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SPECTRA IN THE 70 Å - 345 Å WAVELENGTH REGION
OF ELEMENTS INJECTED INTO THE PLT TOKAMAK*

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ABSTRACT

High resolution spectra of the elements Fe, Ni, Zn, Ge, Se, and Mo injected into the PLT tokamak have been recorded by the 2 meter Schwob-Fraenkel soft x-ray multichannel spectrometer (SOXMOS). Spectra were recorded every 50 ms during the time before and after injection. The spectral lines of the injected element were very strong in the spectrum recorded immediately after injection, and the transitions in the injected element were easily distinguished from the transitions in the intrinsic elements (mostly Fe, Ti, and Cr). An accurate wavelength scale was established using well-known reference transitions in the intrinsic elements. The spectra recorded just prior to injection were subtracted from the spectra recorded after injection, and the resulting spectrum is composed almost entirely of transitions from the injected element. A large number of $\Delta n=0$ transitions in the Li I through K I (except Ne I) isoelectronic sequences of the injected elements were identified in the wavelength region 70 Å to 345 Å.

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INTRODUCTION

The PLT tokamak represents a very useful tool for the study of the spectra of highly-charged ions. Electron temperatures of up to 2.5 keV occur in the center of the Ohmically heated discharge and persist for a time period of up to 1 sec. Since this time period is typically long compared to the ionization and recombination times of the highly-charged ions from the wall material, the spectra of these ions are essentially steady during most of the plateau regime of the discharge. The spectra of transiently injected elements are easily detected against the steady background spectra of the intrinsic elements.

Time resolved spectra of the intrinsic elements (C, O, Ti, Cr, Fe, and Ni) and of injected elements have been recorded using the 2 meter Schwob-Fraenkel soft x-ray multichannel spectrometer (SOXMOS). Spectra were recorded every 50 ms in the 70 Å - 345 Å wavelength region. Corrections were made for nonlinearities in the multichannel detector and the fiber optic transmission line, and an accurate wavelength scale was established using well-known reference lines. A number of spectra were added together to improve the signal-to-noise ratio. The experimental technique and the spectra from the intrinsic elements were presented in Ref. 1. In the present paper, we present the spectra of the injected elements Fe, Ni, Zn, Ge, Se, and Mo.

DATA ANALYSIS

The spectra of the injected elements were recorded by the SOXMOS spectrometer²⁻⁴ fitted with a 600 $\text{\AA}/\text{mm}$ grating and a blaze angle of $1^\circ 31'$. The spectra were detected by a flat MgF_2 -coated microchannel plate (MCP) that was coupled to a 1024 pixel photodiode array by a fiber optic transmission line. On each discharge, data in a 50 $\text{\AA}$ wide wavelength interval could be recorded, and the wavelength region from 70 $\text{\AA}$ to 345 $\text{\AA}$ was covered by moving the MCP. Spectral scans were recorded every 50 ms throughout the discharge, and typically 10 usable scans with strong spectral features were obtained on each discharge. Wavelength corrections were made to account for the nonlinearities in the fiber optic taper and in the pixel positions, and a wavelength scale accurate to 0.01 $\text{\AA}$ was established. At fixed times measured from the beginning of the discharges, the 50 $\text{\AA}$ wide spectra were connected together to produce a composite spectrum covering the 70 $\text{\AA}$ - 345 $\text{\AA}$ wavelength range. The details of the data reduction were given in Ref. 1.

The elements were injected during the plateau regime of Ohmically heated discharges using the laser blowoff technique. Before the time of injection, the recorded spectra are composed of transitions in highly-charged ions of the elements from the wall material (mostly Fe, Ti, and Cr). We shall refer to this spectrum as the background spectrum. At the time of injection, strong spectral features from the injected element appear superimposed on the background spectrum, and these spectral features diminish in the scans following injection. The background spectrum after injection is similar to the background spectrum before injection, and this implies that the injection is a rather minor

perturbation on the plasma. By subtracting the spectrum recorded just before injection from the spectrum recorded after injection, a resulting spectrum is obtained that is composed almost entirely of transitions in the highly-charged ions of the injected elements.

The spectra of the injected elements Fe, Ni, Zn, Ge, Se, and Mo are presented in Figs. 1-6. These spectra are the result of subtracting the scans recorded just before injection from the scans recorded after injection. Nearly all of the emission features are the result of transitions in the injected element that increase dramatically during injection and appear quite strong in the subtracted spectra. A few of the emission features are the result of particularly strong lines of the background elements Fe, Ti, Cr, and Ni that are increasing during the time of injection. These lines appear in the subtracted spectra as weak emission features and are indicated by the label BKG. Many of the dips in the subtracted spectra are the result of background lines that are decreasing during injection.

The identification of the spectral lines is based on previous experimental measurements⁵⁻²³ or on the recommendations of Edlen²⁴⁻²⁸. All of the strong lines in the injected spectra of Fe, Ni, and Zn have been identified. Most of the strong lines in the Ge, Se, and Mo spectra have been identified, but several features remain unidentified. Transitions in the isoelectronic sequences Li I through K I (except Ne I) have been identified. With the exception of several Na I transitions, all of these transitions are of the type $\Delta n=0$ and terminate on

levels within the ground configurations of the ions. The present identifications are summarized in Table I, and the presently measured and the previous wavelengths are also listed. The estimated accuracy of our measured wavelengths is $0.02 \text{ \AA}$.

CONCLUSIONS

We have presented survey spectra of the elements Fe, Ni, Zn, Ge, Se, and Mo that were injected into the PLT tokamak plasma. An accurate wavelength scale was established, and the wavelengths were measured to an accuracy of $0.02 \text{ \AA}$. A number of new transitions in Ge, Se, and Mo were identified.

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FIGURE CAPTIONS

Fig. 1 PLT spectrum of injected iron.

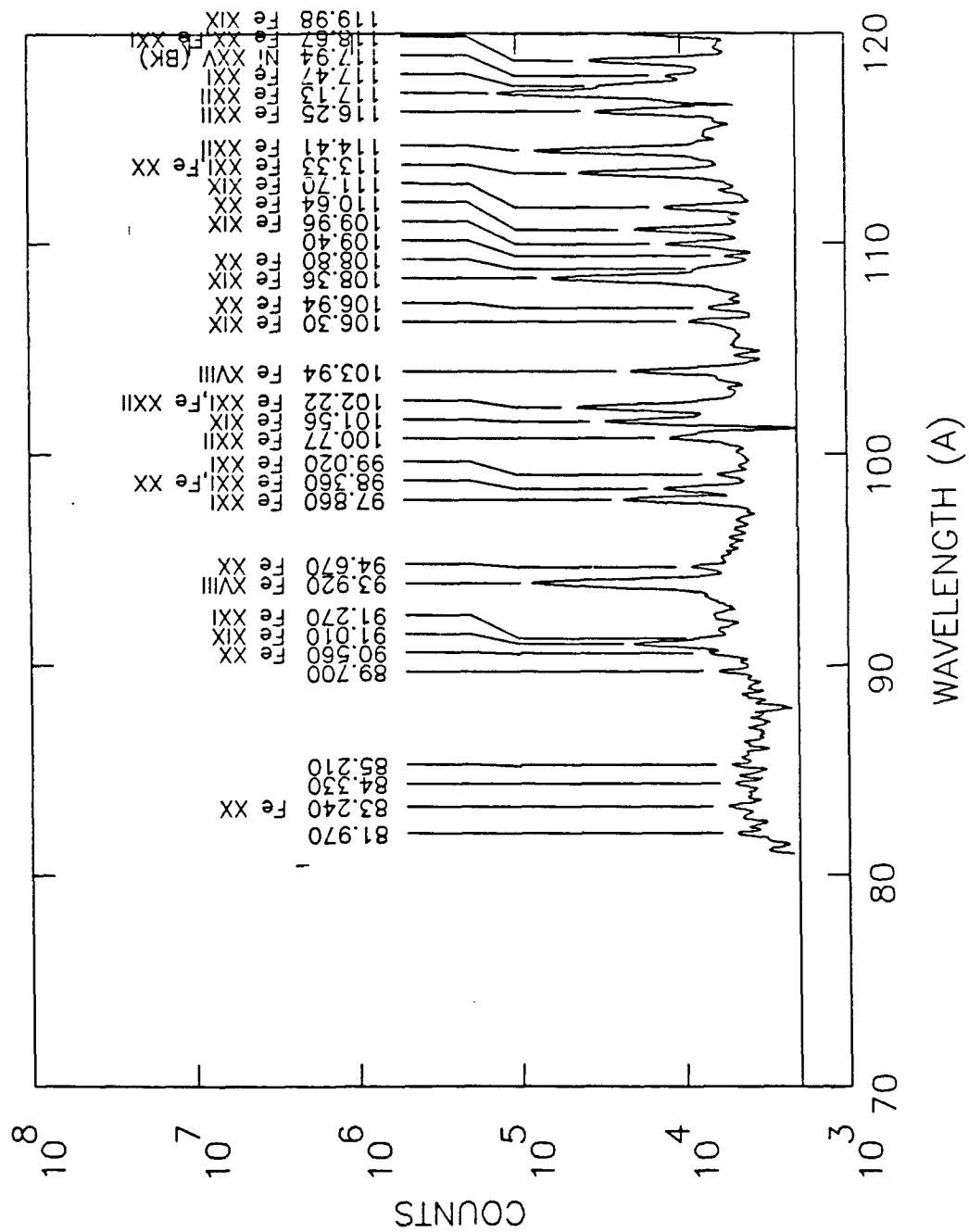
Fig. 2 PLT spectrum of injected nickel.

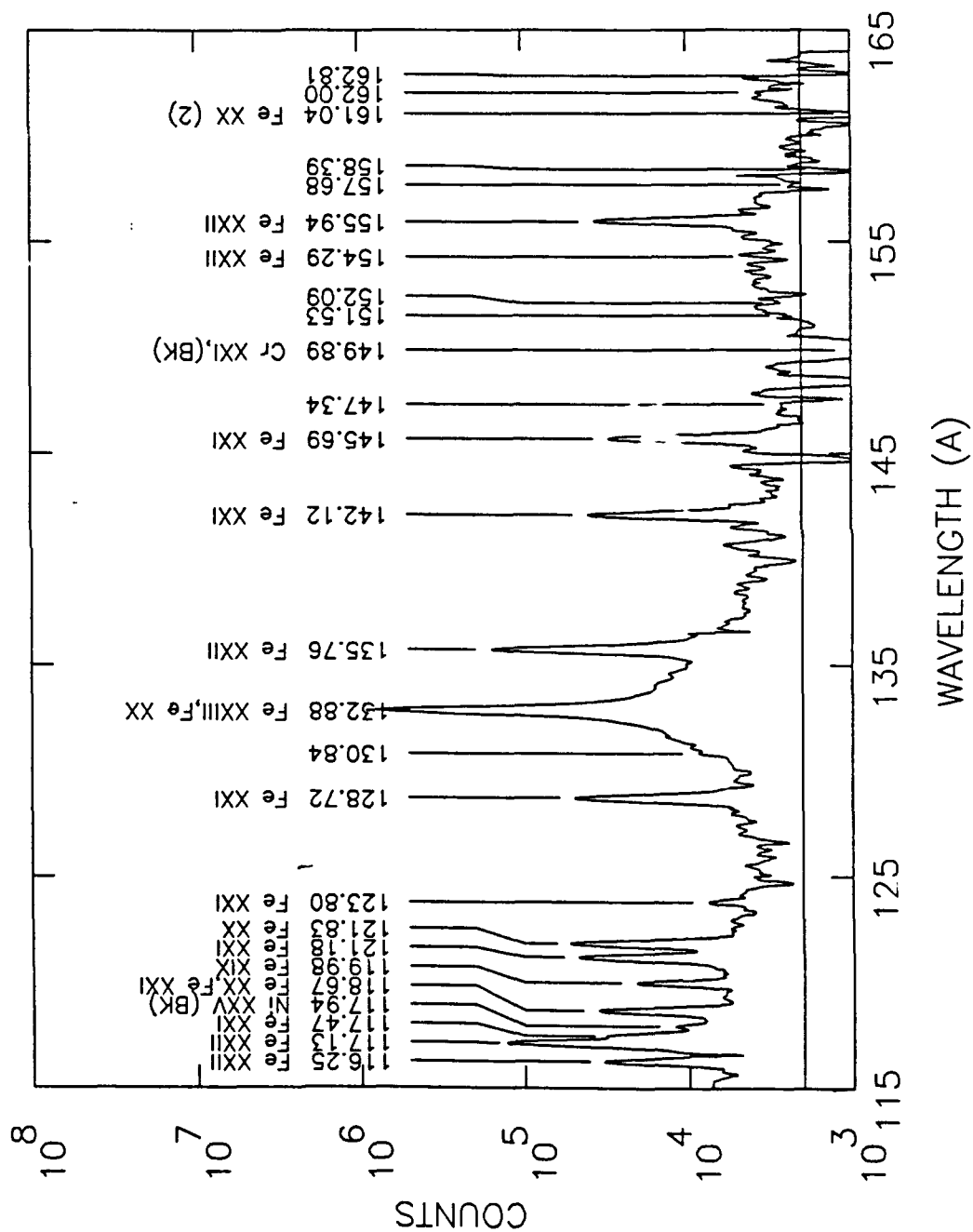
Fig. 3 PLT spectrum of injected zinc.

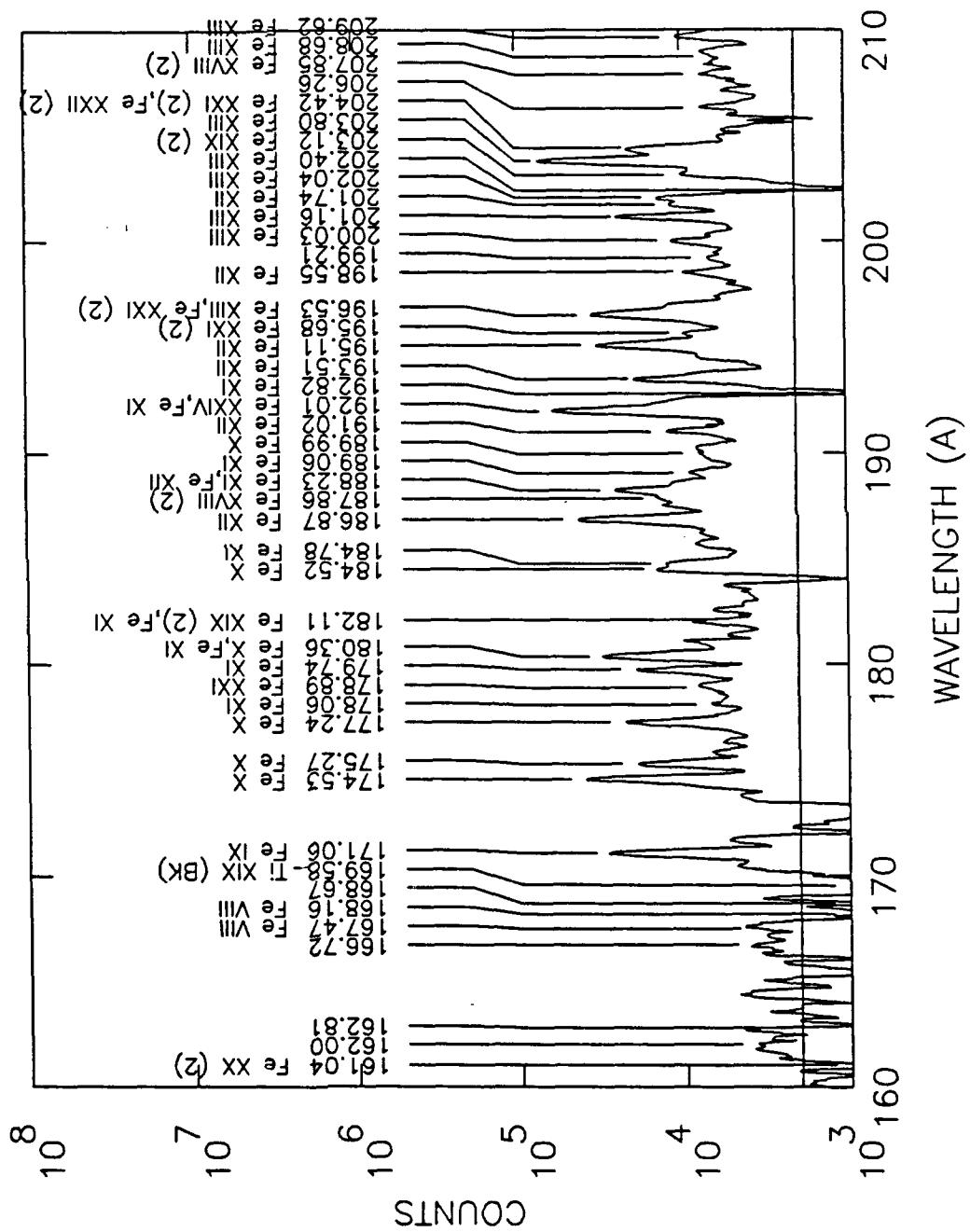
Fig. 4 PLT spectrum of injected germanium.

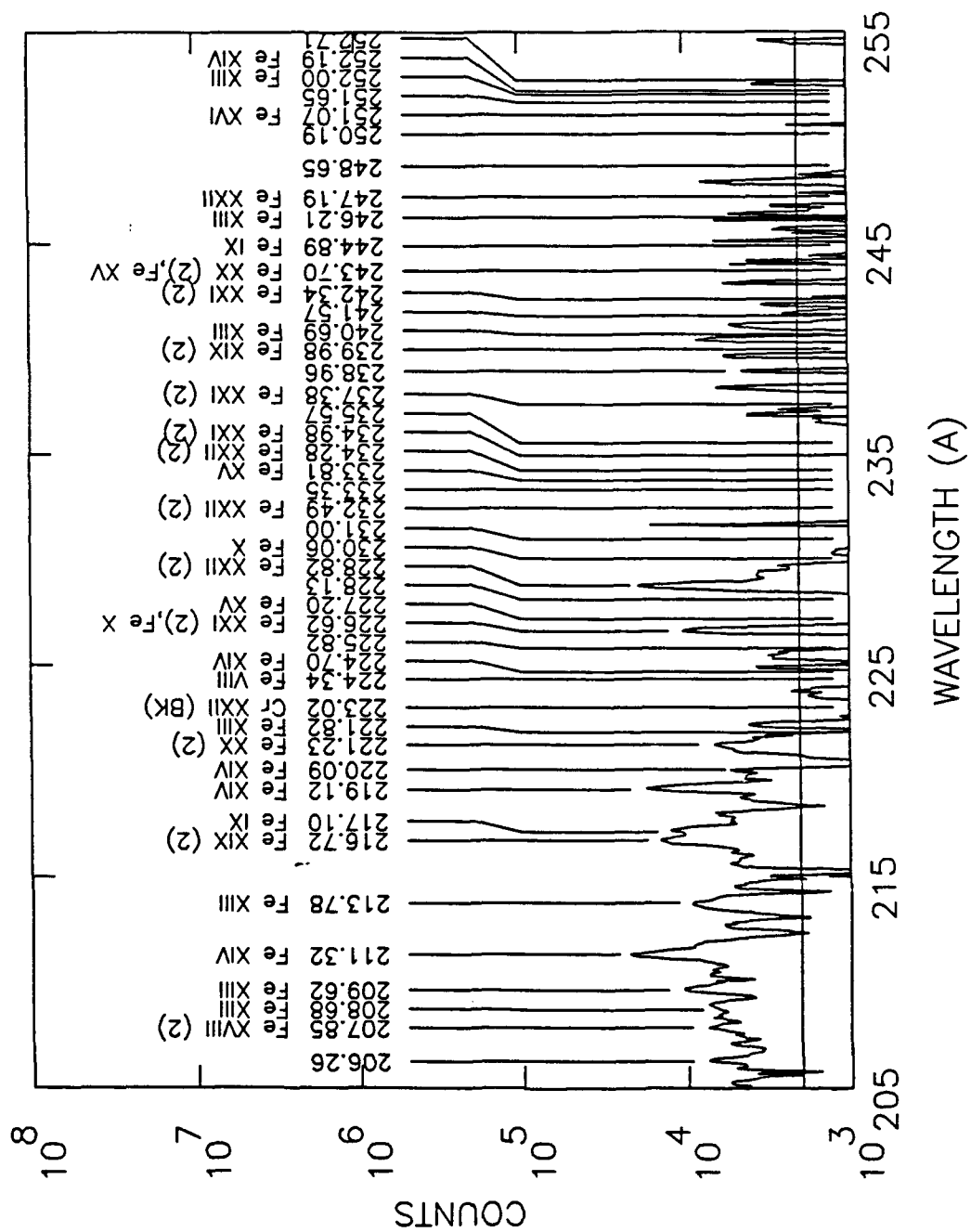
Fig. 5 PLT spectrum of injected selenium.

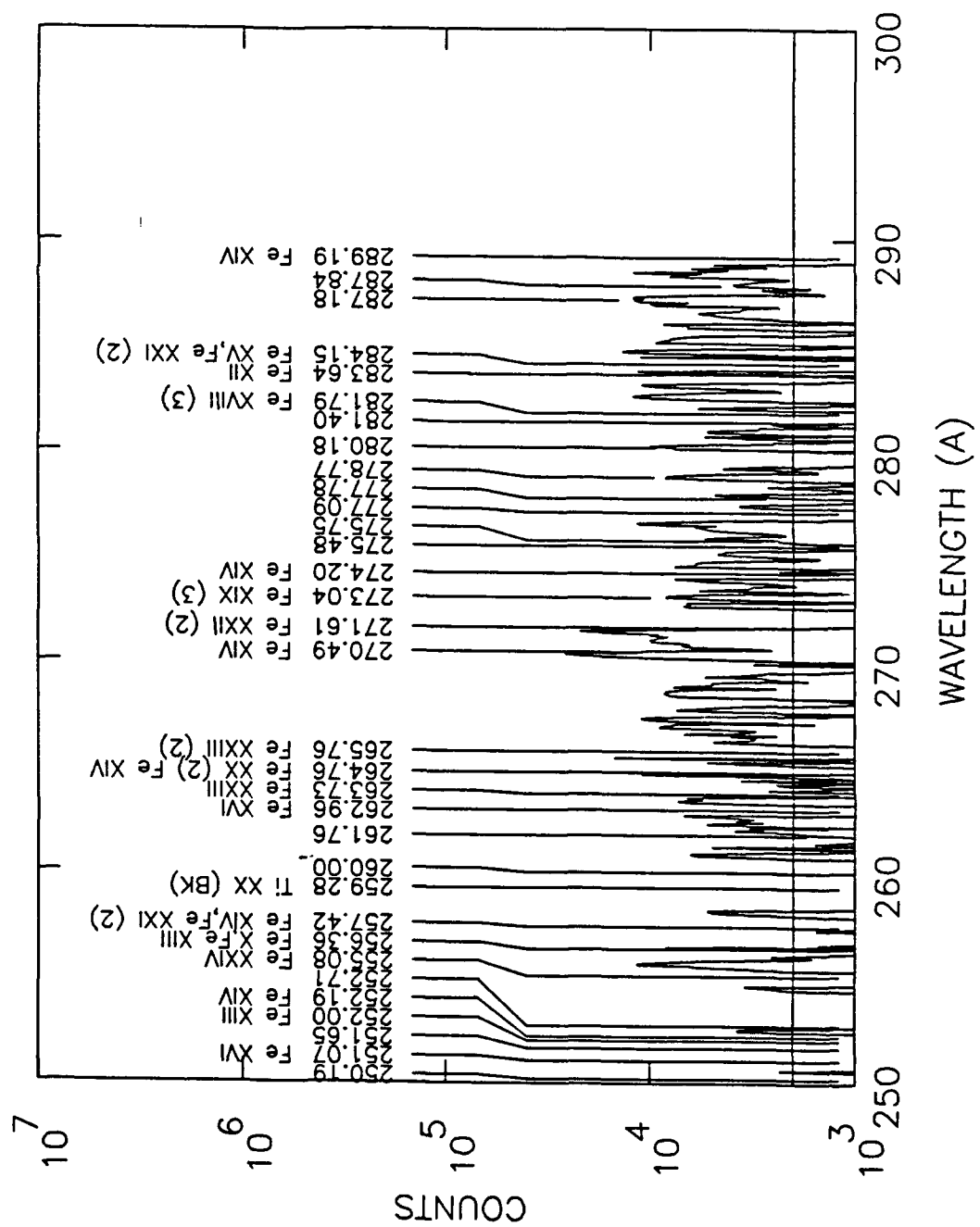
Fig. 6 PLT spectrum of injected molybdenum.

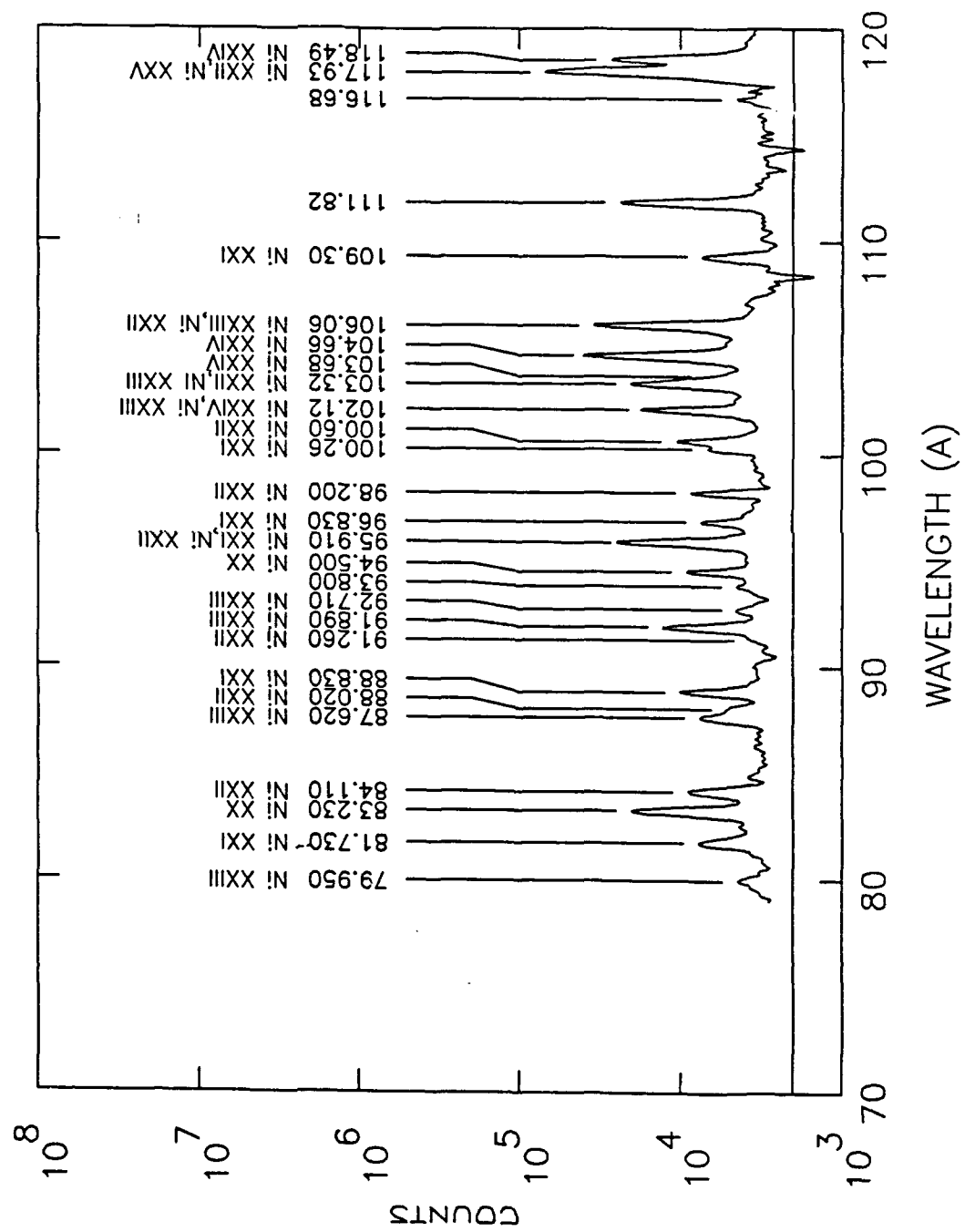


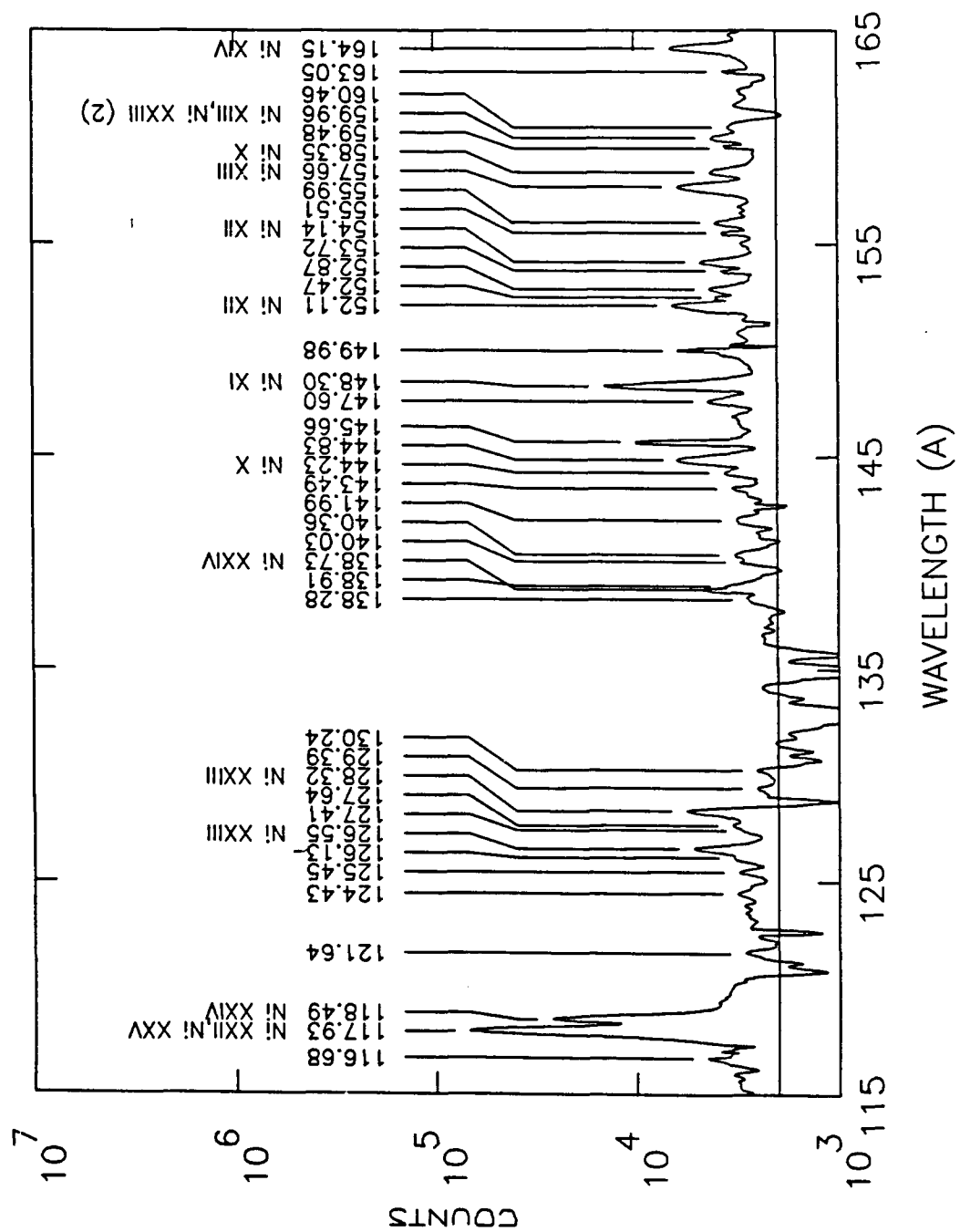


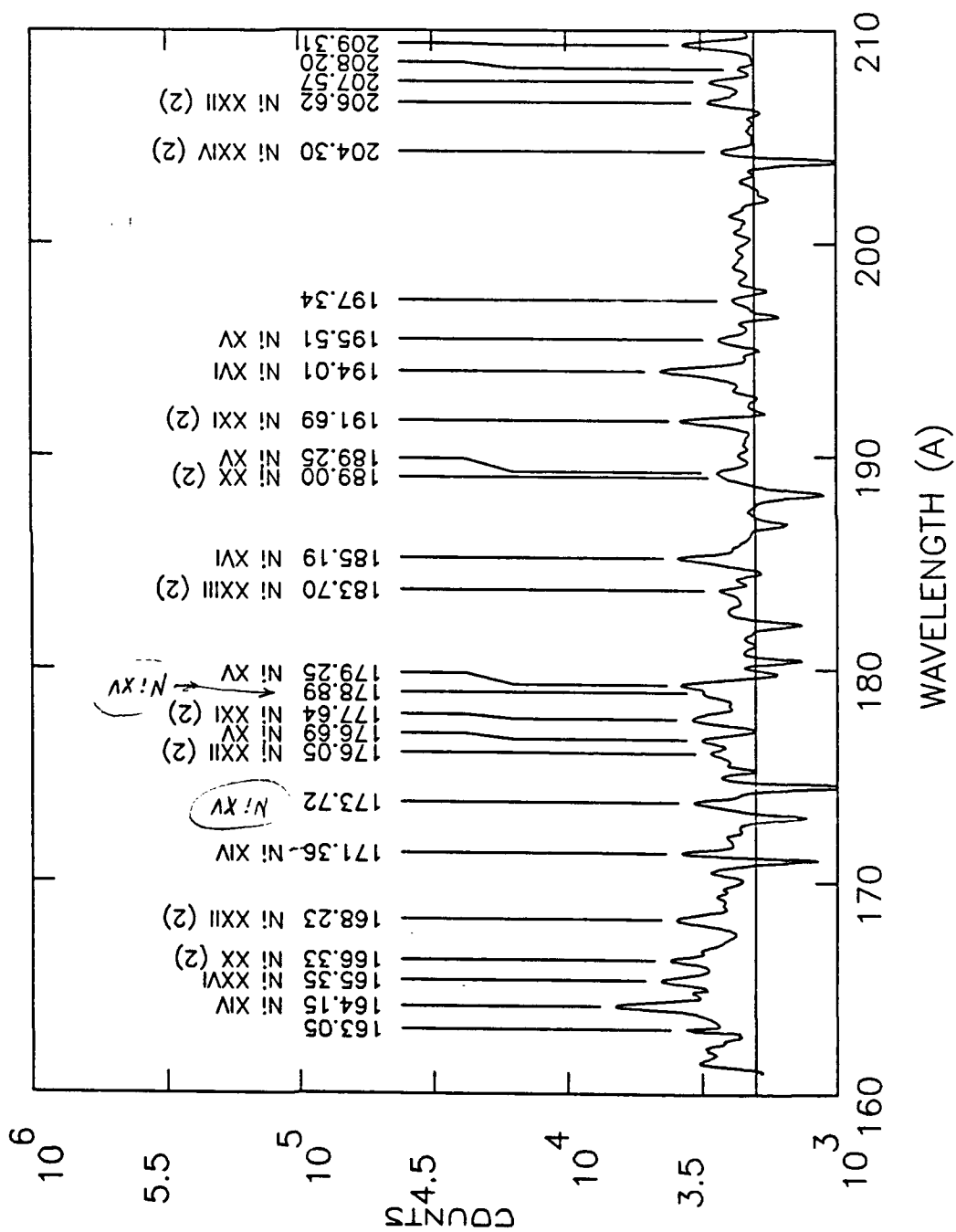


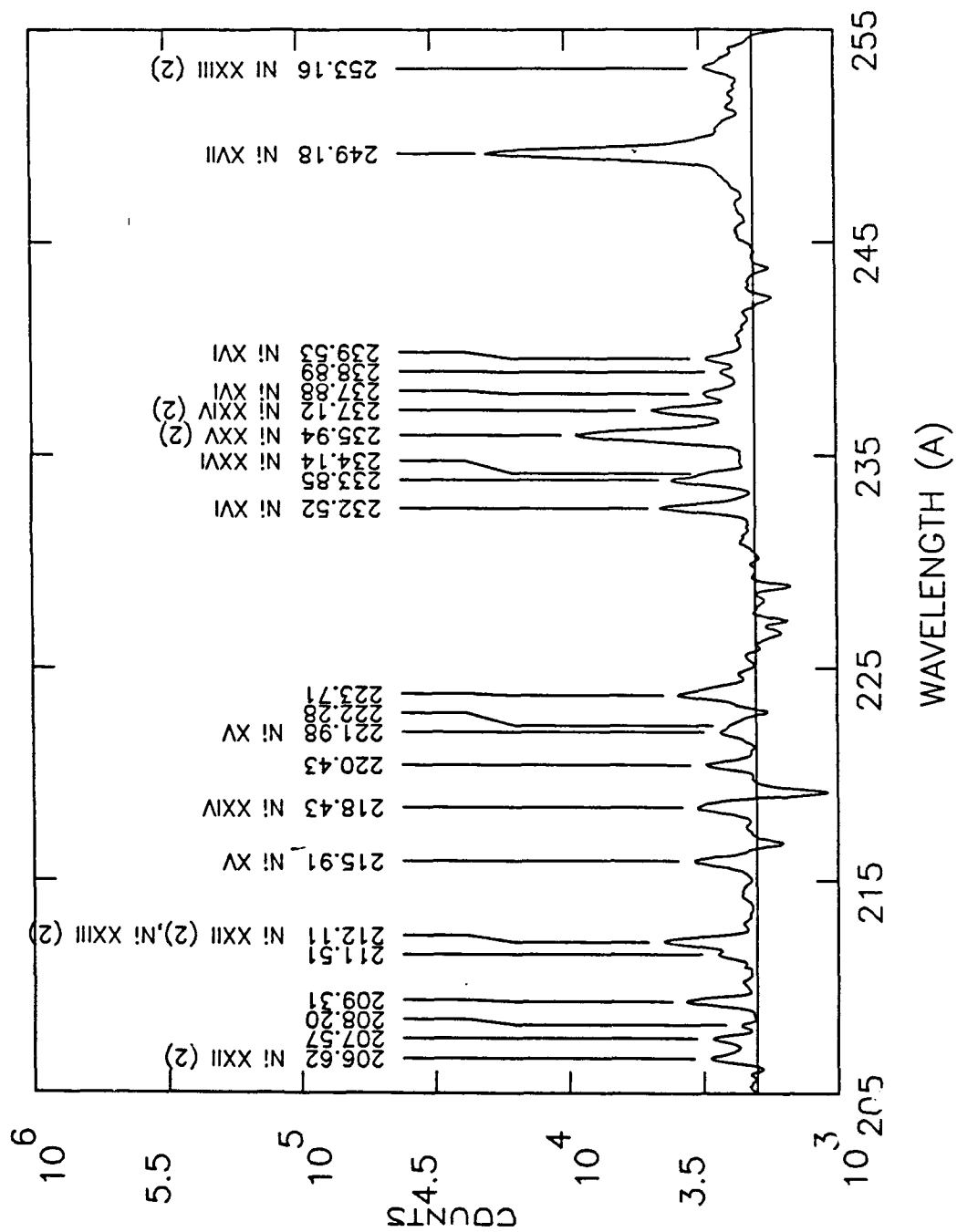


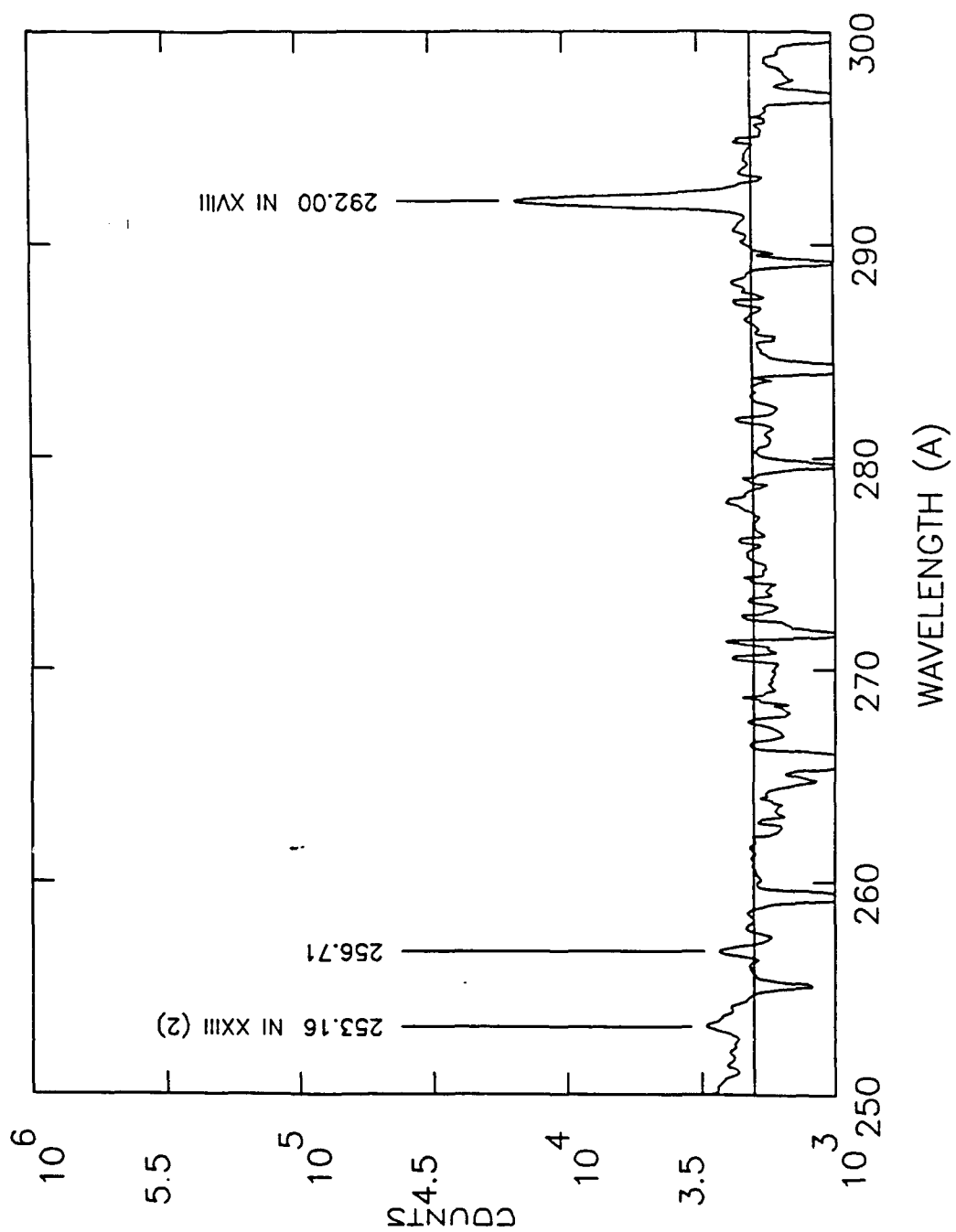


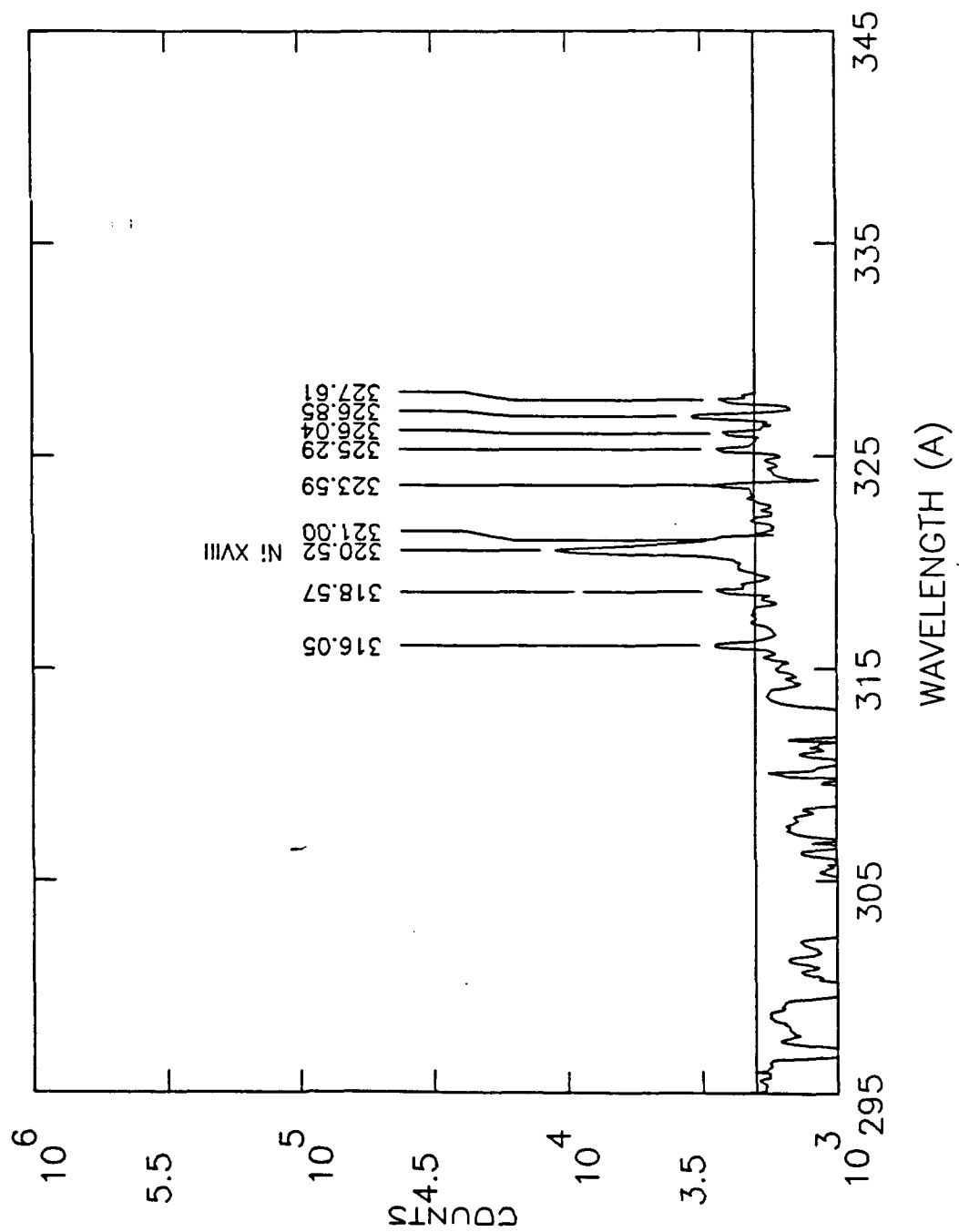


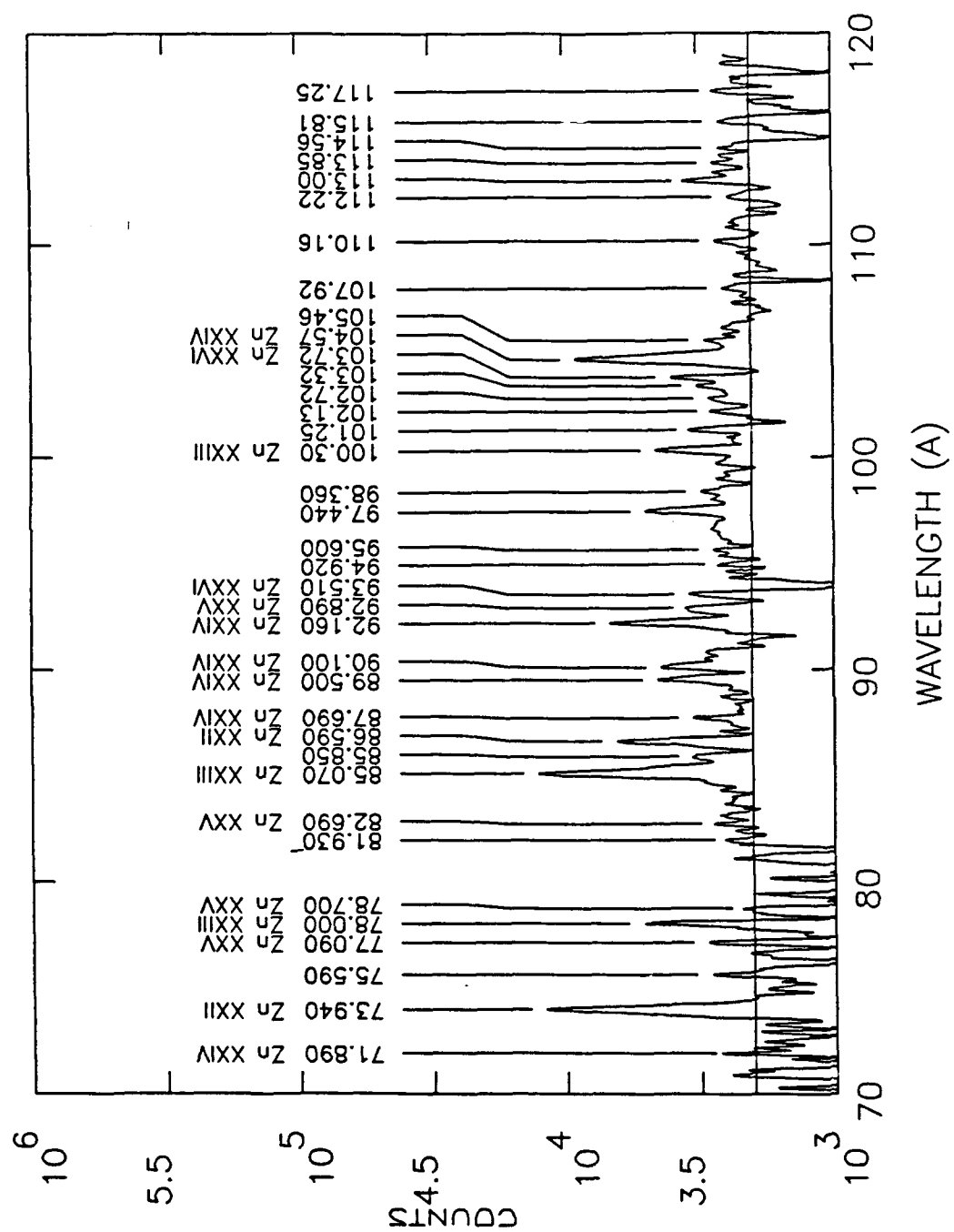


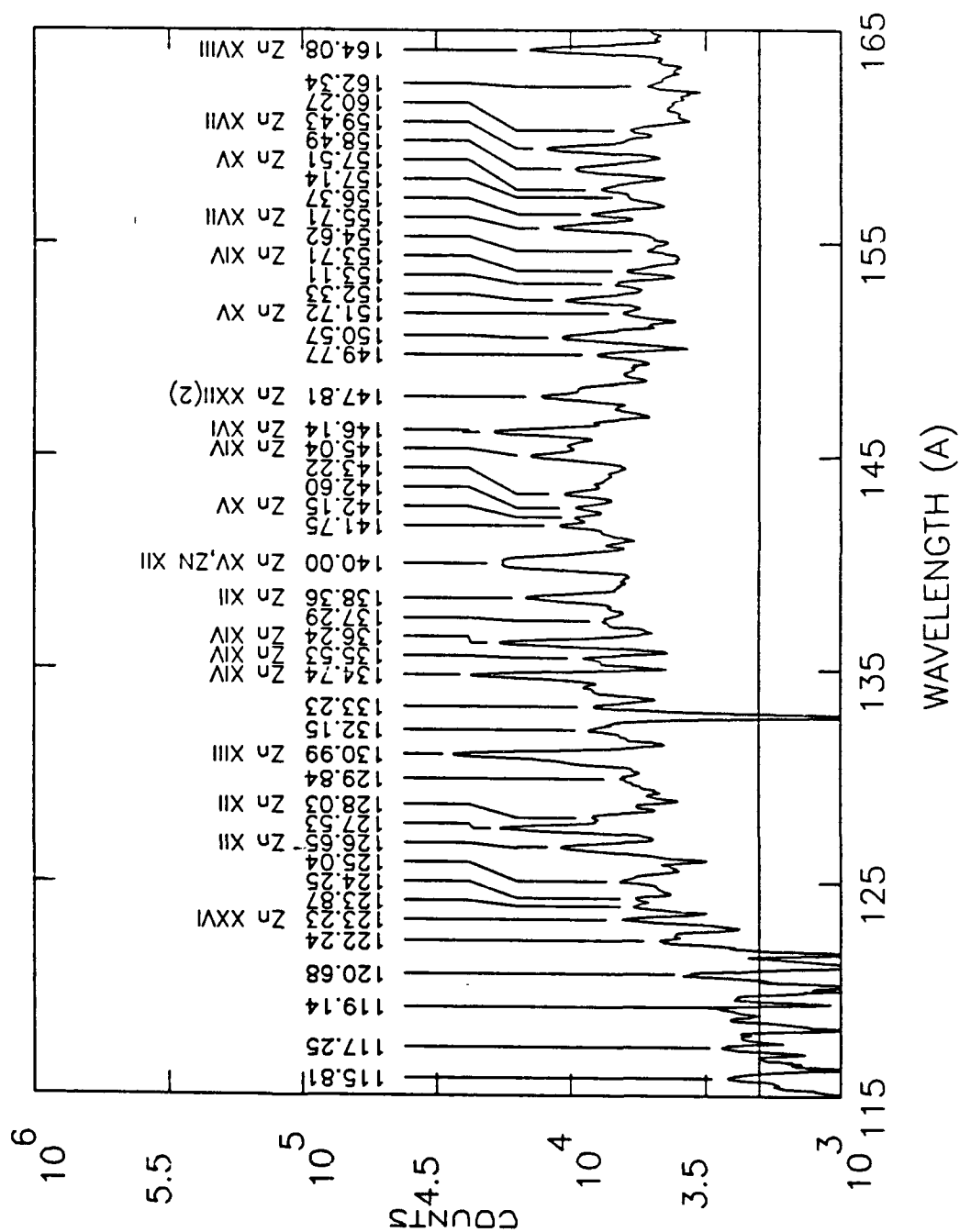


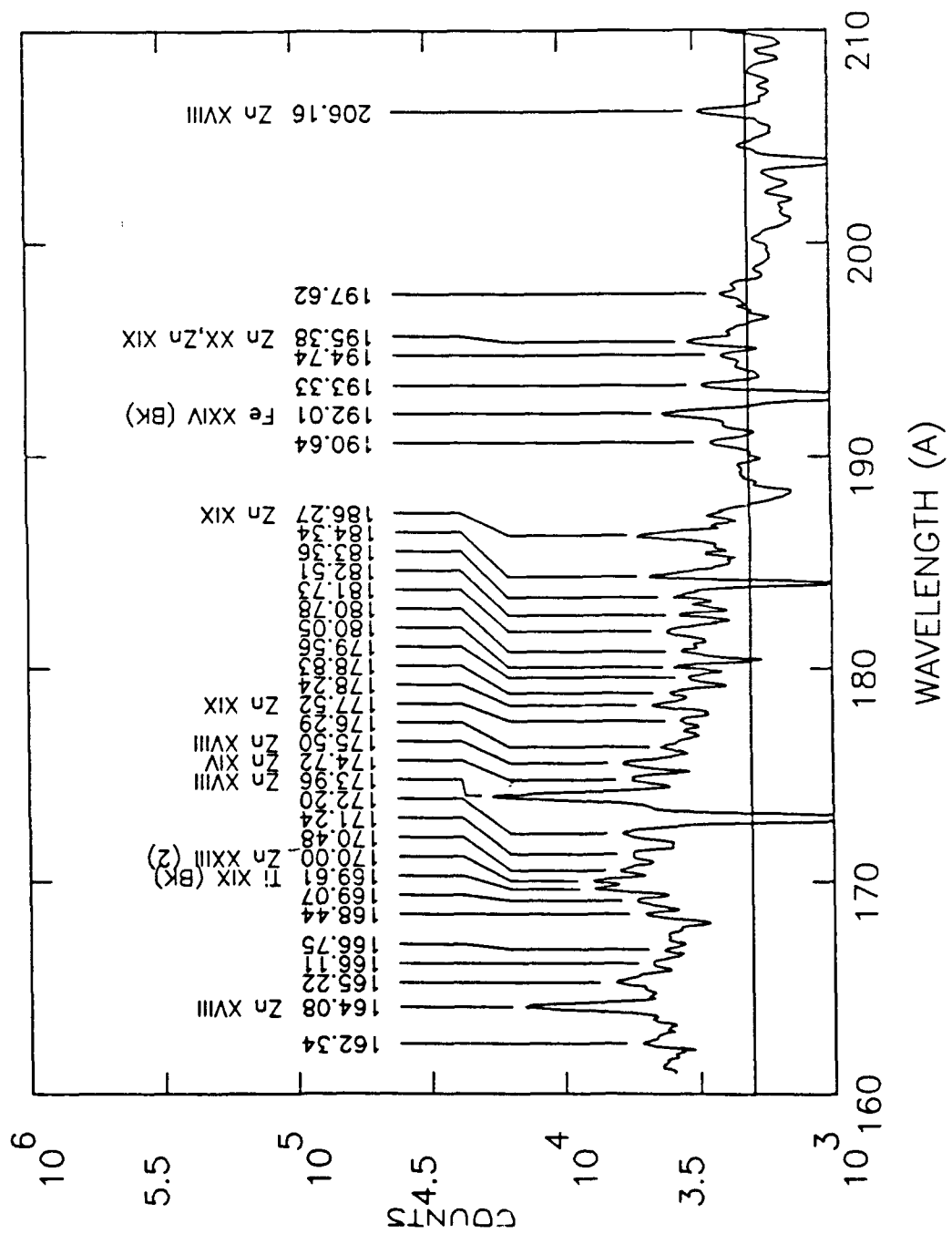


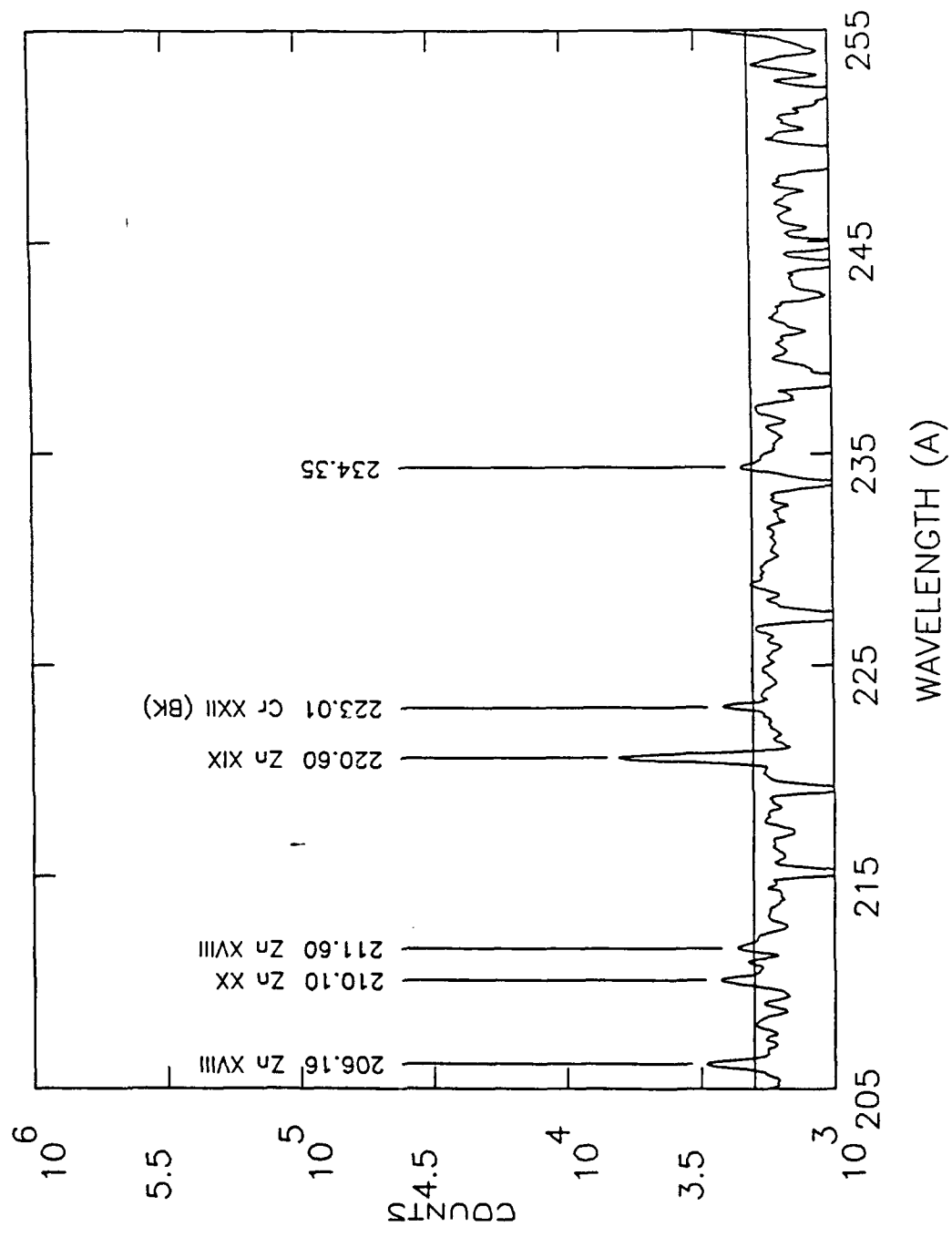


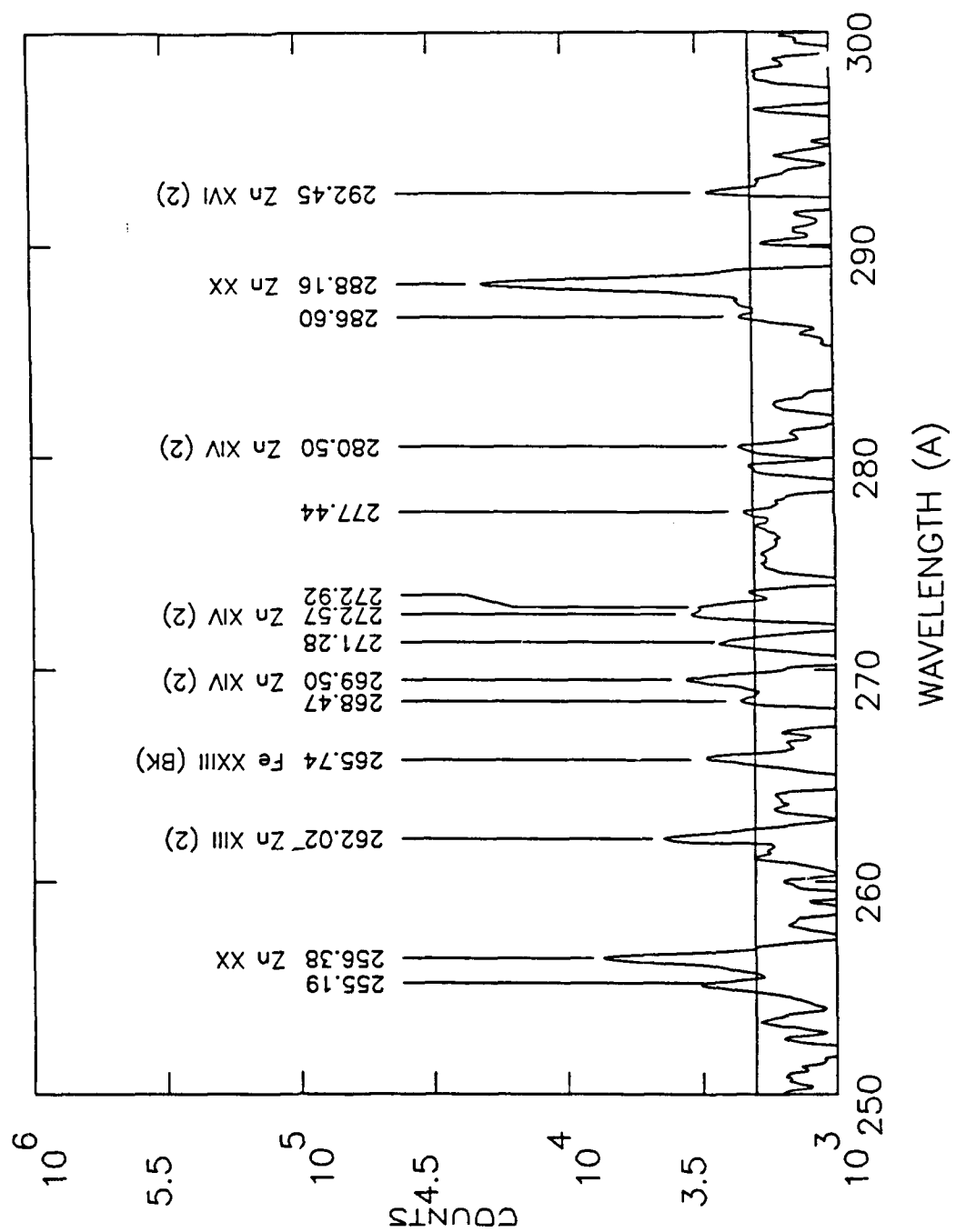


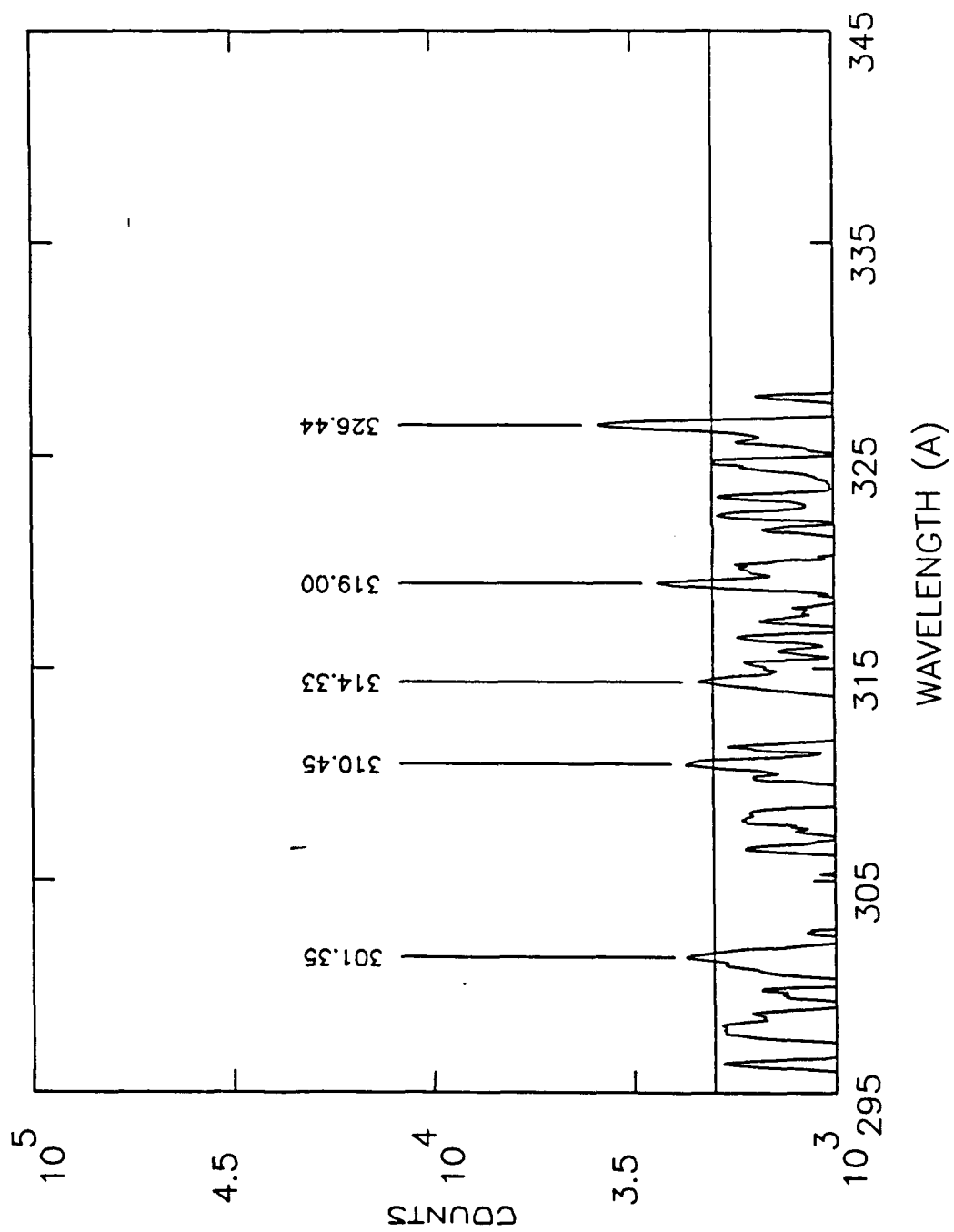


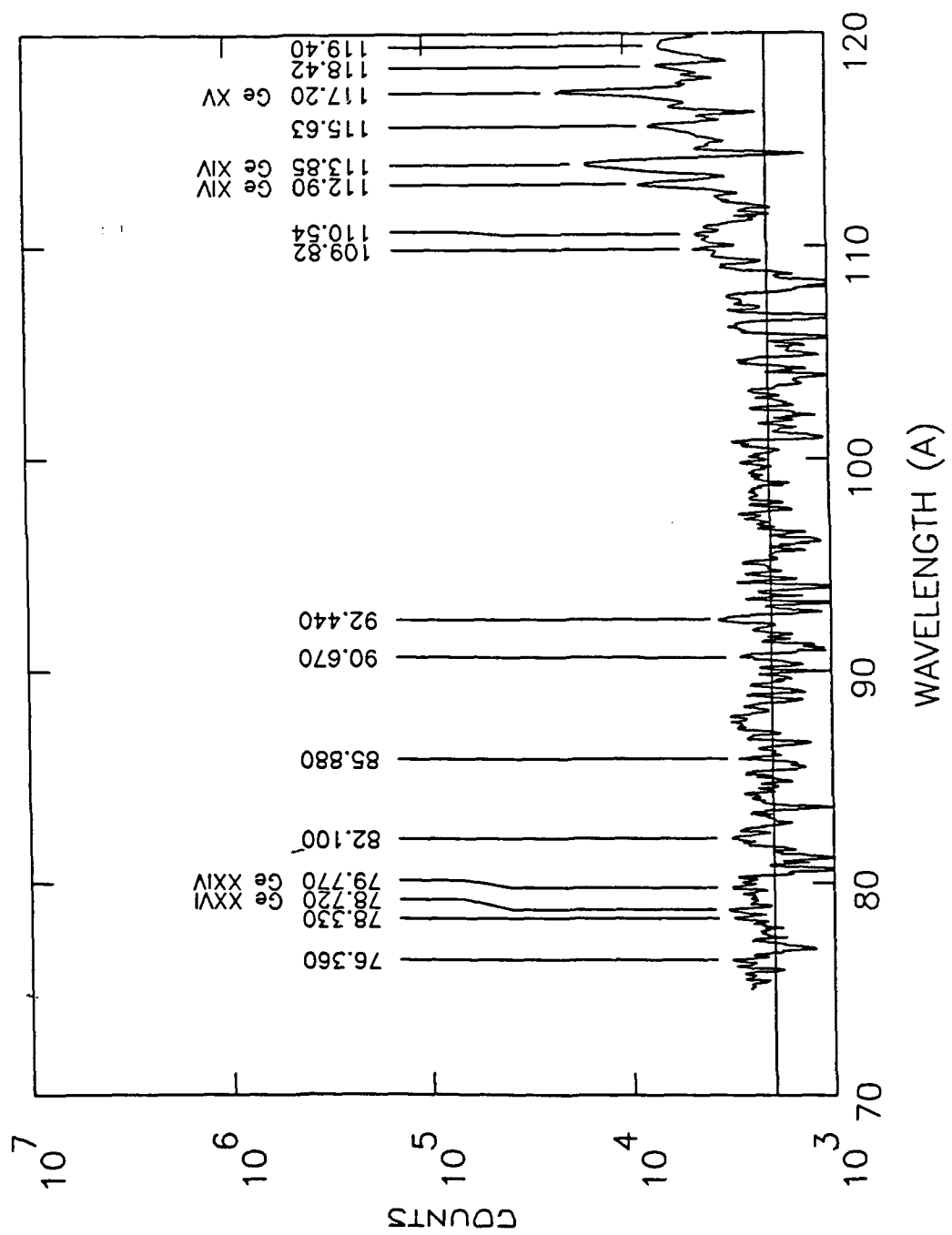


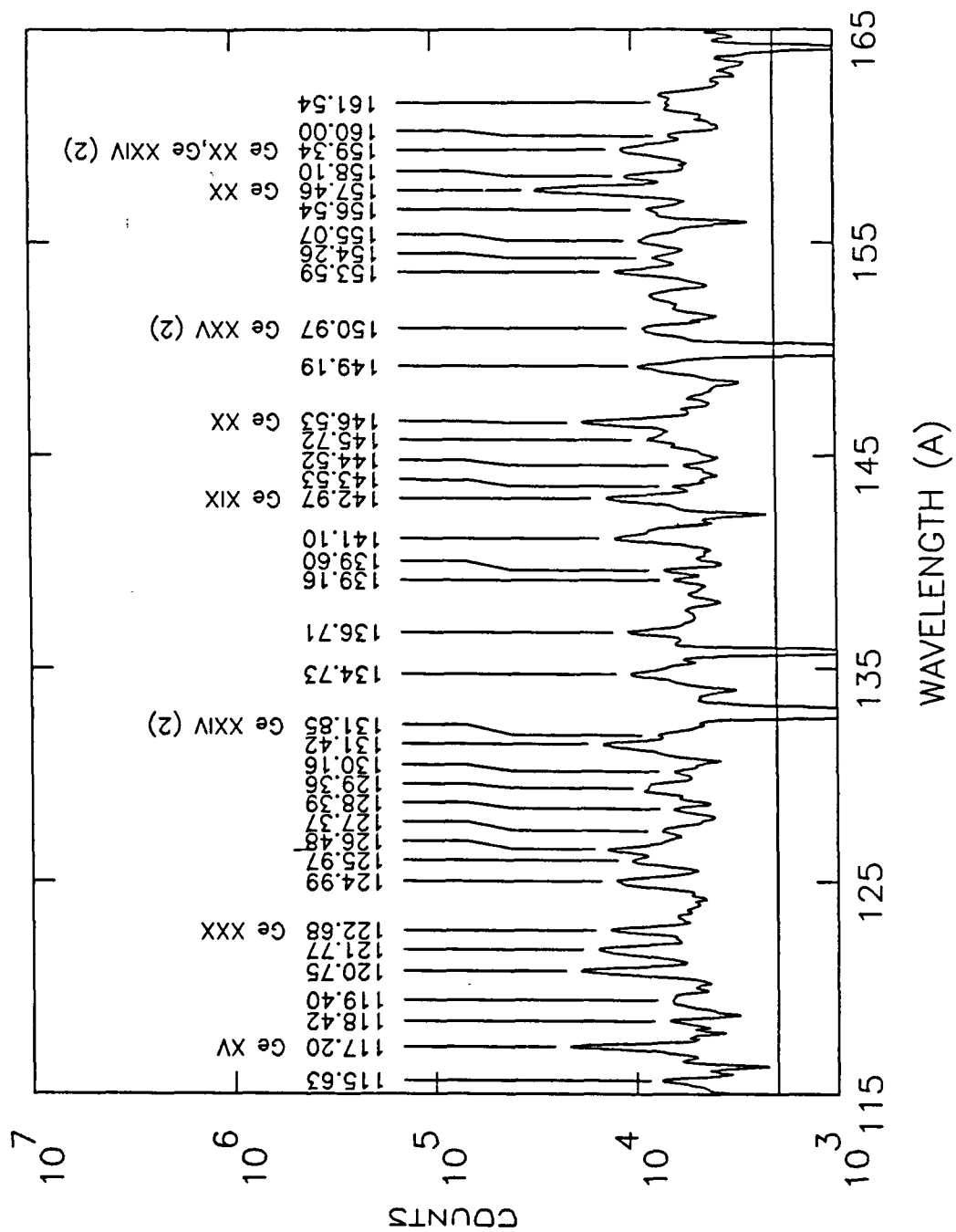


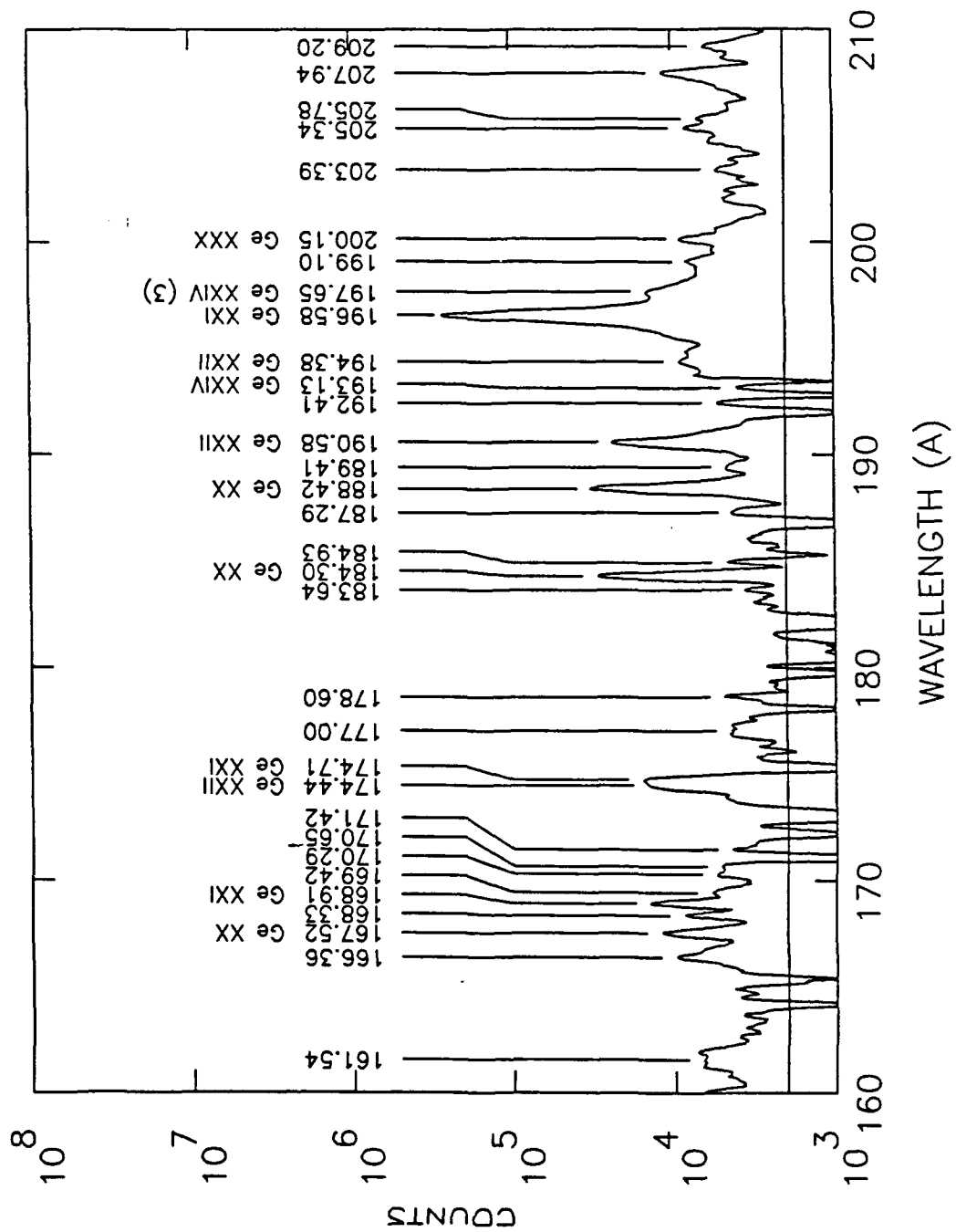


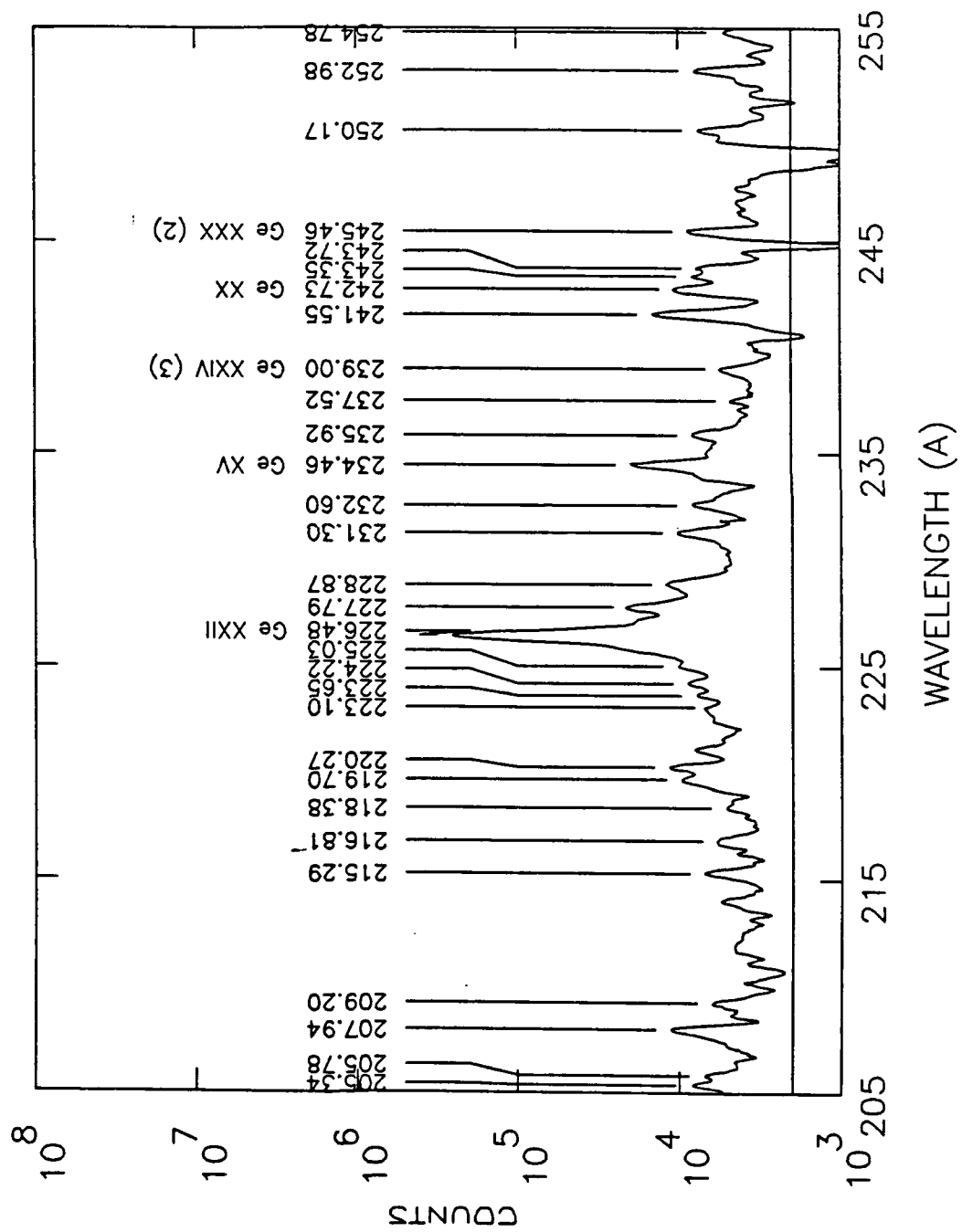


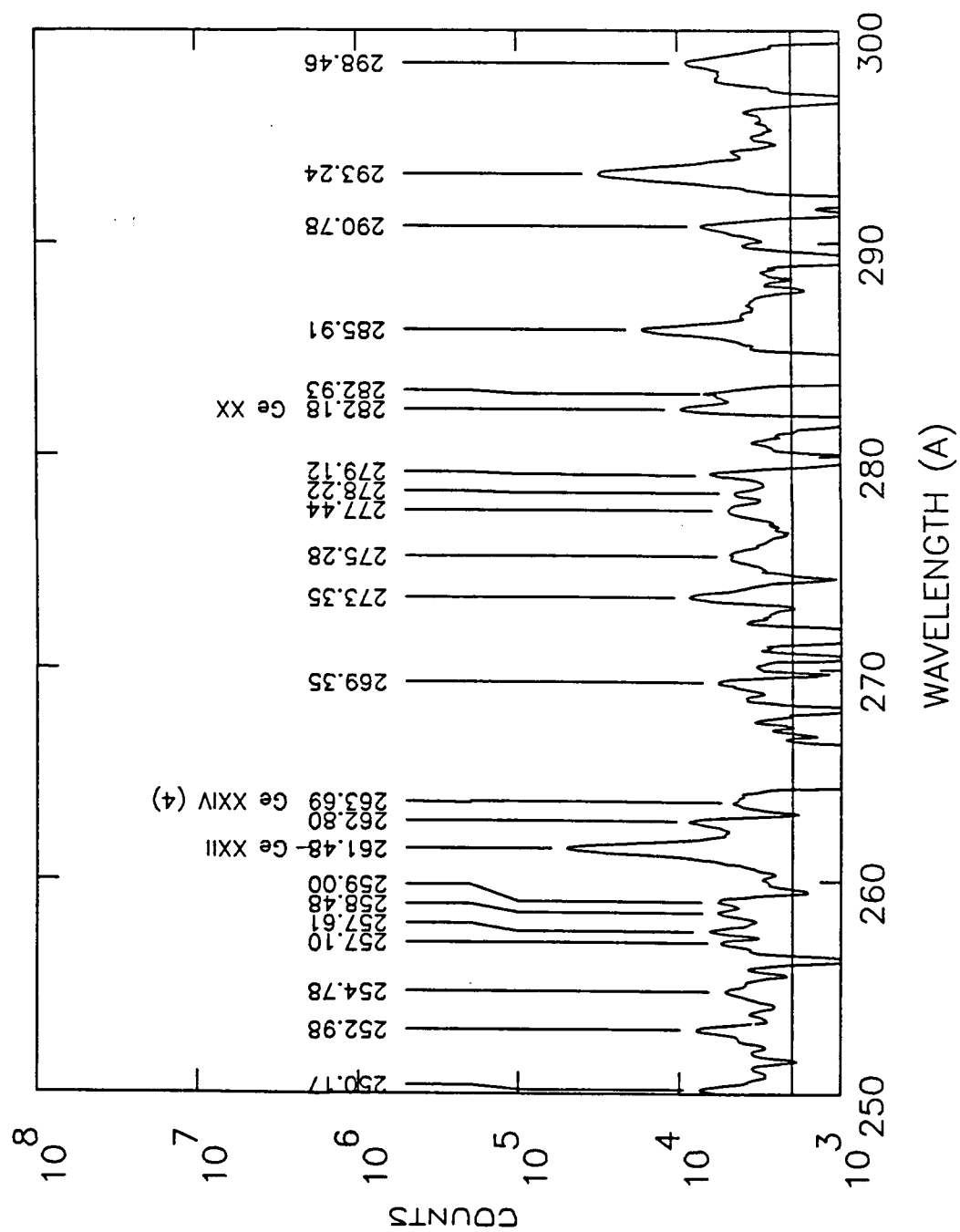


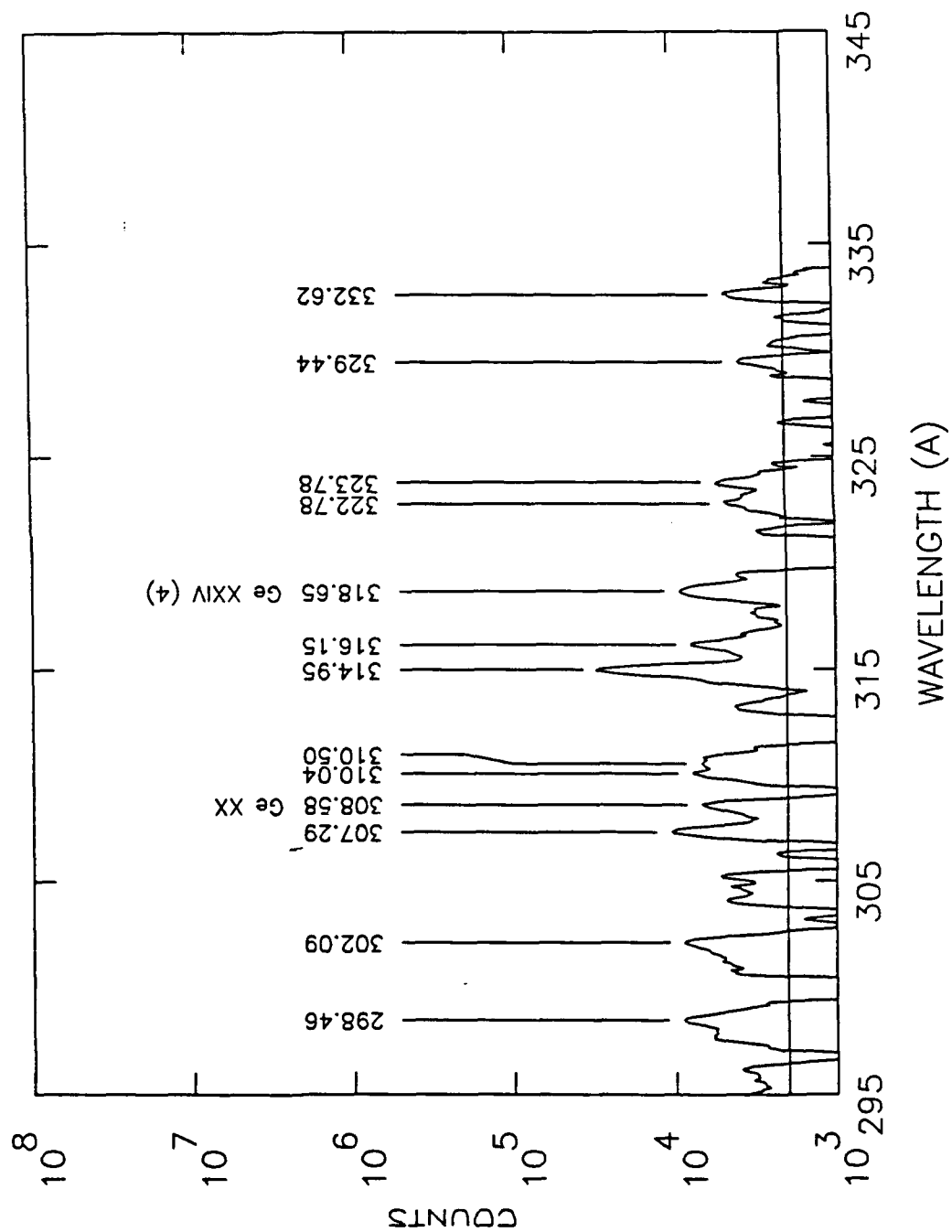






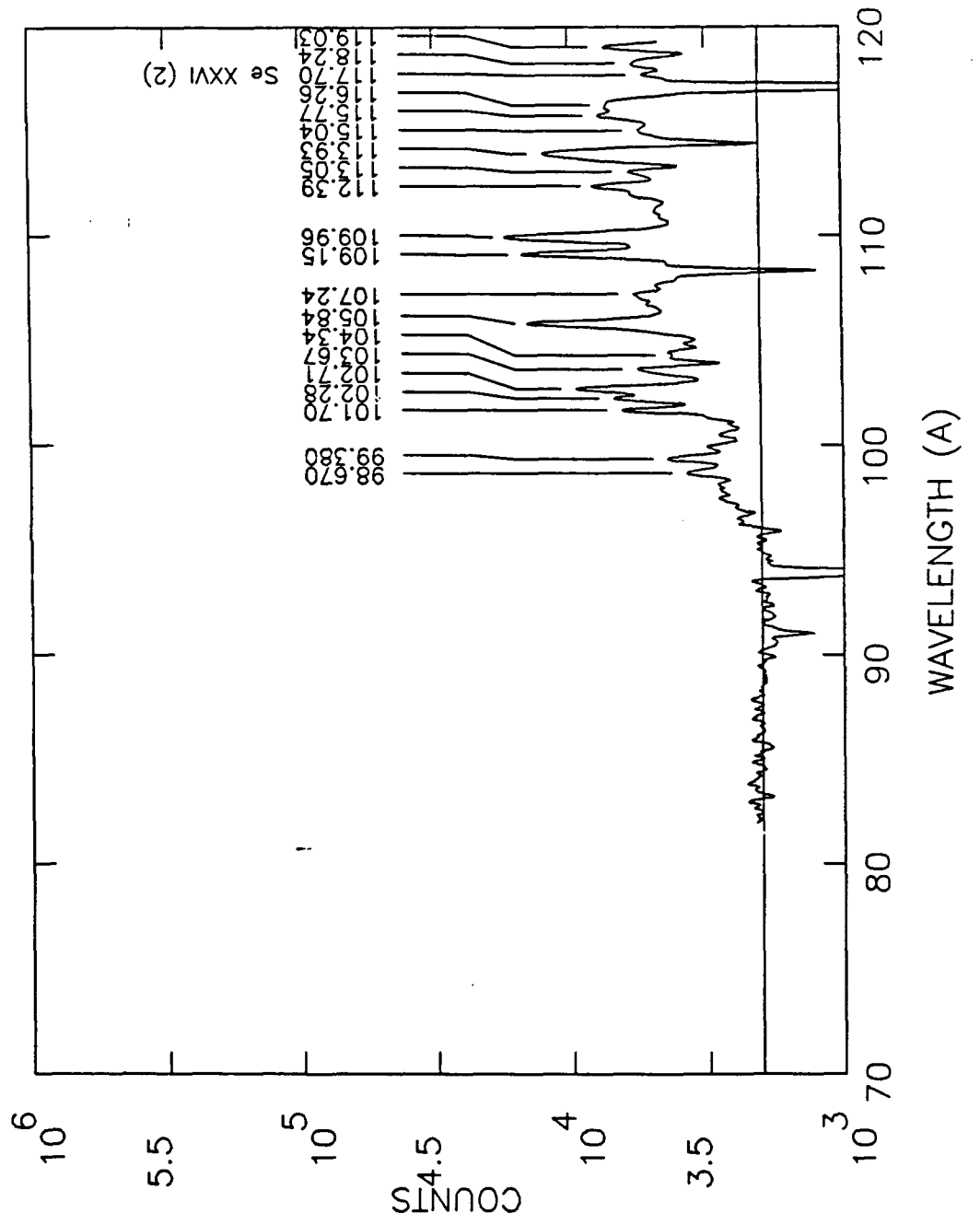


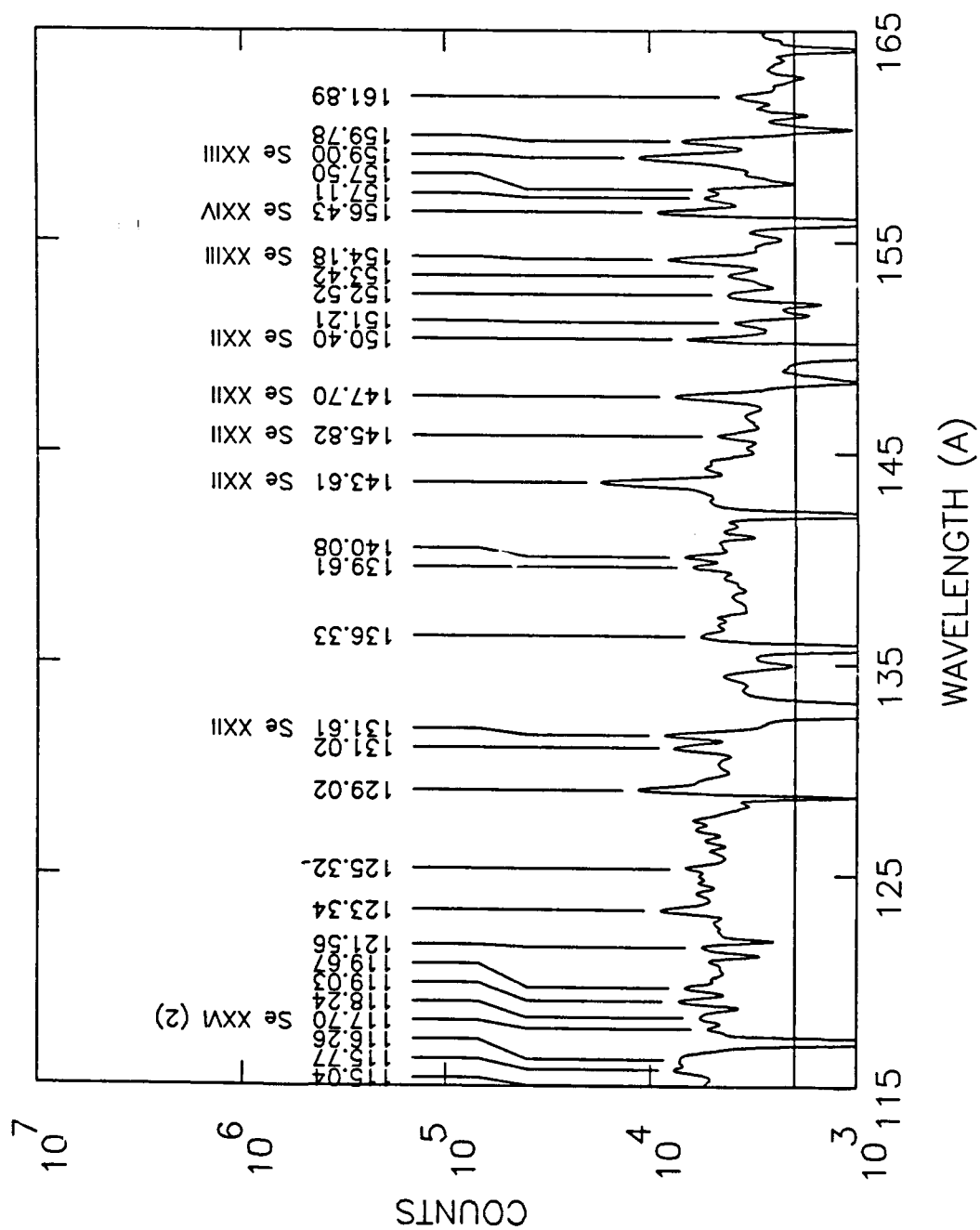


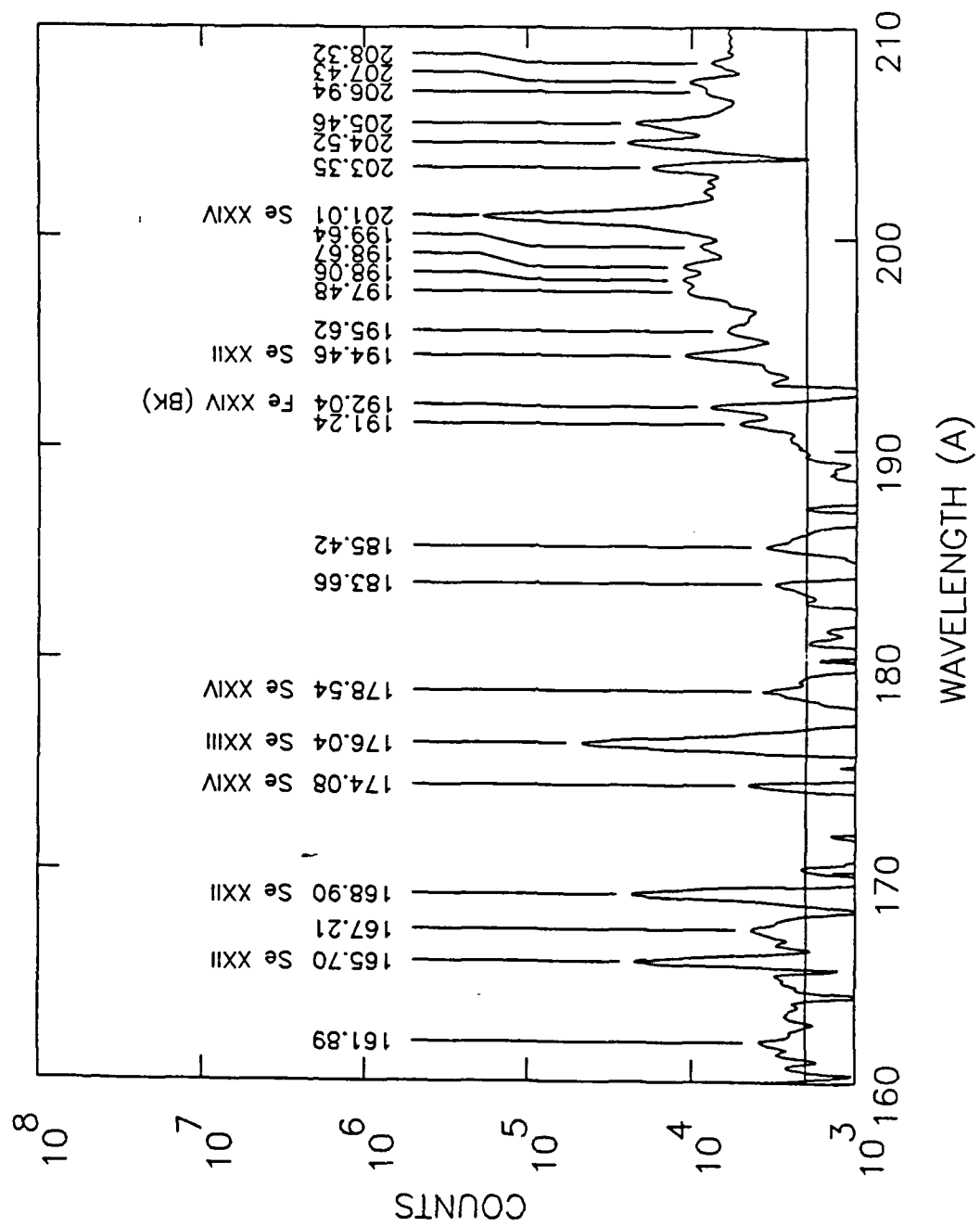


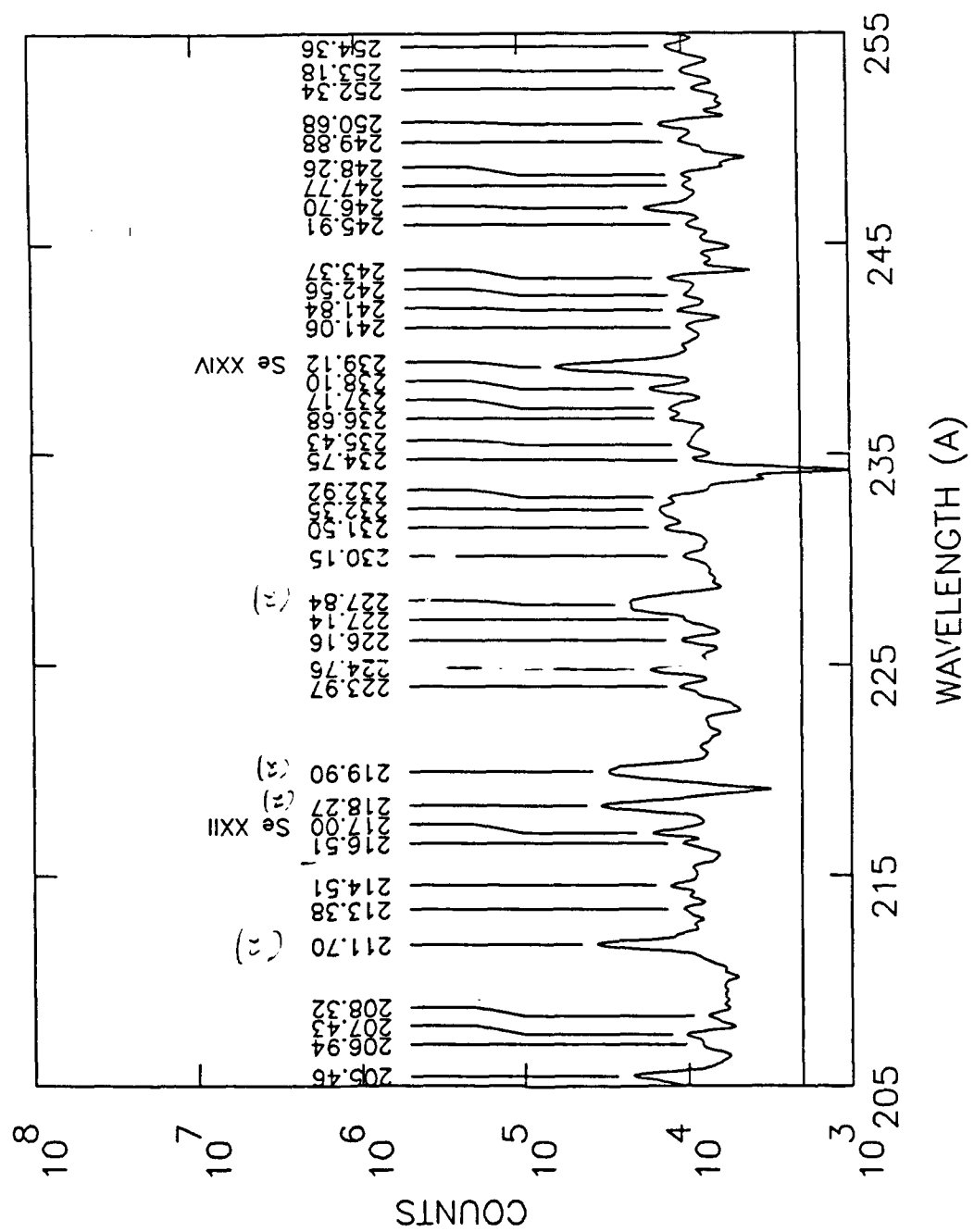
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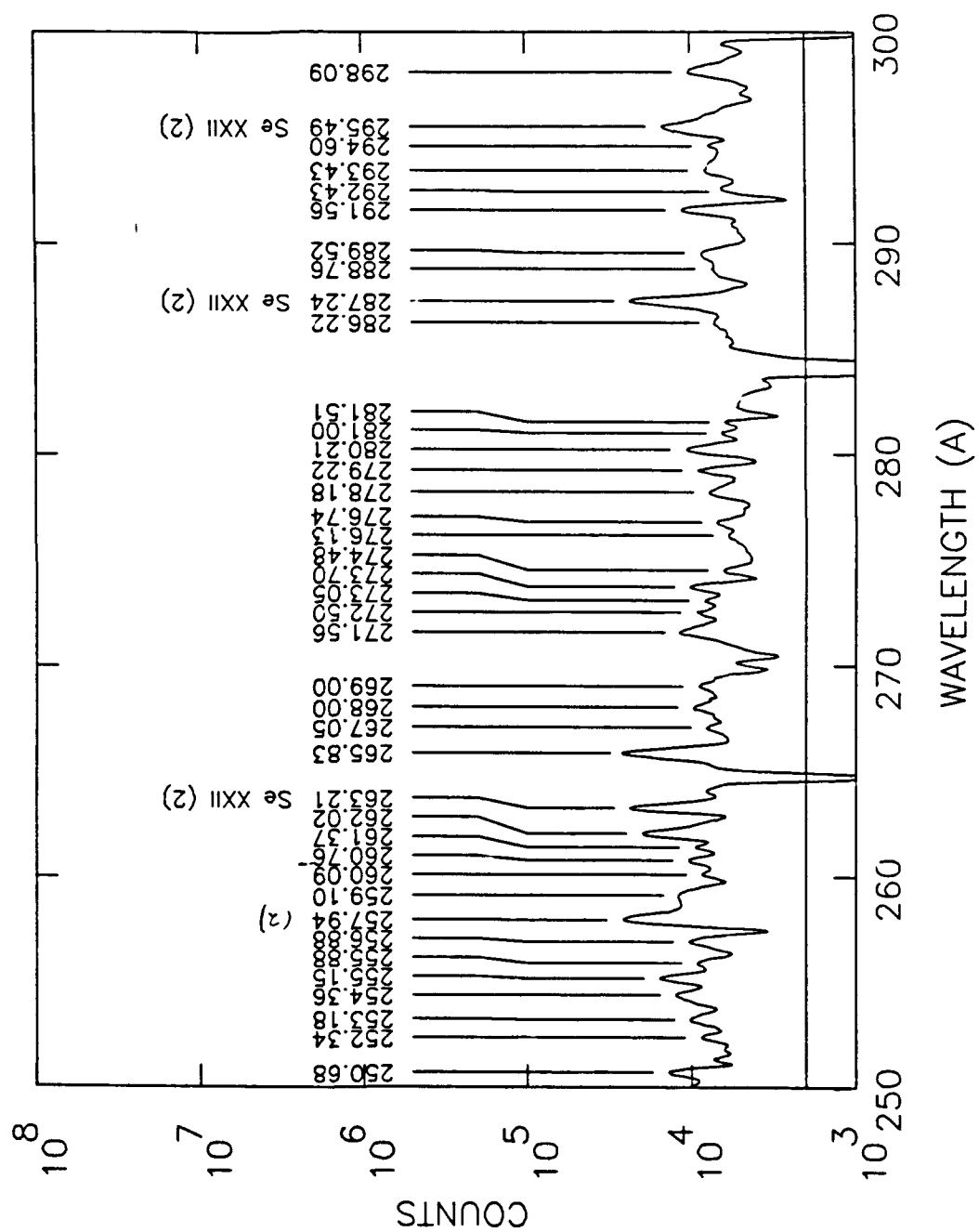
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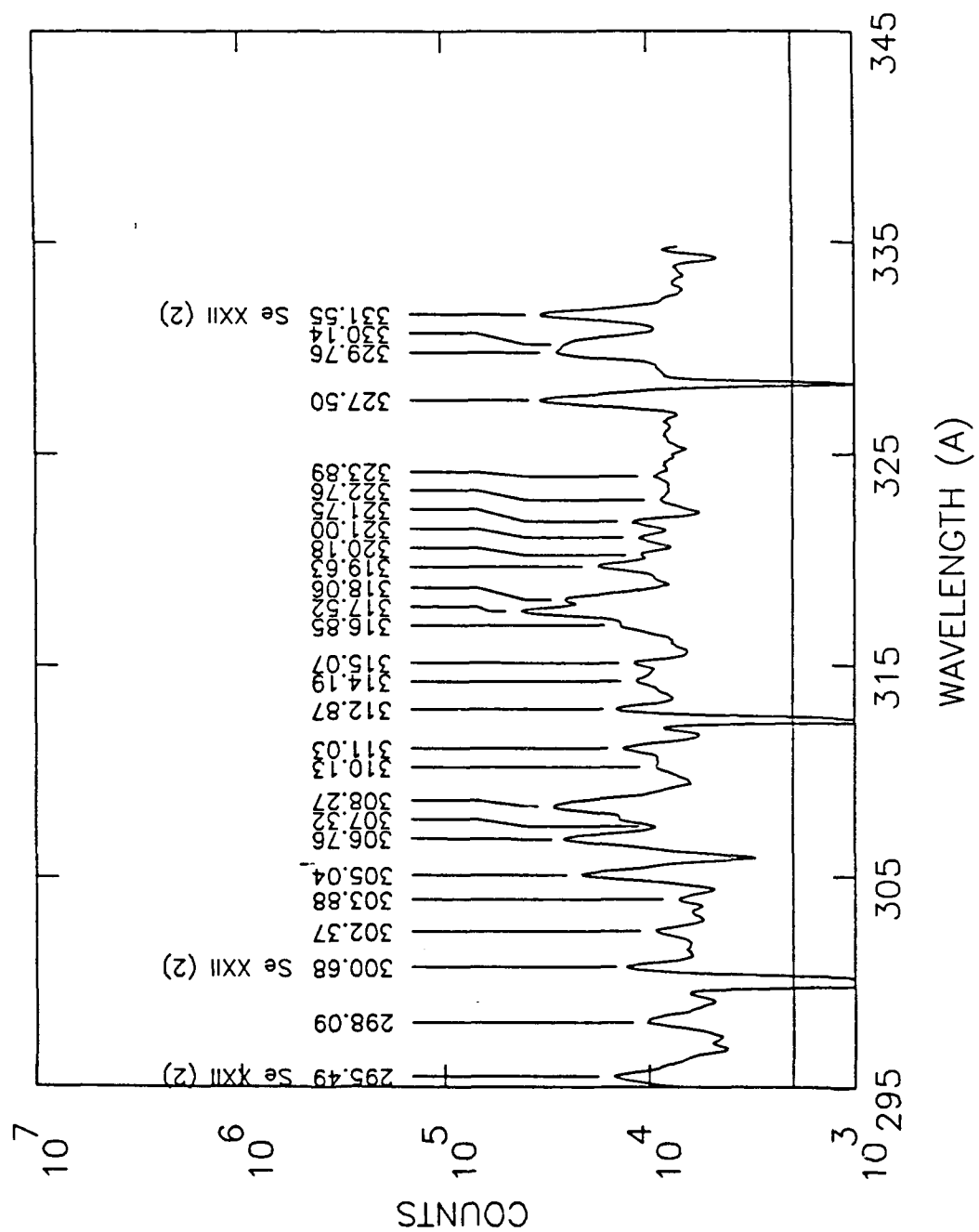


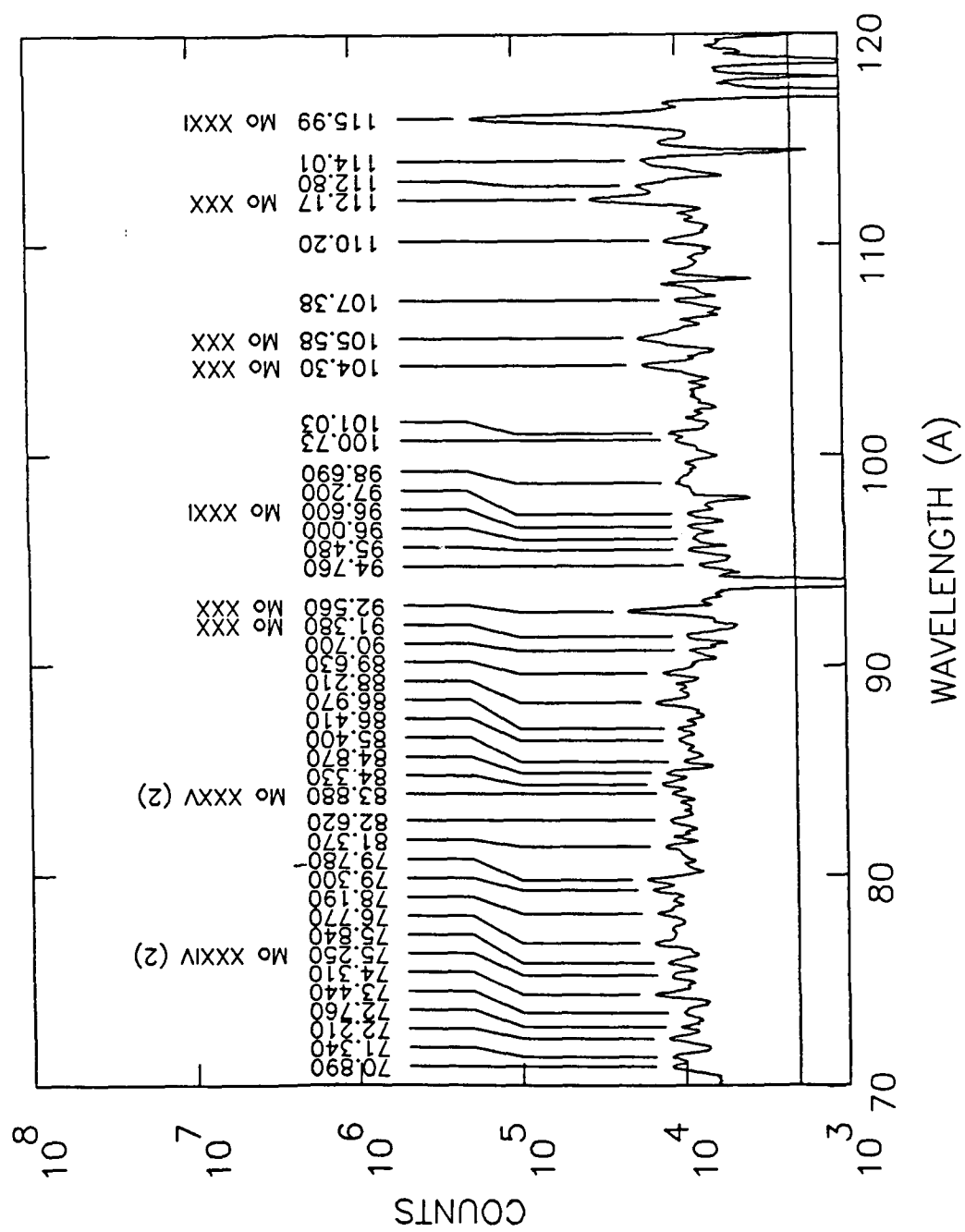


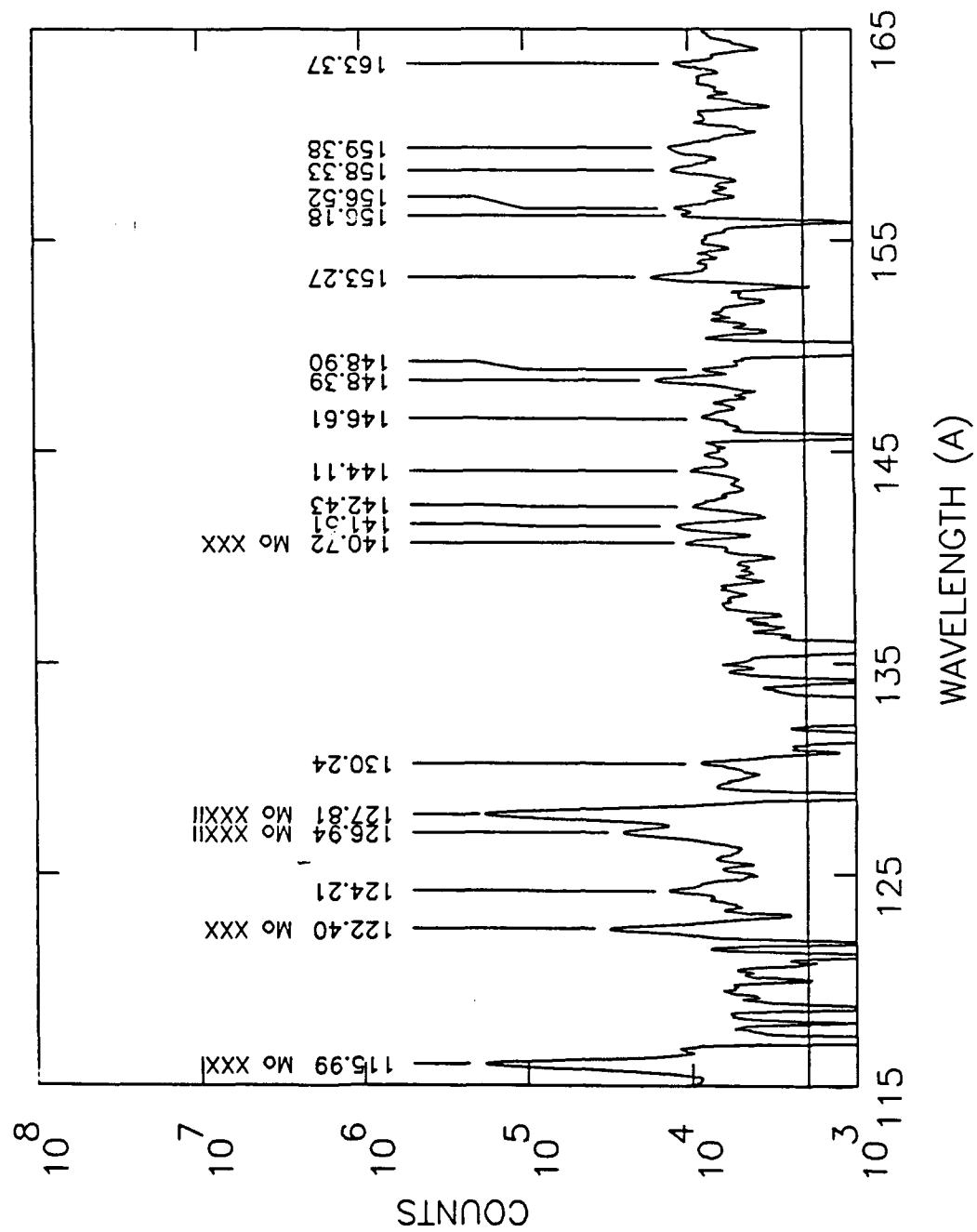


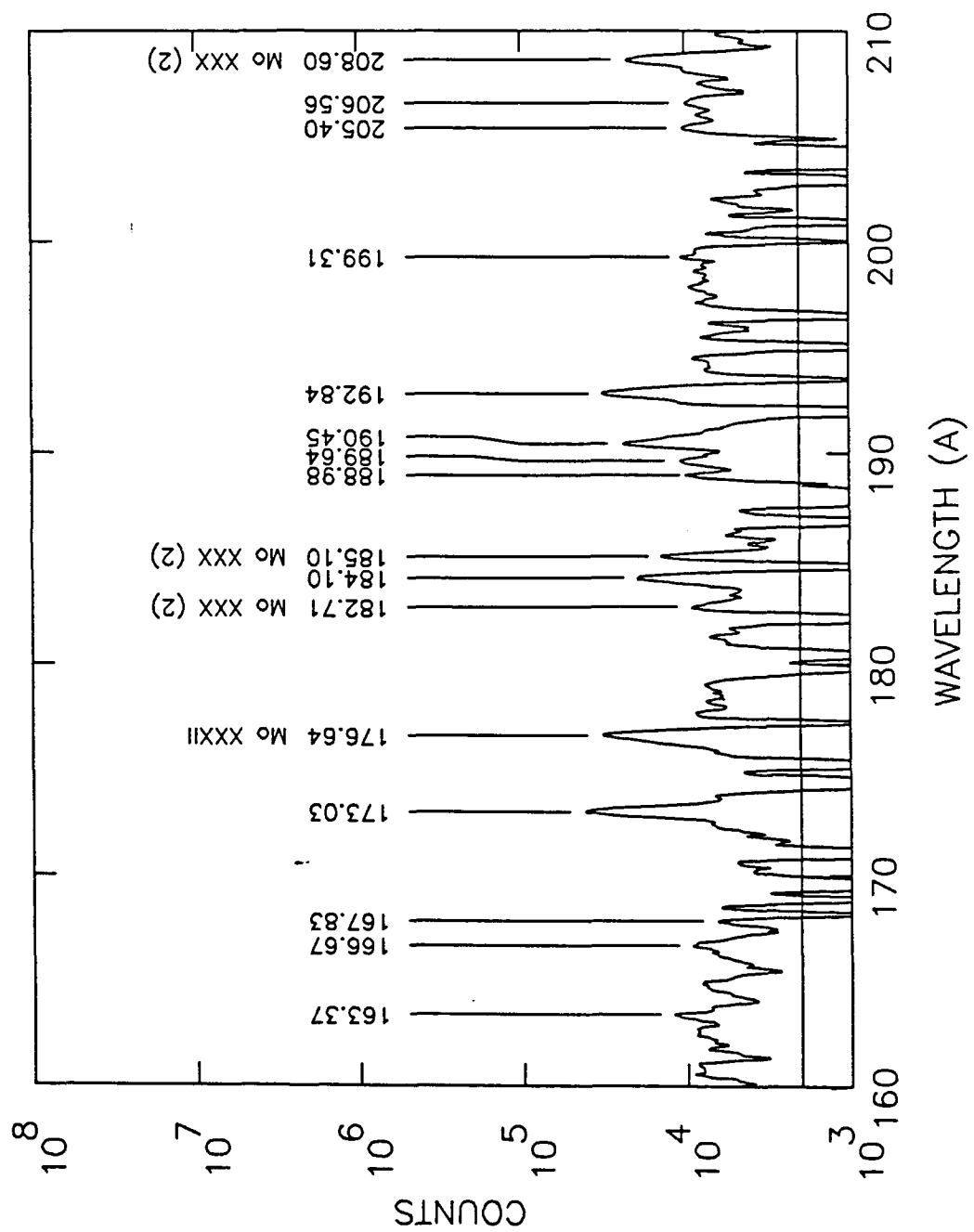


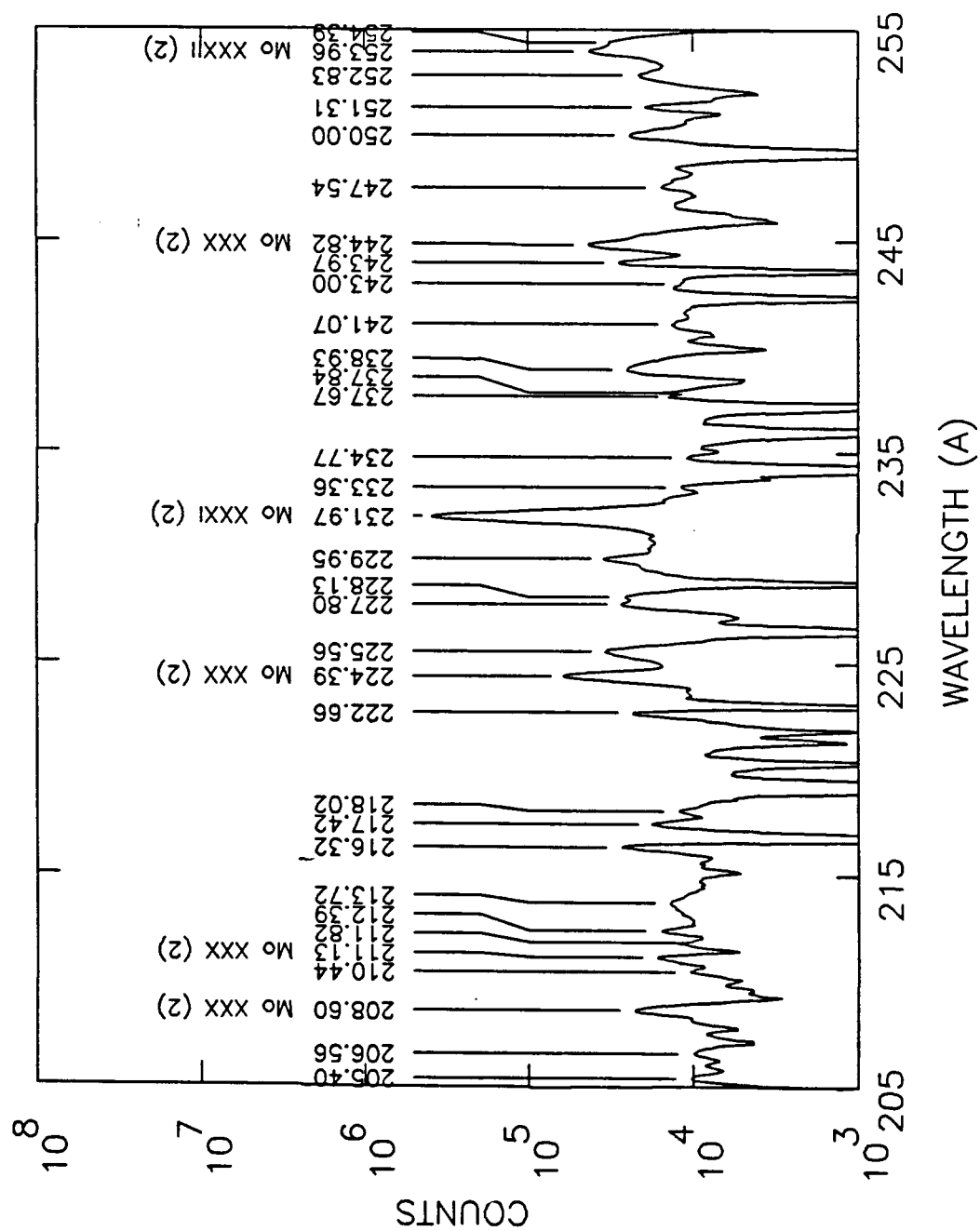


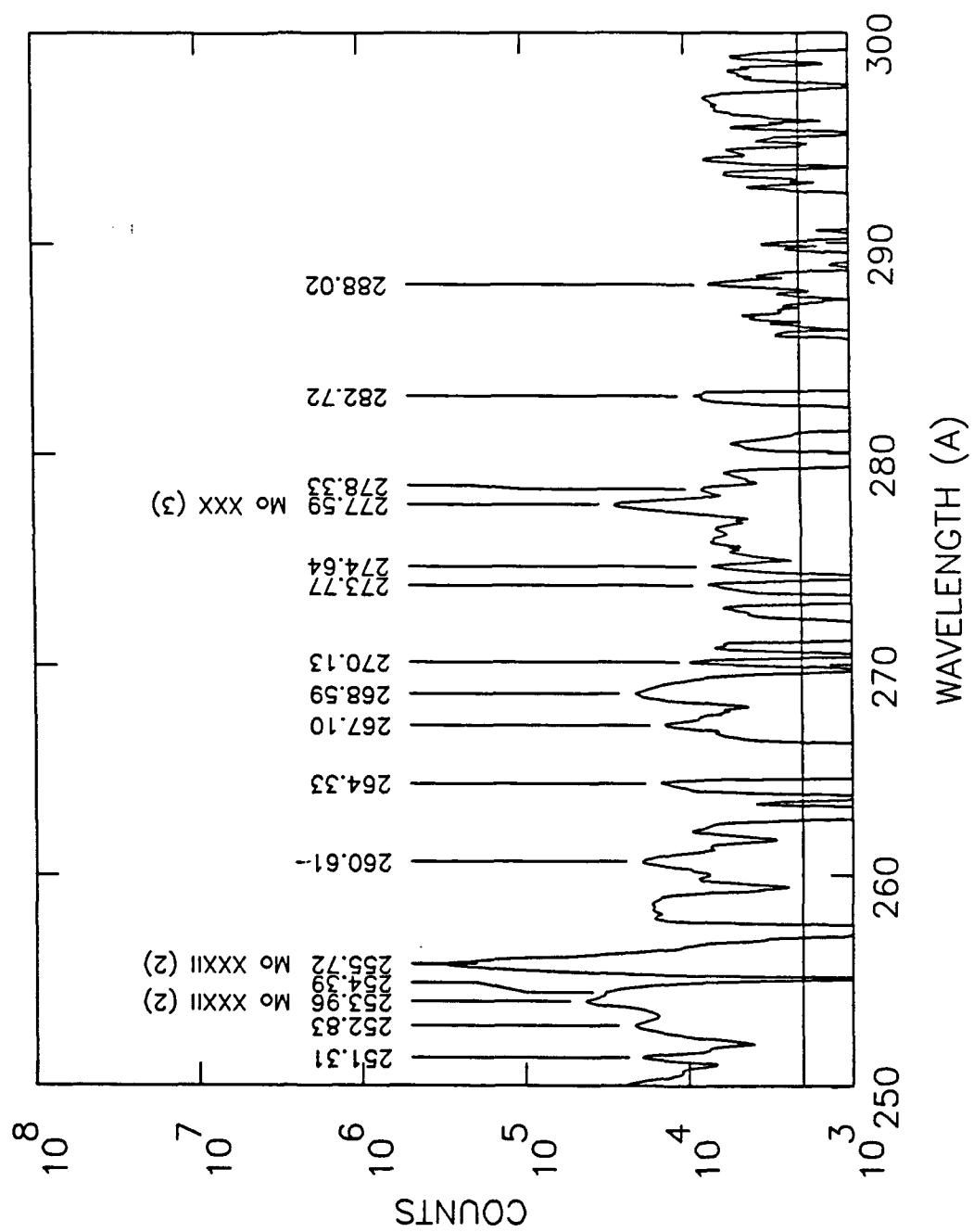












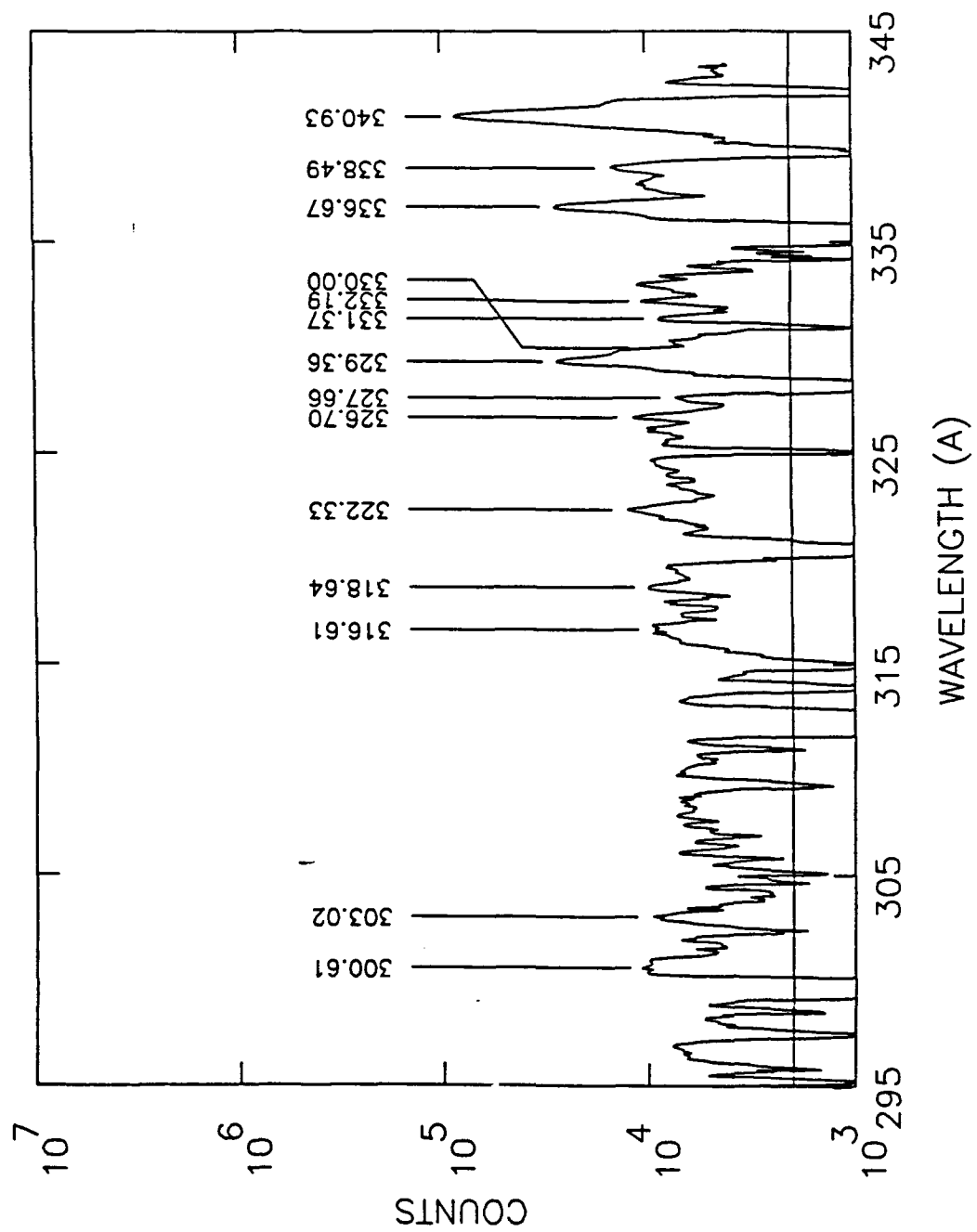


Table I. Classification of Spectral Lines, Presently Measured Wavelengths, and Previous Wavelengths.

Transition	Wavelengths (in Angstroms)											
	Pres	Prev	Pres	Prev	Pres	Prev	Pres	Prev	Pres	Prev	Pres	Prev
Li I												
	Fe XXIV		Ni XXVI		Zn XXVIII		Ge XXX		Se XXXII		Mo XL	
2s-2p												
$2S_{1/2}-2P_{3/2}$	192.01 ^B	192.01 ^a	165.35	165.38 ^a	142.44 ^a	122.68	122.68	122.68 ^a		105.64 ^a		
$2S_{1/2}-2P_{1/2}$	255.08 [?]	255.08 ^a	234.14 ^B	234.09 ^a	215.99 ^a	200.15	200.15	200.18 ^a		186.25 ^a		
Be I												
	Fe XXIII		Ni XXV		Zn XXVII		Ge XXIX		Se XXXI		Mo XXXIX	
2s ² -2s2p												
$1S_0-1P_1$	132.88	132.88 ^a	117.93 ^B	117.94 ^a	104.67 ^a			92.81 ^a		82.18 ^a		
$1S_0-3P_1$	263.73 [?]	263.74 ^a	238.89	238.86 ^a	217.66 ^a			199.48 ^a		183.75 ^a		

B I

	Fe XXII	Ni XXIV	Zn XXVI	Ge XXVIII	Se XXX	Mo XXXVIII
$2s^2 2p-2s 2p^2$						
$2P_{1/2}-2P_{3/2}$	100.77	100.77 ^b	87.46 ^b	75.82 ^b	65.64 ^b	56.74 ^b
$2P_{1/2}-2P_{1/2}$	102.22 ^B	102.22 ^b	88.61 ^b	76.8 ^b	66.4 ^b	57.3 ^b
$2P_{3/2}-2P_{3/2}$	114.41	114.41 ^b	102.12 ^B	91.17 ^b	81.37 ^b	72.55 ^b
$2P_{3/2}-2P_{1/2}$	116.25	116.27 ^b	103.68 ^b	92.6 ^b	82.6 ^b	73.5 ^b
$2P_{1/2}-2S_{1/2}$	117.13	117.18 ^b	104.66 ^B	93.51	83.5 ^b	74.6 ^b
$2P_{1/2}-2D_{3/2}$	135.76	135.76 ^b	118.49	103.72	90.67	79.56 ^b
$2P_{3/2}-2D_{5/2}$	155.94	155.94 ^b	138.73	123.23	109.04 ^b	96.12 ^b
$2P_{1/2}-4P_{1/2}$	247.19?	247.20 ^b	218.43	194.32 ^b	174.05 ^b	156.97 ^b

C I

	FeXXI	Ni XXIII	Zn XXV	Ge XXVII	Se XXIX	Mo XXXVII
$2s^2 2p^2 - 2s 2p^3$						
$3p_0 - 3s_1$	91.27 ^c	79.95	79.97 ^c	70.02 ^c	61.21 ^c	53.41 ^c
$3p_1 - 3s_1$	97.86	87.62	87.67 ^c	78.70	78.71 ^d	63.55 ^c
$1d_2 - 1p_1$	98.36 ^B	98.36 ^c	87.99 ^c	78.89 ^c	70.79 ^c	63.52 ^c
$3p_2 - 1d_2$	99.02	99.03 ^c	87.53 ^c	77.09	77.11 ^d	59.05 ^c
$3p_2 - 3s_1$	102.22 ^B	102.21 ^c	91.87 ^c	82.69	82.64 ^d	66.72 ^c
$3p_0 - 3p_1$	108.11 ^c	92.71	92.72 ^c	79.46 ^c	68.07 ^c	58.32 ^c
$1d_2 - 1d_2$	113.33	113.29 ^c	102.12 ^B	102.07 ^c	92.15 ^c	74.80 ^c
$3p_1 - 3p_1$	117.47	117.49 ^c	103.22 ^c	90.84 ^c	80.06 ^c	70.63 ^c
$3p_1 - 3p_0$	118.67 ^B	118.69 ^c	104.66 ^B	104.70 ^c	92.52 ^c	72.42 ^c
$3p_2 - 3p_2$	121.18	121.19 ^c	106.06 ^B	106.05 ^c	92.89	92.85 ^d
$3p_2 - 3p_1$	123.80	123.82 ^c	109.09 ^c	96.11 ^c	81.37 ^d	71.56 ^c
$3p_0 - 3d_1$	128.72	128.73 ^c	111.82	111.83 ^c	84.66 ^c	74.57 ^c
$3p_1 - 3d_2$	142.12	142.14 ^c	126.55	126.59 ^c	85.08 ^c	74.49 ^c
$3p_2 - 3d_3$	145.69	145.70 ^c	128.32	128.32 ^c	100.82 ^c	89.77 ^c
$1d_2 - 3d_3$	178.89	178.85 ^c	162.19 ^c	148.32 ^c	99.28 ^c	87.19 ^c
					136.60 ^c	126.54 ^c

N I

	Fe XX	Ni XXII	Zn XXIV	Ge XXVI	Se XXVIII	Mo XXXVI
$2s^2 2p^3 - 2s 2p^4$						
$4S_{3/2} - ^2P_{3/2}$	80.49 ^f	71.49 ^f	63.35 ^d	55.93 ^f	49.20 ^f	
$2D_{3/2} - ^2P_{1/2}$	83.24	72.52 ^f	63.33 ^f	55.38 ^f	48.46 ^f	
$2D_{3/2} - ^2P_{3/2}$	90.56	80.56 ^f	71.89	64.34 ^f	57.68 ^f	
$2D_{5/2} - ^2P_{3/2}$	93.78 ^f	84.11	75.59	67.84 ^d	60.90 ^f	
$2D_{3/2} - ^2S_{1/2}$	94.67	84.25 ^f	75.29 ^d	67.43 ^d	60.40 ^f	
$2P_{3/2} - ^2P_{1/2}$	98.36 ^B	88.02	78.98 ^d	70.99 ^d	63.83 ^f	
$2P_{1/2} - ^2S_{1/2}$	106.94	95.91 ^B	86.27 ^d	77.51 ^d	69.41 ^f	
$2P_{3/2} - ^2P_{3/2}$	108.80	100.13 ^f	92.77 ^f	86.41 ^f	80.84 ^f	
$2D_{3/2} - ^2D_{3/2}$	110.64	98.20	87.69	78.72	70.87 ^f	
$2D_{5/2} - ^2D_{5/2}$	113.33	100.60	89.50	79.64 ^d	70.84 ^f	
$4S_{3/2} - ^4P_{1/2}$	118.67 ^B	103.32	90.10	78.56 ^f	68.70 ^f	
$4S_{3/2} - ^4P_{3/2}$	121.83	106.06	92.16	80.06 ^d	69.51 ^f	
$4S_{3/2} - ^4P_{5/2}$	132.88 ^B	117.93 ^B	104.57	92.62 ^d	81.60 ^f	

O I

	Fe XIX	Ni XXI	Zn XXIII	Ge XXV	Se XXVII	Mo XXXV
$2s^2 2p^4 - 2s 2p^5$						
$1D_2 - ^1P_1$	91.01	81.73	81.70 ^a	73.59 ^a	66.38 ^a	59.88 ^a
$3P_2 - ^3P_1$	101.56	88.83	88.82 ^a	78.00	68.61 ^a	60.58 ^a
$3P_1 - ^3P_0$	106.30		93.93 ^a	83.22 ^a	73.88 ^a	65.67 ^a
$3P_2 - ^3P_2$	108.36	95.91 ^B	95.86 ^a	85.07	75.51 ^a	67.17 ^S
$3P_0 - ^3P_1$	109.96	96.83	96.80 ^a	85.29 ^a	75.21 ^a	66.41 ^a
$3P_1 - ^3P_1$	111.70	100.26	100.24 ^a	90.58 ^a	82.38 ^a	75.39 ^a
$3P_1 - ^3P_2$	119.98	109.30	109.31 ^a	100.30	92.44	85.81 ^a
						41.94 ^S
						41.99 ^a
						41.04 ^a
						55.93 ^a
						65.83 ^a

F I

	Fe XVIII	Ni XX	Zn XXII	Ge XXIV	Se XXVI	Mo XXXIV
$2s^2 2p^5 - 2s 2p^6$						
$2P_{3/2} - ^2S_{1/2}$	93.92	83.23	83.18 ^a	73.94	65.93 ^S	58.84 ^a
$2P_{1/2} - ^2S_{1/2}$	103.94	94.50	94.50 ^a	86.59	79.77	73.87 ^a
						37.63 ^S
						37.66 ^a
						56.54 ^a

Na I

	Fe XVI	Ni XVIII	Zn XX	Ge XXII	Sa XXIV	Mo XXXII
3s-3p						
$2S_{1/2}-2P_{3/2}$	335.40? 335.40 ^e	292.00 291.979	256.38 256.41 ^h	226.48 226.51 ^h	201.01 201.06 ⁱ	127.31 127.81 ^j
$2S_{1/2}-2P_{1/2}$	360.76 ^e	320.52 320.549	288.16 288.22 ^h	261.48 261.52 ^h	239.12 239.16 ⁱ	176.64 176.62 ^j
3p-3d						
$2P_{1/2}-2D_{3/2}$	251.07? 251.07 ^e	220.43 220.439	195.38 195.38 ^h	174.44 ^B 174.40 ^h	156.43 156.49 ⁱ	104.30 ^B 104.27 ^j
$2P_{3/2}-2D_{5/2}$	262.98? 262.98 ^e	233.85 ^B 233.769	210.10 210.16 ^h	190.58 190.61 ^h	174.08 174.12 ⁱ	126.94 126.94 ^j
$2P_{3/2}-2D_{3/2}$	265.019	236.339	213.31 ^h	194.38 194.44 ^h	178.54 178.63 ⁱ	134.619

Mg I

	Fe XV	Ni XVII	Zn XIX	Ge XXI	Se XXIII	Mo XXXI					
3s ² -3s3p											
1S ₀ - ¹ P ₁	284.15?	249.18	249.18 ^o	220.60	220.58 ^m	196.58	196.57 ^k	176.04	175.92 ^k	115.99	115.99 ^l
1S ₀ - ³ P ₁		417.26 ^o		366.82 ^u		293.24	293.4 ^x	265.83	265.7 ^x	190.45	190.5 ^x
3s3p-3s3d											
3P ₀ - ³ D ₁		224.75 ^r	197.34	197.39 ^v							
3P ₁ - ³ D ₂	227.20?	227.21 ^o		199.87 ^v	177.52	177.66 ^m	159.14 ^k		143.36 ^k	96.60	96.56 ^j
3P ₂ - ³ D ₃	233.81?	233.86 ^o	207.57	207.50 ^v	186.27	186.35 ^m	168.91	168.90 ^k	154.18	154.04 ^k	112.65 ^l
1P ₁ - ¹ D ₂	243.70?	243.79 ^o	215.91 ^B	215.89 ^v	193.33	193.39 ^m	174.71 ^B	174.78 ^k	159.00	158.86 ^k	113.90 ^l
3s3p-3p ²											
3P ₂ - ³ P ₂				266.15 ^v	234.35	234.38 ^m					

Al I

	Fe XIV	Ni XVI	Zn XVIII	Ge XX	Se XXII	Mo XXX
$3s^2 3p-3s^2 3d$						
$2P_{1/2}-^2D_{3/2}$	211.32	185.19	185.22°	146.53	146.52°	131.61
			164.08		131.69°	
$2P_{3/2}-^2D_{5/2}$	219.12	194.01	194.04°	157.46	157.55°	143.61
			173.96		143.69°	104.30 ^B
$2P_{3/2}-^2D_{3/2}$	220.09			159.34 ^B	159.25°	145.82
			175.50		145.80°	105.58
$3s^2 3p-3s^2 3p^2$						
$2P_{1/2}-^2P_{3/2}$	252.19?		218.39°	167.52	167.49°	147.70
			190.64		147.62°	92.56
$2P_{1/2}-^2P_{1/2}$	257.42?		223.09°		170.81°	150.40
			194.74		150.33°	91.38
$2P_{3/2}-^2P_{3/2}$	264.75?		232.52	184.30	184.34°	165.70
			206.16		165.83°	
$2P_{3/2}-^2P_{1/2}$	270.49?		237.88	188.42 ^B	188.37°	169.05°
			211.03°		112.17 ^B	112.16°
$2P_{1/2}-^2S_{1/2}$	274.20?		239.53	188.42 ^B	188.42°	168.90
			211.60		168.90°	112.17 ^B
$2P_{3/2}-^2S_{1/2}$	289.19?					
$2P_{1/2}-^2D_{3/2}$				220.9??	220.88°	194.46
						122.40
$2P_{3/2}-^2D_{5/2}$				242.73	242.8°	217.00
						140.72
	353.83°		272.09°			140.77°

Si I

	Fe XIII	Ni XV	Zn XVII	Ge XIX	Se XXI	Mo XXIX
$3s^2 3p^2 - 3s 3p^3$						
$3p_0 - ^3S_1$	240.69? 240.71°	209.18 ⁿ	183.51 ^m			
$3p_1 - ^3S_1$	246.21? 246.21°	215.91 ^B 215.94 ⁿ	191.57 ^m			
$3p_2 - ^3S_1$	252.00? 251.95°	221.98 221.93 ⁿ	197.62 197.58 ^m			
$3s^2 3p^2 - 3s^2 3p 3d$						
$1d_2 - ^1F_3$	196.53 196.53°	173.72 173.73 ⁿ	155.71 155.76 ^m	141.10	129.02 ^B	
$3p_1 - ^3D_2$	200.03 200.02°	174.99 ^r	155.04 ^m			
$3p_1 - ^3D_1$	201.16 201.12°	176.10 ⁿ	162.21 ^m			
$3p_0 - ^3P_1$	202.04 202.04°	176.69 176.69°	150.85 ^m			
$3p_1 - ^3P_0$	202.40? 202.42°					
$3p_2 - ^3D_2$		178.89 178.87 ⁿ	158.98 ^m			
$3p_2 - ^3D_3$	203.80 203.83°	179.25 179.27°	159.43 159.47 ^m	142.97 143.04 ^k	129.02 ^B 129.5 ^s	
$1s_0 - ^1P_1$	208.68 208.68°		165.03 ^m			
$3p_1 - ^3P_2$	209.62 209.62°	184.89 ⁿ				
$3p_2 - ^3P_2$	213.78 213.77°	189.25 ^B 189.21 ⁿ	169.69 ^m			
$1d_2 - ^1D_2$	221.82? 221.82°	195.51 195.52 ⁿ				

P I

	Fe XII	Ni XIV	Zn XVI	Ge XVIII	Se XX	Mo XXVIII
$3s^2 3p^3 - 3s^2 3p^2 ({}^3P) 3d$						
$2D_{3/2} - {}^2F_{5/2}$	186.87B 186.88q					
$2D_{5/2} - {}^2F_{7/2}$	186.87B 186.88e	164.15 164.13e	146.14 146.23m	131.42 131.3s	119.03 119.7s	
$2P_{1/2} - {}^2D_{3/2}$	188.23B 188.22e	164.80n				
$2P_{3/2} - {}^2D_{5/2}$	191.02 191.05e	168.37n				
$4S_{3/2} - {}^4P_{1/2}$	192.39 192.39e	168.12e				
$4S_{3/2} - {}^4P_{3/2}$	193.51 193.51e	169.68e				
$4S_{3/2} - {}^4P_{5/2}$	195.11 195.12e	171.36 171.36e	152.33 152.40m	136.71 136.7s	123.34 123.3s	
$3s^2 3p^3 - 3s^2 3p^2 ({}^1D) 3d$						
$2P_{1/2} - {}^2P_{3/2}$	198.55 198.56e					

S I

	Fe XI	Ni XIII	Zn XV	Ge XVII	Se XIX	Mo XXVII
$3p^4-3p^3(4s)3d$						
$3p_2-3d_2$	178.06	178.06 ^e	155.12 ⁿ	137.06 ^m		
$3p_2-3d_3$	180.36 ^B	180.40 ^e	157.66 ^B	157.73 ^r	140.00 ^B	139.85 ^m
$3p_1-3d_2$	182.11 ^B	182.17 ^e	159.96 ^B	159.97 ⁿ	142.74 ^m	
$3p^4-3p^3(2d)3d$						
$1d_2-1F_3$	179.74	179.76 ^e	157.66 ^B	157.55 ⁿ	140.00 ^B	140.43 ^m
$1d_2-1d_2$	184.78	184.79 ^e	161.56 ⁿ	143.68 ^m		
$3p_2-3p_2$	188.23 ^B	188.22 ^e	164.15 ^B	164.15 ⁿ	142.15	142.18 ^m
$3p_1-3p_1$	189.06	189.12 ^e				
$3p_1-3s_1$	192.01 ^B	192.02 ^q				
$3p_1-3p_2$	192.82 [?]	192.81 ^e				
$3p^4-3p^3(2p)3d$						
$3p_2-3p_2$			151.72	151.77 ^m		
$1d_2-1F_3$			167.51	167.52 ^m		

Ar I

	Fe IX	Ni XI	Zn XIII	Ge XV	Se XVII	Mo XXV				
$3p^6-3p^53d$										
$1S_0-1P_1$	171.06	148.30	148.37 ^r	130.99	131.06 ^m	117.20	117.25 ^k	105.84	105.9 ^s	74.31
$1S_0-3D_1$	217.10	217.10 ^o	186.98 ^w							
$1S_0-3P_1$	244.89?	244.91 ^o	211.51	211.44 ^w						

K I

	Fe VIII	Ni X	Zn XII	Ge XIV	Se XVI	Mo XXIV
$3p^63d-3p^53d^2(^3F)$						
$2D_{3/2}-2D_{3/2}$	167.47 167.49 ^o	144.23 144.21 ^r	126.65 126.74 ^m	112.90 112.96 ^k	101.70 102.2 ^s	
$2D_{5/2}-2D_{5/2}$	168.16? 168.17 ^o	144.99 ^r	127.53 127.62 ^m	113.85 113.93 ^k	102.71 102.6 ^s	
$2D_{5/2}-2F_{7/2}$	185.22 ^o	158.35 158.37 ^t	138.36 138.42 ^m	122.82 ^k	109.9 ^s	
$2D_{3/2}-2F_{5/2}$	186.61 ^o	159.97 ^t	140.00 ^B 140.12 ^m			
$3p^63d-3p^53d^2(^3P)$						
$2D_{5/2}-2P_{3/2}$	168.55 ^o	145.78 ^t	128.03 128.01 ^m			
$2D_{3/2}-2P_{1/2}$	168.93 ^o	146.12 ^t	128.34 ^m			
$3p^63d-3p^53d^2(^1D)$						
$2D_{5/2}-2F_{7/2}$	224.34? 224.35 ^o					

- ^aB. Edlen, Ref. 25
- ^bB. Edlen, Ref. 26
- ^cB. Edlen, Ref. 28
- ^dBehring et al., Ref. 20
- ^eBehring et al., Ref. 11
- ^fB. Edlen, Ref. 27
- ^gB. Edlen, Ref. 24
- ^hKononov et al., Ref. 14
- ⁱBrown et al., Ref. 21
- ^jBurkhalter et al., Ref. 12
- ^kFawcett and Hayes, Ref. 10
- ^lReader, Ref. 18
- ^mSugar and Kaufman, Ref. 23
- ⁿFawcett and Hayes, Ref. 7
- ^oHinnov et al., Ref. 22
- ^pFawcett and Hatter, Ref. 15
- ^qBromage et al., Ref. 13
- ^rBehring et al., Ref. 6
- ^sStratton et al., Ref. 17
- ^tGoldsmith and Fraenkel, Ref. 5

Cl I

	Fe X	Ni XII	Zn XIV	Ge XVI	Se XVIII	Mo XXVI
$3p^5-3p^4(^3P)3d$						
$2P_{3/2}-^2D_{5/2}$	174.53	174.53 ^e	152.11	152.15 ^r	134.74	134.80 ^m
$2P_{1/2}-^2D_{3/2}$	175.27	175.26 ^e	153.17 ^t	135.53	135.59 ^m	121.8 ^s
$2P_{3/2}-^2P_{3/2}$	177.24	177.24 ^e	154.14	154.18 ^r	136.24	136.31 ^m
$2P_{1/2}-^2P_{1/2}$	180.36 ^B	180.41 ^r	157.80 ^t	140.27 ^m		
$3p^5-3p^4(^1D)3d$						
$2P_{3/2}-^2S_{1/2}$	184.52	184.54 ^e	160.56 ⁿ	138.18 ^m		
$2P_{1/2}-^2S_{1/2}$	189.99	190.04 ^e	166.88 ⁿ	145.04	145.03 ^m	
$2P_{3/2}-^2D_{5/2}$	226.36?	226.33 ^r				
$2P_{3/2}-^2D_{3/2}$	230.08?	230.13 ^r				
$2P_{3/2}-^2P_{1/2}$			174.72	174.70 ^m		
$2P_{1/2}-^2P_{1/2}$				185.78 ^m		
$3p^5-3p^4(^3P)3d$						
$2P_{3/2}-^4D_{3/2}$	256.36?	256.37 ^r				
$3p^5-3p^4(^1S)3d$						
$2P_{1/2}-^2D_{3/2}$			153.71	153.69 ^m		

^uPeacock et al., Ref. 19

^vFawcett et al., Ref. 8

^wSvensson et al., Ref. 9

^xFinkenthal et al., Ref. 18

Bblend.

Sobserved in second order.