

Energy Levels of Chromium, Cr I through Cr XXIV

Jack Sugar and Charles Corliss

Institute for Basic Standards, National Bureau of Standards, Washington, D.C. 20234

The energy levels of the chromium atom in all of its stages of ionization, as derived from the analyses of atomic spectra, have been compiled. In cases where only line classifications are given in the literature, level values have been derived. The percentages for the two leading components of the calculated eigenvectors of the levels are given where available. Ionization energies and *g*-factors are also given.

Key Words: Atomic energy levels; atomic spectra; chromium.

Contents

	Page		Page
1. Introduction	317	Cr XI	365
2. Acknowledgments	318	Cr XII	367
3. Energy Level Tables	320	Cr XIII	368
Cr I	320	Cr XIV	370
Cr II	335	Cr XV	372
Cr III	343	Cr XVI	373
Cr IV	349	Cr XVII	375
Cr V	352	Cr XVIII	377
Cr VI	354	Cr XIX	378
Cr VII	356	Cr XX	379
Cr VIII	359	Cr XXI	380
Cr IX	361	Cr XXII	381
Cr X	363	Cr XXIII	382
		Cr XXIV	383

1. Introduction

This is the second of a new series of compilations of atomic energy levels in the iron period (the *3d* shell) that supplies a much needed updating of the compilation of C. E. Moore (1952). The first by Reader and Sugar (1975) gave energy level data for all stages of ionization of iron. Since the introduction in that article explains details of the compilation that apply equally to the present work, it is reproduced here with appropriate changes.

We give the energy levels of the chromium atom and all of its ions as derived from the analyses of atomic spectra. These include primarily levels arising from outer-shell excitations. For the high stages of ionization, inner-shell excitations are included since the distinction in energy becomes less clear.

For most of the level systems given here the energy level data have been drawn from widely scattered sources in the literature. For many of the ions the original papers do not give energy level values, but only classifications of observed lines. In these cases we have derived the level values for inclusion here. We have also derived some of the ionization energies from the observed levels.¹

¹ Values for ionization energies are usually derived in their equivalence in cm^{-1} . The conversion factor $8065.479 \text{ cm}^{-1}/\text{eV}$, as given by E. R. Cohen and B. N. Taylor, *J. Phys. Chem. Ref. Data* **2**, 663 (1973), was used to obtain values in eV.

Copyright © 1977 by the U.S. Secretary of Commerce on behalf of the United States. This copyright will be assigned to the American Institute of Physics and the American Chemical Society, to whom all requests regarding reproduction should be addressed.

For a large number of ions, too few levels are known to permit the derivation of an experimental value of the ionization energy. In these cases we have quoted estimated values obtained by extrapolation along isoelectronic sequences. Although it is not possible to give a quantitative uncertainty for these extrapolated values, they are probably accurate to a few units of the last significant figure listed. Edlén (1971) has recently published a set of semiempirical formulas that could be used to obtain new estimates for a number of the ionization energies.

Although in most cases we used only published papers as sources of data, unpublished material was included when it constituted a considerable improvement.

Nearly all of the data are the results of observations of various types of laboratory light sources. However, they are sometimes supplemented by data obtained from solar observations. This is particularly true where spin-forbidden lines are required to establish the absolute energy of a system of excited levels and also where parity-forbidden transitions between levels of a ground configuration are used to obtain accurate relative energies for the low levels. Whenever both solar data and equivalent laboratory data were available for a given level system or part of a level system, preference was generally given to the laboratory data in order to avoid the problem of blended lines of various elements in the solar spectra. Our source of data was always the original literature. For a convenient source of wavelengths of chromium lines below

2000 Å we refer the reader to the recent compilation by Kelly and Palumbo (1973).

Almost every level in the present compilation is accompanied by a quantum mechanical designation (or name). The treatment of the level designations is sometimes a troublesome question. For a given configuration a certain number of terms of various types (^5H , ^7H , etc. in LS coupling, for example) are theoretically expected, and spectroscopists have traditionally tried to give such definite names to terms, even though g values, intensities, and arrangement of the levels may indicate that no such "pure" name is appropriate. It is thus of interest to know just how well the name of a level describes its quantum properties. To this end, we have included the results of theoretical calculations which express the percentage composition of levels in terms of the basis states of a single configuration, or more than one configuration where configuration interaction is important.

The percentage compositions have the following meaning. Suppose that for a given configuration there is a set of n basis states, written symbolically as $\psi_1, \psi_2, \dots, \psi_n$. Usually these basis states are taken to be the LS states for a configuration, but other coupling schemes are often used. Then the eigenvector ψ_A of an actual energy level A can be expressed as

$$\psi_A = \alpha_1\psi_1 + \alpha_2\psi_2 + \dots + \alpha_n\psi_n,$$

where $\alpha_1^2 + \alpha_2^2 + \dots + \alpha_n^2 = 1$. The squared quantities α_1^2, α_2^2 , etc. represent the percentage composition of a given level. Generally, levels are given names corresponding to the basis state having the largest percentage. The percentage compositions are determined in the theoretical calculations by finding the eigenvalues and eigenvectors of the energy matrix.

In the columns of the present tables headed "Leading components" we give first the percentage of the basis state corresponding to the level's name; next the second largest percentage together with the related basis state. We have not listed any second component whose percentage is less than 5 percent. The percentages show that in many cases it is not possible to group the levels into meaningful terms. However, where levels have been arranged into terms in the original papers or in subsequent theoretical calculations, we have generally retained these groupings.

Of course, the percentage compositions cannot be considered to be as reliable as experimental quantities inasmuch as a new calculation using a different approximation, such as the introduction of configuration interaction where none had been used before, might yield a different set of percentages. For some levels the percentages may change drastically in a new calculation. Therefore the compositions given here should be considered only as a useful guide to the true quantum character of the levels.

It should be noted that the theoretical calculations involved in obtaining the percentage compositions are of two types. The semiempirical method treats the radial integrals appearing in the energy matrix as parameters whose values are determined by a least-squares fit to the observed levels. In the *ab initio* method, the radial integrations are carried out with wavefunctions found by solving the wave equation for a given atom, as in a Hartree-Fock calculation or variation thereof. In the

present tables, the percentages are mostly taken from published least-squares level-fitting calculations. When only *ab initio* calculations are found in the literature, we have used them if there appears to be a reasonable correspondence with the experimental data. For higher ionization stages there has been less effort to relate quantitatively the theoretical results to the observations by means of least-squares calculations.

For configurations of equivalent electrons, repeating terms sometimes occur. These are generally distinguished by their seniority number. In the present compilation they are designated in the notation of Nielson and Koster (1963). For example, in the $3d^5$ configuration there are three ^2D terms with seniorities of 1, 3, and 5, respectively. These terms are denoted as $^2\text{D}1$, $^2\text{D}2$, and $^2\text{D}3$ by Nielson and Koster.

The labeling of terms by lower case letters, a, b, c , etc. (for example $a^5\text{D}$, $z^5\text{D}^o$, etc.) has been dropped, except for CrI and II where their use in connection with various wavelength tables makes their retention desirable.

We used the following procedure for carrying out the present compilation. First, a complete list of references for each stage of ionization was drawn up, based primarily on the following bibliographies:

- i. papers cited by Moore (1952)
- ii. C. E. Moore (1969)
- iii. L. Hagan and W. C. Martin (1972)
- iv. card file of publications since June 1971 maintained by the NBS Atomic Energy Levels Data Center

Then, each paper was scanned for new energy level data and the levels compiled or derived from the classified lines. Of course, many more papers were read than were actually used in the compilation. A selection of data was made that, in our judgment, represents the most accurate and reliable available. After a preliminary compilation for all ions was carried out, we returned to CrI to check the level values, review and incorporate any new papers that had appeared in the meantime, and prepare CrI text. This retracing was continued through all of the ions. A final check for new data was made on June 30, 1976, at which time the compilations were considered completed. The text for each ion is not a complete review of the literature but is intended to credit the major contributions.

2. Acknowledgments

Throughout this work we have made extensive use of the bibliographical files and reprint collection maintained in the Atomic Energy Levels Data Center by Dr. Lucy Hagan. Our thanks are extended to her for her generous cooperation. The compilation has also benefited greatly from the preprints that were generously provided by many of our colleagues.

We would like to thank Dr. W. C. Martin for many helpful discussions.

This work was carried out with the partial support of the U.S. Energy Research and Development Administration.

References for Introduction

- Edlén, B. (1971), in *Topics in Modern Physics* (Colorado Associated University Press, Boulder).
- Hagan, L., and Martin, W. C. (1972), *Bibliography of Atomic Energy Levels and Spectra, July 1968 through June 1971*, Nat. Bur. Stand. (U.S.) Spec. Publ. 363 (U.S. Gov't. Printing Office, Washington, D.C.).

- Kelly, R. L., and Palumbo, L. J. (1973), Atomic and Ionic Emission Lines Below 2000 Angstroms—Hydrogen Through Krypton, NRL Report 7599 (U.S. Gov't. Printing Office, Washington, D.C.).
- Moore, C. E. (1952), Atomic Energy Levels, Nat. Bur. Stand. (U.S.) Circ. 467, Vol. II (U.S. Gov't. Printing Office, Washington, D.C.).
- Moore, C. E. (1969), Bibliography on the Analyses of Optical Atomic Spectra, Section 2, Nat. Bur. Stand. (U.S.), Spec. Publ. 306 (U.S. Gov't. Printing Office, Washington, D.C.).
- Nielson, C. W., and Koster G. F. (1963), Spectroscopic Coefficients for the p^n , d^n , and f^n Configurations (The M.I.T. Press, Cambridge).
- Reader, J., and Sugar, J. (1975), Energy Levels of Iron, Fe I through Fe XXVI, J. Phys. Chem. Ref. Data **4**, 353.

Cr I

Z = 24

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1 S_3$ Ionization energy = 54570 cm^{-1} (6.7659 eV)

The energy levels are from Kiess (1953) who remeasured the entire spectrum and extended the earlier work of Catalan and Sancho (1931) and a number of other investigators. The bulk of the g -factors for the levels are obtained from Catalan and Sancho and are supplemented by those of Kiess, which were given to three decimal places. The four place g -factors for $3d^5(^6S)4p^1 P_3^o$ and $^1 P_4^o$ were measured in an atomic beam by Budick, Goshen, and Marcus (1964).

Using the $3d^5 ns$ and $3d^5 np$ series of three to five Rydberg terms Kiess derived the ionization energy with an estimated uncertainty of $\pm 2 \text{ cm}^{-1}$.

The alphabetic prefixing of terms with lower case letters for distinguishing repeating terms of the same type has been retained from Kiess except where the levels were reinterpreted by Roth (1970) on the basis of his theoretical treatment.

Roth has calculated the odd-parity configurations $3d^5 4p$, $3d^4 4s 4p$, and $3d^3 4s^2 4p$ with configuration interaction. His

percentage compositions and designation changes for the experimental levels are adopted here. Roth distinguished repeating terms of the $3d^n$ core by the letters a, b, \dots rather than by seniority. The percentages include the sum of seniority states contributing to the term.

Percentages for the configuration $3d^5 4s$ were taken from an ab initio calculation by Vizbaraite, Kupliauskis, and Tutlys (1968).

References

- Budick, B., Goshen, R. J., and Marcus, S. (1964), *Bul. Am. Phys. Soc.* **9**, 90.
 Catalan, M. A., and Sancho, P. M. (1931), *An. Soc. Esp. Fisica y Quimica (Madrid)* **29**, 327.
 Kiess, C. C. (1953), *J. Res. Natl. Bur. Std. (U.S.)* **51**, 247.
 Roth, C. (1970), *J. Res. Natl. Bur. Std. (U.S.)* **74A**, 157.
 Vizbaraite, J., Kupliauskis, Z., and Tutlys, V. (1968), *Lietuvos Fizikos Rinkiny* **8**, 497.

Cr I

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^5(^6S)4s$	a^7S	3	0.00	2.007	100	
$3d^5(^6S)4s$	a^5S	2	7593.16	2.006	100	
$3d^4 4s^2$	a^5D	0	7750.78			
		1	7810.82	1.501		
		2	7927.47	1.496		
		3	8095.21	1.501		
		4	8307.57	1.497		
$3d^5(^4G)4s$	a^5G	2	20 517.40	0.37	100	
		6	20 519.60	1.33	100	
		3	20 520.92	0.93	100	
		4	20 523.69	1.13	100	
		5	20 523.94	1.25	100	
$3d^5(^4P)4s$	a^5P	3	21 840.84	1.6	98	
		2	21 847.88	1.847	98	
		1	21 856.94	2.500	100	
$3d^4 4s^2$	a^3P	0	23 163.27			
		1	23 512.00			
		2	24 093.16			
$3d^5(^6S)4p$	z^7P^o	2	23 305.01	2.334	69	31 $3d^4(^5D)4s4p(^3P^o)^7P^o$
		3	23 386.35	1.9176	70	30
		4	23 498.84	1.7510	71	29

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ 4s ²	<i>a</i> ³ H	4	23 933.90			
		5	24 056.11			
		6	24 200.23			
3d ⁵ (⁴ D)4s	<i>b</i> ⁵ D	0	24 277.06		100	
		4	24 282.34	1.51	100	
		1	24 286.54	1.48	100	
		2	24 299.89	1.51	98	
		3	24 303.94	1.55	98	
3d ⁵ (⁴ G)4s	<i>a</i> ³ G	3	24 833.86		100	
		4	24 897.55		100	
		5	25 038.61		100	
3d ⁴ 4s ²	<i>a</i> ³ F	2	24 940.61			
		3	25 106.34			
		4	25 177.39			
3d ⁴ (⁵ D)4s4p(³ P°)	<i>z</i> ⁷ F°	0	24 971.21		100	
		1	25 010.64	1.52	100	
		2	25 089.20	1.50	100	
		3	25 206.02	1.49	100	
		4	25 359.62	1.51	100	
		5	25 548.64	1.51	100	
3d ⁵ (⁶ S)4p	<i>z</i> ⁵ P°	3	26 787.50	1.670	92	
		2	26 796.28	1.830	91	
		1	26 801.93	2.512	92	
3d ⁵ (⁴ P)4s	<i>b</i> ³ P	0	27 163.20		100	
		1	27 176.22		100	
		2	27 223.05		98	
3d ⁴ (⁵ D)4s4p(³ P°)	<i>z</i> ⁷ D°	1	27 300.19	3.01	99	
		2	27 382.18	1.99	66	23 ⁷ P°
		3	27 500.37	1.76	58	29 ⁷ P°
		4	27 649.71	1.66	58	30 ⁷ P°
		5	27 825.45	1.61	100	
3d ⁴ 4s ²	<i>b</i> ³ G	3	27 597.22			
		4	27 703.84			
		5	27 816.88			
3d ⁴ (⁵ D)4s4p(³ P°)	<i>y</i> ⁷ P°	2	27 728.87	2.341	44	34 ⁷ D°
		3	27 820.23	1.929	40	41
		4	27 935.26	1.761	41	42
3d ⁵ (⁴ D)4s	<i>a</i> ³ D	3	28 637.00		100	
		1	28 679.43		100	
		2	28 682.18		98	

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm^{-1})	<i>g</i>	Leading components (%)	
					First	Second
$3d^4(^5D)4s4p(^3P^\circ)$	$y\ ^5P^\circ$	1	29 420.90	2.513	95	
		2	29 584.62	1.836	95	
		3	29 824.75	1.669	96	
$3d^4(^5D)4s4p(^3P^\circ)$	$z\ ^5F^\circ$	1	30 787.30	0.002	96	
		2	30 858.82	0.997	96	
		3	30 965.46	1.245	96	
		4	31 106.37	1.345	95	
		5	31 280.35	1.396	96	
$3d^5(^2D3)4s$	$b\ ^3D$	3	31 009.00		56	18 (2D1) 3D
		2	31 028.33		50	24 (4F) 5I
		1	31 048.85		45	41 (4F) 5F
$3d^5(^2I)4s$	$a\ ^3I$	7	31 048.00		100	
		6	31 049.33		100	
		5	31 055.35		100	
$3d^5(^4F)4s$	$a\ ^5F$	1	31 352.42		59	31 (2D3) 3D
		2	31 355.21		74	12
		3	31 364.33		88	6
		4	31 377.96		100	
		5	31 393.40		100	
$3d^44s^2$	$a\ ^1G$	4	31 987.06			
$3d^44s^2$	$a\ ^1I$	6	32 097.36			
$3d^5(^2F1)4s$	$b\ ^3F$	2	33 040.10		79	14 (2D3) 3D
		3	33 060.74		83	13
		4	33 113.27		100	
$3d^4(^5D)4s4p(^3P^\circ)$	$z\ ^5D^\circ$	0	33 338.20		89	8 $^3P^\circ$
		1	33 423.79	1.499	93	
		2	33 542.11	1.497	96	
		3	33 671.55	1.497	97	
		4	33 816.06	1.499	97	
$3d^4(^5D)4s4p(^3P^\circ)$	$z\ ^3P^\circ$	0	33 762.56		88	8 $^5D^\circ$
		1	33 897.26	1.49	92	
		2	34 190.49	1.55	95	
$3d^5(^2I)4s$	$b\ ^1I$	6	33 762.74		100	
$3d^44s^2$	$c\ ^3D$	1	33 906.65			
		3	33 934.88			
		2	33 935.65			
$3d^6$	$c\ ^5D$	4	35 398.02			
		3	35 501.26			
		2	35 572.94			
		1	35 618.51			
		0	35 640.69			

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3 <i>d</i> ⁵ (⁴ F)4 <i>s</i>	<i>c</i> ³ F	2	35 807.90		100	
		3	35 813.73		100	
		4	35 862.82		98	
3 <i>d</i> ⁵ (² H)4 <i>s</i>	<i>b</i> ³ H	4	35 870.53		98	
		5	35 884.40		98	
		6	35 934.02		100	
3 <i>d</i> ⁴ (⁵ D)4 <i>s</i> 4 <i>p</i> (³ P°)	<i>z</i> ³ F°	2	35 897.87		95	
		3	36 034.22		95	
		4	36 212.15		95	
3 <i>d</i> ⁵ (² F ₂)4 <i>s</i>	<i>d</i> ³ F	3	36 552.13		100	
		2	36 558.55		100	
		4	36 577.73		100	
3 <i>d</i> ⁵ (⁶ S)5 <i>s</i>	<i>e</i> ⁷ S	3	36 895.73			
3 <i>d</i> ⁵ (² G ₂)4 <i>s</i>	<i>c</i> ³ G	3	37 205.88		98	
		5	37 233.50		96	
		4	37 244.17		98	
3 <i>d</i> ⁵ (⁶ S)5 <i>s</i>	<i>e</i> ⁵ S	2	37 883.34			
3 <i>d</i> ⁵ (² H)4 <i>s</i>	<i>a</i> ¹ H	5	38 537.68		98	
3 <i>d</i> ⁴ (⁵ D)4 <i>s</i> 4 <i>p</i> (³ P°)	<i>z</i> ³ D°	1	38 597.06		96	
		2	38 730.67		96	
		3	38 911.33		96	
3 <i>d</i> ⁵ (² G ₂)4 <i>s</i>	<i>b</i> ¹ G	4	39 158.63		98	
3 <i>d</i> ⁴ (⁵ D)4 <i>s</i> 4 <i>p</i> (¹ P°)	<i>y</i> ⁵ F°	1	40 906.46	0.004	84	12 3 <i>d</i> ⁵ (⁴ G)4 <i>p</i> ⁵ F°
		2	40 971.29	1.28	83	12
		3	41 086.26	1.246	83	12
		4	41 224.78	1.360	82	13
		5	41 393.47		82	14
3 <i>d</i> ⁴ (⁵ D)4 <i>s</i> 4 <i>p</i> (¹ P°)	<i>x</i> ⁵ P°	1	40 930.31	2.455		
		2	40 982.97	1.76		
		3	41 043.35	1.640		
3 <i>d</i> ⁴ (⁵ D)4 <i>s</i> 4 <i>p</i> (¹ P°)	<i>y</i> ⁵ D°	0	41 224.80		52	14 3 <i>d</i> ⁵ (⁴ P)4 <i>p</i> ⁵ D°
		1	41 289.17	1.503	54	14
		2	41 409.03	1.504	56	13
		3	41 575.10	1.503	58	13
		4	41 782.19	1.500	62	14
3 <i>d</i> ⁴ (³ H)4 <i>s</i> 4 <i>p</i> (³ P°)	<i>z</i> ⁵ H°	3	42 025.60		61	20 3 <i>d</i> ⁵ (⁴ G)4 <i>p</i> ⁵ H°
		4	42 079.81		55	19 3 <i>d</i> ⁵ (⁴ G)4 <i>p</i> ⁵ H°
		5	42 153.74		48	17 3 <i>d</i> ⁵ (⁴ G)4 <i>p</i> ⁵ H°
		6	42 252.17		38	25 3 <i>d</i> ⁵ (⁴ G)4 <i>p</i> ⁵ G°
		7	42 387.32		65	24 3 <i>d</i> ⁵ (⁴ G)4 <i>p</i> ⁵ H°

Cr I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)						
					First	Second					
$3d^4(a^3P)4s4p(^3P^\circ)$	x^5D°	0	42 218.37		49	26	$3d^4(^5D)4s4p(^1P^\circ)^5D^\circ$				
		1	42 292.96	1.501	47	26					
		2	42 438.82	1.494	43	21					
		3	42 648.26	1.498	40	22					
		4	42 908.57	1.497	45	20					
$3d^5(^6S)5p$	x^7P°	2	42 238.04								
		3	42 254.11								
		4	42 275.20								
$3d^5(^6S)4d$	e^7D	1	42 253.42								
		2	42 254.52								
		3	42 256.26								
		4	42 258.37								
		5	42 261.06	1.55							
$3d^5(^4G)5p$	z^5G°	2	42 515.35	0.35	61	20	$3d^4(^3H)4s4p(^3P^\circ)^5G^\circ$				
		3	42 538.81		57	19		$3d^4(^3H)4s4p(^3P^\circ)^5G^\circ$			
		4	42 564.85		53	18			$3d^4(^3H)4s4p(^3P^\circ)^5G^\circ$		
		5	42 589.25	1.23	47	16				$3d^4(^3H)4s4p(^3P^\circ)^5G^\circ$	
		6	42 605.81	1.32	37	27					$3d^4(^3H)4s4p(^3P^\circ)^5H^\circ$
$3d^4(a^3P)4s4p(^3P^\circ)$	z^5S°	2	43 124.88	1.93	46	46	$3d^5(^4P)4p^5S^\circ$				
$3d^5(^6S)4d$	e^5D	4	44 050.87								
		3	44 068.72								
		2	44 080.90								
		1	44 088.92								
		0	44 092.80								
$3d^5(^6S)5p$	w^5P°	1	44 125.90	2.74							
		2	44 186.92	1.79							
		3	44 259.36	1.68							
$3d^4(^3H)4s4p(^3P^\circ)$	z^5I°	4	44 246.70		99						
		5	44 307.96		99						
		6	44 393.10		99						
		7	44 514.44		99						
		8	44 666.55		100						
$3d^4(a^3F)4s4p(^3P^\circ)$	y^5G°	2	44 299.98	0.35	85						
		3	44 373.34	0.93	80						
		4	44 534.46		68	18	$3d^4(a^3F)4s4p(^3P^\circ)^5F^\circ$				
		5	44 591.46	1.25	46	29		$3d^4(a^3F)4s4p(^3P^\circ)^5F^\circ$			
		6	44 746.26	1.34	85	5			$3d^4(^3G)4s4p(^3P^\circ)^5G^\circ$		
$3d^4(a^3P)4s4p(^3P^\circ)$	v^5P°	1	44 666.74	2.47	78	8	$3d^5(^4D)4p^5P^\circ$				
		2	44 875.19		76	9					
		3	45 113.22	1.65	70	13					

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (a ³ F)4s4p(³ P°)	<i>x</i> ⁵ F°	1	45 201.84	1.41	66	28 3d ⁵ (⁴ G)4p ⁵ F°
		2	45 225.20		63	27 3d ⁵ (⁴ G)4p ⁵ F°
		3	45 255.51		58	26 3d ⁵ (⁴ G)4p ⁵ F°
		4	45 286.08		50	23 3d ⁵ (⁴ G)4p ⁵ F°
		5	45 306.45		34	37 3d ⁴ (a ³ F)4s4p(³ P°) ⁵ G°
3d ⁵ (⁴ G)4p	<i>z</i> ³ H°	6	45 348.73		68	16 ⁵ H°
		5	45 354.18		49	32
		4	45 358.63		59	25
3d ⁵ (⁴ G)4p	<i>y</i> ⁵ H°	3	45 566.02	0.52	76	22 3d ⁴ (³ H)4s4p(³ P°) ⁵ H°
		4	45 614.88		51	28 3d ⁵ (⁴ G)4p ³ H°
		5	45 663.28		43	38 3d ⁵ (⁴ G)4p ³ H°
		6	45 707.36		58	20 3d ⁵ (⁴ G)4p ³ H°
		7	45 741.49		74	25 3d ⁴ (³ H)4s4p(³ P°) ⁵ H°
3d ⁵ (⁶ S)6s	<i>f</i> ⁷ S	3	45 643.38	2.05		
3d ⁵ (⁴ P)4p	<i>y</i> ³ P°	1	45 719.20		45	24 3d ⁴ (a ³ P)4s4p(³ P°) ³ P°
		0	45 722.59		39	31
		2	45 734.32		49	20
3d ⁵ (⁴ G)4p	<i>y</i> ³ F°	2	45 966.45		75	8 3d ⁴ (a ³ F)4s4p(³ P°) ³ F°
		3	46 000.36		80	8
		4	46 058.20		83	7
3d ⁵ (⁶ S)6s	<i>f</i> ⁵ S	2	45 967.81			
3d ⁵ (⁴ P)4p	<i>y</i> ³ D°	1	46 077.09	1.24	22	19 3d ⁵ (⁴ D)4p ⁵ F°
		2	46 109.26		23	14 3d ⁵ (⁴ D)4p ⁵ F°
		3	46 174.40		37	15 3d ⁴ (a ³ F)4s4p(³ P°) ⁵ D°
3d ⁴ (a ³ F)4s4p(³ P°)	<i>w</i> ⁵ D°	0	46 081.27		40	25 3d ⁴ (a ³ P)4s4p(³ P°) ⁵ D°
		1	46 298.32		42	20
		2	46 349.50		40	22
		3	46 368.35		36	27
		4	46 422.46		39	34
3d ⁴ 4s5s	<i>f</i> ⁷ D	1	46 448.60	2.99		
		2	46 524.84	1.99		
		3	46 637.21	1.77		
		4	46 783.06	1.63		
		5	46 958.98	1.61		
3d ⁴ (³ G)4s4p(³ P°)	<i>w</i> ⁵ F°	2	46 677.06	1.25	20	18 3d ⁵ (⁴ D)4p ⁵ F°
		1	46 678.35		21	18
		3	46 688.24		23	22
		5	46 704.98		33	30
		4	46 720.54		23	24

Cr I—Continued

Configuration	Term	J	Level (cm ⁻¹)	g	Leading components (%)	
					First	Second
3d ⁴ (³ H)4s4p(³ P°)	z ³ G°	3	46 846.77		42	20 3d ⁴ (a ³ F)4s4p(³ P°) ³ G°
		4	46 905.03		40	21 3d ⁴ (a ³ F)4s4p(³ P°) ³ G°
		5	46 985.87		34	20 3d ⁵ (⁴ G)4p ³ G°
3d ⁵ (⁴ P)4p	u ⁵ P°	3	46 878.61	1.68	47	20 3d ⁵ (⁴ D)4p ⁵ P°
		2	46 967.70	1.84	51	20
		1	47 021.75	2.42	55	20
3d ⁴ (³ H)4s4p(³ P°)	x ⁵ G°	2	47 047.47	0.45	67	15 3d ⁵ (⁴ G)4p ⁵ G°
		3	47 125.70	0.96	62	14
		4	47 189.87		60	15
		6	47 222.27	1.44	70	19
		5	47 228.80	1.27	63	16
3d ⁵ (⁴ G)4p	y ³ G°	3	47 048.48		73	12 3d ⁴ (³ H)4s4p(³ P°) ³ G°
		4	47 054.91		69	16
		5	47 055.31		62	24
3d ⁴ (a ³ P)4s4p(³ P°)	z ³ S°	1	47 088.40		72	8 3d ⁵ (⁴ P)4p ³ S°
3d ⁴ (³ H)4s4p(³ P°)	z ³ I°	5	47 586.06		61	28 3d ⁴ (³ G)4s4p(³ P°) ⁵ H°
		6	47 630.43		57	34
		7	47 692.63		52	40
3d ⁴ (³ G)4s4p(³ P°)	x ⁵ H°	3	47 621.31		79	12 3d ⁴ (³ H)4s4p(³ P°) ⁵ H°
		4	47 688.51		82	11 3d ⁴ (³ H)4s4p(³ P°) ⁵ H°
		5	47 793.82		56	30 3d ⁴ (³ H)4s4p(³ P°) ³ I°
		6	47 942.29		53	35 3d ⁴ (³ H)4s4p(³ P°) ³ I°
		7	48 140.18		49	42 3d ⁴ (³ H)4s4p(³ P°) ³ I°
3d ⁴ (⁵ D)4s5p(³ P°)	v ⁵ F°	1	47 629.66			
		2	47 631.51			
		3	47 636.25			
		4	47 639.84	1.34		
		5	47 644.76			
3d ⁵ (⁶ S)6p	w ⁷ P°	2	47 697.44			
		3	47 708.59			
		4	47 719.08			
3d ⁵ (⁶ S)5d	g ⁷ D	1	47 700.18			
		2	47 700.95			
		3	47 702.30			
		4	47 704.66			
		5	47 709.80			
3d ⁵ (⁴ P)4p	v ⁵ D°	1	47 772.30	1.37	49	26 3d ⁴ (a ³ F)4s4p(³ P°) ⁵ D°
		2	47 786.10	1.39	49	26
		0	47 788.08		46	27
		3	47 814.40	1.53	49	25
		4	47 866.48	1.50	52	23

Cr I—Continued

Configuration	Term	J	Level (cm ⁻¹)	g	Leading components (%)	
					First	Second
3d ⁵ (⁴ G)4p	u ⁵ F°	1	47 877.55	0.00	15	15 3d ⁴ (a ³ P)4s4p(³ P°) ³ P°
		2	47 917.93	1.04	35	19 3d ⁴ (a ³ F)4s4p(³ P°) ⁵ F°
		3	47 974.53	1.36	35	20
		5	47 985.76	1.38	39	25
		4	48 014.40		39	23
		4	48 042.80			
3d ⁴ (a ³ F)4s4p(³ P°)	³ D°	1	48 210.04		59	7 3d ⁵ (⁴ G)4p ⁵ F°
		2	48 217.83		61	6
		3	48 251.91		64	5
3d ⁴ (a ³ P)4s4p(³ P°)	x ³ P°	0	48 226.36		29	24 3d ⁵ (⁴ P)4p ³ P°
		1	48 331.30		28	15
		2	48 458.67		42	19
3d ⁴ (³ H)4s4p(³ P°)	y ³ H°	4	48 288.37		76	
		5	48 310.39		89	
		6	48 445.35		83	
3d ⁴ 4s5s	f ⁵ D	0	48 488.23			
		1	48 507.56			
		2	48 558.57			
		3	48 661.59	1.46		
	4	48 824.50	1.46			
	x ³ G°	3	48 515.08			
4		48 562.16				
5		48 786.39				
3d ⁴ (a ³ F)4s4p(³ P°)	³ F°	3	48 636.14		60	15 3d ⁴ (³ G)4s4p(³ P°) ³ F°
3d ⁴ (a ³ P)4s4p(³ P°)	x ³ D°	1	48 839.90		38	20 3d ⁵ (⁴ P)4p ³ D°
		2	49 027.58		46	14
		3	49 310.86		61	7
3d ⁵ (⁶ S)7s	g ⁷ S	3	49 177.83			
3d ⁵ (⁶ S)7s	g ⁵ S	2	49 321.51			
3d ⁴ (a ³ F)4s4p(³ P°)	w ³ G°	3	49 370.70		40	9 3d ⁴ (³ H)4s4p(³ P°) ³ G°
		4	49 453.94		40	13
		5	49 538.06		51	17
3d ⁴ (³ G)4s4p(³ P°)	w ⁵ G°	2	49 466.77		65	18 3d ⁵ (⁴ G)4p ⁵ G°
		3	49 519.72	1.04	53	14
		4	49 573.03		63	19
		5	49 617.61		70	17
		6	49 635.16	1.35	73	17

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁵ (4P)4p	y ³ S°	1	49 477.04		73	17 3d ⁴ (a ³ P)4s4p(³ P°) ³ S°
		e ³ F	2	49 586.38		
			3	49 717.88		
			4	49 863.50		
3d ⁵ (4D)4p	t ⁵ P°	1	49 588.97	2.48	46	30 3d ⁵ (4P)4p ⁵ P°
		3	49 812.46	1.77	31	26
3d ⁴ (a ³ F)4s4p(³ P°)	¹ D°	2	49 598.08	1.88	20	14 3d ⁵ (4D)4p ⁵ P°
3d ⁵ (4D)4p	x ³ F°	4	49 620.69		56	15 3d ⁴ (³ G)4s4p(³ P°) ³ F°
		3	49 650.22		43	18
		2	49 652.76		37	18
3d ⁵ (4P)4p	y ⁵ S°	2	49 822.59	2.00	30	31 3d ⁴ (a ³ P)4s4p(³ P°) ⁵ S°
3d ⁵ (4D)4p	s ⁵ F°	1	50 018.80		44	29 3d ⁴ (³ G)4s4p(³ P°) ⁵ F°
		2	50 057.61		43	29
		3	50 102.04	1.27	44	29
		4	50 210.87	1.25	30	21
		5	50 253.27	1.39	46	33
3d ⁵ (4D)4p	w ³ D°	1	50 105.54		66	11 3d ⁵ (4P)4p ³ D°
		2	50 184.10		57	14
		3	50 264.48		51	18
3d ⁵ (4D)4p	u ⁵ D°	4	50 557.56	1.54	44	15 3d ⁵ (4D)4p ⁵ F°
		3	50 628.11	1.54	60	7 3d ⁵ (4P)4p ⁵ D°
		2	50 654.76	1.51	68	8 3d ⁵ (4P)4p ⁵ D°
		0	50 661.20		69	10 3d ⁵ (4P)4p ⁵ D°
		1	50 662.77	1.46	71	9 3d ⁵ (4P)4p ⁵ D°
3d ⁴ (³ G)4s4p(³ P°)	w ³ F°	2	50 890.15		41	27 3d ⁵ (4D)4p ³ F°
		3	50 950.42		42	26
		4	51 059.79		46	23
3d ⁵ (⁶ S)8s	h ⁵ S	2	51 035.68			
3d ⁵ (4D)4p	w ³ P°	0	51 176.88		71	11 3d ⁴ (a ³ P)4s4p(³ P°) ³ P°
		1	51 246.87		68	8 3d ⁴ (a ³ P)4s4p(³ P°) ³ P°
		2	51 286.52		45	32 3d ⁴ (a ³ P)4s4p(³ P°) ¹ D°
3d ⁴ (³ H)4s4p(³ P°)	z ¹ H°	5	51 401.24		68	11 3d ⁵ (² I)4p ¹ H°
3d ⁴ (³ D)4s4p(³ P°)	t ⁵ D°	0	51 999.62		94	
		1	52 003.06		94	
		2	52 012.44		93	
		3	52 031.72		92	
		4	52 064.27		92	

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (¹ I)4s4p(³ P°)	<i>y</i> ³ I°	5	52 591.94	1.42	48	33 3d ⁵ (² I)4p ³ I°
		6	52 660.61		58	39
		7	52 677.88		59	39
3d ⁴ (³ G)4s4p(³ P°)	³ G°	4	52 720.07		72	14 3d ⁴ (³ H)4s4p(³ P°) ³ G°
3d ⁴ (<i>a</i> ¹ G)4s4p(³ P°)	<i>x</i> ³ H°	5	52 885.39		57	27 3d ⁵ (² I)4p ³ H°
		6	52 914.94		68	26
		4	52 963.44		47	26
3d ⁴ (³ D)4s4p(³ P°)	<i>r</i> ⁵ F°	1	53 011.65		85	6 3d ⁵ (⁴ D)4p ⁵ F°
		2	53 037.52		84	6
		3	53 073.90		83	6
		4	53 117.54		81	6
		5	53 172.33		85	7
3d ⁴ 4s4d	<i>e</i> ⁷ G	1	53 148.35			
		2	53 177.87			
		3	53 228.49			
		4	53 298.90			
		5	53 393.50			
		6	53 517.85			
		7	53 662.64			
3d ⁴ 4s4d	<i>h</i> ⁷ D	2	53 195.03			
		3	53 284.34			
		4	53 375.46			
		5	53 627.75			
3d ⁴ 4s4d	<i>e</i> ⁷ F	1	53 215.40			
		2	53 279.80			
		3	53 384.72			
		4	53 526.22			
		5	53 706.06			
		6	53 927.47			
3d ⁴ 4s5p	<i>s</i> ⁵ D°	2	53 541.25			
		3	53 640.74			
		4	53 782.77			
3d ³ (⁴ F)4s ² 4p	<i>v</i> ³ G°	3	53 804.84		28	22 3d ⁵ (⁴ F)4p ³ G°
		4	53 927.59		26	22
		5	54 078.13		25	22
3d ⁴ 4s5p	<i>s</i> ⁵ P°	1	53 963.05			
		2	54 032.63			
		3	54 132.88			

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ 4s5p	<i>q</i> ⁵ F°	1	54 198.23			
		2	54 252.19			
		3	54 328.95			
		4	54 425.29			
		5	54 536.53			
	<i>e</i> ⁵ F	1	54 296.76			
		2	54 383.36			
		3	54 476.29			
		4	54 572.84			
		5	54 660.31			
3d ⁵ (² I)4p	<i>z</i> ³ K°	6	54 316.83	56	42	3d ⁴ (¹ I)4s4p(³ P°) ³ K°
		7	54 404.94	54	46	
		8	54 498.27	59	41	
Cr II (⁶ S _{5/2})	<i>Limit</i>	.....	54 570			
3d ⁴ 4s5s	<i>g</i> ⁵ D	0	54 646.20			
		1	54 671.90			
		2	54 818.55			
		3	54 986.82			
		4	55 209.01			
3d ⁴ (³ H)4s4p(¹ P°)	<i>w</i> ³ H°	4	54 736.55	42	20	3d ⁵ (² I)4p ³ H°
		5	54 799.18	41	21	
		6	54 886.82	42	24	
3d ⁴ (¹ I)4s4p(³ P°)	³ K°	6	54 800.26	55	40	3d ⁵ (² I)4p ³ K°
3d ⁴ 4s5s	<i>e</i> ³ D	1	54 804.69			
		2	54 974.64			
		3	55 204.79			
3d ⁵ (⁴ G)5p	<i>v</i> ³ H°	4	54 810.94			
		6	54 866.57			
		5	54 929.72			
3d ⁴ (³ D)4s4p(³ P°)	<i>v</i> ³ D°	1	54 956.59	33	28	3d ⁵ (^a ² D)4p ³ D°
		2	55 152.63	30	26	
		3	55 451.64	30	19	
3d ⁵ (² I)4p	<i>z</i> ¹ K°	7	54 970.23	79	10	³ K°
3d ⁵ (^a ² D)4p	<i>v</i> ³ F°	2	54 992.93	30	20	3d ⁵ (^a ² F)4p ³ F°
		3	55 101.87	22	15	
		4	55 207.40	30	18	
3d ⁵ (⁴ G)5p	<i>u</i> ³ F°	4	55 120.77			
		3	55 352.72			
		2	55 473.67			

Cr I—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁵ (² I)4p	<i>y</i> ¹ I°	6	55 516.69		35	28 3d ⁴ (¹ I)4s4p(³ P°) ³ H°
3d ⁵ (² I)4p	<i>x</i> ³ I°	5	55 686.46		29	30 3d ⁴ (¹ I)4s4p(³ P°) ³ I°
		6	55 741.11		34	30
		7	55 799.10		39	32
3d ⁴ (¹ I)4s4p(³ P°)	<i>u</i> ³ H°	5	55 874.98		61	12 3d ⁵ (² H)4p ³ H°
		6	55 908.12		37	37 3d ⁵ (² I)4p ¹ I°
		4	55 915.50		67	12 3d ⁵ (² H)4p ³ H°
3d ⁵ (² I)4p	<i>y</i> ¹ H°	5	55 945.08		43	12 3d ⁴ (³ G)4s4p(³ P°) ¹ H°
3d ⁵ (⁴ F)4p	<i>v</i> ⁵ G°	2	56 155.12		46	44 3d ³ (⁴ F)4s ² ⁵ G°
		3	56 209.81		43	38
		4	56 279.56		51	40
		5	56 361.86		55	38
		6	56 449.10		59	34
3d ⁴ (³ D)4s4p(³ P°)	<i>v</i> ³ P°	2	56 591.88		42	18 3d ⁵ (<i>a</i> ² D)4p ³ P°
		1	56 722.60		40	10 3d ⁴ (³ D)4s4p(³ P°) ¹ P°
		0	56 802.50		56	19 3d ⁵ (<i>a</i> ² D)4p ³ P°
3d ⁴ (<i>a</i> ³ F)4s4p(¹ P°)	<i>u</i> ³ G°	3	56 985.67		21	16 3d ⁴ (³ D)4s4p(³ P°) ³ F°
		4	57 033.60		24	15 3d ⁴ (³ H)4s4p(³ P°) ³ G°
		5	57 088.25		25	23 3d ⁴ (³ H)4s4p(³ P°) ³ G°
3d ⁴ (<i>a</i> ¹ S)4s4p(³ P°)	<i>u</i> ³ P°	2	57 087.70		43	22 3d ⁵ (<i>a</i> ² D)4p ³ P°
		1	57 132.59		40	21
		0	57 154.59		40	22
3d ⁴ 4s6p	<i>p</i> ⁵ F°	1	57 096.62			
		2	57 100.66			
		3	57 186.60			
		4	57 237.50			
		5	57 327.66			
	<i>4</i> °	3	57 141.85			
3d ³ (⁴ F)4s ² 4p	<i>t</i> ³ F°	2	57 220.67		14	24 3d ⁴ (³ D)4s4p(³ P°) ³ F°
		3	57 276.42		10	10 3d ⁵ (⁴ F)4p ³ F°
		4	57 335.47		13	16 3d ⁵ (⁴ F)4p ³ F°
3d ⁵ (⁴ G)5s	<i>e</i> ⁵ G	2	57 350.65			
		3	57 361.24			
		4	57 372.78			
		5	57 382.93			
		6	57 389.32			
3d ⁵ (<i>a</i> ² F)4p	<i>t</i> ³ G°	3	57 557.03		40	14 3d ⁵ (⁴ F)4p ⁵ F°
		4	57 587.36		21	18 3d ⁵ (⁴ F)4p ⁵ F°
		5	57 702.36		58	20 3d ⁴ (<i>a</i> ³ F)4s4p(³ P°) ³ G°

Cr I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^44s5p$	r^5D°	0	57 958.42			
		1	57 995.04			
		2	58 063.80			
		3	58 147.76			
		4	58 292.62			
	e^3G	3	57 984.94			
		5	57 990.23			
$3d^5(a^2F)4p$	s^3F°	2	58 162.84		26	15 $3d^5(a^2D)4p^3F^\circ$
		4	58 167.89		25	20
		3	58 202.65		25	23
$3d^5(^4F)4p$	u^3D°	1	58 725.28		18	33 $3d^5(^4F)4p^5D^\circ$
		2	58 860.23		39	28 $3d^4(^3D)4s4p(^3P^\circ)^3D^\circ$
		3	59 122.15		25	25 $3d^4(^3D)4s4p(^3P^\circ)^3D^\circ$
$3d^5(^2H)4p$	t^3H°	4	58 728.29		23	16 $3d^5(^2I)4p^3H^\circ$
		5	58 754.58		24	17
		6	58 775.36		26	17
$3d^5(^4P)5p$	t^3D°	2	58 772.03			
		1	58 870.20			
		3	58 924.12			
$3d^4(a^3F)4s4p(^1P^\circ)$	r^3F°	2	59 357.90		51	11 $3d^5(^4F)4p^3F^\circ$
		3	59 417.01		46	9
		4	59 487.71		50	9
$3d^4(^3H)4s4p(^1P^\circ)$	w^3I°	5	59 806.27		64	16 $3d^5(^2H)4p^3I^\circ$
		6	59 884.27		74	13
		7	59 957.46		77	13
$3d^5(^2H)4p$	x^1H°	5	60 005.60		13	20 $3d^5(a^2G)4p^3G^\circ$
$3d^4(a^3P)4s4p(^1P^\circ)$	x^3S°	1	60 084.09		48	19 $^3P^\circ$
$3d^44s6p$	q^5D°	0	60 241.5			
		1	60 291.04			
		2	60 374.94			
		3	60 493.42			
	q^3F°	4	60 627.96			
		2	60 253.00			
		3	60 326.04			
$3d^5(^2H)4p$	v^3I°	4	60 367.38			
		5	60 427.63		50	16 $3d^5(a^2G)4p^1H^\circ$
		6	60 527.55		74	11 $3d^5(a^2G)4p^3H^\circ$
$3d^5(^2H)4p$	x^1I°	7	60 656.97		85	6 $3d^5(^2I)4p^3I^\circ$
		6	60 441.42		49	17 $3d^5(a^2G)4p^3H^\circ$

Cr I—Continued

Configuration	Term	J	Level (cm ⁻¹)	g	Leading components (%)	
					First	Second
3d ⁵ (a ² G)4p	s ³ G°	5	60 467.85		30	21 3d ⁵ (² H)4p ³ I°
		4	60 503.94		40	9 3d ⁵ (² H)4p ³ G°
		3	60 518.16		33	16 3d ⁵ (a ² F)4p ¹ F°
3d ⁵ (a ² D)4p	s ³ D°	3	60 615.84		17	24 3d ⁵ (⁴ F)4p ³ D°
		2	60 629.87		25	24 3d ⁴ (a ¹ D)4s4p(³ P°) ³ D°
		1	60 678.12		29	22 3d ⁴ (a ¹ D)4s4p(³ P°) ³ D°
3d ⁴ 4s6p	o ⁵ F°	1	60 683.53			
		2	60 781.25			
		3	60 904.84			
		4	61 056.41			
		5	61 184.95			
3d ⁵ (b ² F)4p	p ³ F°	3	60 819.50		40	21 3d ⁴ (¹ F)4s4p(³ P°) ³ F°
		4	60 960.58		39	24
3d ⁵ (a ² G)4p	s ³ H°	4	60 870.63		52	13 3d ⁴ (³ H)4s4p(¹ P°) ³ H°
		5	61 008.07		41	11 3d ⁴ (³ H)4s4p(¹ P°) ³ H°
		6	61 191.64		35	27 3d ⁵ (² H)4p ¹ I°
3d ⁴ 4s6p	r ⁵ P°	1	61 065.96			
		2	61 107.95			
		3	61 198.68			
3d ⁵ (² H)4p	r ³ G°	3	61 078.28		24	19 3d ⁵ (b ² F)4p ³ G°
		4	61 123.20		19	15 3d ⁵ (b ² F)4p ³ G°
		5	61 161.35		15	15 3d ⁵ (a ² G)4p ³ H°
3d ⁴ (a ¹ D)4s4p(³ P°)	t ³ P°	0	61 387.86		77	7 3d ⁵ (a ² D)4p ³ P°
		1	61 527.34		65	8 3d ⁵ (a ² D)4p ³ P°
		2	61 675.72		58	8 3d ³ (⁴ F)4s ² 4p ⁵ F°
3d ⁴ 4s5s	e ⁵ P	1	61 558.17			
		2	61 687.56			
		3	61 850.17			
3d ⁵ (⁴ F)4p	q ³ G°	3	61 930.05		48	15 3d ⁴ (³ G)4s4p(¹ P°) ³ G°
		4	61 976.50		32	20 3d ³ (⁴ F)4s ² 4p ⁵ F°
		5	62 037.60		31	15 3d ⁴ (³ G)4s4p(¹ P°) ³ H°
3d ⁴ 4p ²	f ⁷ F	3	62 034.44			
		4	62 188.83			
		5	62 472.80			
		6	62 658.38			
3d ⁵ (⁴ G)4d	f ⁵ G	2	62 646.60			
		3	62 661.96			
		4	62 671.00			
		6	62 673.92			
		5	62 690.96			

Cr I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^44s5s$	e^5H	3	64 712.04			
		4	64 751.42			
		5	64 802.08			
		6	64 836.30			
		7	64 940.28			
$3d^44s4p$	r^3H°	4	62 762.06			
		5	62 830.26			
		6	62 903.03			
	q^3H°	4	63 116.80			
		5	63 144.36			
		6	63 182.94			
$3d^54p$	p^3H°	4	63 841.81			
		5	63 927.27			
		6	63 997.86			
$3d^54p$	p^3G°	3	66 008.95			
		4	66 094.06			
		5	66 180.34			

Cr II

Z=24

V-I isoelectronic sequence

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 6S_{5/2}$ Ionization energy = $133\,060\text{ cm}^{-1}$ (16.4975 eV)

Kiess (1951) carried out the principal analysis of this spectrum using his extensive measurements of wavelengths and Zeeman-effect data. Changes in several of his term designations for the $3d^4 4p$ configuration suggested by Roth (1969) on the basis of theoretical calculations have been adopted here. For these terms the alphabetical prefixing by Kiess has been dropped.

The percentage compositions for $3d^4 4p$ are by Roth. Repeating terms of the $3d^4$ core are labeled in alphabetical order rather than by seniority. The percentages represent the sum of seniority states contributing the same core term. Shadmi, Oreg, and Stein (1968) have calculated the $3d^5$, $3d^4 4s$, and

$3d^3 4s^2$ configurations but give percentages only for a^2H and b^2H , apparently the only highly mixed terms. No changes of designations were made except for the e^2G and e^2D terms.

The ionization energy was derived by Russell (1950) utilizing the two-member $3d^4 ns$ series.

References

- Kiess, C. C. (1951), J. Res. Natl. Bur. Std. (U.S.) **47**, 385.
 Roth, C. (1969), J. Res. Natl. Bur. Std. (U.S.) **73A**, 125.
 Russell, H. N. (1950), J. Opt. Soc. Am. **40**, 618.
 Shadmi, Y., Oreg., J., and Stein, J. (1968), J. Opt. Soc. Am. **58**, 909.

Cr II

Configuration	Term	J	Level (cm ⁻¹)	g	Leading components (%)	
					First	Second
$3d^5$	a^6S	5/2	0.00			
$3d^4(^5D)4s$	a^6D	1/2	11 962.00	3.323		
		3/2	12 032.72	1.867		
		5/2	12 148.00	1.669		
		7/2	12 303.98	1.578		
		9/2	12 496.79	1.554		
$3d^4(^5D)4s$	a^4D	1/2	19 528.38	0.000		
		3/2	19 631.28	1.192		
		5/2	19 798.01	1.370		
		7/2	20 024.18	1.427		
$3d^5$	a^4G	5/2	20 512.62	0.599		
		11/2	20 512.75	1.278		
		7/2	20 518.33	0.994		
		9/2	20 519.85	1.161		
$3d^5$	a^4P	5/2	21 822.86	1.590		
		1/2	21 824.25	2.693		
		3/2	21 824.82	1.717		
$3d^5$	b^4D	7/2	25 033.95	1.432		
		1/2	25 035.64	-0.045		
		3/2	25 043.10	1.207		
		5/2	25 047.04	1.381		
$3d^4(^3P)4s$	b^4P	1/2	29 952.08	2.685		
		3/2	30 307.60	1.756		
		5/2	30 864.61	1.572		
$3d^5$	a^2I	11/2	30 143.72			
		13/2	30 150.16			

Cr II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)		
					First	Second	
$3d^4(^3H)4s$	a^4H	7/2	30 156.94	0.667			
		9/2	30 219.04	0.978			
		11/2	30 298.77	1.162			
		13/2	30 391.94	1.234			
$3d^4(^3F)4s$	a^4F	3/2	31 083.11	0.418			
		5/2	31 117.59	1.032			
		7/2	31 168.78	1.246			
		9/2	31 219.49	1.340			
$3d^5$	a^2D	5/2	31 351.15				
		3/2	31 531.62				
$3d^5$	a^2F	7/2	32 355.94				
		5/2	32 603.73				
$3d^5$	b^4F	7/2	32 836.84				
		3/2	32 844.92				
		9/2	32 854.46				
		5/2	32 855.09				
$3d^4(^3G)4s$	b^4G	5/2	33 418.11	0.588			
		7/2	33 521.23	1.024			
		9/2	33 619.13	1.185			
		11/2	33 694.47	1.276			
$3d^4(^3H)4s$	a^2H	9/2	34 631.14		62	35 $3d^5^2H$	
		11/2	34 813.06		57	41	
$3d^4(^3P)4s$	a^2P	1/2	34 659.48	0.670			
		3/2	35 356.06	1.331			
$3d^4(^3F)4s$	b^2F	5/2	35 569.02	0.876			
		7/2	35 607.60	1.144			
$3d^5$	b^2H	9/2	35 610.50		61	37 $3d^4(^3H)4s^2H$	
		11/2	35 707.66		58	42	
$3d^5$	a^2G	7/2	36 101.82				
		9/2	36 272.66				
$3d^4(^3D)4s$	c^4D	7/2	38 269.67				
		5/2	38 315.00				
		3/2	38 362.56				
		1/2	38 396.36				
$3d^4(^3G)4s$	b^2G	7/2	38 509.07	0.910			
		9/2	38 563.15	1.100			
$3d^4(a^1G)4s$	c^2G	7/2	39 684.00				
		9/2	39 824.52				
$3d^5$	c^2F	5/2	39 742.36				
		7/2	39 877.28				

Cr II—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (¹ I)4s	<i>b</i> ² I	13/2	40 202.14			
		11/2	40 228.44			
3d ⁴ (¹ S)4s	<i>a</i> ² S	1/2	40 415.34			
3d ⁴ (³ D)4s	<i>b</i> ² D	5/2	42 898.12			
		3/2	42 986.73			
3d ⁵	<i>b</i> ² S	1/2	44 307.44			
3d ⁴ (¹ D)4s	<i>c</i> ² D	3/2	45 669.54			
		5/2	45 730.74			
3d ⁴ (⁵ D)4p	<i>z</i> ⁶ F ^o	1/2	46 823.64	-0.689	100	
		3/2	46 905.52	1.124	100	
		5/2	47 040.54	1.314	100	
		7/2	47 227.50	1.378	100	
		9/2	47 464.94	1.416	100	
		11/2	47 751.98		100	
3d ⁵	<i>d</i> ² D	5/2	47 354.63			
		3/2	47 372.75			
3d ⁴ (⁵ D)4p	<i>z</i> ⁶ P ^o	3/2	48 399.19	2.382	83	
		5/2	48 491.39	1.875	98	
		7/2	48 632.36	1.710	100	
3d ⁴ (⁵ D)4p	<i>z</i> ⁴ P ^o	1/2	48 749.57	2.844	67	31 (⁵ D) ⁶ D ^o
		3/2	49 006.15	1.802	55	42
		5/2	49 706.47	1.624	71	27
3d ⁴ (⁵ D)4p	<i>z</i> ⁶ D ^o	5/2	49 351.96	1.628	73	26 (⁵ D) ⁴ P ^o
		1/2	49 493.00	3.155	69	31
		3/2	49 564.80	1.824	58	41
		7/2	49 646.25	1.577	99	
		9/2	49 838.43	1.570	98	
3d ⁴ (¹ F)4s	<i>d</i> ² F	7/2	50 667.33			
		5/2	50 687.63			
3d ⁴ (⁵ D)4p	<i>z</i> ⁴ F ^o	3/2	51 584.44	0.406	97	
		5/2	51 669.75	1.025	97	
		7/2	51 789.21	1.248	96	
		9/2	51 943.04	1.338	96	
3d ⁵	<i>d</i> ² G	7/2	52 298.12			
		9/2	52 321.30			
3d ³ 4s ²	<i>c</i> ⁴ F	3/2	53 051.55			
		5/2	53 271.07			
		7/2	53 566.22			
		9/2	53 923.57			

Cr II—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (⁵ D)4p	z ⁴ D°	1/2	54 418.08	0.007	98	
		3/2	54 499.70	1.178	98	
		5/2	54 625.76	1.376	98	
		7/2	54 784.67	1.430	98	
	e ² G	7/2	54 444.19			
		9/2	54 678.95			
3d ⁴ (³ F)4s	d ⁴ F	5/2	55 023.30			
3d ⁴ (³ P)4s	c ⁴ P	3/2	55 081.7			
3d ⁴ (³ P)4s	b ² P	3/2	59 130.51			
	e ² D	3/2	59 527.05			
		5/2	59 570.23			
3d ⁴ (³ H)4p	z ⁴ H°	7/2	63 601.20	0.680	82	16 (³ G) ⁴ H°
		9/2	63 706.62	1.030	80	16
		11/2	63 849.11	1.138	80	15
		13/2	64 030.85	1.234	83	13
3d ⁴ (a ³ P)4d	y ⁴ D°	1/2	63 802.41	0.000	87	7 (a ³ F) ⁴ D°
		3/2	64 061.82	1.199	86	8
		5/2	64 448.84	1.380	85	10
		7/2	64 924.30	1.411	80	14
3d ⁴ (a ³ P)4p	z ² S°	1/2	65 029.67		73	7 (a ³ P) ⁴ P°
3d ⁴ (a ³ F)4p	z ⁴ G°	5/2	65 156.84	0.593	79	14 (³ G) ⁴ G°
		7/2	65 257.03	0.920	70	12
		9/2	65 384.04	1.120	59	10
		11/2	65 709.53	1.265	73	13
3d ⁴ (³ H)4p	z ⁴ I°	9/2	65 217.61		96	
		11/2	65 419.95		95	
		13/2	65 618.41		96	
		15/2	65 812.63		100	
3d ⁴ (³ H)4p	z ² G°	7/2	65 543.06		49	33 (a ³ F) ² G°
		9/2	65 680.15		41	31
3d ⁴ (a ³ P)4p	y ⁴ P°	1/2	66 256.77	2.545	76	13 (a ³ P) ² S°
		5/2	66 277.16	1.502	92	
		3/2	66 355.13	1.671	90	
3d ⁴ (a ³ P)4p	² P°	3/2	66 649.71		53	15 (a ³ F) ² D°
		1/2	66 872.12		79	14 (a ³ P) ² S°
3d ⁴ (a ³ P)4p	y ⁴ F°	5/2	67 012.28		71	13 (a ³ F) ² D°
		3/2	67 070.48		51	21 (a ³ P) ² P°
		7/2	67 393.80		76	10 (³ H) ⁴ G°
		9/2	67 448.82		63	18 (³ H) ⁴ G°

Cr II—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (³ H)4p	y ⁴ G°	7/2	67 334.20		60	18 (a ³ F) ⁴ F°
		5/2	67 344.42		66	13 (a ³ F) ⁴ G°
		9/2	67 353.60		51	32 (a ³ F) ⁴ F°
		11/2	67 369.33		65	22 (a ³ F) ⁴ G°
3d ⁴ (a ³ F)4p	² D°	3/2	67 379.92		28	32 (a ³ F) ⁴ F°
		5/2	67 387.30		50	18
3d ⁴ (³ H)4p	z ² I°	11/2	67 506.34		93	
		13/2	67 589.06		95	
3d ⁴ (a ³ F)4p	x ⁴ D°	1/2	67 859.91		88	11 (a ³ P) ⁴ D°
		5/2	67 868.05		77	13
		3/2	67 870.50		84	12
		7/2	67 875.68		69	19
3d ⁴ (a ³ P)4p	z ⁴ S°	3/2	68 305.73		70	17 (a ³ P) ² P°
3d ⁴ (³ H)4p	z ² H°	9/2	68 477.11		81	12 (a ¹ G) ² H°
		11/2	68 737.99		84	10
3d ⁴ (a ³ F)4p	z ² F°	5/2	68 583.44		50	21 (³ G) ² F°
		7/2	68 760.00		59	18
3d ⁴ (³ G)4p	y ⁴ H°	7/2	68 843.51		83	16 (³ H) ⁴ H°
		9/2	68 992.55		82	14
		11/2	69 170.60		82	13
		13/2	69 388.40		85	13
3d ⁴ (a ³ P)4p	² D°	3/2	69 348.36		65	28 (a ³ F) ² D°
		5/2	69 954.20		66	20
3d ⁴ (³ G)4p	⁴ F°	5/2	69 478.06		71	11 (³ D) ⁴ F°
		9/2	69 498.27		60	13 (a ³ F) ² G°
		7/2	69 506.16		60	11 (a ³ F) ² G°
		3/2	69 638.77		81	13 (³ D) ⁴ F°
3d ⁴ (a ³ F)4p	y ² G°	7/2	69 903.46		42	25 (³ H) ² G°
		9/2	70 107.83		37	25
3d ⁴ (³ G)4p	x ⁴ G°	5/2	70 317.04		60	17 (³ H) ⁴ G°
		7/2	70 427.22		61	19 (³ H) ⁴ G°
		9/2	70 679.22		44	22 (³ G) ² H°
		11/2	70 879.95		41	38 (³ G) ² H°
3d ⁴ (³ G)4p	y ² H°	9/2	70 394.46		57	19 (³ G) ⁴ G°
		11/2	70 399.04		47	34
3d ⁴ (³ G)4p	y ² F°	5/2	70 584.64		45	32 (a ³ F) ² F°
		7/2	70 852.24		59	20
3d ⁴ (³ G)4p	x ² G°	7/2	72 648.79		79	11 (³ H) ² G°
		9/2	72 716.91		75	13

Cr II—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (³ D)4p	w ⁴ D°	1/2	73 406.68		96	
		3/2	73 411.94		91	
		5/2	73 436.27		87	
		7/2	73 485.60		89	
3d ⁴ (a ¹ G)4p	x ² F°	7/2	74 114.48		64	19 (³ D) ⁴ F°
		5/2	74 436.14		77	7 (³ D) ² F°
3d ⁴ (³ D)4p	w ⁴ F°	3/2	74 273.48		82	13 (³ G) ⁴ F°
		5/2	74 318.86		48	40 (³ D) ⁴ P°
		7/2	74 423.84		89	6 (³ D) ⁴ F°
		9/2	74 504.51		86	13 (³ G) ⁴ F°
3d ⁴ (¹ I)4p	² I°	11/2	74 421.76		85	12 (a ¹ G) ² H°
		13/2	74 743.33		64	35 (¹ I) ² K°
3d ⁴ (¹ I)4p	² K°	13/2	74 424.35		65	33 (¹ I) ² I°
		15/2	74 958.80		100	
3d ⁴ (a ¹ G)4p	x ² H°	9/2	74 455.90		82	11 (³ H) ² H°
		11/2	74 707.42		72	11 (¹ I) ² I°
3d ⁴ (³ D)4p	x ⁴ P°	5/2	74 484.25		53	30 (³ D) ⁴ F°
		3/2	74 718.05		93	
		1/2	74 920.80		96	
3d ⁴ (³ D)4p	y ² P°	1/2	74 854.08		55	40 (a ¹ S) ² P°
		3/2	74 984.93		61	33
3d ⁴ (a ¹ G)4p	w ² G°	7/2	75 716.74		82	8 (³ G) ² G°
		9/2	75 810.10		80	12
3d ⁴ (³ D)4p	w ² F°	7/2	76 879.03		73	12 (a ¹ G) ² F°
		5/2	76 987.78		72	13
3d ⁴ (¹ I)4p	w ² H°	11/2	77 078.96		88	8 (³ G) ² H°
		9/2	77 270.40		90	8
3d ⁴ (a ¹ S)4p	x ² P°	3/2	77 713.66		31	26 (³ D) ² D°
		1/2	77 777.58		48	32 (³ D) ² P°
3d ⁴ (³ D)4p	x ² D°	5/2	77 935.24		65	26 (a ¹ D) ² D°
		3/2	78 109.64		48	22 (a ¹ S) ² P°
3d ⁴ (a ¹ D)4p	w ² D°	3/2	80 288.25		74	13 (³ D) ² D°
		5/2	80 420.43		65	21
3d ⁴ (a ¹ D)4p	v ² F°	5/2	81 232.91		86	
		7/2	81 432.36		89	

Cr II—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (⁵ D)5s	<i>e</i> ⁶ D	1/2	82 692.26			
		3/2	82 763.45			
		5/2	82 881.30			
		7/2	83 041.20			
		9/2	83 240.20			
3d ⁴ (a ¹ D)4p	<i>w</i> ² P°	1/2	82 854.00		89	9 (³ D) ² P°
		3/2	82 920.03		78	11
3d ⁴ (⁵ D)5s	<i>e</i> ⁴ D	1/2	84 208.28			
		3/2	84 318.54			
		5/2	84 494.20			
		7/2	84 725.96			
3d ⁴ (¹ F)4p	<i>u</i> ² F°	5/2	84 604.99		89	
		7/2	84 677.39		87	
3d ⁴ (¹ F)4p	<i>v</i> ² G°	7/2	85 573.43		95	
		9/2	85 939.50		97	
3d ⁴ (¹ F)4p	<i>v</i> ² D°	5/2	86 507.38		75	13 (<i>b</i> ³ P) ² D°
		3/2	86 511.08		79	12
3d ⁴ (⁵ D)4d	<i>e</i> ⁶ G	3/2	86 594.82			
		5/2	86 654.43			
		7/2	86 738.36			
		9/2	86 847.30			
		11/2	86 980.42			
		13/2	87 137.34			
3d ⁴ (⁵ D)4d	<i>e</i> ⁶ P	3/2	86 667.95			
		5/2	86 691.77			
		7/2	86 782.07			
3d ⁴ (⁵ D)4d	<i>f</i> ⁶ D	1/2	87 314.0			
		3/2	87 354.62			
		5/2	87 413.27			
		7/2	87 515.10			
		9/2	87 687.66			
3d ⁴ (⁵ D)4d	<i>e</i> ⁶ F	1/2	87 542.12			
		3/2	87 594.60			
		5/2	87 666.00			
		7/2	87 758.88			
		9/2	87 948.70			
3d ⁴ (⁵ D)4d	<i>e</i> ⁴ P	1/2	88 426.2			
		3/2	88 636.7			
		5/2	88 923.2			

Cr II—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	<i>g</i>	Leading components (%)	
					First	Second
3d ⁴ (⁵ D)4d	<i>e</i> ⁴ G	5/2	89 056.10			
		7/2	89 174.10			
		9/2	89 325.60			
		11/2	89 508.63			
3d ⁴ (⁵ D)4d	<i>f</i> ⁴ D	1/2	89 269.88			
		3/2	89 337.70			
		5/2	89 475.08			
		7/2	89 621.25			
3d ⁴ (⁵ D)4d	<i>e</i> ⁴ F	3/2	90 512.50			
		5/2	90 591.10			
		7/2	90 725.50			
		9/2	90 851.00			
3d ⁴ (<i>b</i> ³ F)4p	⁴ G°	7/2	90 986.31		95	
		9/2	91 103.36		98	
3d ⁴ (<i>b</i> ³ P)4p	<i>u</i> ² D°	5/2	91 426.31		50	18 (¹ F) ² D°
		3/2	91 556.54		53	21 (<i>b</i> ³ F) ² D°
3d ⁴ (⁵ D)4d	<i>e</i> ⁶ S	5/2	91 954.78			
3d ⁴ (³ G)5s	<i>f</i> ⁴ G	9/2	105 365.2			
		11/2	105 421.9			
Cr III (⁵ Do)	<i>Limit</i>	.....	133 060			

Cr III

Ti I isoelectronic sequence

Z=24

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 5D_0$ Ionization energy = $249\,700\text{ cm}^{-1}$ (30.96 eV)

The analysis was begun by White (1929) who found systems of triplet and quintet terms, which were later unified by Bowen (1937). F. L. Moore considerably augmented this work and provided his unpublished results to C. E. Moore (1952) for inclusion in her compilation. Ekberg (1976) has remeasured the spectrum and established 76 new levels while rejecting 26 of those found by Moore. We give the results of Ekberg and the $3d^3(4F)4d^5H$ term found by White (1929).

The percentage composition of the levels of $3d^4$ are from Pasternak and Goldschmidt (1972). Shadmi, Caspi, and Oreg (1969) calculated $3d^4$, $3d^3 4s$, and $3d^2 4s^2$ with configuration interaction but gave percentages only for the highly mixed 3P terms of $3d^3 4s$, which are quoted here.

The composition of $3d^3 4p$ is from Roth (1968). His percentages include the sum of seniority states contributing to the same core term.

The ionization energy was derived by Catalan and Velasco (1952) from the 2-member $3d^3 ns$ series.

References

- Bowen, I. S. (1937), Phys. Rev. **52**, 1153.
 Catalan, M. A., and Velasco, R. (1952), An. Real Soc. Esp. Fis. y Quim. **48A**, 247.
 Ekberg, J. O. (1976), Physica Scripta **14**, 109.
 Moore, C. E. (1952), Atomic Energy Levels, Natl. Bur. Std. (U.S.) Circ. 467, Vol. II (U.S. Gov't Printing Office, Washington, D.C.).
 Pasternak, A., and Goldschmidt, Z. B. (1972), Phys. Rev. **6A**, 55.
 Roth, C. (1968), J. Res. Natl. Bur. Std. (U.S.) **72A**, 505.
 Shadmi, Y., Caspi, E., and Oreg, J. (1969), J. Res. Natl. Bur. Std. (U.S.) **73A**, 173.
 White, H. E. (1929), Phys. Rev. **33**, 914.

Cr III

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^4$	5D	0	0.00	100	
		1	62.22	100	
		2	183.16	100	
		3	356.55	100	
		4	576.08	100	
$3d^4$	3P_2	0	16 771.36	58	41 3P_1
		1	17 168.56	59	41
		2	17 851.18	59	41
$3d^4$	3H	4	17 273.70	99	
		5	17 396.92	99	
		6	17 530.65	100	
$3d^4$	3F_2	2	18 451.84	77	22 3F_1
		3	18 511.18	77	22
		4	18 583.39	77	21
$3d^4$	3G	3	20 703.64	98	
		4	20 852.95	98	
		5	20 996.04	99	
$3d^4$	1G_2	4	25 138.87	64	35 1G_1
$3d^4$	3D	3	25 726.44	100	
		2	25 780.94	100	
		1	25 848.31	100	

Cr III—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3d ⁴	¹ I	6	26 014.89	100	
3d ⁴	¹ S ₂	0	27 372.32	77	22 ¹ S ₁
3d ⁴	¹ D ₂	2	32 151.99	77	22 ¹ D ₁
3d ⁴	¹ F	3	37 005.16	100	
3d ⁴	³ F ₁	4	43 286.71	79	21 ³ F ₂
		2	43 304.53	77	22
		3	43 322.17	78	22
3d ⁴	³ P ₁	2	43 441.99	59	41 ³ P ₂
		1	43 916.59	59	41
		0	44 141.36	59	41
3d ³ (⁴ F)4s	⁵ F	1	49 492.46	100	
		2	49 628.25	100	
		3	49 828.91	100	
		4	50 091.17	100	
		5	50 410.06	100	
3d ⁴	¹ G ₁	4	49 768.65	65	35 ¹ G ₂
3d ³ (⁴ F)4s	³ F	2	56 651.37	100	
		3	56 993.08	100	
		4	57 423.40	100	
3d ³ (⁴ P)4s	⁵ P	1	63 045.74	100	
		2	63 174.30	99	
		3	63 421.92	100	
3d ⁴	¹ D ₁	2	65 763.21	78	22 ¹ D ₂
3d ³ (² G)4s	³ G	3	65 892.38	100	
		4	66 030.01	100	
		5	66 225.09	99	
3d ³ (⁴ P)4s	³ P	0	69 601.50	59	41 (² P) ³ P
		1	69 781.89	56	34
		2	70 292.86	71	15
3d ³ (² G)4s	¹ G	4	69 659.74	97	
3d ³ (² P)4s	³ P	2	70 191.01	63	26 (⁴ P) ³ P
		1	70 345.56	53	41
		0	70 487.01	59	41
3d ³ (² D ₂)4s	³ D	1	70 981.26	65	19 (² D ₁) ³ D
		3	71 323.06	79	21 (² D ₁) ³ D
		2	71 323.27	59	21 (² P) ³ P

Cr III—Continued

Configuration	Term	J	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3d ³ (² H)4s	³ H	4	71 677.19	97	
		5	71 737.56	99	
		6	71 870.17	100	
3d ³ (² P)4s	¹ P	1	73 881.54	96	
3d ³ (² D ₂)4s	¹ D	2	74 788.88	77	22 (² D ₁) ³ D
3d ³ (² H)4s	¹ H	5	75 351.63	100	
3d ³ (² F)4s	³ F	4	84 374.12	100	
		3	84 484.76	100	
		2	84 572.53	100	
3d ³ (² F)4s	¹ F	3	87 770.68	100	
3d ³ (⁴ F)4p	⁵ G°	2	93 766.21	100	
		3	94 029.99	100	
		4	94 376.29	100	
		5	94 801.70	100	
		6	95 306.09	100	
3d ³ (⁴ F)4p	⁵ F°	1	96 149.25	52	35 (⁴ F) ³ D°
		2	96 386.31	44	29 (⁴ F) ⁵ D°
		3	97 121.42	61	37 (⁴ F) ⁵ D°
		4	97 359.81	73	25 (⁴ F) ⁵ D°
		5	97 619.48	98	
3d ³ (⁴ F)4p	⁵ D°	0	96 693.97	97	
		3	96 714.04	51	35 (⁴ F) ⁵ F°
		1	96 774.38	79	18
		2	96 922.02	56	42
		4	97 098.28	72	26
3d ³ (⁴ F)4p	³ D°	1	97 077.96	57	30 (⁴ F) ⁵ F°
		2	97 306.59	67	13 (⁴ F) ⁵ F°
		3	97 683.99	79	9 (⁴ F) ⁵ D°
3d ³ (⁴ F)4p	³ G°	3	99 841.67	93	5 (² G) ³ G°
		4	100 100.66	93	
		5	100 423.01	92	
3d ³ (⁴ F)4p	³ F°	2	101 444.57	96	
		3	101 746.21	95	
		4	102 100.76	96	
3d ³ (² D ₁)4s	³ D	3	102 236.46	79	21 (² D ₂) ³ D
		2	102 333.49	78	22
		1	102 401.80	77	23
3d ³ (² D ₁)4s	¹ D	2	105 626.89	78	22 (² D ₂) ¹ D

Cr III—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3 <i>d</i> ³ (⁴ P)4 <i>p</i>	⁵ P°	1	108 250.89	99	
		2	108 461.40	98	
		3	108 795.84	99	
3 <i>d</i> ³ (⁴ P)4 <i>p</i>	⁵ D°	0	108 697.63	55	37 (⁴ P) ³ P°
		1	108 864.98	60	34
		2	109 570.89	59	33
		3	109 722.79	96	
		4	110 154.89	97	
3 <i>d</i> ³ (⁴ P)4 <i>p</i>	³ P°	2	108 972.90	52	38 (⁴ P) ⁵ D°
		0	109 458.11	47	41
		1	109 570.62	54	37
3 <i>d</i> ³ (² G)4 <i>p</i>	³ H°	4	109 534.25	85	13 (² H) ³ H°
		5	109 944.98	83	14
		6	110 507.18	85	15
3 <i>d</i> ³ (² G)4 <i>p</i>	³ G°	3	111 376.09	86	5 (⁴ F) ³ G°
		4	111 644.76	89	5
		5	111 856.97	86	5
3 <i>d</i> ³ (² G)4 <i>p</i>	³ F°	4	112 372.88	52	37 (² G) ¹ G°
		2	112 399.84	73	13 (² D ₂) ³ F°
		3	112 467.01	70	8 (² D ₂) ³ F°
3 <i>d</i> ³ (² G)4 <i>p</i>	¹ G°	4	113 115.21	59	30 (² G) ³ F°
3 <i>d</i> ³ (² G)4 <i>p</i>	¹ F°	3	113 328.80	72	12 (² D ₂) ¹ F°
3 <i>d</i> ³ (⁴ P)4 <i>p</i>	⁵ S°	2	113 357.04	95	
3 <i>d</i> ³ (² G)4 <i>p</i>	¹ H°	5	113 419.93	77	18 (² H) ¹ H°
3 <i>d</i> ³ (² P)4 <i>p</i>	¹ D°	2	113 767.13	43	22 (² D ₂) ¹ D°
3 <i>d</i> ³ (² P)4 <i>p</i>	³ P°	0	113 861.47	62	22 (² D ₂) ³ P°
		1	113 899.43	57	23
		2	114 599.14	47	22
3 <i>d</i> ³ (² P)4 <i>p</i>	³ D°	1	114 716.79	70	22 (⁴ P) ³ D°
		2	115 182.15	59	21
		3	115 554.28	48	31
3 <i>d</i> ³ (² H)4 <i>p</i>	³ H°	4	115 571.96	83	13 (² G) ³ H°
		5	115 670.74	85	14
		6	115 844.58	85	15
3 <i>d</i> ³ (² D ₂)4 <i>p</i>	¹ P°	1	116 372.92	30	28 (⁴ P) ³ D°
3 <i>d</i> ³ (² D ₂)4 <i>p</i>	³ F°	2	116 391.66	40	25 (⁴ P) ³ D°
		3	116 969.09	37	32 (² P) ³ D°
		4	117 101.58	68	17 (² D ₁) ³ F°

Cr III—Continued

Configuration	Term	J	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3d ³ (² P)4p	³ S°	1	116 451.19	60	13 (⁴ P) ³ D°
3d ³ (⁴ P)4p	³ D°	3	116 532.95	44	21 (² D2) ³ F°
		1	116 774.00	21	32 (² P) ³ S°
		2	116 782.05	34	31 (² P) ³ D°
3d ³ (² H)4p	³ I°	5	117 145.85	98	
		6	117 488.95	99	
		7	117 923.89	100	
3d ³ (² D2)4p	³ D°	1	118 165.15	69	17 (² D2) ³ F°
		2	118 422.99	72	16
		3	118 599.11	71	15
3d ³ (² H)4p	¹ G°	4	118 900.53	81	15 (² F) ¹ G°
3d ³ (² D2)4p	³ P°	2	119 421.42	41	38 (² P) ³ P°
		1	119 489.02	42	33
		0	119 625.62	45	35
3d ³ (² H)4p	¹ H°	5	119 612.80	78	18 (² G) ¹ H°
3d ³ (² D2)4p	¹ F°	3	119 846.47	61	18 (² D1) ¹ F°
3d ³ (² H)4p	¹ I°	6	120 432.99	99	
3d ³ (² H)4p	³ G°	5	120 700.27	89	
		4	120 749.55	89	
		3	120 767.26	90	
3d ³ (⁴ P)4p	³ S°	1	121 446.77	87	
3d ³ (² P)4p	¹ P°	1	122 396.49	71	17 (² D2) ¹ F°
3d ³ (² D2)4p	¹ D°	2	123 105.84	46	41 (² P) ¹ D°
3d ³ (² F)4p	³ F°	2	128 754.62	95	
		3	128 784.13	94	
		4	128 850.49	94	
3d ³ (² F)4p	³ G°	3	131 116.36	92	5 (² H) ³ G°
		4	131 265.66	92	5 (² H) ³ G°
		5	131 450.16	95	
3d ³ (² F)4p	¹ D°	2	132 070.71	79	18 (² D1) ¹ D°
3d ³ (² F)4p	³ D°	3	132 117.50	92	5 (² D1) ³ D°
		2	132 499.78	91	5
		1	132 734.22	94	5
3d ³ (² F)4p	¹ G°	4	133 969.57	83	15 (² H) ¹ G°
3d ³ (² F)4p	¹ F°	3	134 887.54	94	

Cr III—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3 <i>d</i> ³ (² D1)4 <i>p</i>	³ D°	1	146 936.18	77	19 (² D2) ³ D°
		2	146 973.33	77	18
		3	147 090.73	77	17
3 <i>d</i> ³ (² D1)4 <i>p</i>	¹ D°	2	148 573.81	53	20 (² D2) ¹ D°
3 <i>d</i> ³ (² D1)4 <i>p</i>	³ F°	2	149 344.03	62	20 (² D2) ³ F°
		3	149 383.64	73	23
		4	149 626.30	75	23
3 <i>d</i> ³ (² D1)4 <i>p</i>	³ P°	2	151 351.27	75	23 (² D2) ³ P°
		1	151 687.44	75	24
		0	151 852.12	75	24
3 <i>d</i> ³ (² D1)4 <i>p</i>	¹ F°	3	152 037.21	77	20 (² D) ¹ F°
3 <i>d</i> ³ (⁴ F)4 <i>d</i>	⁵ H	3	152 927.3		
		4	153 099.1		
		5	153 314.6		
		6	153 571.7		
		7	153 871.7		
3 <i>d</i> ³ (² D1)4 <i>p</i>	¹ P°	1	156 929.93	75	24 (² D2) ¹ P°
Cr IV (⁴ F _{3/2})	<i>Limit</i>	.....	249 700		

Cr IV

Sc I isoelectronic sequence

Z=24

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4F_{3/2}$ Ionization energy = $396\,000\text{ cm}^{-1}$ (49.1 eV)

The initial analysis was by White (1929) and was later extended by Bowen (1937). The compilation by C. E. Moore (1952) consists of the unpublished analysis by F. L. Moore. Ekberg (1973) reobserved the spectrum and greatly extended the analysis but reported no levels above $211\,574\text{ cm}^{-1}$. He found thirteen of Moore's levels to be false. In view of this we give the levels reported by Ekberg (1973) and omit the levels given by Moore only. The percentage compositions are from a fitted calculation by Poppe (1976).

The ionization energy is an extrapolated value by Lotz (1967).

References

- Bowen, I. S. (1937), Phys. Rev. **52**, 1153.
 Ekberg, J. O. (1973), Physica Scripta **7**, 55.
 Lotz, W. J. (1967), J. Opt. Soc. Am. **57**, 873.
 Moore, C. E. (1952), Atomic Energy Levels, Vol. II, Natl. Bur. Std. (U.S.)
 Circ. 467 (U.S. Gov't Printing Office, Washington, D.C.)
 Poppe, R. (1976) private communication.
 White, H. E. (1929), Phys. Rev. **33**, 672.

Cr IV

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^3$	$4F$	3/2	0.0	100	
		5/2	235.8	100	
		7/2	555.6	100	
		9/2	945.6	100	
$3d^3$	$4P$	1/2	14 059.0	100	
		3/2	14 177.1	99	
		5/2	14 471.3	100	
$3d^3$	$2G$	7/2	15 051.8	100	
		9/2	15 401.6	99	
$3d^3$	$2P$	3/2	19 438.6	67	25 $2D$
		1/2	19 519.2	100	
$3d^3$	$2D_2$	3/2	20 649.9	52	32 $2P$
		5/2	20 664.3	78	21 $2D_1$
$3d^3$	$2H$	9/2	21 065.9	99	
		11/2	21 320.7	100	
$3d^3$	$2F$	7/2	34 362.8	100	
		5/2	34 555.7	100	
$3d^3$	$2D_1$	5/2	52 975.3	78	21 $2D_2$
		3/2	53 142.0	77	23
$3d^2(3F)4s$	$4F$	3/2	103 994.7	100	
		5/2	104 257.1	100	
		7/2	104 628.6	100	
		9/2	105 104.1	100	
$3d^2(3F)4s$	$2F$	5/2	109 940.2	100	
		7/2	110 690.4	100	

Cr IV—Continued

Configuration	Term	J	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3d ² (¹ D)4s	² D	5/2	118 570.0	68	32 (³ P) ⁴ P°
		3/2	118 726.5	67	33
3d ² (³ P)4s	⁴ P	1/2	119 013.3	100	
		3/2	119 250.6	67	33 (¹ D) ² D°
		5/2	119 670.0	68	32 (¹ D) ² D°
3d ² (³ P)4s	² P	1/2	124 409.2	100	
		3/2	124 732.9	99	
3d ² (¹ G)4s	² G	9/2	127 193.9	100	
		7/2	127 206.3	100	
3d ² (³ F)4p	⁴ G°	5/2	157 359.5	95	
		7/2	157 931.1	97	
		9/2	158 627.5	98	
		11/2	159 448.0	100	
3d ² (³ F)4p	⁴ F°	3/2	158 525.9	96	
		5/2	158 891.2	97	
		7/2	159 350.5	97	
		9/2	159 862.1	97	
3d ² (³ F)4p	² F°	5/2	160 303.9	76	7 (³ F) ² D°
		7/2	160 935.8	80	13 (³ F) ⁴ D°
3d ² (³ F)4p	² D°	3/2	160 985.0	55	29 (³ F) ⁴ D°
		5/2	162 299.6	52	31
3d ² (³ F)4p	⁴ D°	1/2	161 353.4	94	5 (³ P) ⁴ D°
		5/2	161 493.9	58	21 (³ F) ² D°
		3/2	161 754.8	65	25 (³ F) ² D°
		7/2	162 063.3	82	12 (³ F) ² F°
3d ² (³ F)4p	² G°	7/2	164 908.6	95	5 (¹ G) ² G°
		9/2	165 428.9	95	4
3d ² (³ P)4p	² S°	1/2	167 895.1	99	
3d ² (³ P)4p	⁴ S°	3/2	171 079.7	85	14 (¹ D) ² P°
3d ² (¹ D)4p	² P°	3/2	172 182.1	79	14 (³ P) ⁴ S°
		1/2	172 821.6	96	
3d ² (¹ D)4p	² F°	5/2	172 634.7	86	7 (³ F) ² F°
		7/2	173 364.4	83	7 (³ P) ⁴ D°
3d ² (³ P)4p	⁴ D°	1/2	173 430.6	94	5 (³ F) ⁴ D°
		3/2	173 657.9	91	5 (³ F) ⁴ D°
		5/2	174 094.8	87	5 (³ F) ⁴ D°
		7/2	174 844.9	88	7 (¹ D) ² F°
3d ² (¹ D)4p	² D°	3/2	174 538.4	81	6 (³ F) ² D°
		5/2	174 967.4	80	6

Cr IV—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3d ² (³ P)4p	⁴ P°	1/2	176 689.1	99	
		3/2	176 915.3	99	
		5/2	177 405.0	96	
3d ² (¹ G)4p	² G°	7/2	177 914.4	95	5 (³ F) ² G°
		9/2	178 028.1	95	5
3d ² (³ P)4p	² D°	5/2	181 241.5	81	11 (³ F) ² D°
		3/2	181 276.3	79	10
3d ² (¹ G)4p	³ H°	9/2	182 677.7	99	
		11/2	183 442.6	100	
3d ² (³ P)4p	² P°	1/2	183 718.7	99	
		3/2	183 873.9	96	
3d ² (¹ G)4p	² F°	7/2	186 978.8	96	
		5/2	187 516.7	97	
3d ² (¹ S)4p	² P°	1/2	210 556.7	98	
		3/2	211 574.0	98	
3d ² (³ F)4d	⁴ G	5/2	232 573		
		7/2	232 905		
		9/2	233 244		
		11/2	233 655		
3d ² (³ F)4d	⁴ H	7/2	233 365		
		9/2	233 718		
		11/2	234 108		
		13/2	234 508		
Cr v (³ F ₂)	Limit	.....	396 000		

Cr v

CaI isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 \ ^3F_2$ Ionization energy = 560200 cm^{-1} (69.46 eV)

The initial analysis is due to White (1929) who reported levels of the $3d^2$, $3d4s$, $3d4p$, and $3d4d$ configurations. Additions and revisions were made by Cady and Edlén and were communicated to Moore for inclusion in her AEL compilation (1952). The spectrum was completely reobserved by Ekberg (1972) whose results are quoted here. He added the 1S_0 level of $3d^2$ and all the known levels of $3d4d$ and $3d5s$. The one term of $3d4d$ due to White was found to be false.

The ionization energy was derived by Ekberg from the series $3d4s$ and $3d5s$ with an estimated uncertainty of 0.04 eV.

References

- Ekberg, J. O. (1972), *Physica Scripta* **7**, 59.
 Moore, C. E. (1952), *Atomic Energy Levels*, Vol. II, Natl. Bur. Std. (U.S.), Circ. 467 (U.S. Gov't. Printing Office, Washington, D.C.).
 White, H. E. (1929), *Phys. Rev.* **33**, 538.

Cr v

Configuration	Term	J	Level (cm^{-1})
$3d^2$	3F	2	0.0
		3	508.2
		4	1141.7
$3d^2$	1D	2	13 188.0
$3d^2$	3P	0	15 491.8
		1	15 676.6
		2	16 041.0
$3d^2$	1G	4	22 019.2
$3d^2$	1S	0	51 146.4
$3d4s$	3D	1	167 176.4
		2	167 491.0
		3	168 089.5
$3d4s$	1D	2	171 698.1
$3d4p$	$^1D^\circ$	2	226 119.8
$3d4p$	$^3D^\circ$	1	228 001.8
		2	228 489.1
		3	229 120.8
$3d4p$	$^3F^\circ$	2	229 551.7
		3	230 316.3
		4	231 392.9
$3d4p$	$^3P^\circ$	1	234 618.4
		0	234 668.5
		2	234 846.4
$3d4p$	$^1F^\circ$	3	237 529.5
$3d4p$	$^1P^\circ$	1	239 917.5

Cr v—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
3d 4d	¹ F	3	316 674.9
3d 4d	³ D	1	317 893.8
		2	318 227.6
		3	318 601.7
3d 4d	³ G	3	319 119.1
		4	319 516.8
		5	320 074.4
3d 4d	¹ P	1	319 284.0
3d 4d	³ S	1	322 528.1
3d 4d	³ F	2	325 104.1
		3	325 472.5
		4	325 884.2
3d 4d	¹ D	2	329 350.3
3d 4d	³ P	0	330 084.8
		1	330 245.1
		2	330 536.8
3d 4d	¹ G	4	331 811.2
3d 5s	³ D	1	356 744.8
		2	356 981.3
		3	357 675.9
3d 5s	¹ D	2	358 653.8
Cr VI (² D _{3/2})	<i>Limit</i>	.....	560 200

Cr VI

K1 isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 D_{3/2}$ Ionization energy = $731\,020\text{ cm}^{-1}$ (90.636 eV)

The first known terms were found by Gibbs and White (1926, 1929) who reported the positions of the $3p^6 3d^2 D$, $4s^2 S$, and $4p^2 P^\circ$ terms. The $nf^2 F^\circ$ series for $n = 5$ to 10 was identified by Alexander, Feldman, and Fraenkel (1965) and the missing $4f^2 F^\circ$ by Gabriel, Fawcett, and Jordan (1965) who replaced the false levels of this term given earlier by Kruger and Weissberg (1937). The $4p^2 P^\circ - 4d^2 D$ multiplet was found by Fawcett (1970). Observations of open $3p^6$ -core configurations were first reported by Feldman and Fraenkel (1966) who identified the $3p^6 3d - 3p^5 3d 4s$ transition array. Some of these lines were classified by Cowan (1967). Gabriel, Fawcett, and Jordan (1966) classified 6 lines of the $3p^6 3d - 3p^5 3d^2$ group.

The spectrum was reobserved in the range of 400–2500 Å by Ekberg (1973). He interpreted a considerable number of new lines and verified the earlier work. His revisions of the

values for the known levels and his additions to the analysis are quoted here. The ionization energy is derived by Ekberg from the nh series with an estimated uncertainty of $\pm 6\text{ cm}^{-1}$

References

- Alexander, E., Feldman, U., and Fraenkel, B. S. (1965), *J. Opt. Soc. Am.* **55**, 650.
 Cowan, R. D. (1967), *Astrophys. J.* **147**, 377.
 Ekberg, J. O. (1973), *Physica Scripta* **8**, 35.
 Fawcett, B. C. (1970), *J. Phys.* **B3**, 1732.
 Feldman, U., and Fraenkel, B. S. (1966), *Astrophys. J.* **145**, 959.
 Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1965), *Nature* **206**, 390.
 Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1966), *Proc. Phys. Soc. (London)* **87**, 825.
 Gibbs, R. C., and White, H. E. (1926), *Proc. Nat. Acad. Sci. (U.S.)* **12**, 675.
 Gibbs, R. C., and White, H. E. (1929), *Phys. Rev.* **33**, 157.
 Kruger, P. G., and Weissberg, S. G. (1937), *Phys. Rev.* **52**, 314.

Cr VI

Configuration	Term	J	Level (cm^{-1})
$3p^6(1S)3d$	2D	$3/2$	0
		$5/2$	940
$3p^6(1S)4s$	2S	$1/2$	227 857.9
$3p^6(1S)4p$	$^2P^\circ$	$1/2$	296 573.2
		$3/2$	298 396.7
$3p^5(2P^\circ)3d^2(^1G)$	$^2F^\circ$	$5/2$	356 962
		$7/2$	359 165
$3p^5(2P^\circ)3d^2(^1D)$	$^2F^\circ$	$7/2$	371 618
		$5/2$	378 677
$3p^6(1S)4d$	2D	$3/2$	402 661.7
		$5/2$	402 888.6
$3p^5(2P^\circ)3d^2(^3F)$	$^2F^\circ$	$5/2$	440 135.2
		$7/2$	442 945.4
$3p^6(1S)5s$	2S	$1/2$	461 253.0
$3p^6(1S)4f$	$^2F^\circ$	$5/2$	481 956.0
		$7/2$	482 517.1
$3p^6(1S)5p$	$^2P^\circ$	$1/2$	487 589.5
		$3/2$	488 561.9
$3p^5(2P^\circ)3d^2(^3P)$	$^2P^\circ$	$1/2$	493 247.1
		$3/2$	494 911.2
$3p^5(2P^\circ)3d^2(^3F)$	$^2D^\circ$	$5/2$	496 958
		$3/2$	497 495

Cr VI—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
3p ⁶ (¹ S)5d	² D	3/2	534 381.7
		5/2	534 489.7
3p ⁶ (¹ S)6s	² S	1/2	562 064.1
3p ⁶ (¹ S)5f	² F ^o	5/2	568 957.4
		7/2	568 993.0
3p ⁶ (¹ S)5g	² G	7/2	572 272.3
		9/2	572 274.4
3p ⁶ (¹ S)6p	² P ^o	1/2	574 135
		3/2	575 742
3p ⁵ 3d(³ P ^o)4s	² P ^o	1/2	578 566
		3/2	580 697
3p ⁵ 3d(³ F ^o)4s	⁴ F ^o	7/2	584 371
		5/2	586 273
3p ⁵ 3d(³ F ^o)4s	² F ^o	7/2	591 137
		5/2	594 926
3p ⁵ 3d(³ D ^o)4s	⁴ D ^o	7/2	607 615
		5/2	608 631
		3/2	609 166
3p ⁵ 3d(¹ D ^o)4s	² D ^o	5/2	610 497
		3/2	611 568
3p ⁵ 3d(¹ F ^o)4s	² F ^o	5/2	614 385
		7/2	616 079
3p ⁵ 3d(³ D ^o)4s	² D ^o	5/2	618 491
		3/2	619 419
3p ⁶ (¹ S)6f	² F ^o	5/2	618 583
		7/2	618 849
3p ⁶ (¹ S)6g	² G	7/2	620 696.3
		9/2	620 700.5
3p ⁶ (¹ S)6h	² H ^o	9/2,11/2	621 162.9
3p ⁶ (¹ S)7f	² F ^o	5/2	648 521
		7/2	648 533
3p ⁶ (¹ S)7h	² H ^o	9/2,11/2	650 310.8
3p ⁶ (¹ S)8f	² F ^o	5/2,7/2	667 973
3p ⁶ (¹ S)9f	² F ^o	5/2,7/2	681 307
3p ⁶ (¹ S)10f	² F ^o	5/2,7/2	690 781
Cr VII (¹ S ₀)	<i>Limit</i>	.....	731 020

Cr VII

Ar I isoelectronic sequence

Z=24

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^6 1S_0$ Ionization energy = $1\,291\,900\text{ cm}^{-1}$ (160.18 eV)

The levels are taken from an extensive analysis by Ekberg (1976). The few earlier identifications are referenced in his work. The designations and percentage composition for the levels are also from Ekberg. A value for the ionization energy of $1\,291\,900\text{ (600) cm}^{-1}$ was derived by him by extrapolation.

The same value may be derived from the 3-member *ns* series.

Reference

Ekberg, J. O. (1976), *Physica Scripta* 13, 245.

Cr VII

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3s^2 3p^6$	$1S$	0	0.0		
$3s^2 3p^5 3d$	$3P^\circ$	0	341 179.3	100	
		1	342 773.5	100	
		2	346 137.1	99	
$3s^2 3p^5 3d$	$3F^\circ$	4	357 543.7	100	
		3	360 171.9	97	
		2	363 060.9	96	
$3s^2 3p^5 3d$	$1D^\circ$	2	382 682.3	77	19 $3D^\circ$
$3s^2 3p^5 3d$	$3D^\circ$	3	382 737.4	74	26 $1F^\circ$
		1	385 828.3	99	
		2	386 616.6	78	20 $1D^\circ$
$3s^2 3p^5 3d$	$1F^\circ$	3	389 226.2	72	25 $3D^\circ$
$3s^2 3p^5 3d$	$1P^\circ$	1	493 035.4	100	
$3s 3p^6 3d$	$3D$	1	608 679.6	100	
		2	609 142.7	100	
		3	609 887.8	100	
$3s 3p^6 3d$	$1D$	2	627 826.7	100	
$3s^2 3p^5 (2P^\circ_{3/2}) 4s$	$2[3/2]^\circ$	2	668 858.6	100	
		1	672 427.7	85	15 $(2P^\circ_{1/2}) 2[1/2]^\circ$
$3s^2 3p^5 (2P^\circ_{1/2}) 4s$	$2[1/2]^\circ$	0	678 534.7	100	
		1	682 610.2	85	15 $(2P^\circ_{3/2}) 2[3/2]^\circ$
$3s^2 3p^5 4p$	$3S$	1	734 605.3		
$3s^2 3p^5 4p$	$3D$	2	745 328.9		
		3	745 631.1		
		1	748 629.3		

Cr VII—Continued

Configuration	Term	J	Level (cm ⁻¹)	Leading components (%)	
				First	Second
3s ² 3p ⁵ 4p	³ P	2	751 649.3		
		0	757 035.8		
		1	758 572.1		
3s ² 3p ⁵ 4p	¹ P	1	754 378.9		
3s ² 3p ⁵ 4p	¹ D	2	758 374.4		
3s ² 3p ⁵ (² P _{3/2} ^o)4d	² [1/2] ^o	0	856 292.2	100	
		1	857 234.5	75	20 (² P _{3/2} ^o) ² [3/2] ^o
3s ² 3p ⁵ (² P _{3/2} ^o)4d	² [3/2] ^o	2	859 407.1	85	15 (² P _{1/2} ^o) ² [3/2] ^o
		1	866 502.8	79	21 (² P _{3/2} ^o) ² [1/2] ^o
3s ² 3p ⁵ (² P _{3/2} ^o)4d	² [7/2] ^o	4	860 444.3	100	
		3	861 198.4	93	
3s ² 3p ⁵ (² P _{3/2} ^o)4d	² [5/2] ^o	2	864 129.5	88	11 (² P _{1/2} ^o) ² [5/2] ^o
		3	865 155.8	88	6 (² P _{3/2} ^o) ² [7/2] ^o
3s ² 3p ⁵ (² P _{1/2} ^o)4d	² [5/2] ^o	2	872 231.6	88	12 (² P _{3/2} ^o) ² [5/2] ^o
		3	873 146.1	92	7 (² P _{3/2} ^o) ² [5/2] ^o
3s ² 3p ⁵ (² P _{1/2} ^o)4d	² [3/2] ^o	2	873 565.5	85	15 (² P _{3/2} ^o) ² [3/2] ^o
		1	875 380.5	95	
3s ² 3p ⁵ (² P _{3/2} ^o)4f	² [3/2] ^o	1	941 811		
		2	943 149.1		
3s ² 3p ⁵ (² P _{3/2} ^o)4f	² [9/2] ^o	5	944 416.8		
		4	945 475.7		
3s ² 3p ⁵ (² P _{3/2} ^o)4f	² [5/2] ^o	3	944 866.7		
		2	954 623		
3s ² 3p ⁵ (² P _{3/2} ^o)4f	² [7/2] ^o	3	947 917.4		
		4	948 943.9		
3s ² 3p ⁵ (² P _{3/2} ^o)5s	² [3/2] ^o	1	951 122		
3s ² 3p ⁵ (² P _{1/2} ^o)4f	² [7/2] ^o	3	956 454		
		4	957 205.1		
3s ² 3p ⁵ (² P _{1/2} ^o)4f	² [5/2] ^o	3	957 004.6		
3s ² 3p ⁵ (² P _{1/2} ^o)5s	² [1/2] ^o	1	960 366		
3s3p ⁶ 4p	¹ P ^o	1	994 105		
3s ² 3p ⁵ (² P _{3/2} ^o)5d	² [3/2] ^o	1	1 033 485		
3s ² 3p ⁵ (² P _{1/2} ^o)5d	² [3/2] ^o	1	1 042 568		

Cr VII—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3s^23p^5(^2P^{\circ}_{3/2})6s$	$^2[3/2]^{\circ}$	1	1 075 627		
$3s^23p^5(^2P^{\circ}_{1/2})6s$	$^2[1/2]^{\circ}$	1	1 085 446		
Cr VIII ($^2P^{\circ}_{3/2}$)	<i>Limit</i>	.....	1 291 900		

Cr VIII

Cl I isoelectronic sequence

 $Z=24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^5 \ ^2P^{\circ}_{3/2}$ Ionization energy = $1\,490\,000\text{ cm}^{-1}$ (184.7 eV)

All the known levels are derived from transitions to the $3s^2 3p^5 \ ^2P^{\circ}$ ground term. Edlén (1937) identified lines originating from all levels of the $3s^2 3p^4 4s$ configuration except for the $^4P_{1/2}$. Earlier, Weissberg and Kruger (1936) had reported lines from the 2P term of this configuration as well as from the 2S term of $3s 3p^6$. The transitions from $3s^2 3p^4 3d$ were identified by Gabriel, Fawcett, and Jordan (1966) and by Fawcett and Gabriel (1966). Those from $3s^2 3p^4 4d$ were given by Fawcett, Cowan, and Hayes (1972). Line identifications in the $3p^4 4d-3p^4 4f$ transition array were also given in this paper but cannot be used to derive energy levels because they do not combine with known levels.

The recent measurements of the $3s^2 3p^5-3s 3p^6$ doublet by

Smitt, Svensson, and Outred (1976) are used to determine the ground term interval.

The ionization energy is an extrapolated value by Lotz (1967).

References

- Edlén, B. (1937), *Z. Phys.* **104**, 407.
 Fawcett, B. C., and Gabriel, A. H. (1966), *Proc. Phys. Soc.* **88**, 262.
 Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), *J. Phys.* **B5**, 2143.
 Gabriel, A. H., Fawcett B. C., and Jordan, C. (1965), *Nature* **206**, 390.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.
 Smitt, R., Svensson, L. A., and Outred, M. (1976), *Physica Scripta* **13**, 293.
 Weissberg, S. G., and Kruger, P. G. (1936), *Phys. Rev.* **49**, 872.

Cr VIII

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p^5$	$^2P^{\circ}$	3/2	0
		1/2	9892
$3s 3p^6$	2S	1/2	242 065
$3s^2 3p^4(^1D)3d$	2S	1/2	461 540
$3s^2 3p^4(^1D)3d$	2P	3/2	479 310
		1/2	482 910
$3s^2 3p^4(^1D)3d$	2D	5/2	487 780
		3/2	496 170
$3s^2 3p^4(^3P)4s$	4P	5/2	735 880
		3/2	741 060
$3s^2 3p^4(^3P)4s$	2P	3/2	749 640
		1/2	755 740
$3s^2 3p^4(^1D)4s$	2D	5/2	769 240
		3/2	769 550
$3s^2 3p^4(^1S)4s$	2S	1/2	805 260
$3s^2 3p^4(^3P)4d$	2D	5/2	946 200
		3/2	947 300
$3s^2 3p^4(^1P)4d$	2S	1/2	966 400
$3s^2 3p^4(^1D)4d$	2P	3/2	970 600
		1/2	972 200

Cr VII—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
$3s^23p^4(^1D)4d$	² D	5/2	976 100
		3/2	977 400
Cr IX (³ P ₂)	<i>Limit</i>	.....	1 490 000

Cr IX

S I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^4 \ ^3P_2$ Ionization energy = $1\ 688\ 000\ \text{cm}^{-1}$ (209.3 eV)

Edlén (1937) provided the initial spectral classifications by identifying the $3p^4-3p^3 4s$ transitions. Both singlet and triplet levels were detected but not the connection between them.

Classifications in the $3p^4-3p^3 3d$ transition array were made by Gabriel, Fawcett, and Jordan (1965) and by Fawcett and Gabriel (1966). Some new measurements were later provided by Fawcett (1971) as well as two newly classified lines of this group. The $3s 3p^5$ configuration was found by Fawcett (1970). Classified lines of the $3p^4-3p^3 4d$ and $3p^3 3d-3p^3 4f$ arrays were reported by Fawcett, Cowan, and Hayes (1972). The latter array could not be used to derive $3p^3 4f$ levels because of the lack of transitions to known levels.

Smitt, Svensson, and Outred (1976) give improved measurements of the $3s^2 3p^4-3s 3p^5$ transitions. They also found the

intersystem line $^3P_2-^1P^{\circ}_1$ and identified the $^1S_0-^1P_1^{\circ}$ line. The relative positions of all the levels are therefore known.

The ionization energy is an extrapolated value by Lotz (1976).

References

- Edlén, B. (1937), *Z. Phys.* **104**, 188.
 Fawcett, B. C., and Gabriel, A. H. (1966), *Proc. Phys. Soc. (London)* **88**, 262.
 Fawcett, B. C. (1970), *J. Phys.* **B3**, 1732.
 Fawcett, B. C. (1971), *J. Phys.* **B4**, 1577.
 Fawcett, B. C., Cowan, R. D., and Hayes R. W. (1972), *J. Phys.* **B5**, 2143.
 Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1965), *Proc. Phys. Soc.* **87**, 825.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.
 Smitt, R., Svensson, L. A., and Outred, M. (1976), *Physica Scripta* **13**, 293.

Cr IX

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p^4$	3P	2	0
		1	7821
		0	9549
$3s^2 3p^4$	1D	2	30 284
$3s^2 3p^4$	1S	0	66 855
$3s 3p^5$	$^3P^{\circ}$	2	239 068
		1	245 317
		0	249 016
$3s 3p^5$	$^1P^{\circ}$	1	305 561
$3s^2 3p^3(^2D^{\circ}) 3d$	$^3P^{\circ}$	2	454 510
$3s^2 3p^3(^4S^{\circ}) 3d$	$^3D^{\circ}$	3	474 790
		2	479 570
		1	482 760
$3s^2 3p^3(^2D^{\circ}) 3d$	$^1D^{\circ}$	2	493 310
$3s^2 3p^3(^2D^{\circ}) 3d$	$^1F^{\circ}$	3	507 750
$3s^2 3p^3(^2D^{\circ}) 3d$	$^1P^{\circ}$	1	531 880
$3s^2 3p^3(^4S^{\circ}) 4s$	$^3S^{\circ}$	1	821 100
$3s^2 3p^3(^2D^{\circ}) 4s$	$^3D^{\circ}$	1	845 900
		2	846 260
		3	847 870

Cr IX—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
$3s^23p^3(^2D^\circ)4s$	$^1D^\circ$	2	854 730
$3s^23p^3(^2P^\circ)4s$	$^1P^\circ$	1	881 810
$3s^23p^3(^4S^\circ)4d$	$^3D^\circ$	2	1 028 500
		3	1 028 900
		1	1 029 100
$3s^23p^3(^2D^\circ)4d$	$^1D^\circ$	2	1 066 800
$3s^23p^3(^2D^\circ)4d$	$^1F^\circ$	3	1 070 100
$3s^23p^34d$	$^1P^\circ$	1	1 102 600
Cr X ($^4S_{3/2}$)	<i>Limit</i>	.....	1 688 000

Cr X

P1 isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^3 \ ^4S_{3/2}$ Ionization energy = $1\ 971\ 000\ \text{cm}^{-1}$ (244.4 eV)

The levels of $3s3p^4$ are due to Smitt, Svensson, and Outred (1976) who gave improved measurements and additional classifications in the $3s^2 3p^3$ - $3s3p^4$ array, previously interpreted by Fawcett and Peacock (1967) and by Fawcett (1970). The important $^4S^\circ$ - $^2P^\circ$ forbidden lines of the $3s^2 3p^3$ configuration, which unify the term systems, were identified by Feldman and Doschek (1976) in solar coronal spectra. Transitions from $3p^2 3d$ to the ground configuration were identified by Gabriel, Fawcett, and Jordan (1966), Fawcett, Gabriel, and Saunders (1967), and most completely by Fawcett (1970). Lines of the $3s^2 3p^3$ - $3s^2 3p^2 4s$ array were classified by Fawcett, Cowan, and Hayes (1972). These authors also identified lines arising from the $3p^2 4f$ configuration but the lower levels have not been determined.

The ionization energy was obtained by Lotz (1967) by extrapolation.

References

- Fawcett, B. C., Gabriel, A. H., and Saunders, P. A. H. (1967), Proc. Phys. Soc. **90**, 863.
 Fawcett, B. C., and Peacock, N. J. (1967), Proc. Phys. Soc. **91**, 973.
 Fawcett, B. C. (1970), J. Phys. **B3**, 1732.
 Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5**, 2143.
 Feldman, U., and Doschek, G. A. (1976), Private Communication.
 Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1966), Proc. Phys. Soc. **87**, 825.
 Lotz, W. J. (1967), J. Opt. Soc. Am. **57**, 873.
 Smitt, R., Svensson, L. A., and Outred, M. (1976), Physica Scripta **13**, 293.

Cr X

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p^3$	$^4S^\circ$	$3/2$	0
$3s^2 3p^3$	$^2D^\circ$	$3/2$	37 103
		$5/2$	39 450
$3s^2 3p^3$	$^2P^\circ$	$1/2$	63 935
		$3/2$	67 157
$3s3p^4$	4P	$5/2$	233 890
		$3/2$	239 987
		$1/2$	242 922
$3s3p^4$	2D	$3/2$	289 637
		$5/2$	290 606
$3s3p^4$	2P	$3/2$	333 412
		$1/2$	337 370
$3s3p^4$	2S	$1/2$	348 760
$3s^2 3p^2(^3P)3d$	2P	$3/2$	432 830
		$1/2$	440 870
$3s^2 3p^2(^3P)3d$	4P	$5/2$	442 010
		$3/2$	444 960
		$1/2$	446 710
$3s^2 3p^2(^1D)3d$	2D	$5/2$	476 680
		$3/2$	476 820
$3s^2 3p^2(^1D)3d$	2P	$1/2$	491 650
		$3/2$	496 430

Cr x—Continued

Configuration	Term	J	Level (cm^{-1})
$3s^23p^2(^3P)3d$	2F	$7/2$	500 880
$3s^23p^2(^3P)3d$	2D	$5/2$	519 280
		$3/2$	520 820
$3s^23p^2(^3P)4s$	4P	$1/2$	928 500
		$3/2$	933 400
		$5/2$	939 100
$3s^23p^2(^3P)4s$	2P	$1/2$	943 300
		$3/2$	949 800
$3s^23p^2(^1D)4s$	2D	$5/2$	967 000
		$3/2$	967 800
Cr XI (3P_0)	<i>Limit</i>	.....	1 971 000

Cr XI

SiI isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^2 \ ^3P_0$ Ionization energy = $2\ 184\ 000\ \text{cm}^{-1}$ (270.8 eV)

Fawcett (1970, 1971) gave the first interpretation of the $3s^2 3p^2$ – $3s 3p^3$ array. The level values were later revised by Smitt, Svensson, and Outred (1976) on the basis of their more accurate measurements. The connection between the singlet and triplet systems results from this later work and from the solar coronal line at $3996.8\ \text{\AA}$ (air) identified by Jefferies (1969) as arising from the forbidden 1D_2 – 3P_2 transition in $3s^2 3p^2$.

The levels of $3s^2 3p 3d$ are from Fawcett (1971). Those of $3s^2 3p 4s$ and $3s^2 3p 4d$ are due to Fawcett, Cowan, and Hayes

(1972). In table I of this reference the line given as $98.48\ \text{\AA}$ must be changed to $99.48\ \text{\AA}$ to fit its classification.

The ionization energy was extrapolated by Lotz (1967).

References

- Fawcett, B. C. (1970), *J. Phys.* **B3**, 1732.
 Fawcett, B. C. (1971), *J. Phys.* **B4**, 1577.
 Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), *J. Phys.* **B5**, 2143.
 Jefferies, J. T. (1969), *Mem. Soc. Roy. Sci. Liege, Collect.* **8**, **17**, 213.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.
 Smitt, R., Svensson, L. A., and Outred, M. (1976), *Physica Scripta* **13**, 293.

Cr XI

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p^2$	3P	0	0
		1	5536
		2	11 980
$3s^2 3p^2$	1D	2	36 994
$3s 3p^3$	$^3D^\circ$	1	242 346
		2	242 456
		3	243 916
$3s 3p^3$	$^3P^\circ$	0	278 059
		1	278 394
		2	278 698
$3s 3p^3$	$^1D^\circ$	2	306 570
$3s 3p^3$	$^3S^\circ$	1	356 424
$3s 3p^3$	$^1P^\circ$	1	372 498
$3s^2 3p 3d$	$^3P^\circ$	2	418 980
		1	425 480
$3s^2 3p 3d$	$^1D^\circ$	2	427 090
$3s^2 3p 3d$	$^3D^\circ$	1	434 240
		2	436 210
		3	436 550
$3s^2 3p 3d$	$^1F^\circ$	3	478 590
$3s^2 3p 4s$	$^3P^\circ$	0	1 008 800
		1	1 010 700
		2	1 021 100
$3s^2 3p 4s$	$^1P^\circ$	1	1 028 100

Cr XI—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
3s ² 3p4d	³ D°	3	1 237 900
3s ² 3p4d	¹ F°	3	1 255 500
Cr XII (² P° _{1/2})	<i>Limit</i>	.....	2 184 000

Cr XII

All isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 3p^2 P_{1/2}^{\circ}$ Ionization energy = 2 404 000 cm^{-1} (298.0 eV)

The $3p-4d$ doublet was identified by Edlén (1936). Thirty years later new observations of this spectrum by Gabriel, Fawcett, and Jordan (1966) resulted in the discovery of the $3p-3d$ doublet. The non-diagonal line of this multiplet was identified by Fawcett, Gabriel, and Saunders (1967) by means of a laser-produced plasma.

The 2P and 2D terms of the low-lying $3s3p^2$ configuration were first reported by Fawcett and Peacock (1967) again utilizing a laser plasma. Fawcett (1970) revised the classification of the $3s^2 3p^2 P^{\circ}-3s3p^2 D$ multiplet and added the $^2P^{\circ}-^2S$ lines. He also reported the $^4P-^4S^{\circ}$ lines of the $3s3p^2-3p^3$ array. The quartet term position relative to the doublet system is not observed or predicted and therefore cannot be included here.

Fawcett (1971) later revised the wavelengths of the $3s^2 3p-3s3p^2$ array from new plates taken with the theta pinch source. His value of 412.46 Å for the $^2P_{3/2}^{\circ}-^2D_{3/2}$ line is inconsistent with the $^2P_{1/2}^{\circ}-^2D_{3/2}$ principal line and was not used here. He also reported the $3p-3d$ doublet of the same array. Calculated wavelengths enabled Fawcett, Cowan, Kononov, and Hayes (1972) to identify more lines from the theta

pinch spectrum. They classified the $3d-4f$ doublet and several quartet transitions unconnected with the doublets.

The ground term $^2P^{\circ}$ splitting is obtained from the solar coronal line 8153.8 Å classified by Jefferies (1969).

The value for the ionization energy was obtained by extrapolation by Lotz (1967).

References

- Edlén, B. (1936), *Z. Phys.* **103**, 536.
 Fawcett, B. C., Gabriel, A. H., and Saunders, P. A. H. (1967), *Proc. Phys. Soc.* **90**, 863.
 Fawcett, B. C., and Peacock, N. J. (1967), *Proc. Phys. Soc.* **91**, 973.
 Fawcett, B. C. (1970), *J. Phys.* **B3**, 1732.
 Fawcett, B. C. (1971), *J. Phys.* **B4**, 1577.
 Fawcett, B. C., Cowan, R. D., Kononov, E. Y., and Hayes, R. W. (1972), *J. Phys.* **B5**, 1255.
 Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1966), *Proc. Phys. Soc.* **87**, 825.
 Jefferies, J. T. (1969), *Mem. Soc. Roy. Sci. Liege, Collect.* **8**, **17**, 213.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.

Cr XII

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p$	$^2P^{\circ}$	1/2	0
		3/2	12 261
$3s3p^2$	2D	3/2	254 450
		5/2	255 620
$3s3p^2$	2S	1/2	313 600
$3s3p^2$	2P	1/2	333 240
		3/2	339 250
$3s^2 3d$	2D	3/2	408 700
		5/2	409 840
$3s^2 4d$	2D	3/2	1 319 000
		5/2	1 319 660
$3s^2 4f$	$^2F^{\circ}$	5/2	1 395 000
		7/2	1 395 400
Cr XIII (1S_0)	<i>Limit</i>	.....	2 404 000

Cr XIII

Mg I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 {}^1S_0$ Ionization energy = $2\,862\,000\text{ cm}^{-1}$ (354.8 eV)

The $3s^2 {}^1S_0$ - $3s4p {}^1P_1^\circ$ resonance line was identified by Edlén (1936). He also reported two unconnected triplet systems, one containing levels of $3s3p$, $3s4s$, $3s4d$, and $3s5d$, and the other $3s3d$, $3s4f$, and $3s5f$. The analysis was resumed thirty years later by Fawcett, Gabriel, and Saunders (1967) who unified the triplets by discovering the $3s3p {}^3P^\circ$ - $3s3d {}^3D$ multiplet. They also identified the resonance line $3s^2 {}^1S_0$ - $3s3p {}^1P_1^\circ$. An interpolated value for the position of $3s3p {}^3P_1^\circ$ relative to the ground state was given by Ekberg (1971) and was adopted in the present compilation.

The analysis was extended to $3p^2$ by Fawcett and Peacock (1967) who identified the $3s3p {}^3P^\circ$ - $3p^2 {}^3P$ multiplet. Fawcett (1970) later found the 1S_0 of $3p^2$, the 1D_2 of $3s3d$ and all the levels of $3p3d$ presently known.

The analysis was augmented by Fawcett, Cowan, Kononov, and Hayes (1972) with their identification of transitions from $3s4f {}^1F_3^\circ$, $3s4d {}^1D_2$, and levels of $3p4f$. Some of the last group

are not connected to known levels and are therefore not used here.

Improved measurements of the $3s3p {}^3P^\circ$ - $3s3d {}^3D$ multiplet were made by Fawcett, Cowan, and Hayes (1972). In addition, they reported the 1D_2 of $3s3d$ and the 1D_2 of $3p^2$.

The ionization energy is an extrapolated value obtained by Lotz (1967).

References

- Edlén, B. (1936), *Z. Phys.* **103**, 536.
 Ekberg, J. O. (1971), *Physica Scripta* **4**, 101.
 Fawcett, B. C., Gabriel, A. H., and Saunders, P. A. H. (1967), *Proc. Phys. Soc.* **90**, 863.
 Fawcett, B. C., and Peacock, N. J. (1967), *Proc. Phys. Soc.* **91**, 973.
 Fawcett, B. C. (1970), *J. Phys.* **B3**, 1732.
 Fawcett, B. C., Cowan, R. D., Kononov, E. Y., and Hayes, R. W. (1972), *J. Phys.* **B5**, 1255.
 Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), *J. Phys.* **B5**, 2143.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.

Cr XIII

Configuration	Term	J	Level (cm^{-1})
$3s^2$	1S	0	0
$3s3p$	${}^3P^\circ$	0	201 810+x
		1	205 740+x
		2	214 930+x
$3s3p$	${}^1P^\circ$	1	304 610
$3p^2$	3P	0	480 500+x
		1	486 590+x
		2	497 560+x
$3p^2$	1D	2	483 150
$3p^2$	1S	0	569 440
$3s3d$	3D	1	586 920+x
		2	587 550+x
		3	588 440+x
$3s3d$	1D	2	662 240
$3p3d$	${}^3F^\circ$	2	803 560+x
		3	809 890+x
		4	817 250+x
$3p3d$	${}^3P^\circ$	2	855 570+x
$3p3d$	${}^3D^\circ$	3	859 350+x

Cr XIII—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
3p3d	¹ P°	1	885 300
3s4s	³ S	1	1 383 620+x
3s4p	¹ P°	1	1 492 920
3s4d	³ D	1	1 614 400+x
		2	1 614 800+x
		3	1 615 530+x
3s4d	¹ D	2	1 617 500
3s4f	³ F°	2	1 676 850+x
		3	1 676 970+x
		4	1 677 110+x
3s4f	¹ F°	3	1 690 800
3p4f	¹ F	3	1 914 480+x
3p4f	³ G	4	1 918 900+x
		5	1 928 480+x
3p4f	³ F	4	1 929 780+x
3p4f	³ D	3	1 939 180+x
3s5d	³ D	2	2 074 690+x
		3	2 074 880+x
3s5f	³ F°	4	2 104 330+x
Cr XIV (² S _{1/2})	<i>Limit</i>	.....	2 862 000

Cr XIV

Na I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 3s^2 S_{1/2}$ Ionization energy = $3\,098\,500\text{ cm}^{-1}$ (384.17 eV)

Edlén (1936) reported three independent systems of doublets: $3s\text{-}np$, $3p\text{-}nd$ (and $3p\text{-}4s$), and $3d\text{-}nf$. These were unified by Fawcett and Peacock (1967) who identified the $3s\text{-}3p$ and $3p\text{-}3d$ doublets. This permitted us to determine the ionization energy from the three member nf series with an estimated uncertainty of $\pm 700\text{ cm}^{-1}$. The remeasured $3p\text{-}3d$ doublet by Fawcett, Cowan, and Hayes (1972) was used in the

present compilation. The $2p^5 3s^2 {}^2P^\circ$ term was found by Feldman and Cohen (1967).

References

- Edlén, B. (1936), *Z. Phys.* **100**, 621.
 Fawcett, B. C., and Peacock, N. J. (1967), *Proc. Phys. Soc.* **91**, 973.
 Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), *J. Phys.* **B5**, 2143.
 Feldman, U., and Cohen, L. (1967), *J. Opt. Soc. Am.* **57**, 1128.

Cr XIV

Configuration	Term	J	Level (cm^{-1})
$2p^6 3s$	2S	1/2	0
$2p^6 3p$	${}^2P^\circ$	1/2	242 720
		3/2	256 540
$2p^6 3d$	2D	3/2	587 870
		5/2	589 570
$2p^6 4s$	2S	1/2	1 478 520
$2p^6 4p$	${}^2P^\circ$	1/2	1 573 840
		3/2	1 579 180
$2p^6 4d$	2D	3/2	1 700 580
		5/2	1 701 350
$2p^6 4f$	${}^2F^\circ$	5/2	1 749 890
		7/2	1 750 140
$2p^6 5s$	2S	1/2	2 102 810
$2p^6 5p$	${}^2P^\circ$	1/2	2 149 290
		3/2	2 152 020
$2p^6 5d$	2D	3/2	2 210 410
		5/2	2 210 730
$2p^6 5f$	${}^2F^\circ$	5/2	2 235 340
		7/2	2 235 500
$2p^6 6s$	2S	1/2	2 424 510
$2p^6 6p$	${}^2P^\circ$	1/2	2 450 980
		3/2	2 452 060
$2p^6 6d$	2D	3/2	2 485 030
		5/2	2 485 240

Cr XIV—Continued

Configuration	Term	J	Level (cm^{-1})
$2p^66f$	$^2F^\circ$	5/2	2 499 140
		7/2	2 499 310
$2p^67s$	2S	1/2	2 612 080
$2p^67p$	$^2P^\circ$	1/2,3/2	2 629 090
$2p^67d$	2D	3/2	2 649 120
		5/2	2 649 570
$2p^67f$	$^2F^\circ$	5/2	2 658 260
		7/2	2 658 330
$2p^68p$	$^2P^\circ$	1/2,3/2	2 742 280
$2p^68d$	2D	3/2	2 755 540
		5/2	2 755 410
$2p^68f$	$^2F^\circ$	7/2	2 761 640
$2p^69d$	2D	3/2	2 828 110
		5/2	2 827 300
$2p^53s^2$	$^2P^\circ$	3/2	4 593 500
		1/2	4 658 300
Cr xv (1S_0)	<i>Limit</i>	.....	3 098 500

Cr XV

Ne I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^6 \ ^1S_0$ Ionization energy = 8 151 000 cm^{-1} (1010.6 eV)

Only resonance lines are classified for this ion. Tyrén (1938) identified the lines due to the $2s^2 2p^5 3s$, $3d$ and $4d$ as well as the $2s 2p^6 3p$ levels. Swartz, Kastner, Rothe, and Neupert (1971) tentatively identified $2s^2 2p^5 4s$, $4d$, $5d$, and $6d$. They note that the identification of $2s^2 2p^5 4s$ is doubtful; it is therefore omitted here. We obtained the jl -coupling designations for levels of the $2p^5 nd$ configurations from a comparison with similar rare gas spectra.

Kastner, Behring, and Cohen (1975) identified transitions between $2p^5 3p$ and $2p^5 4d$ but there is no connection with known levels.

We derived the ionization energy from the $2s^2 2p^5 ({}^2P_{3/2}^\circ) nd \ ^2[3/2]$, series for $n = 3, 4, 5$. The $n = 6$ term does not fit well to a series calculation. The estimated uncertainty in the series limit is $\pm 5000 \text{ cm}^{-1}$.

References

- Kastner, S. O., Behring, W. E., and Cohen, L. (1975), *Astrophys. J.* **199**, 777.
 Swartz, M., Kastner, S., Rothe, E., and Neupert, W. (1971), *J. Phys.* **B4**, 1747.
 Tyrén, F. (1938), *Z. Phys.* **111**, 314.

Cr xv

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^6$	1S	0	0
$2s^2 2p^5 ({}^2P_{3/2}^\circ) 3s$	$(3/2, 1/2)^\circ$	1	4 727 500
$2s^2 2p^5 ({}^2P_{1/2}^\circ) 3s$	$(1/2, 1/2)^\circ$	1	4 793 200
$2s^2 2p^5 ({}^2P_{3/2}^\circ) 3d$	$^2[1/2]^\circ$	1	5 259 000
$2s^2 2p^5 ({}^2P_{3/2}^\circ) 3d$	$^2[3/2]^\circ$	1	5 324 200
$2s^2 2p^5 ({}^2P_{1/2}^\circ) 3d$	$^2[3/2]^\circ$	1	5 406 300
$2s 2p^6 3p$	$^3P^\circ$	1	5 894 500
$2s 2p^6 3p$	$^1P^\circ$	1	5 921 000
$2s^2 2p^5 ({}^2P_{3/2}^\circ) 4d$	$^2[3/2]^\circ$	1	6 576 000
$2s^2 2p^5 ({}^2P_{1/2}^\circ) 4d$	$^2[3/2]^\circ$	1	6 641 000
$2s^2 2p^5 ({}^2P_{3/2}^\circ) 5d$	$^2[3/2]^\circ$	1	7 148 000
$2s^2 2p^5 ({}^2P_{1/2}^\circ) 5d$	$^2[3/2]^\circ$	1	7 215 000
$2s^2 2p^5 ({}^2P_{3/2}^\circ) 6d$	$^2[3/2]^\circ$	1	7 452 000
$2s^2 2p^5 ({}^2P_{1/2}^\circ) 6d$	$^2[3/2]^\circ$	1	7 524 000
Cr XVI (${}^2P_{3/2}^\circ$)	<i>Limit</i>	.....	8 151 000

Cr XVI

F I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^5 \ ^2P_{3/2}^\circ$ Ionization energy = $8\,850\,000\text{ cm}^{-1}$ (1097 eV)

Cohen, Feldman, and Kastner (1968) classified many lines of the $2s^2 2p^5 - 2s^2 2p^4 3s$ and $3d$ transition arrays. This work was revised and extended by Feldman, Doschek, Cowan, and Cohen (1973) who also included energy level values. Since they used only resonance lines to evaluate the levels, we derived new values from their list of classified lines. The ground term $2s^2 2p^5 \ ^2P^\circ$ interval was obtained by Fawcett (1971) from his identification of the $1s^2 2s^2 2p^5 - 1s^2 2s 2p^6$ doublet at $\sim 100\text{ \AA}$, in agreement with the value provided by Feldman et al. (1973) from much shorter wavelength data. We used the new measurements of these lines by Doschek, Feldman, Cowan, and Cohen (1974) in combination with the data of Feldman et al. (1973) to derive the levels.

The $2s^2 2p^6 \ ^2S_{1/2} - 2s^2 2p^5 3s \ ^2P^\circ$ multiplet is from Feldman et al. (1973).

The ionization energy was obtained by extrapolation by Lotz (1967).

References

- Cohen, L., Feldman, U., and Kastner, S. O. (1968), *J. Opt. Soc. Am.* **58**, 331.
 Doschek, G. A., Feldman, U., Cowan, R. D., and Cohen, L. (1974), *Astrophys. J.* **188**, 417.
 Fawcett, B. C. (1971), *J. Phys.* **B4**, 981.
 Feldman, U., Doschek, G. A., Cowan, R. D., and Cohen, L. (1973), *J. Opt. Soc. Am.* **63**, 1445.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.

Cr XVI

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^5$	$^2P^\circ$	$3/2$	0
		$1/2$	70 800
$2s^2 2p^6$	2S	$1/2$	937 900
$2s^2 2p^4(^3P)3s$	4P	$5/2$	5 048 700
		$3/2$	5 072 300
		$1/2$	5 109 300
$2s^2 2p^4(^3P)3s$	2P	$3/2$	5 118 200
		$1/2$	5 143 400
$2s^2 2p^4(^1D)3s$	2D	$5/2$	5 193 500
		$3/2$	5 196 100
$2s^2 2p^4(^1S)3s$	2S	$1/2$	5 323 500
$2s^2 2p^4(^3P)3d$	4P	$1/2$	5 607 600
		$3/2$	5 620 600
		$5/2$	5 640 200
$2s^2 2p^4(^3P)3d$	4F	$5/2$	5 622 700
$2s^2 2p^4(^3P)3d$	2P	$1/2$	5 628 500
		$3/2$	5 671 200
$2s^2 2p^4(^3P)3d$	2D	$3/2$	5 648 100
		$5/2$	5 680 800
$2s^2 2p^4(^3P)3d$	2F	$5/2$	5 659 000
$2s^2 2p^4(^1D)3d$	2S	$1/2$	5 734 600
$2s^2 2p^4(^1D)3d$	2P	$3/2$	5 756 200

Cr XVI—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
$2s^2 2p^4(^1D)3d$	² D	5/2	5 757 100
		3/2	5 780 500
$2s^2 2p^4(^1S)3d$	² D	5/2	5 857 200
		3/2	5 870 600
$2s^2 2p^5(^3P^{\circ})3s$	² P [°]	3/2	5 950 200
		1/2	5 986 600
Cr XVII (³ P ₂)	<i>Limit</i>	.....	8 850 000

Cr XVII

O I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^4 \ ^3P_2$ Ionization energy = $9\,560\,000\text{ cm}^{-1}$ (1185 eV)

The splitting of the ground term is known from the line classifications of Fawcett (1971) for the transitions $2s^2 2p^4 - 2s 2p^5$. The $^1P^\circ$ term of the latter configuration is given relative to an estimated position of $2s^2 2p^4 \ ^1D_2$ by Edlén (1972). Doschek, Feldman, and Cohen (1973) classified the lines of the array $2s^2 2p^4 - 2s^2 2p^3 3s$ but found no connection between the singlets and triplets. They also identified the 1S_0 of $2s^2 2p^4$. The $2s^2 2p^3 3d$ levels are due to Fawcett and Hayes (1975). The transition $2s 2p^5 \ ^1P_1^\circ - 2p^6 \ ^1S_0$ was reported by Doschek, Feldman, Davis, and Cowan (1975).

The value for the ionization energy was derived by Lotz (1967) by extrapolation.

References

- Doschek, G. A., Feldman, U., and Cohen, L. (1973), *J. Opt. Soc. Am.* **63**, 1463.
 Doschek, G. A., Feldman, U., Davis, J., and Cowan, R. D. (1975), *Phys. Rev.* **A12**, 980.
 Edlén, B. (1972), *Sol. Phys.* **24**, 356.
 Fawcett, B. C. (1971), *J. Phys.* **B4**, 981.
 Fawcett, B. C., and Hayes, R. W. (1975), *Mon. Not. R. Astr. Soc.* **170**, 185.
 Lotz, W. J. (1967), *J. Opt. Soc. Am.* **57**, 873.

Cr XVII

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^4$	3P	2	0
		0	58 140
		1	60 370
$2s^2 2p^4$	1D	2	135 650+x
$2s^2 2p^4$	1S	0	263 200+x
$2s 2p^5$	$^3P^\circ$	2	813 600
		1	858 140
		0	887 910
$2s 2p^5$	$^1P^\circ$	1	1 116 600+x
$2p^6$	1S	0	1 887 300+x
$2s^2 2p^3(^4S^\circ)3s$	$^3S^\circ$	1	5 453 800?
$2s^2 2p^3(^2D^\circ)3s$	$^3D^\circ$	1	5 546 900?
		2	5 549 400
		3	5 568 900
$2s^2 2p^3(^2D^\circ)3s$	$^1D^\circ$	2	5 589 400?+x
$2s^2 2p^3(^2P^\circ)3s$	$^1P^\circ$	1	5 701 000+x
$2s^2 2p^3(^4S^\circ)3d$	$^3D^\circ$	3	5 948 500
$2s^2 2p^3(^2D^\circ)3d$	$^3D^\circ$	2	6 070 000
		3	6 075 000
$2s^2 2p^3(^2D^\circ)3d$	$^1F^\circ$	3	6 125 100+x
$2s^2 2p^3(^2P^\circ)3d$	$^3P^\circ$	2	6 131 000

Cr xvii—Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)
2s ² 2p ³ (² P°)3d	³ D°	3	6 164 800
		1	6 189 000
		2	6 214 600
Cr xviii (4S° _{3/2})	<i>Limit</i>	.....	9 560 000

Cr XVIII

N I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^3 \ ^4S_{3/2}$ Ionization energy = $10\,480\,000\text{ cm}^{-1}$ (1299 eV)

Four lines of the $2s^2 2p^3 \ ^2D^\circ - 2s 2p^4 (^2P, \ ^2D)$ multiplets were classified by Fawcett (1971). The analysis of this transition array was extended and partly revised by Doschek, Feldman, Cowan, and Cohen (1974). The position of the doublets relative to ground state is based on the estimated position of $2s^2 2p^3 \ ^2P_{1/2}^\circ$ by Fawcett (1975). The $^2S_{1/2}$ of $2s 2p^4$ was later reported by Feldman, Doschek, Cowan, and Cohen (1975). Fawcett and Hayes (1975) classified the resonance line arising from $2s^2 2p^2 (^3P) 3d \ ^4P_{5/2}$ and observed the $2s^2 2p^2 (^1D) 3d \ ^2F_{7/2}$ level of the doublet system. They also located the $2p^5$ configuration from transitions to $2s 2p^4 \ ^2D$. The $^2D_{3/2} - ^2P_{3/2}^\circ$ line of this multiplet was reported by Doschek, Feldman, Davis, and Cowan (1975).

The ionization energy was obtained by Lotz (1967) by extrapolation.

References

- Doschek, G. A., Feldman, U., Cowan, R. D., and Cohen, L. (1974), *Astrophys. J.* **188**, 417.
 Doschek, G. A., Feldman, U., Davis, J., and Cowan, R. D. (1975), *Phys. Rev.* **A12**, 980.
 Fawcett, B. C., (1971), *J. Phys.* **B4**, 981.
 Fawcett, B. C., (1975), *At. Data. Nucl. Data Tables* **16**, 135.
 Fawcett, B. C., and Hayes, R. W. (1975), *Mon. Not. R. Astr. Soc.* **170**, 185.
 Feldman, U., Doschek, G. A., Cowan, R. D., and Cohen, L. (1975), *Astrophys. J.* **196**, 613.
 Lotz, W. (1967), *J. Opt. Soc. Am.* **57**, 873.

Cr XVIII

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^3$	$^4S^\circ$	3/2	0
$2s^2 2p^3$	$^2D^\circ$	3/2	119 900+x
		5/2	144 600+x
$2s^2 2p^3$	$^2P^\circ$	1/2	220 000+x
		3/2	258 300+x
$2s 2p^4$	4P	5/2	668 200
		3/2	715 000
		1/2	732 500
$2s 2p^4$	2D	3/2	916 800+x
		5/2	925 400+x
$2s 2p^4$	2S	1/2	1 056 000+x
$2s 2p^4$	2P	3/2	1 097 200+x
		1/2	1 164 000+x
$2p^5$	$^2P^\circ$	3/2	1 732 900+x
		1/2	1 807 500+x
$2s^2 2p^2 (^3P) 3d$	4P	5/2	6 443 000
$2s^2 2p^2 (^1D) 3d$	2F	7/2	6 555 000+x
Cr XIX (3P_0)	<i>Limit</i>	.....	10 480 000

Cr XIX

C I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^2 \ ^3P_0$ Ionization energy = $11\,260\,000\text{ cm}^{-1}$ (1396 eV)

All observed levels are due to the analysis of Feldman, Doschek, Cowan, and Cohen (1975). They did not find the connection between singlets and triplets. The predicted position of the $2s^2 2p^2 \ ^1D_2$ level was given by Fawcett and Cowan (1975).

The value for the ionization energy was extrapolated by Lotz (1967).

References

- Fawcett, B. C., and Cowan, R. D. (1975), *Mon. Not. R. Astr. Soc.* **171**, 1.
 Feldman, U., Doschek, G. A., Cowan, R. D., and Cohen, L. (1975), *Astrophys. J.* **196**, 613.
 Lotz, W. (1967), *J. Opt. Soc. Am.* **57**, 873.

Cr XIX

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2$	3P	0	0
		1	47 800
		2	82 300
$2s^2 2p^2$	1D	2	185 300+x
$2s 2p^3$	$^3D^\circ$	2	671 600
		3	686 670
$2s 2p^3$	$^3P^\circ$	2	804 700
$2s 2p^3$	$^3S^\circ$	1	959 600
$2s 2p^3$	$^1D^\circ$	2	977 100+x
$2s 2p^3$	$^1P^\circ$	1	1 091 300+x
$2p^4$	3P	2	1 450 000
		1	1 514 300
Cr XX ($^2P^\circ_{1/2}$)	<i>Limit</i>	.....	11 260 000

Cr XX

B I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 2p^2 P^{\circ}_{1/2}$ Ionization energy = $12\,070\,000\text{ cm}^{-1}$ (1496 eV)

The levels are obtained from the identification of the $2s^2 2p^2 P^{\circ} - 2s 2p^2 P$ multiplet by Doschek, Feldman, and Cohen (1975) and by Fawcett and Hayes (1975).

The value for the ionization energy was extrapolated by Lotz (1967).

References

- Doschek, G. A., Feldman, U., and Cohen, L. (1975), J. Opt. Soc. Am. **65**, 463.
 Fawcett, B. C. and Hayes, R. W. (1975), Mon. Not. R. Astr. Soc. **170**, 185.
 Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.

Cr XX

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p$	$2P^{\circ}$	1/2	0
		3/2	83 000
$2s 2p^2$	$2P$	1/2	847 800
		3/2	861 600
Cr XXI ($1S_0$)	<i>Limit</i>	.....	12 070 000

Cr XXI

Be I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 \ ^1S_0$ Ionization energy = $13\ 180\ 000\ \text{cm}^{-1}$ (1634 eV)

Widing (1975) classified the resonance line arising from $2s2p \ ^3P_1^o$. The $^3P_0^o$ and $^3P_2^o$ of $2s2p$ are from the predicted fine structure splitting by Goldsmith, Oren, Crooker, and Cohen (1973). Fawcett and Hayes have identified two lines of the $2s2p \ ^3P^o - 2s3d \ ^3D$ multiplet.

The ionization energy is extrapolated by Lotz (1967).

References

- Fawcett, B. C. and Hayes, R. W. (1975), Mon. Not. R. Astr. Soc. **170**, 185.
 Goldsmith, S., Oren, L., Crooker, A. M., and Cohen, L. (1973), Astrophys. J. **184**, 1021.
 Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.
 Widing, K. G. (1975), Astrophys. J. **197**, L33.

Cr XXI

Configuration	Term	J	Level (cm^{-1})
$2s^2$	1S	0	0
$2s2p$	$^3P^o$	0	$317\ 560+x$
		1	$341\ 170$
		2	$404\ 080+y$
$2s3d$	3D	2	$7\ 721\ 000$
		3	$7\ 773\ 000+y$
Cr XXII ($^2S_{1/2}$)	<i>Limit</i>	.....	13 180 000

Cr XXII

Li I isoelectronic sequence

 $Z = 24$ Ground state: $1s^2 2s^2 \ ^2S_{1/2}$ Ionization energy = $13\ 884\ 000\ \text{cm}^{-1}$ (1721.4 eV)

The $2s-3p$, $2p-3s$, and $2p-3d$ doublets were reported by Goldsmith, Feldman, Oren, and Cohen (1972). The $2p$ levels were connected to the ground level by the identification of the $2s-2p$ lines by Widing and Purcell (1976) in solar flare spectra. Aglitskii, Boiko, Pikuz, and Faenov (1974) confirmed the lines identified by Goldsmith et al. (1972) and added the $2s-4p$ and $2p-4d$ doublets.

We derived the ionization energy from the $2-4p$ Rydberg terms.

References

- Aglitskii, E. V., Boiko, V. A., Pikuz, S. A., and Faenov, A. Y. (1974), *Kvantovaya Elektron. (Moscow)* **1**, 1731.
 Goldsmith, S., Feldman, U., Oren, L., and Cohen, L. (1972), *Astrophys. J.* **174**, 209.
 Widing, K. G. and Purcell, J. D. (1976), *Astrophys. J.* **204**, L151.

Cr XXII

Configuration	Term	J	Level (cm^{-1})
$2s$	$\ ^2S$	$1/2$	0
$2p$	$\ ^2P^\circ$	$1/2$	357 540
		$3/2$	448 430
$3s$	$\ ^2S$	$1/2$	7 826 000
$3p$	$\ ^2P^\circ$	$1/2$	7 898 000
		$3/2$	7 924 000
$3d$	$\ ^2D$	$3/2$	7 964 000
		$5/2$	7 966 000
$4p$	$\ ^2P^\circ$	$1/2, 3/2$	10 534 000
$4d$	$\ ^2D$	$3/2$	10 553 000
Cr XXIII ($\ ^1S_0$)	<i>Limit</i>	.....	13 620 000

Cr XXIII

He I isoelectronic sequence

 $Z=24$ Ground state: $1s^2\ ^1S_0$ Ionization energy = $60\ 350\ 000\ \text{cm}^{-1}$ (7482 eV)

The $1s2p\ ^1,^3P^\circ$ resonance transitions were identified by Swartz, Kastner, Rothe, and Neupert (1971) as an unresolved spectral feature at $2.20\ \text{\AA}$. Wavelengths of the separate lines obtained from solar flare spectra were given by Neupert (1971). The agreement with the theoretical values calculated by Swartz et al. (1971) using the formulas of Doyle (1969) is within 0.01%.

The ionization energy was extrapolated by Lotz (1967).

References

- Doyle, H. T. (1969), *Adv. Atom. Molec. Phys.* **5**, 369.
 Lotz, W. (1967), *J. Opt. Soc. Am.* **57**, 873.
 Neupert, W. (1971), *Solar Phys.* **18**, 474.
 Swartz, M., Kastner, S., Rothe, E., and Neupert, W. (1971), *J. Phys.* **B4**, 1747.

Cr xxiii

Configuration	Term	J	Level (cm^{-1})
$1s^2$	1S	0	0
$1s2p$	$^3P^\circ$	1	45 540 000
$1s2p$	$^1P^\circ$	1	45 890 000
Cr xxiv ($^2S_{1/2}$)	<i>Limit</i>	.....	60 350 000

Cr XXIV

H I isoelectronic sequence

 $Z=24$ Ground state: $1s^2S_{1/2}$ Ionization energy = $63\,675\,300\text{ cm}^{-1}$ (7894.79 eV)

The theoretical values calculated by Erikson for the terms of this hydrogen-like ion are so much superior to the observed values that we have quoted them (up to $n=4$). The binding energy of the $1s$ electron is given with an uncertainty of $\pm 200\text{ cm}^{-1}$; the levels are given relative to this value. For comparison, the observed value of $2p^2P_{1/2,3/2}^{\circ}$

reported by Swartz, Kastner, Rothe, and Neupert (1971) is $48\,000\,000\text{ cm}^{-1}$.

References

Erikson, G. W., to be published in J. Phys. Chem. Ref. Data.
Swartz, M., Kastner, S., Rothe, E., and Neupert, W. (1971), J. Phys. **B4**, 1747.

Cr xxiv

Configuration	Term	J	Level (cm^{-1})
$1s$	2S	$1/2$	0
$2p$	$^2P^{\circ}$	$1/2$	47 719 300
		$3/2$	47 843 000
$2s$	2S	$1/2$	47 722 800
$3p$	$^2P^{\circ}$	$1/2$	56 597 500
		$3/2$	56 634 200
$3s$	2S	$1/2$	56 598 600
$3d$	2D	$3/2$	56 634 100
		$5/2$	56 646 200
$4p$	$^2P^{\circ}$	$1/2$	59 699 800
		$3/2$	59 715 300
$4s$	2S	$1/2$	59 700 300
$4d$	2D	$3/2$	59 715 300
		$5/2$	59 720 400
$4f$	$^2F^{\circ}$	$5/2$	59 720 400
		$7/2$	59 722 900
	Limit	.....	63 675 300