Table I. Iron group isotopes

Z	A	fraction	I	μ(nm)	Q(barns)	reference
20 Ca	40	.96941				
	42	.00647				
	43	.00135	7/2	–1.3172	–0.062	Q43
	44	.02086				
	46	.00004				
	48	.00187				
21 Sc	45	1.	7/2	+4.749	–0.22	OR, Q45
22 Ti	46	.080				
	47	.073	5/2	–0.787	+0.303	OR, Q47, Q49
	48	.738				
	49	.055	7/2	–1.102	+0.25	OR, Q49
	50	.054				
23 V	50	.00250	6	+3.341	+0.17	OR, Q50, Q51
	51	.99750	7/2	+5.142	–0.043	OR, Q51
24 Cr	50	.04345				
	52	.83789				
	53	.09501	3/2	–0.470	+0.03	OR, Q53
	54	.02365				
25 Mn	55	1.	5/2	+3.446	+0.33	OR, Q55
26 Fe	54	.058				
	56	.9172				
	57	.022	1/2	+0.0903	0	OR
	58	.0028				
27 Co	59	1.	7/2	+4.61	+0.35	OR, Q59
28 Ni	58	.6827				
	60	.2610				
	61	.0113	3/2	–0.748	+0.162	OR, Q61
	62	.0359				
	64	.0091				

and too blended for any solar analysis. In A stars and in Population II stars the isotopic error would be significant.

It is imperative that laboratory measurements be made to determine the isotopic splitting of every energy level of every stable isotope of every atom and ion as is now routinely done for actinides and for diatomic molecules. The hyperfine splitting should be measured as well for those isotopes with nuclear spin. The data should be presented in a form that is directly usable.

Large telescopes should be equipped with spectrographs that are capable of producing high resolution spectra of bright stars, resolution better than 1 km s^{-1}.

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is significant isotopic splitting in these elements that has not been considered. The one exception is a paper by Brault and Holweger (1981) on the isotopic splitting of Ni in the infrared. In Table I are listed all the stable isotopes of the iron group elements, their isotopic abundances from Anders and Grevesse (1990), the nuclear spin, the nuclear magnetic moment, and the nuclear electric quadrupole moment. The isotopes with nuclear spin have hyperfine splitting and every iron group element has some hyperfine splitting. The magnitudes of the magnetic moment and the spin give an indication of the strength of the hyperfine splitting. Figure 1 shows schematic isotopic splitting patterns for Ti, Cr, Fe and Ni for a positive isotopic splitting. The actual patterns for each line are not evenly spaced and can have the opposite sign as well. Table II lists all the isotopic splitting data for Ti, Cr, Fe, and Ni that I have been able to find in the literature. No data have been published for ions of these elements. Ca is not included because there are more data for Ca than for all the other iron group elements combined. The largest shift in the table corresponds to a Doppler shift of 11 km s^{-1}.

In natural mixtures essentially all atomic lines are asymmetric because of isotopic and hyperfine components. In astrophysics the effects of these components have been generally ignored in the case of Ti, Cr, Fe, and Ni. Ignoring isotopic or hyperfine splitting introduces the following systematic errors:

The use of bisectors to determine velocity fields is incorrect.

Fourier analysis of line profiles to determine rotational, microturbulent, and macroturbulent velocities is incorrect.

Damping constants are overestimated.

When the stronger components become saturated, the weak components are still on the linear part of the curve of growth. They make a larger contribution to the total feature than their fractional abundance might suggest. This introduces the additional systematic errors:

Wavelengths of saturated lines are shifted relative to the isotopic abundance weighted position.

Abundances determined from equivalent widths are wrong. Abundances should be determined by spectrum synthesis.

In addition, the Doppler width and Voigt profile differ significantly from isotope to isotope.

Table III lists computed equivalent width as a function of abundance in the sun for one of the Ni lines in Table II, both with and without isotopic splitting. The equivalent widths were found by integrating synthetic spectra computed at a resolution of 2 x 10^6. The isotopic effects are partially masked because the empirical solar model (Maltby et al. 1986) used for the calculation includes depth-dependent microturbulent velocity that increases from 0.5 km s^{-1} at the temperature minimum to 1.8 km s^{-1} in the convection zone. (These microturbulent velocities in the model will have to be corrected for isotopic errors.) The maximum abundance error of +0.120 in the log, or 32%, occurs at 70 mÅ. The abundance error is negligible below 13 mÅ. This particular line is too strong

SIGNIFICANT EFFECTS PRODUCED BY ISOTOPIC SPLITTING

Robert L. Kurucz

Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA 02138

ABSTRACT

In natural isotopic mixtures essentially all atomic lines are asymmetric because of isotopic and hyperfine components. In astrophysics the effects of isotopic components have been generally ignored in the case of Ti, Cr, Fe, and Ni. Ignoring isotopic splitting introduces the following systematic errors: 1) the use of bisectors to determine velocity fields is incorrect; 2) Fourier analysis of line profiles to determine rotational, microturbulent, and macroturbulent velocities is incorrect; and 3) damping constants are overestimated. When the stronger components become saturated, the weak components are still on the linear part of the curve of growth. This introduces the additional systematic errors: 4) wavelengths of saturated lines are shifted; and 5) abundances determined from equivalent widths are wrong. In addition the Doppler width and Voigt profile of each isotope are significantly different. It is imperative that laboratory measurements be made to determine the isotopic splitting of every energy level of every stable isotope of every atom and ion as is now routinely done for actinides and for diatomic molecules. Hyperfine splitting should be measured as well for those isotopes with nuclear spin.

Subject headings: abundances — line profiles — hyperfine structure

I am reducing solar central intensity spectra taken by James Brault with the FTS spectrograph on the McMath telescope at Kitt Peak. The spectra were observed with resolving power greater than 522000 in the visible. All lines in the spectra are blended. When the spectra are plotted at very high dispersion and compared with computed spectra (Kurucz 1992), they do not look "right". The damping wings do not look like Voigt profiles and the lines seem to be asymmetric. Because of blending and missing lines and uncertainties in continuum placement, however, this is difficult to demonstrate from the comparison. In fact, many of the lines are naturally asymmetric due to hyperfine splitting. I have included hyperfine splitting in my spectrum calculations for Sc, V, Mn, and Co for lines that have laboratory data available. Removing those lines from consideration, the remaining lines still give the same impression. I wondered whether there might not be other isotopes of Ti, Cr, Fe, and Ni with hyperfine splitting that could cause an asymmetry. There are, but the effect is small. That led me to discover that there

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Robert L. Kurucz
Harvard-Smithsonian Center for Astrophysics

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