	3	3333.30	1	3411.67	1
2899.37	12	2949.61	2	3125.45	5	3223.82	3	3333.86	2	3414.75	3
2899.92	4	2951.01	3	3126.07	4	3225.19	5	3334.69	3	3415.66	4
2900.52	8	2951.20	1	3126.33	4	3225.55	3	3337.28	2	3417.81	4
2901.81	6	2955.15	1	3127.79	8	3228.13	3	3339.34	1	3417.98	5

748-345—65——5

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
3418.66	1	3516.33	1	3644.70	1	3738.94	2	3832.31	3	3961.70	8
3420.83	1	3517.17	1	3649.08	2	3739.59	1	3833.07	2	3961.85	2
3421.94	1	3518.49	10	3650.73	4	3739.80	1	3833.23	2	3962.85	2
3422.43	1	3519.65	3	3651.46	1	3744.80	5	3834.35	3	3963.24	3
3423.26	2	3521.32	2	3651.98	1	3748.98	3	3834.69	4	3964.90	1
3425.20	3	3522.97	3	3653.37	1	3750.38	5	3836.10	5	3965.26	2
3426.08	2	3523.19	3	3654.13	1	3756.13	2	3836.30	2	3966.28	8
3426.72	1	3527.86	1	3654.63	5	3757.06	1	3838.77	2	3966.55	1
3432.04	10	3529.61	1	3657.09	3	3758.35	1	3844.10	2	3966.88	1
3432.63	2	3529.84	2	3658.04	2	3758.84	1	3848.10	3	3969.30	2
3434.47	4	3530.66	1	3659.20	1	3760.22	4	3850.38	4	3971.63	1
3436.89	1	3532.29	1	3661.48	3	3760.69	1	3858.02	4	3972.70	2
3437.60	4	3532.82	8	3662.47	3	3760.96	3	3859.11	2	3973.71	1
3438.85	2	3542.08	2	3664.38	1	3761.37	1	3861.78	1	3974.32	1
3440.06	1	3543.74	5	3665.07	2	3763.11	1	3864.10	1	3974.67	2
3440.59	1	3544.59	1	3665.46	1	3763.97	1	3866.59	4	3976.94	1
3440.97	1	3549.26	1	3666.38	2	3764.90	8	3870.72	1	3977.32	8
3441.57	2	3550.65	3 h	3668.47	5	3766.02	1	3872.64	2	3977.69	1
3442.40	2	3551.41	3	3668.88	1	3766.75	5	3874.83	1	3978.17	1
3443.24	2	3551.65	2	3671.11	4	3768.42	5	3877.29	4 h	3978.60	1
3444.30	4	3555.26	2	3675.50	3	3768.95	3	3878.21	4	3979.66	1
3445.83	1	3558.81	2	3676.08	4	3769.93	1	3878.80	2	3979.88	3
3447.83	5	3563.50	8	3677.59	3	3770.80	2	3881.69	1	3980.23	1
3450.10	5	3564.13	5	3678.30	5	3773.47	5	3883.30	5	3980.48	1
3450.66	2	3564.76	1	3679.91	2 h	3776.07	6	3883.98	3	3980.87	2
3453.80	5	3572.30	9 s	3681.69	5	3779.29	4	3884.28	1	3981.39	1
3454.86	1	3573.09	1	3683.52	2	3779.73	1	3886.30	1	3981.68	1
3458.06	2	3575.62	2	3685.76	3	3780.29	2	3892.40	2	3982.07	1
3459.44	1	3577.16	1	3687.67	5	3780.94	2	3895.63	3	3982.46	3
3459.86	2	3578.68	5	3687.86	1	3782.82	3	3898.41	4	3982.70	1
3461.20	3	3582.97	3	3693.61	8 s	3783.81	1	3899.36	3	3983.36	5
3466.24	3	3586.64	1	3695.46	4	3785.07	3 s	3900.67	2	3983.52	1
3467.02	3	3590.84	2	3698.74	3	3786.11	1	3901.29	1	3983.84	5
3468.55	1	3591.21	3	3700.24	3	3787.90	4	3901.81	1	3984.42	6
3468.66	2	3591.90	2	3701.59	2	3788.19	1	3906.82	1	3985.04	1
3469.05	5	3593.50	5	3702.89	1	3789.73	5	3909.22	1	3985.65	1
3470.06	1	3599.03	1	3703.33	3	3791.21	1	3910.57	5	3986.10	1
3470.33	3	3603.65	2	3705.14	1	3791.42	1	3912.29	1	3986.75	2
3471.68	1	3604.48	1	3706.05	3 h	3792.52	4	3913.03	1	3987.04	1
3474.46	4	3605.31	4	3707.63	2	3792.95	4	3913.53	2	3987.18	2
3475.51	5	3605.79	3	3708.37	2	3793.61	1	3916.62	1	3987.61	2
3478.36	3	3606.20	3	3708.66	2	3794.17	3	3921.08	2	3990.07	1
3479.25	3	3609.61	1	3711.17	4	3794.77	3	3922.86	2	3990.59	1
3479.84	2	3612.33	1	3713.44	1	3795.30	2	3923.62	3	3991.47	2
3482.09	3	3616.23	2	3715.62	4	3796.16	2	3924.49	8	3992.31	1
3482.61	2	3617.39	3	3716.47	1	3797.34	2	3934.09	4	3992.99	2
3483.31	3	3617.62	8 s	3719.92	3	3797.69	2	3934.69	1	3994.33	8
3485.75	2	3620.78	1	3721.68	4	3800.43	2	3935.02	5	3995.95	2
3487.55	1	3621.24	1	3723.78	1	3801.49	3	3935.90	1	3997.78	5
3489.31	1	3622.20	5	3724.15	5	3803.18	5	3936.21	1	3998.09	1
3489.62	1	3625.58	1	3724.37	5	3806.26	2	3937.20	3	3999.38	5
3490.99	2	3626.41	1	3725.52	1	3807.31	2	3937.37	3	4000.15	2
3491.36	1 b l	3627.42	2	3726.45	1	3807.61	1	3938.11	1	4000.81	1
3491.51	2 b l	3629.25	5	3728.78	1	3811.17	4	3941.26	1	4001.07	1
3494.83	5	3629.96	1	3729.95	2	3811.70	3	3941.41	1	4001.98	8
3495.83	1	3631.99	1	3729.92	2	3812.47	4	3942.44	5	4002.68	2
3500.32	10 s	3632.45	1	3730.71	1	3814.95	2	3943.90	6	4005.73	1
3503.75	3	3633.16	5	3732.49	5	3817.61	3 s	3945.41	5	4007.27	1
3506.99	3	3634.39	1	3733.74	1	3820.16	5	3946.22	8	4008.33	1
3509.57	2	3634.91	1	3734.02	4	3822.63	1	3948.59	3	4009.37	1
3510.07	2	3642.23	1	3734.77	1	3822.79	2	3951.99	2	4010.17	1
3510.21	1	3642.49	1	3736.05	3	3823.32	3	3953.67	2	4010.87	2
3511.18	1	3643.06	3	3736.57	2	3824.10	4	3954.72	5	4011.18	2
3512.04	1	3643.64	2	3737.14	1	3824.57	2	3955.23	5	4011.50	5
3512.99	1	3644.00	2	3738.67	1	3830.94	2	3956.35	2	4013.55	1

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
4014.23	1	4099.57	1	4182.47	4	4265.66	3	4339.40	3	4402.47	1
4014.99	1	4100.08	1	4183.21	1	4267.19	5	4339.65	1	4403.02	1
4020.59	1	4101.08	1	4184.41	8	4268.64	2	4341.18	1	4403.58	1
4022.82	1	4102.71	2	4188.42	3	4270.37	1	4342.64	1	4404.69	2
4023.71	5	4103.37	4	4188.89	1	4270.79	1	4343.41	2	4405.10	3
4024.11	3	4108.34	2	4189.04	1	4273.11	2	4343.50	2	4405.78	1
4025.54	2	4109.13	1	4189.32	3	4274.96	1	4343.77	2	4406.00	2
4027.64	5	4110.39	1	4192.17	1	4276.78	2	4344.68	1	4408.15	3
4028.50	1	4111.68	2	4192.58	1	4277.60	2	4346.93	2	4408.83	1
4029.75	1	4112.02	8	4194.72	1	4278.23	1	4347.27	4	4410.23	1
4030.08	1	4112.80	3	4196.42	1	4285.15	2	4347.87	1	4410.86	2
4033.65	1	4113.36	3	4197.23	4	4285.54	1	4349.15	2	4411.83	1
4034.34	1	4115.06	1	4198.99	8	4286.17	1	4349.66	3	4413.36	1
4035.02	1	4116.35	2	4200.16	2	4286.17	1	4350.72	1	4416.92	1
4036.93	1	4119.84	1	4205.09	1	4288.23	1	4351.18	1	4417.19	1
4038.18	5	4120.17	1	4205.44	2	4288.76	1	4352.16	1	4417.39	1
4039.81	8	4121.26	3	4207.18	1	4290.25	1	4354.75	2	4417.80	1
4042.43	8	4122.28	2	4207.77	2	4290.53	5	4355.20	1	4420.29	1
4044.05	8	4122.99	1	4210.64	2	4294.84	1 b l	4355.97	1	4421.87	1
4044.86	1	4123.72	1	4214.22	1	4294.96	3 b l	4356.49	2	4422.44	1
4046.65	1	4123.98	3	4214.47	8	4295.26	1	4358.46	2	4423.65	1
4047.26	1	4125.13	1	4215.30	1	4295.75	3	4358.74	2	4424.66	1
4047.94	8	4125.57	5	4216.78	3	4297.94	2	4358.99	2	4426.94	1
4048.82	1	4125.88	2	4217.68	5	4299.43	8	4359.69	2	4428.45	1
4049.16	3	4126.33	1	4218.65	1	4301.34	5	4360.95	8	4428.94	2
4051.17	5	4127.25	2	4219.82	2	4301.92	1	4361.52	4	4430.13	8
4051.98	2	4129.14	3	4220.70	1	4303.23	3	4362.84	2	4431.57	2
4052.36	1	4132.86	1	4221.17	1	4303.52	3	4363.64	1	4431.91	2
4053.25	2	4133.16	1	4221.78	3	4303.99	1	4366.49	1	4432.43	2
4053.51	1	4133.46	1	4222.11	1	4304.66	1	4367.28	2	4432.59	2
4054.77	2	4134.49	1	4223.20	3	4305.82	1	4368.54	2	4433.08	1
4055.20	1	4137.38	1	4224.30	2	4305.82	1	4369.45	1	4433.79	1
4057.31	4	4138.19	1	4225.54	3	4308.45	1	4369.63	1	4435.33	1
4059.90	2	4140.04	1	4228.46	1	4310.42	1	4369.84	4	4435.82	1
4061.12	1	4140.54	2	4229.77	1	4311.28	1	4370.22	1	4436.85	1
4062.50	5	4141.18	1	4230.11	1	4311.73	1	4370.39	2	4437.48	4
4062.89	1	4141.91	1	4230.68	3	4312.60	1	4370.94	1	4437.94	2
4064.19	3	4142.40	4	4231.16	1	4313.17	4	4372.83	2	4439.90	2
4065.42	8	4144.38	2	4232.31	1	4313.46	3	4375.24	1	4441.36	8
4065.95	3	4144.67	2	4236.99	6	4313.85	1	4375.86	1	4442.10	2
4066.84	1	4146.14	3	4237.88	2	4314.37	1	4376.78	1	4442.88	2
4067.60	2	4150.00	1	4239.17	1	4314.69	4	4376.99	1	4445.00	2
4068.83	1	4150.59	2	4240.58	2	4315.42	2	4377.62	5	4445.31	2
4069.96	2	4150.85	1	4241.38	1	4315.60	1	4377.86	2	4445.81	4
4072.80	3	4152.03	5	4242.67	2	4316.51	1	4379.83	5	4446.52	1
4074.34	1	4153.43	4	4245.40	2	4318.42	2	4380.74	1	4447.87	3
4075.86	1	4158.47	3	4245.64	1	4320.38	4	4381.58	3	4448.18	2
4077.19	2	4161.56	1	4246.29	2	4320.55	2	4382.01	5	4450.09	3
4079.80	2	4161.77	3	4247.09	1	4321.80	1	4384.01	1	4450.33	3
4081.46	1	4162.19	1	4247.86	1	4322.04	1	4385.50	5	4450.43	1 b l
4082.00	1	4163.87	1	4251.83	1	4323.08	2	4386.00	1	4452.49	8
4082.31	5	4165.79	2	4252.05	2	4324.41	1	4386.66	1	4456.13	2
4083.89	3	4166.93	1	4252.63	3	4324.69	1	4386.82	1	4456.60	1
4084.44	2	4168.75	2	4253.03	3	4324.83	2	4387.58	4	4458.07	1
4085.77	4	4168.84	1	4253.29	1	4325.30	2	4388.25	2	4458.43	2
4086.56	5	4169.65	8	4254.83	3	4325.41	1	4389.26	2	4459.39	8
4089.33	1	4170.60	1	4256.47	2	4328.92	4	4392.08	5	4460.62	2
4090.20	5	4172.15	1	4257.43	2	4329.65	1	4392.46	5	4461.92	2
4091.10	3	4172.96	3	4258.08	1	4330.49	1	4394.11	1	4462.21	1
4091.25	2	4173.19	2	4259.46	1	4331.84	2	4394.54	1	4463.71	8
4091.34	8	4174.22	1	4262.99	1	4332.87	1	4395.81	8	4464.62	1
4092.07	1	4175.29	1	4263.74	1	4333.95	5	4396.27	1	4466.01	2
4095.24	5	4177.44	5	4264.06	1	4334.34	1	4397.17	4	4466.74	2
4095.84	4	4177.80	2	4264.91	1	4337.96	2	4398.29	2	4468.91	1
4096.83	1	4181.61	3	4265.49	3	4338.79	1	4402.15	1	4470.40	2

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
4470.61	1	4531.85	3	4597.69	4	4659.51	2	4728.60	1	4840.78	2
4472.94	1	4532.33	10	4598.95	5	4659.76	1	4730.66	3	4842.55	5
4474.07	5	4533.92	3	4600.75	4	4660.91	8	4733.37	3	4846.85	2
4474.44	4	4534.34	1	4602.58	8	4661.56	1	4736.67	5	4848.11	8
4475.83	1	4534.89	1	4603.86	1	4662.08	1	4740.92	2	4848.58	1
4476.15	1	4535.48	2	4605.24	4	4662.20	1	4741.44	2	4848.92	1
4476.67	1	4537.14	1	4606.95	1	4663.30	1	4743.55	2	4849.30	1
4477.31	1	4538.54	2	4607.99	1	4664.74	1	4744.08	5	4850.11	1
4478.01	1	4540.61	1	4609.87	2	4665.96	1	4745.22	2 w	4850.60	2
4478.60	2	4541.26	10	4611.15	2	4667.15	1	4748.58	2	4851.49	4
4480.11	4	4542.04	1	4611.70	3	4668.14	1	4749.71	2	4853.71	3
4480.97	1	4542.67	1	4611.88	3	4669.71	1	4750.51	3	4855.36	2
4481.37	1	4546.68	2	4612.77	4	4670.54	8	4751.55	2	4856.08	8
4481.89	2	4547.23	1	4613.08	1	4671.10	1	4752.80	1	4856.92	2
4482.35	2	4547.90	1	4615.40	1	4671.25	1	4757.11	1 w	4857.41	5
4482.96	1	4548.23	1	4616.43	1	4673.38	2	4758.51	2	4858.87	1
4484.04	1	4549.36	2	4617.11	1	4673.58	1	4759.28	2	4861.98	1
4484.68	4	4550.01	1	4617.34	2	4674.11	1	4760.99	1	4862.35	1
4484.78	3 b l	4551.23	1	4617.73	8	4674.79	8	4763.67	1	4863.11	1
4485.30	3	4551.69	2	4618.28	2	4675.06	3	4764.45	3	4863.48	1
4485.98	8	4552.25	10	4621.94	2	4675.51	1	4767.81	8 l	4866.00	1
4486.81	1	4552.83	3	4622.74	5	4677.76	1	4770.46	5	4869.33	2
4487.05	2	4553.50	2	4624.07	3	4679.02	5	4772.33	2	4870.13	2
4487.42	1	4554.12	2	4625.01	1	4680.46	5	4773.46	2	4875.00	3
4487.99	2	4556.27	1	4625.29	2	4682.02	3	4774.56	5	4876.56	2
4488.58	8	4556.66	1	4625.64	8	4682.19	2	4775.46	3	4880.61	2
4489.54	1	4559.34	1	4626.50	1	4682.70	5	4779.27	2	4882.26	4
4490.78	1	4559.67	2	4627.08	1	4683.23	1	4788.32	8	4883.81	1
4492.18	1	4560.42	1	4627.66	1	4683.45	3	4791.97	2	4884.46	2
4492.90	8	4560.95	2	4628.00	1	4684.04	2	4795.39	2	4886.71	2 h
4493.96	1	4561.85	1	4628.16	1	4687.80	10	4797.54	1	4889.65	2
4494.53	1	4563.32	2	4628.49	1	4688.50	1	4798.75	3	4894.90	2
4496.00	1	4563.84	2	4629.50	1	4689.54	8	4801.50	5	4895.68	1
4496.71	1	4564.34	2	4630.12	1	4690.33	3	4802.69	2	4896.10	4
4497.01	1	4565.05	2	4631.62	1	4690.56	3	4808.25	10	4896.90	1
4497.38	1	4565.81	3	4632.27	5	4691.77	3	4811.10	3	4897.24	1
4500.38	1	4566.85	2	4634.24	2	4692.65	8	4813.58	1	4897.93	1
4500.71	1	4567.34	1	4635.05	2	4694.52	8	4813.91	1	4898.71	1
4500.89	1	4567.63	1	4635.68	8	4695.75	8	4814.38	2	4899.46	2
4501.97	2	4568.31	1	4636.28	2	4696.44	2	4815.73	1	4900.00	1
4502.86	5	4568.70	1	4637.20	2	4697.17	5 w	4816.18	1	4901.81	2
4503.93	1	4569.38	2	4639.14	2	4698.00	2	4816.75	1	4904.38	2
4504.43	1	4569.63	3	4639.54	8	4698.86	2	4817.18	1	4905.37	2
4506.45	1	4570.36	4	4639.88	2	4699.57	8	4817.62	2	4906.16	1
4506.97	1	4570.82	2	4640.19	6	4700.62	2	4818.09	1	4906.96	8
4508.44	1	4570.98	2	4641.10	2	4701.50	1	4818.96	1	4907.90	4
4511.36	3 b l	4571.12	1	4646.39	1	4706.20	8	4820.81	2	4909.71	3 b l
4511.44	4 b l	4572.14	9	4646.98	8	4706.96	3	4821.18	2	4911.43	1
4512.15	3	4574.24	1	4648.15	5	4709.51	8	4822.13	2	4911.92	4
4514.96	2	4574.93	3	4649.43	1	4709.97	2	4824.03	2	4913.37	1
4515.24	1	4577.02	2	4649.66	1	4711.83	5	4825.16	1	4914.00	8
4516.93	1	4581.39	2 w	4649.87	2	4712.05	1	4825.85	3	4914.65	3
4517.77	1	4582.08	1	4651.01	1	4713.07	8	4827.53	4	4915.36	4
4519.13	1	4583.46	1	4651.20	1	4714.15	8	4828.10	3	4921.70	2
4519.62	6	4585.94	1	4651.66	2	4714.53	1	4830.11	3	4924.51	10
4521.48	1	4586.63	1	4652.38	2	4714.87	2	4832.49	1	4925.29	2
4522.40	1	4586.89	5	4652.69	5	4715.23	5	4833.25	2	4927.02	1
4523.20	1	4587.20	1	4653.38	4	4717.03	2	4834.33	1	4928.37	1
4523.98	1	4587.98	8	4653.79	2	4717.47	2	4834.78	3	4932.10	8
4524.53	1	4590.89	1	4654.72	2	4718.49	2	4835.65	1	4933.03	1
4528.05	3	4591.93	1	4655.98	5	4719.03	2	4836.25	1	4935.08	2
4528.92	2	4593.25	5	4656.78	3	4722.36	1	4837.17	1	4935.95	4
4529.93	1	4594.69	2	4657.90	1	4722.61	2	4838.34	1	4938.40	4
4530.37	1	4595.27	4	4658.36	3	4724.75	2	4839.33	4	4939.73	5
4531.49	2	4596.83	2	4658.73	4	4725.50	1	4840.51	5	4940.25	3

TABLE 1.—*Wavelengths and intensities of absorption lines of* Pr—Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
4942.70	1	5061.33	2	5291.60	1	5400.92	3	5522.40	8 b l	5678.69	1
4944.00	2	5062.10	3	5292.28	8	5402.58	3	5522.65	3 w	5681.05	1 b l
4944.79	2	5062.89	3	5295.93	5	5403.02	1	5523.32	2 h	5687.42	10 b l
4947.13	2	5063.40	4	5297.70	5	5408.19	3	5523.89	10	5691.05	2 b l
4947.81	1	5067.45	2 h	5298.75	5 b l	5409.42	2	5524.29	1	5695.46	4
4948.15	1	5069.56	1	5298.92	3	5410.49	2	5527.90	1	5696.36	1
4949.30	1	5072.41	1	5299.77	3	5412.95	1	5528.48	2	5697.17	1
4951.31	8	5075.88	2 wh	5300.43	3	5413.31	2	5530.21	10	5697.96	1
4954.76	2	5076.72	2 wh	5301.68	1	5416.51	3	5531.18	4	5698.60	1
4955.22	1	5084.49	1	5303.60	2	5416.98	1	5532.16	2	5700.57	1 w
4955.98	6	5086.47	2	5304.17	4	5418.75	3 b l	5536.27	1	5701.10	1
4960.17	5	5087.10	4	5304.54	1	5419.00	3 b l	5538.35	5	5701.54	5
4960.97	2	5093.93	2	5305.88	4	5420.27	2	5544.33	1	5702.19	1
4961.54	1	5095.42	3	5306.36	2	5422.36	2	5545.23	1	5704.36	1
4962.17	1	5096.35	2	5307.18	3 b l	5423.16	1 b l	5546.20	1	5705.38	1
4964.50	2	5098.94	3	5309.06	4	5424.50	3	5549.17	8	5705.85	1
4965.06	1	5108.57	2	5312.55	3	5425.82	1	5549.79	4	5707.59	2 w
4970.97	2	5109.24	3	5313.62	8	5427.25	3	5551.06	2 wh	5708.29	3
4971.17	1	5113.92	1	5314.30	2	5427.72	1	5551.83	3 w	5710.02	1
4971.55	1	5114.74	1	5314.64	1	5432.50	1	5555.56	2	5710.44	1
4971.99	3	5115.25	2	5315.17	3 h	5432.89	10	5558.07	1	5710.95	1
4972.58	1	5116.29	2	5316.56	12 w	5437.28	5	5558.82	1	5713.61	3 vw
4974.94	5	5117.32	2	5319.03	3	5438.13	2	5560.05	4	5714.62	2
4975.79	5	5118.36	1	5320.32	1	5438.74	2	5561.13	3	5715.96	1
4976.41	5	5118.88	1	5322.63	8	5439.43	3	5562.30	2	5716.29	2
4977.49	1	5120.59	2	5324.99	2	5441.85	2	5563.47	1	5717.03	1
4978.36	2	5121.26	2	5334.66	1 b l	5442.52	2	5563.94	1	5717.63	1
4979.14	3	5128.45	3	5334.85	1 b l	5443.09	2	5564.80	1 w	5718.12	8
4986.54	1	5129.15	1	5336.52	1	5443.88	1	5565.52	2 h	5721.49	2
4987.42	1	5129.88	1	5337.42	2	5446.42	2	5569.02	5	5722.23	8
4992.34	2	5133.44	10	5342.00	3	5448.91	2	5577.37	3	5724.12	1
4995.35	3	5139.82	5	5342.85	2	5449.60	3	5578.79	4	5724.54	4
4997.47	2	5147.48	3	5343.65	3	5450.74	3	5581.91	3	5724.95	1
4998.80	1	5149.92	2	5344.31	1	5452.26	2	5582.36	2	5726.35	1
4999.74	1	5156.80	1	5344.94	1	5452.89	1	5588.28	3	5726.76	2 hw
5000.63	2	5168.32	2	5345.24	2	5453.22	2	5588.80	1	5727.00	3
5003.20	3	5173.14	2	5345.53	2	5453.74	1	5589.26	1	5727.55	1
5007.65	5 b l	5173.90	2	5347.10	2	5457.05	2	5589.66	2	5729.26	1
5009.43	2	5176.41	1	5348.80	3	5457.98	1	5591.48	2	5729.54	1
5015.73	1	5177.37	3	5351.45	2	5459.06	3	5592.71	3	5731.12	1
5018.17	2	5178.38	2	5352.05	2	5459.85	1	5594.88	3 w	5731.76	4
5018.62	6	5179.79	1	5353.64	5	5460.26	10	5599.75	2 w	5738.83	4 b l
5018.97	4	5183.45	3	5358.98	8	5462.34	3	5608.76	1	5740.59	1
5019.78	4	5184.50	2	5363.40	2	5462.82	3	5611.17	1	5743.71	4
5024.76	2	5185.83	1	5364.37	3	5467.86	2	5611.80	1	5744.92	2
5026.92	4 b l	5187.53	1	5365.31	2	5469.49	4	5612.01	2 h	5746.51	2
5029.02	5 b l	5194.42	8	5366.70	1	5469.90	2	5617.62	2	5751.85	1
5029.45	2	5195.50	8	5372.43	3	5479.86	12	5620.59	1	5760.19	1
5029.77	1	5212.46	2	5374.24	4	5481.76	8	5624.03	1	5768.49	1
5031.05	3	5227.95	3	5375.44	1	5486.67	5	5624.93	2	5779.27	2
5033.11	2	5246.08	2	5376.76	1	5487.57	5	5627.26	1	5780.05	1
5033.39	4	5249.28	1	5377.71	3	5488.91	3	5630.92	1	5792.25	1
5034.57	1	5249.84	2	5378.57	1	5489.41	1	5633.14	2	5803.50	1
5037.78	2	5253.13	1	5381.13	5	5490.54	1 b l	5634.90	1	5804.57	2
5043.34	1	5255.84	1	5381.60	3 w	5490.77	1 b l	5635.24	2	5805.90	4
5043.85	5	5256.76	1	5385.25	2	5491.66	1	5636.94	3	5807.21	2
5045.56	5	5258.68	1	5385.84	2	5496.22	8	5642.06	1 w	5807.92	1
5046.13	1	5259.24	2	5386.08	1	5504.69	3	5645.65	2	5808.48	1
5046.64	1	5262.19	2	5386.63	1	5505.88	1	5653.01	5	5809.52	2
5053.44	4	5283.03	2	5388.83	8	5509.61	5	5653.88	2	5810.35	1
5055.09	2	5284.40	1	5389.82	3 w	5511.26	3 b l	5656.61	1	5811.19	1
5055.73	2	5285.64	10	5390.73	3	5514.48	1	5663.44	2	5811.78	3
5056.59	2	5287.60	2 wh	5392.76	3	5516.19	4	5672.22	3	5812.67	3
5058.32	3	5288.68	2	5395.83	12	5517.71	4	5673.41	1	5813.73	1
5059.71	1	5289.33	8	5398.87	2 h	5520.30	2 w	5678.20	2	5818.06	1

TABLE 1. — *Wavelengths and intensities of absorption lines of* Pr — Continued

λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.	λ_{air}	Int.
5818.93	1	5820.79	6 s	5823.23	1	5828.93	1	5831.81	1	5834.51	2
5819.95	1	5821.33	4 w	5824.14	2	5829.32	1	5832.25	2	5835.12	8
5820.10	1	5822.43	2 w	5824.65	3	5830.05	1	5832.98	1	5837.71	5
5820.34	2 w	5822.97	1	5825.14	1	5831.45	3	5833.73	2	5839.03	1

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Selected Abstracts

Hydrodynamic fluctuations and Stokes' law friction, R. Zwanzig, *J. Res.* **68B** (*Math. and Math. Phys.*), *No. 4, 143–145* (*Oct.–Dec. 1964*).

The frictional force on a Brownian motion particle can be expressed by means of the time-correlation of the fluctuating force on the particle. We show that this method, applied to a spherical particle in a viscous incompressible fluid, leads to Stokes' Law. The calculation is based on the theory of hydrodynamic fluctuations due to Landau and Lifshitz, and on a hydrodynamic theorem due to Faxen.

Tables of electron radial functions and tangents of phase shifts for light nuclei (Z–1 through 10), C. P. Bhalla, *NBS Mono. 81*, (*Aug. 6, 1964*), *$3.25*.

To facilitate the theoretical analyses of beta-decay experiments in light nuclei electronic radial wave functions, evaluated at the nuclear radius, and tangents of phase-shifts are tabulated for total angular momentum equal to 1/2 and 3/2. Separate tables for electrons and positrons are given for ten values of Z, starting from Z equal to one, in steps of unity and for beta momentum values from 0.1 mc to 42.0 mc in steps of 0.1 mc. The nucleus is represented as a sphere with uniform charge distribution. The nuclear radius, p, is taken to be $1.2A^{1/3}10^{-13}$ cm in the major body of these tables. However, additional tables for $Z=6$ and $Z=7$ are given for $p=1.1A^{1/3}10^{-13}$ cm and $p=1.3A^{1/3}10^{-13}$ cm.

Project FIST. Fault isolation by semi-automatic techniques, G. Shapiro, O. B. Laug, G. J. Rogers, and P. M. Fulcomer, Jr., *NBS Mono. 83*, (*Sept. 17, 1964*), *55 Cents*.

The method of Fault Isolation by Semi-automatic Techniques developed at the National Bureau of Srandards, to which the acronym FIST has been applied, creates a new field of metrology which permits the measurement of the dynamic performance of electronic circuits by unskilled personnel under field operating conditions. It is a diagnostic tool for rapidly isolating faults in modularized, non-computer type electronic equipment without removing the modules from the prime equipment.

The system consists of test points and associated circuitry which are built into the prime equipment, and a small, hand-carried, general-purpose test instrument. The test points are located on an easily accessible test panel and are arranged in an order which permits rapid checking of the modules in a logical sequence.

Fault isolation is accomplished by testing the dynamic performance of each module with a test instrument which is basically a device for comparing the peak-to-peak amplitudes of two periodic voltage waveforms. Since many circuit properties other than voltage must be measured, transformation networks are provided to convert the characteristic being measured to a periodic voltage which is within the range of the test instrument.

The tests are usually made while the module under test is performing its normal function with the normal inputs to the module providing the stimuli for the tests when this is not possible, a stimulus generator is used to furnish the necessary signal or signals.

These techniques have been reduced to practice. This report describes the hardware required and discusses practical ways in which the necessary circuitry can be built into the prime equipment. The simplicity of the programming and the speed with which a complex piece of electronic equipment can be checked are demonstrated. Finally, a prototype test instrument capable of simultaneously testing four characteristics of the module or of its stimuli is described in detail.

United States standard for the colors of signal lights, F. C. Breckenridge, *NBS Handb. 95* (*Aug. 21, 1964*), *25 cents*.

The standard provides in part I basic chromaticity definitions defining the chromaticities that are considered safe for use as representing the named colors. These are the basis for the selection of the national standard filters and for the tolerances given in part II for duplicating them. The procurement requirements of parts III and IV are based primarily on sets of these filters in combination with prescribed sources although provision is also made for procurement under the basic chromaticity definitions in cases in which it is impracticable to base the procurement on filters. Part V provides guidance in selecting signal colors for new uses, and part VI provides methods for special laboratory tests and serves as a technical interpretation of the practical tests prescribed in parts III and IV.

Studies of photodissociation of molecular ions, G. H. Dunn, *Book, Atomic Collision Processes, pp. 997–1005* (*North-Holland Publ. Co., Amsterdam, The Netherlands, 1964*).

Preliminary results are reported on the measurement of the photodissociation cross section of H_2^+. Measurements have been made at a number of wavelengths between 3000 Å and 9000 A, and a comparison is made with available theory. Disagreement of the measurements with theory suggest that improvement of the theory is justified for detailed comparisons with experiment.

A linear decrease with ion source pressure of the photodissociation cross section at 5500 Å is observed. This dependence yields a lower limit of 10^{-15} cm² on the collision cross section for depopulating vibrational states of H_2^+ participating in photodissociation at 5500 Å.

White light was also used to observe photodissociation of H_2^+ and N_2^+, and an average cross section was calculated from the data and the spectral distribution of the lamp used.

An effort to observe photodissociation of H_3^+ yielded no results except to place an upper limit of 10^{-20} cm² on the average cross section.

Mechanical and dielectric relaxation of crystalline polymers in relation to degree of crystallinity and morphology, E. Passaglia, *Soc. Plastic Engrs., pp. 169–177* (*July 1964*).

Mechanical and dielectric relaxation as related to the morphology of crystalline polymers is reviewed. The behavior with temperature of the imaginary part of the complex dielectric constant and the mechanical loss factor, tan δ, at constant frequency is discussed in detail for two typical crystalline polymers: poly(chlorotrifluoroethylene) and polypropylene. Three relaxations are typically observed: a low temperature relaxation occurring at temperatures below the dilotometric glass transition temperature; a glass temperature relaxation occurring near the glass transition temperature, and a high temperature relaxation occurring between the glass temperature and the melting point. The activation parameters are given for these relaxations, and the influence of morphology on them is discussed along with possible molecular interpretations.

Unitary symmetry in photoproduction and other electromagnetic interactions, C. A. Levinson, H. J. Lipkin, and S. Meshkov, *Physics Letters* **7**, *No. 1, 81–84* (*Oct. 15, 1963*).

U-spin is rigorously conserved to all orders in the electromagnetic interaction and in the strong interactions which are invariant under SU_3. Predictions which follow from U-spin conservation are given for 1) photoproduction, 2) meson photoproduction, 3) electromagnetic decays of baryon resonances, 4) static electromagnetic properties for the baryon octet, 5) photoproduction of two mesons, and 6) photoproduction of Z^-.

Initial preparation and metastable transitions in mass spectra, H. M. Rosenstock, V. H. Dibeler, and F. N. Harllee, *J. Chem. Phys.* **40,** *No. 2, 591–594 (Jan. 15, 1964).*

Variation of initial preparation to search for non-equilibrium kinetic effects (Frey) is discussed in connection with the kinetics of unimolecular ionic decomposition processes occurring in the mass spectrometer. A particular example, dependence of the rates of competing metastable transitions of hexyl ions on mode of preparation is studied in detail. The hexyl ions were prepared by electron impact ionization and decomposition of a variety of normal alkanes, *n*-hexyl bromide and di-*n*-hexyl ether. At low electron energies (30 ev) the ratio of the competing metastable transitions is constant within experimental error. This supports the applicability of the quasi-equilibrium theory of mass spectra to such processes. At higher electron energies there is a slight dependence of the ratio on parent ion mass.

Inelastic electron scattering from rare gases, determination of oscillator strengths in the continuum, C. E. Kuyatt and J. A. Simpson, *Proc. Third Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963, pp. 191–200 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).*

The inelastic scattering of 500–1000 eV electrons from the rare gases has been measured for small angle collisions and energy losses to 100 eV. Approximate relative oscillator strengths for continuum excitations of helium and neon have been derived from the forward scattering intensities. The results in helium are in good agreement with the latest uv measurements and with calculations. In the case of neon, previous experiments and calculations differ considerably. The present results agree well with the most recent uv measurements, except that the electron measurements do not show a sharp L ionization edge. This difference can probably be attributed to the effect of preionization lines with a resonance shape which have recently been observed.

The characterization of large single crystals by high-voltage X-ray Laue photographs, H. S. Peiser and E. P. Levine, *(Proc. 11th Ann. Conf. Applications of X-ray Analysis, Aug. 1962), Book, Advances in X-ray Analysis* **6,** *158–163 (Plenum Press Inc., New York, N.Y., 1963).*

Large single crystals can be examined by conventional X-ray diffraction procedures only at their surface or by destructive sectioning. With the limitations inherent in polychromatic X-ray photography, high-voltage Laue pictures are shown to give some information on the internal quality of large crystals. Asterism in conventional Laue photographs is contrasted with streaks due to geometric effects in Laue patterns of large crystals. Detail within the streaks reveals sub-grain structure. A primary extinction effect can be used as striking proof of good crystals being capable of scattering coherently over large distances.

The calculations of autoionization probabilities, J. W. Cooper, *Proc. Third Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963, pp. 595–599 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).*

Calculations have been carried out for the autoionization probabilities and level widths of the doubly excited states $(2snp)^{1,3}P$ and $(ns^2p)^{1,3}P^{n=2,3,4}$ in He. Although the model used for the calculations was crude, the level widths computed agree order of magnitude-wise with recent experimental observations. The probable effect of the strong coupling between levels of the above series for $n>2$ and of additional configuration mixing is discussed. The calculations point up the fact that the important region for the autoionization process corresponds to small radial distances from the nucleus. It was also found that the results were relatively insensitive to the exact form of the wave functions and for the calculations.

The basis of the functional assumption in the theory of the Boltzmann equation, M. S. Green and R. A. Piccirelli, *Phys. Rev. 132, No. 3, 1388 (Nov. 1963).*

The long-time behavior of the *n*-particle probability densities for a large, dilute system of point particles interacting with short-range forces is studied. The main result is an exact series for the *n*-particle density which consists of two parts. The first part is a time-independent functional of the singlet density which is expressed as a funtional power series and which is a direct analog of the equilibrium density series. The second part is also a functional power series in the singlet density but the coefficients depend on time and on the initial correlations. The coefficients of both series are given explicitly in terms of operators which are determined by the dynamics of isolated groups of particles. It is demonstrated that these operators vanish for phase points corresponding to motions during which there are two or more groups of particles which either are statistically and dynamically independent or are such that each of them is dynamically connected to the rest by no more than one particle. It is argued that all the terms of the exact series are finite and that the terms of second part (the error) decrease with increasing time so that the first part is the asymptotic form proposed by Bogoliubov. The relevance of the results for the Boltzmann equation is indicated.

Energy dependence for the photodetachment of I^- near threshold, B. Steiner, M. L. Seman, and L. M. Branscomb, *Proc. Third Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963, pp. 537–542 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).*

The photodetachment of atomic iodine negative ions has been observed in a crossed beam experiment with much higher spectral resolution than previously used in this laboratory. The iodine negative ions were formed in a discharge through an ammonia-iodine vapor mixture and mass analyzed in the apparatus used in previous experiments. The photon beam originated in a high pressure xenon lamp and was resolved in an F/1.5 monochromator. The threshold region near 4040 Å has been scanned with a photon beam half width of 18 Å, and the region down to 3000 Å with a half width of 33 Å. Transitions ascribed to ${}^1S_0 \rightarrow {}^2P^0_{3/2}$ and ${}^1S_0 \rightarrow {}^2P^0_{1/2}$ were observed. The experimental slit function has been unfolded from the first threshold region to reveal the "true" threshold behavior. The derived radiative attachment cross section in region of the threshold will be presented.

Nuclear magnetic resonances of ^{69}Ga and ^{71}Ga in gallium-substituted yttrium iron garnet, R. L. Streever and G. A. Uriano, *Phys. Rev. Letters* **12,** *No. 22, J516 1–3—J516 3–3 (June 1, 1964).*

We have recently observed the nuclear magnetic resonance of ^{69}Ga and ^{71}Ga in the mixed garnet system $3Y_2O_3{\cdot}(5-x)Fe_2O_3{\cdot}xGa_2O_3$. The resonance has been observed at 77 °K over a concentration range from x=.25 to x=2.6 and at room temperature over a smaller concentration range. The resonance frequency for ^{71}Ga at 77 °K reaches a maximum at about x=1.5 of 30.0 MHZ (in zero applied field) corresponding to a hyperfine field of about 2.3 tesla (23 kilogauss). The resonance is from nuclei of ions on (d) sites and the hyperfine field is believed to arise from an unpaired spin density on the gallium ion which is coupled strongly with nearest neighbor iron ions. Gallium ions on (d) sites have eight nearest neighbors (4 neighbors on (a) sites and 4 on (d) sites) and the resonance is particularly interesting because the concentration dependence allows us to separate out the sign and magnitude of the contribution to the field from iron ions on (a) and (d) sites.

Polymorphism of ABO_3-type rare earth borate solid solutions, R.S. Roth, J. L. Waring, and E.M. Levin, *(Proc. Third Rare Earth Research Conf., Apr. 2-24, 1963), Book, Rare Earth Research, Chapter on Structure of Rare Earth Compounds, pp. 1030–1055 (Gordon and Breach Science Publ., Inc., New York, N.Y., 1964).*

Polymorphic relations of solid solutions of the ABO_3-type rare earth borates have been studied by means of quenching techniques and high temperature X-ray diffraction. It has been found that the polymorph reported as the high temperature form of $MdBO_3$ (Levin, Roth, and Martin, 1961) is only metastable and is formed, on cooling, from a phase isostructural with H-$LaBO_3$. The similar polymorph of $SmBO_3$ is apparently stable from room temperature to about 1065 °C. The high vaterite form of $SmBO_3$ is stable from about 1065° to 1285° and the H-$LaBO_3$ type from 1285° to the melting point. Phase equilibrium diagrams have been constructed for the systems involving $LaBO_3$ with many of the other RBO_3 compounds and for $NdBO_3$-$SmBO_3$. The aragonite and vaterite type structures are not stable in the central portion of most of these systems. Instead, the H-$LaBO_3$ and L-$SmBO_3$-type phases appear as the stable polymorphs. The H-$LaBO_3$-type polymorph is a low symmetry distortion of a calcite type structure. As smaller ions are added in solid solution to $LaBO_3$ the distortion becomes less until with LaLo $(BO_3)_2$ an hexagonal phase is formed which may have a dolomite type structure, although the super-structure peaks are not evident. However, this phase apparently disorders to a H-$LaBO_3$ type solid solution rather than to the true calcite type structure. Although the temperature of the high-low inversion of the vaterite-type structures is lowered by the addition of $LaBO_3$ in solid solution, in no case has the high-vaterite structure been obtained at room temperature.

Optically pumped magnetometers and related experiments in high magnetic fields, P. L. Bender, *Book, Quantum Electronics, Ed. P. Grivet and N. Bloembergen, III.* **I,** *263–273 (Columbia University Press, New York, N.Y., 1964).*
Some considerations on optically pumped magnetometers are given. Related experiments in high magnetic fields giving alkali nuclear moments and departures from the Breit-Rabi formula are suggested.

Hydrogen atom addition to solid four-carbon olefins, R. Klein and M. D. Scheer, *J. Phys. Chem.* **67,** *1874–1877 (Sept. 1963).*
An investigation of the hydrogen atom addition to condensed, solid, four-carbon olefins in the 77° K region has shown that the general reaction is terminal hydrogen atom addition to terminal double bonds followed by disproportionation and recombination of the resulting radicals. H atoms also react with the hydrocarbon radical in a similar manner. All of the butene-2 formed from butene-1 and from butadiene-1,3 is *trans,* but that formed from butadiene-1,2 is both *cis* and *trans.* Butadiene-1,3 produces nine eight-carbon dimers, butadiene-1,2, three, and isobutene, none. One of the major products of the H atom addition reaction with butadiene-1,2 is butyne-2.

Anomalous transmission of rare gases for electrons of subexcitation energies, J. A. Simpson, *Proc. Third Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963, pp. 128–134 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).*
Electrons of variable energy ($\Delta E_{1/2} \sim 0.05$ eV) are passed through a chamber containing rare gas at a pressure of some microns. Electrons which are deflected less than 40 mr are energy analyzed (resolution ~ 0.05 eV) and collected. Two types of transmission anomalies, with energy widths essentially instrumental, are observed at energies below those necessary to excite the atom. The first, in He at 19.1 ± 0.1 eV, is an enhanced transmission followed by a decrease in a typical dispersion line shape. The second anomaly in Ne at 15.9 ± 0.15 eV, is not so strong and has a more complicated structure consisting of a doublet (~ 0.1 eV separation). Both components are sharp decreases in transmission without dispersion line shape. A brief description of the apparatus is included.

Electron microscopy and diffraction of aluminum oxide whiskers, D. J. Barber, *Phil. Mag.* **10,** *No. 103, 75–94 (July 1964).*
Whiskers of α-Al_2O_3 have been grown by the condensation and oxidation of aluminium on an alumina substrate, and examined by transmission electron microscopy and diffraction. Unbroken whiskers invariably terminate in a small globule of aluminium and have a 'drumstick' form. The most perfect whiskers are ribbons with their principal surfaces parallel to the (0001) planes; the majority of these have a $\langle 11\bar{2}0 \rangle$ growth direction. With intense heating in the electron beam, such ribbons can be thermally etch pitted. Many drumsticks are tubular rather than ribbonlike and drumsticks containing axial dislocations have also been seen. The effect of intense heating on these whiskers has been investigated. Occasionally, the aluminium globules melt and react with the carbon support film in the microscope to give crystalline Al_4C_3. Alternatively, a globule may explode to form many small globules that immediately develop stems; thus, new whiskers are formed in the microscope. The relevance of these observations to proposed mechanisms for the growth of drumstick whiskers is discussed.

The crystal structure of 1-ethyldecaborane, A. Perloff, *Acta Cryst.* **17,** *332 (1964).*
Direct evidence for the existence of 1-ethyldecaborane has been established by a single crystal X-ray structure analysis using, in part, the method of direct phase determination developed by Karle and Hauptman. The compound crystallizes in the orthorhombic system with $a = 10.11 \pm 0.01$, $b = 14.40 \pm 0.01$, and $c = 7.28 \pm 0.01$ Å. The space group is $P2_12_12_1$ and the unit cell contains four molecules of $B_{10}H_{13}C_2H_5$. The compound is a simple substitution derivative of decaborane and no significant distortion of the decaborane molecule is induced by the substitution.

Optically observed inner shell electron excitation in neutral Kr and Xe, K. Codling and R. P. Madden, *Phys. Rev. Letters* **12,** *No. 4, 106–107 (Jan. 1964).*
The far ultraviolet continuum radiation emitted by the N.B.S. 180 Mev electron synchrotron has been used for the study of the absorption spectra of Kr and Xe in the 120–200A spectral region. Structure involving transitions to neutral atom energy levels has been observed for the first time at energies in excess of 50 ev above the 1st ionization limits of Kr and Xe. These transitions involve the excitation of inner shell d electrons and result in two series for each element, namely $3d^{10}4s^24p^6\ {}^1S_0 - 3d^94s^24p^6\ ({}^2D_{3/2,\,5/2})\ np\ {}^1P^\circ_1$ in Kr, and $4d^{10}5s^25p^6\ {}^1S_0 - 4d^95s^25p^6\ ({}^2D_{3/2,\,5/2})\ np\ {}^1P^\circ_1$ in Xe.

Dielectric polarizability of fluid parahydrogen, J. W. Stewart, *J. Chem. Phys.* **40,** *3297–3306 (June 1964).*
The dielectric constant of liquid and gaseous para-hydrogen has been measured by the capacitance ratio method between 24°K–100°K and 2–326 atmospheres. This encompasses the density range 0.002–0.080 gm/cm³. These data have been combined with recently available PVT results in order to calculate the Clausius-Mosotti function to 0.05% precision. In the range considered, the C–M function, or polarizability, instead of being constant, initially rises with density to a maximum 0.2% above the low density value of 1.00427 cm³/gm, and then falls. The data in this range can be represented to within experimental error by a quadratic function of density. The deviation from constancy is too small for detailed correlation with existing theories of polarizability to be feasible. The results are presented in tabular form. Also the dielectric constant at any desired density can easily be calculated to an accuracy better than 0.1% in $\epsilon - 1$ from the function fitting the polarizability.

Standard potential of the Ag–AgCl electrode in 5% aqueous mannitol, R. Gary and R. A. Robinson, *J. Chem. Eng. Data* **9,** *No. 3, 376–378 (July 1964).*
The standard potential of the Ag–AgCl electrode from 0° to 60° has been determined by e.m.f. measurements on the cell: Pt/H_2:HCl(m) in 5% mannitol; AgCl/Ag. From these data and from data on the same cell containing no mannitol, the relative partial molal quantities $\Delta\bar{G}^\circ$, $\Delta\bar{H}^\circ$ and $\Delta\bar{S}^\circ$ for the change in solvent are calculated. The value of $\Delta\bar{G}^\circ$ for HCl in 5% mannitol at 25° is found to be 54.0 j. mole⁻¹. There is a small but significant change in the e.m.f. of the cell if mannitol is replaced by its diastereoisomer, sorbitol.

Optical investigations of film formation and removal on gold anodes in acidic oxalate solutions, W. E. Reid and J. Kruger, *Nature* **203,** *No. 4943, 402 (July 25, 1964).*
Evidence has been obtained for film formation on gold anodes in acidic oxalate solutions using ellipsometry. The thickness

of the film increases linearly with the potential above 1.1 V (NHE) in 1 M H_2SO_4 and solutions of low oxalate content (4 g/l) to give a thickness of about 20A. The film is reduced at potentials below 1.1 V and also by acidic oxalate solutions. Optical evidence indicates that this film is more likely to be an oxide film rather than chemisorbed oxygen.

Recently discovered autoionizing states of krypton and xenon in the λ 380–600A, R. P. Madden and K. Codling, *J. Opt. Soc. Am.* **54,** *No. 2, 268–269 (Feb. 1964).*

The far ultra-violet continuum radiated by the NBS 180 Mev electron synchrotron has been utilized for the study of the absorption spectra of krypton and xenon in the wavelength region 380–600Å. Many new autoionizing states in both elements, lying 10–40 ev above the first ionization limit, have been discovered. The following series have been identified: $4s^24p^6\ {}^1S_0 - 4q4p^6\ np\ {}^1P_1^0$ and $4s^24p^6\ {}^1S_0 - 4s^24p^45s\ np\ {}^1P_1^0$ in krypton, $5s^25p^6\ {}^1S_0 - 5s5p^0\ np\ {}^1P_1$ in xenon.

"U-spin equalities" and octet symmetry breaking, S. Meshkov, G. A. Snow, and G. B. Yodh, *Phys. Rev. Letters* **13,** *No. 6, 212–217 (Aug. 10, 1964).*

The "U-Spin equalities" are compared with experiment, in order to see to what extent the SU_3 predictions are obeyed. Deviations from pure SU_3 symmetry by an order of magnitude are found. The role of symmetry breaking in the interaction matrix elements is investigated and correlated with the possible appearance of superresonances.

Electrode potentials in fused systems. VII. Effect of ion size on membrane potentials, K. H. Stern and J. A. Stiff, *J. Electrochem. Soc.* **III,** *No. 8, 893–897 (Aug. 1964).*

Concentration cells exhibiting glass membrane potentials have been measured for the AgBr–NaBr, AgCl – KCl, and AgCl – CsCl systems. Only for the first of these can the bulk composition be used to calculate cation transport numbers in the membrane. For the latter two the sodium ion impurities in the melt appear to be potential determining. In the sodium-containing systems the anions appear to be transported as part of a cationic silver complex.

On the identity of three generalized master equations, R. Zwanzig, *Physica* **30,** *1109–1123 (1964).*

Three apparently different quantum mechanical master equations, derived by Prigogine and Resibois, by Montroll, and independently by Nakajima and by Zwanzig, are shown to be identical. The derivation by Zwanzig, based on projection operator and Liouville operator techniques, is repeated in greater detail than in previous articles. The results of Prigogine and Resibois, and of Montroll, are found by making changes in notation.

The oxide films formed on copper single crystal surfaces in water. III. Effect of light, J. Kruger and J. P. Calvert, *J. Electrochem. Soc.* **III,** *No. 9, 1038–1041 (Sept. 1964).*

Studies of the effect of illumination on the growth of oxide films on copper single crystal surfaces immersed in water containing different amounts of dissolved oxygen reveal that while illumination has little effect on the oxidation process when the water is in equilibrium with a 100% oxygen atmosphere, it does lower the rate of film formation when the water is in equilibrium with 1% oxygen. For both the (111) and (100) illumination causes a departure from the rate law observed for oxidation in the dark. At intensities of 290 $\mu w/cm^2$ or higher the film formed on the (111) never grows beyond a limiting thickness of 100 Å. The behavior observed can be explained on the basis of a competition between growth and dissolution reactions, the dissolution reaction being promoted by illumination.

Thermodynamics of aqueous solutions of hydriodic acid from electromotive force measurements of hydrogen-silver iodide cells, H. B. Hetzer, R. A. Robinson, and R. G. Bates, *J. Phys. Chem.* **68,** *No. 7, 1929–1933 (1964).*

Electromotive force measurements of the cell Pt;H_2(g), HI(m), AgI;Ag have been made at 11 temperatures from 0 to 50°. The standard e.m.f. ($E°$) is given within 0.05 mv. by the equation $E° = -0.15242 - 3.19 \times 10^{-4}(t-25) - 2.84 \times 10^{-6}(t-25)^2$, where t is the temperature in degrees Celsius. These values are in excellent agreement with those obtained by Owen from studies of borax-buffered KI solutions at 5, 10, 30, 35, and 40° but differ by 0.14 to 0.17 mv. at 15, 20, and 25°. The activity coefficient ($\gamma_\pm$) of HI at molalities (m) from 0.005 to 0.9 has been derived. The relative partial molal enthalpy (L_2) of HI at 25° was calculated and compared with that for HCl and HBr. At 25° and m=0.1, $\gamma_\pm$ is 0.811 and L_2 is 130 cal. mole^{-1}.

Other NBS Publications

J. Res. NBS 68B (Math. and Math. Phys.), No. 4 (Oct.–Dec. 1964), 75 cents.

Hydrodynamic fluctuations and Stokes' Law friction. R. Zwanzig. (See above abstracts.)

Equivalence of certain inequalities complementing those of Cauchy-Schwarz and Hölder. J. B. Diaz, A. J. Goldman, and F. T. Metcalf.

Weak generalized inverses and minimum variance linear unbiased estimation. M. Zelen and A. J. Goldman.

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The greatest crossnorm. R. Schatten.

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Some problems of ionospheric nonlinearities. D. H. Menzel.

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Ionospheric cross modulation: a microscopic theory. D. Layzer and D. H. Menzel.

VLF noise bands observed by the Alouette I satellite. J. S. Belrose and R. E. Barrington.

Excitation of optical radiation by high power density radio beams. L. R. Megill.

Alteration of the electron density of the lower ionosphere with ground-based transmitters. P. P. Lombardini.

Collision effects in hydromagneto-ionic theory. H. K. Sen and A. A. Wyller.

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