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PLATINUM IN THE MAGNETIC SEQUENCE OF CHEMICALLY PECULIAR STARS

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ABSTRACT

Platinum appears to be present in a number of magnetic Ap stars. It is weak or absent in others. A line-by-line examination of the observational data is made, with special emphasis given to the problem of line blending. Preliminary abundance estimates, based upon an educated guess for the *gf*-value of Pt II λ4046, yield excesses for platinum ranging up to five orders of magnitude. No obvious temperature dependence of the platinum abundance has been found, but the sample of stars studied is still too small to establish the presence or absence of such a trend with any degree of confidence.

Subject headings: line identifications — stars: abundances — stars: peculiar A

I. INTRODUCTION

Since the work of Dworetsky (1969; Dworetsky and Vaughan 1973), the presence of Pt II lines in the manganese stars has become generally accepted. In the magnetic sequence of Ap stars (SrCr, CrEu, etc.), platinum has been found by a number of workers (see the review by Jaschek and Jaschek 1974), but this identification has been considered as less secure. Adelman (1972) wrote that Pt II was definitely present in only one of the 21 cool Ap stars studied in his thesis work. He mentioned several other stars where Pt II might be present, but additional work was required for confirmation. Preston (1974), in his review of Ap and Am stars, discusses Pt II in the CP3 (manganese) stars, but not in the CP2's (magnetic Ap stars).

We have analyzed the statistics of wavelength coincidences with Pt II lines in a number of magnetic Ap stars, and feel the identification is secure in several cases (Cowley 1976*a*, hereafter Paper III; Cowley, Hartoog, and Cowley 1974, hereafter Paper II). There remains the question of the systematics of the occurrence of platinum in the magnetic sequence, which should be compared with a well-delineated trend in the manganese stars, where Pt II lines are commonly found among the cooler stars, and are absent from the hotter ones (cf. Preston 1974, p. 272).

From the point of view of the genesis of the abundance peculiarities, it is important to know whether a single theory of the abundance peculiarities can explain the observations in both sequences of CP stars. After a discussion of the observations, we shall examine the question of whether the platinum which is observed in the cooler magnetic Ap stars can in any way be considered as a continuation of the platinum anomaly of the manganese stars.

An interpretation of the observations is far more difficult for the cooler magnetic Ap stars than for the manganese stars, because of the higher line density in the former. A primary concern of this paper is a careful delineation of this question, along with suggestions for palliative measures. Although some of the discussion is of general application, we shall concentrate our attention on the study of Pt II in the high-resolution (usually 2.4 Å mm^{-1}) spectra obtained at the Dominion Astrophysical Observatory. Details about the individual spectrograms, including dispersions and dates of observation, are given by Cowley (1976*b*).

II. LINE BLENDING

In the early stars with sharp spectral lines, one has the definite impression that one can measure (and frequently identify) "all" of the lines. This is to say that there appears to be a definite hiatus between the lines that one can see in the spectrum, and those lines which atomic theory tells us must be present in some strength but which are too faint for us to detect on the plates and measure. Whether this impression is misleading or useful remains to be seen, but in the magnetic Ap stars it is clear that one has just the opposite impression. The lines seem to merge smoothly into the noise.

It is essential, in the analysis of trace elements, to have a realistic conception of the complications to be expected from line blending. In this section, we shall attempt to approach this problem on a quantitative basis.

Consider the measured wavelengths in a magnetic Ap star such as HR 4816. Figure 1 is a histogram of the intervals *between* the measured stellar wavelengths for a region about 80 Å wide. It is obvious from inspection that the *measurements* do not have a Poisson distribution. In the latter case one would expect, for a similar density of lines, the exponential distribution indicated by the solid line, viz.,

$$N(\Delta\lambda) = \exp(-\rho\Delta\lambda)\,, \tag{1}$$

where $\rho = 2.97$ lines Å^{-1} in our sample. We have discussed elsewhere (e.g., Paper II) the departure from

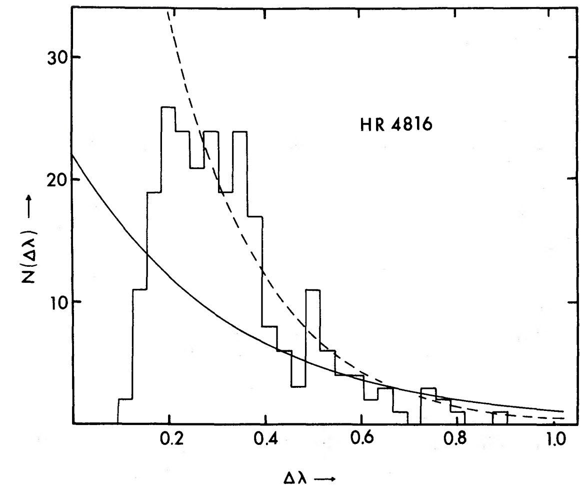

FIG. 1.—Distribution of wavelength intervals between measured lines. The histogram is for an 80 Å region near λ4000 where the density of measured lines is 2.92 $Å^{-1}$. If the lines were Poisson distributed, the distribution of intervals would be given by the solid line. The dashed line is for a higher line density of 5.18 $Å^{-1}$. The smaller intervals are missing because of the finite instrumental resolution. (Data courtesy of W. P. Bidelman.)

randomness in a stellar wavelength list, which precludes the use of the Russell-Bowen (1929) formulae in the analysis of the line list itself. The primary reason that the histogram differs so much from the exponential of equation (1) is the finite resolution of the spectrograms, which causes a dearth of very small wavelength intervals. Two lines are rarely measured separately if they are less than 0.15 Å apart. Nevertheless, we can think of no reason why *in reality* such close lines should not exist, and we shall therefore make Russell and Bowen's assumption of a Poisson distribution of wavelengths, to attempt to evaluate the probability that a given feature is, in reality, a close blend.

Let us assume that the intervals in HR 4816 are unaffected by resolution for $\Delta\lambda \geq 0.3$ Å, and fit an exponential of the form

$$f(\Delta\lambda) = A \exp(-\rho'\Delta\lambda) \tag{2}$$

to the points $f(0.3) = 20$, $f(0.8) = 1.5$, using A and ρ' as fitting parameters. We shall concern ourselves only with ρ', which we *assume* is the true density of lines commensurate with those we have measured. Note carefully that ρ' does not refer to lines *fainter* than those that we have measured. In general, one must think of the unresolved lines that are included in ρ' as typical in strength to those in the wavelength list.

For the data of Figure 1, we found $\rho' = 5.18$. With this value we calculate the probability $p(\Delta\lambda)$ that there *is* a line within an interval $\Delta\lambda$ of a given wavelength. We have

$$p(\Delta\lambda) = 1 - \exp(-\rho'\Delta\lambda) . \tag{3}$$

For $\Delta\lambda = 0.1$ and 0.05, we find $p(\Delta\lambda) = 0.404$ and 0.23, respectively. The conclusions to be drawn are quite startling: nearly every other line will be blended with a line of "typical" strength that was, however, too close (0.1 Å) to be measured separately. Under these conditions, one usually measures the mean position

$$\bar{\lambda} = \frac{W_1\lambda_1 + W_2\lambda_2}{W_1 + W_2} , \tag{4}$$

where the weights W_1 and W_2 may to a first approximation be assumed proportional of the equivalent widths. Thus for lines of comparable strength within 0.1 Å of each other, λ would be off by 0.05 Å, from either wavelength, too much for a measuring error but quite explicable in terms of blends. A measured stellar wavelength list is replete with examples of such wavelength perturbations.

If $|\lambda_2 - \lambda_1| \approx 0.1$ Å, one can see without difficulty (at our resolution of $\sim$2.4 Å mm^{-1}) that a blended feature appears wide, either at the measuring engine, or on tracings, provided $v \sin i \leqslant 10$ km s^{-1}. For $|\lambda_2 - \lambda_1| \approx 0.05$ Å, the blending is much more difficult to detect; our estimate is that about one line in five is subject to such subtle blending.

These factors should be kept in mind in the assessment of identifications and/or abundance determinations of trace elements. *Most* lines are going to require some allowance for blends. When, as in the following section, we examine a number of wavelengths to establish the presence of an element, we must expect to find abundant evidence for line blending. The most useful lines, of course, are the ones for which the blending is at a minimum.

III. PLATINUM IN MAGNETIC Ap STARS

The only star for which it has been possible to establish the platinum identification with a high degree of confidence by means of wavelength coincidence statistics is the manganese star HR 4072 (see Paper II). The Pt II lines are stronger in this star than in any other star that we have examined (with the possible exception of HR 7575). Table 1 gives a summary of

TABLE 1

STATISTICS OF THE PLATINUM COINCIDENCES

Star	$\mathscr{N}$	H/N	p	S
Manganese Stars				
HR 1800........	564	2/15	0.265	+1.1
46 Dra B........	1170	7/15	0.020	+3.3
ι CrB...........	694	2/15	0.270	+1.1
HR 4072........	985	10/15	< 0.001	+6.9
Magnetic Ap Stars				
HR 6958........	1437	2/51	0.760	−0.3
HR 4854........	1798	8/15	0.005	+2.9
HR 465(*b*)......	2039	10/15	< 0.005	+3.3
HR 4816........	1969	5/15	0.260	+0.96
HD 216533......	1850	4/15	0.470	+0.37
HR 7575(*b*).....	2485	7/14	0.060	+1.8

our statistical results for the platinum identification in several stars. The designations *a* and *b* appended to HR 465 and HR 7575 refer to plate epochs given by Cowley (1976*b*). Note that HR 465 (*b*) refers to a plate taken in 1974, when the spectrum was quite different from the unique rare-earth maximum spectrum.

$\mathcal{N}$ is the total number of stellar wavelengths measured and analyzed. It is an important number to keep in mind because, other things being equal, more random coincidences will occur in a star for which more wavelengths were measured. H/N gives the ratio of the number of coincidences or "hits" to the number N of lines sought. The tolerance for a coincidence is ± 0.06 Å, p is a measure of the probability that the coincidences have arisen by chance, and S gives, very roughly, the significance of the coincidences in standard deviations. A more detailed discussion of these parameters is given by Hartoog, Cowley, and Cowley (1973, hereafter Paper I).

The first four stars listed in Table 1 are in the non-magnetic sequence of Ap stars; they are all manganese stars. According to Dworetsky and Vaughan (1973), Pt II is present in all four. We do not question this identification. Since, however, it is clear that Pt II is identified far more securely in HR 4072 than in HR 1800 and ι CrB, the basis for our overall assessment that Pt II probably *is* present in the latter two stars deserves some justification.

It seems reasonable that a positive identification of a trace element can be made in the absence of statistical support, or when the statistical support is mediocre ($0.01 \leq p \leq 0.05$), if: (1) a positive identification, supported by statistics, has been made in another star showing spectral peculiarities related to the one in question (e.g., the manganese star HR 4072 is related to the manganese star HR 1800); and (2) alternate identifications to the element in question cannot be found for measured features. This argument is good for strong spectral features, and weakens along with the line intensities.

We list measured stellar wavelengths and preliminary equivalent widths in mÅ in Table 2 for features near the Pt II wavelengths given by Shenstone (1938), whose intensity estimates are listed in column (2). We have not listed λλ3768.39 and 3970.06 of Pt II because of their proximity to Balmer lines, although they account for some of the "hits" in Table 1. We have not made an entry in the table unless the measured stellar wavelength was within ± 0.06 Å of a Pt II line, except in the case of λ4046.45 (the strongest Pt II line), where we list the nearest measured wavelength.

Dworetsky and Vaughan (1973) have found evidence for isotope shifts in the Pt II spectra. These shifts have not been measured in the laboratory, but the evidence from stellar spectra is that measured shifts range up to 0.06 Å or more (see Table 4 of Paper II). The possibility of isotope shifts increases the difficulty of making line identifications, both by the traditional methods and by wavelength coincidence statistics. There are obvious palliative measures that can be taken to allow for possible isotope shifts, such as employing a larger tolerance window, or using wavelengths adjusted for isotope shifts when they are known. There is, of course, no substitute for a line-by-line examination of the spectra. In general, however, if the laboratory wavelengths are uncertain, the stellar spectroscopist must simply accept the fact that he cannot do quite as good a job as when they are precisely known.

In the present case, we believe that isotope shifts have not seriously affected our results or conclusions.

All of the lines listed in Table 2 are blended in one or another of the stars. These blends must be taken into account if accurate platinum abundances are to be obtained. It is our thesis that the blending problem is so severe that a spectrum synthesis of each feature must eventually be made, taking into account all lines

TABLE 2

MEASURED WAVELENGTHS AND EQUIVALENT WIDTHS OF PLATINUM LINES

λ	I_S	HR 6958	HR 4854	HR 465(*b*)	HR 4816	HD 216533	HR 7575(*b*)
3806.91	5	...	0.955 53::	0.908 24::	...	...	...
4014.31	2	...	...	0.338 8:	0.252 15	...	0.30†
4023.81	3	...	...	0.774 19	...	...	...
4034.17	5	0.199 34	0.199 43	...	0.22 18	...	0.174 68
4046.45	20	0.375 39	0.426 37	0.463 38	0.380 32	0.403 16	0.473 59
4061.66	10	...	...	...	...	...	...
4148.30	5	...	0.252 17	0.312 14	...	...	...
4223.69	3	...	0.647 23	0.705 16	0.720 < 10	...	0.708 32
4288.40	5	...	0.352 23	0.412 27	0.371 16	0.37 14	0.392 23
4514.17	10	0.153 39	0.153 63	0.163 60	0.13 36	...	0.167 61

† This wavelength is from Bidelman 1976.

which may contribute. In order to facilitate such a calculation, we discuss a number of Pt II wavelengths individually.

λ3806.91.—This is a fairly weak Pt II line, and in the early A stars, it appears in a region where the continuum is lowered by overlapping Balmer lines. The feature that was measured in HR 465(*b*) and HR 4854 appears to be too wide to be exclusively Pt II; pFe II–153[1] λ3806.82 and Cr I–214 λ3806.83 may contribute to the features, but they cannot explain the stellar wavelengths.

λ4014.31.—The Pt II line is so weak that it was not measured in HR 4072 by either Cowley, Hartoog, and Cowley (1974) or Dworetsky (1969). Fe I–426, 427 λ4014.28 is a possible alternate identification for HR 465(*b*) and HR 4816.

λ4023.81.—Cr I–268 λ4023.74 will mask the Pt II line unless the former is weak and the latter relatively strong. Apparently only in HR 465(*b*) was the Pt II strong enough to perturb the measured Cr I wavelength. This line is too badly blended in the stars of Table 2 to be useful for an identification or abundance determination.

λ4034.17.—This feature was noted as "wide, blended" when our tracing of HR 7575 was measured for the equivalent widths. Further evidence of a line on the long-wavelength side of λ4034.17 is to be found in the stellar measurements listed in Table 2. There is no obvious identification for the blending feature. In β CrB, where we have concluded that Pt II is weak or absent, there is an ~30 mÅ line at $\bar{\lambda}$*4034.152 (average of 2 plates; the asterisk denotes a *measured stellar wavelength*).

λ4046.45.—In the mercury stars, this feature can be blended with Hg I. However, the dominant contribution from Hg I is likely to be at λ4046.56 (see Cowley and Aikman 1975, Table A1), while the significant displacements in Table 2 are shortward of the Pt II wavelengths. In HR 7575, one can see a separate line of similar intensity to the Pt II feature at $\bar{\lambda}$*4046.310 which is probably Ce II λ4046.34. In the other stars, only one feature is seen, although some asymmetry is more or less evident. It is plausible that Ce II makes the dominant contribution to the measured feature in HR 6958 and HR 4816. Possibly the feature in HR 4854 can be interpreted as Pt II + Ce II. Both Ce II and Pt II are weak in HD 216533, and the measured feature is only marginally above the noise threshold.

In the hotter stars, the λ4046 feature appears to be the most reliable guide to the presence of Pt II from the point of view both of the intrinsic strength of the line and of complications due to blends. In the cooler stars, it is greatly confused by the well-developed wing of Fe I λ4045.82 and several other lines that degrade the entire region, ultimately making it impossible to use.

λ4061.66.—This line is closely blended with Mn I–29 λ4061.74 and is not measured separately. Some indication of the presence of Pt II may be seen from an examination of the profile of the blend, as well as from the measured wavelengths. However, Fe II–189 λ4061.79 is strong, and close enough in wavelength to mold into the blend on the opposite side from the Pt II line, making the usefulness of this strong Pt II line minimal.

λ4148.30.—This feature is usually complex in appearance, though rather weak. It is not easy to identify the lines that are responsible for the wavelength perturbations; but since they are weak, we suggest that this line is a useful indication of Pt II in the hotter stars like HR 465 and HR 4854, provided the wavelength measurement is close.

λ4223.69.—We have measured a line at λ*4223.724 and λ*4223.712 in γ Equ and 10 Aql, respectively, in which Pt II is weak or absent. This is probably Fe I–417 λ4223.73. In HR 7575, an appropriate identification is Pt II + Fe I. In HR 465(*b*) and 4854, where Fe I is slightly weaker, the stellar feature is probably predominantly Pt II.

λ4288.40.—Adelman (1972) has called attention to the presence of this line in some stars in which Pt II was absent. The most likely blending line is Cr I λ4288.40 (Kiess 1953). Since Cr I and Cr II are generally strong in the magnetic Ap stars, and they blend so closely in wavelength, the usefulness of this feature for the study of Pt II is minimal.

λ4514.17.—This is one of the three strongest Pt II lines, but it is blended with Fe I–514 λ4514.19, which is present in the cooler stars. The measured wavelengths and equivalent widths in HR 6958 and HR 4816 are puzzling, since we would be very hesitant to assign this feature to Pt II in either star. The implication is that there is another, unknown contributor to the feature. This overall conclusion may explain the strength of the feature in HR 465(*b*), HR 4854, and HR 7575. In these stars λ4514 seems too strong relative to λ4046.

In the hotter stars ($T \geqslant 10{,}000$ K), λλ4046.45, 4034.17, and 4148.30 are, in this order, probably the most useful lines of Pt II for identification and abundance work, although all three must be used with caution.

IV. ABUNDANCE ESTIMATES

Neither experimental nor theoretical *gf*-values are available for the Pt II lines that we have discussed. Simple estimates based on the Coulomb approximation are precluded because of severe configuration interaction as well as deviations from *LS* coupling. The strongest line, λ4046.45, is an apparent two-electron jump: $5d^7 6s^2\ {}^4F_{5/2}$–$5d^8({}^3F)6p\ {}^4D^o{}_{5/2}$. The transition is possible because of a strong interaction between the $5d^7 6s^2$ configuration and the $5d^8({}^3F)6s$. The most important level contributing to this mixing must be the $6s\,{}^4F_{5/2}$ at 13329.3 cm^{-1}.

If we were to assume the lower level were *entirely* $5d^8({}^3F)6s\ {}^4F_{5/2}$, a straightforward calculation based on the Coulomb approximation would yield $\log gf = -0.37$, which may be regarded as an upper limit. For a somewhat similar transition in the Hg II spectrum, an astrophysical log *gf*-value was derived by Dworetsky, Ross, and Aller (1970) and Cowley and Aikman

[1] A predicted Fe II line in multiplet no. 153 (Moore 1945).

TABLE 3

THEORETICAL EQUIVALENT WIDTHS IN mÅ OF Pt II λ4046.45

T_{eff}	$[Pt/H]_{\odot}$ 4.0	4.5	5.0	5.5
8000	12	31	59	...
9000	9	25	52	82
10000	7	18	40	67
12000	7	19	40	64
14000	6	16	34	57

(1975) in the range −1.5 to −2.0. We estimate that the value for Pt II λ4046.45 must be in the same range.

We have made theoretical calculations of equivalent widths of Pt II λ4046.45 for a series of $\log g = 4$ model atmospheres in order to have some basis for abundance estimates. It is also of interest to see the dependence of the theoretical Pt II strengths on the stellar effective temperature, since many abundance peculiarities are so highly correlated with this parameter.

The results of the calculation are shown in Table 3. $\log g = 4.0$, $\log gf = -2.0$, and a microturbulence of 2 km s^{-1} was assumed throughout. Equivalent widths as small as 20 mÅ are sensitive to the value of this arbitrarily chosen parameter. However, since the reader may easily modify the results with a standard curve of growth, a more complete tabulation is not required. The logarithmic Pt/H ratio is taken as 1.7 for the solar system ($\log H = 12.0$); the entries in Table 3 thus represent enhancements of 10^4, $10^{4.5}$, etc., over that value.

In Table 4, we list interpolation coefficients for calculations of partition functions for Pt I and Pt II, using Bolton's (1970) notation. The fit is within 0.3% or better in the range (5000 K < T < 34,000 K), to values obtained using all levels tabulated by Moore (1958). The third spectrum is not relevant at our temperatures because of the high ionization energy (18.56 eV) of Pt II, so it was safe to assume $u(\text{Pt III}) = g_0(\text{Pt III}) = 9.0$.

If we completely ignore the blending, the 60 mÅ equivalent width of λ4046.45 in HR 7575 would imply an abundance excess of 5 dex, according to Table 3. Allen (1976) adopts $T_{eff} = 8000$ K, $\log g = 4.0$, and a microturbulence of 3.5 km s^{-1} for HR 7575. The latter parameter is somewhat higher than the value 2.0 km s^{-1} assumed in calculating Table 3. Both this and the effects of blending would reduce the over-abundance to perhaps 4.5 dex (if $\log gf = -2.0$). This value for our coolest star should be compared with the following estimate for HD 20031, whose four-color and Hβ photometry are very similar to that for κ Cnc (see Cowley 1975). Adelman (1974*a*) gives 10 mÅ for the equivalent width of Pt II λ4046.45 in HD 200311; and if we use $T_{eff} = 14{,}000$ K by comparison with κ Cnc, we see that the platinum excess in HD 200311 is in the range 4.0–4.5 dex, essentially the same, within the uncertainties, as found in HR 7575. This result is *independent* of the *gf*-value for λ4046.45.

All that we can say at the present time is that the abundance excesses for Pt II range up to 10^4–10^5 ($\log gf_{\lambda 4046} = -2$), with no obvious dependence on the stellar effective temperature, such as is found in the manganese stars. The sample of objects studied is still too small to establish the presence or absence of such a trend with any degree of confidence.

In the extreme platinum star HR 4072, Dworetsky and Vaughan give 54 mÅ for λ4046.45. If we assume that the effective temperature of this star is near 10,000 K, we find, using Table 3, an abundance excess of the order of 10^5–$10^{5.5}$, no more than an order of magnitude higher than our estimates for HR 7575 and HD 200311. Dworetsky (1969) had "tentatively estimated" that platinum is about 1000 times over-abundant in HR 4072, but this was apparently based on a much larger *gf*-value than we have assumed.

It is interesting to compare the platinum abundance excesses with those of mercury found by Cowley and Aikman (1975). This is done in Table 5. Within the uncertainties of the calculation, these figures show a remarkable similarity. The maximum abundance excesses of both platinum and mercury appear to have the same upper bound.

The *range* of the platinum abundances in the sharp-lined magnetic Ap stars cannot be accurately established until reliable Pt II *gf*-values are available and the regions of a number of these lines have been studied by spectrum synthesis. In those stars where Pt II is weak or absent (see the following section), we can, at present, only estimate that the abundances must be 1.0–2.0 dex lower than the values listed in Table 5.

V. DISCUSSION

For the stars listed in Table 2, our conclusions are as follows. Pt II is definitely present in HR 465(*b*), HR 4854, and HR 7575. In the last star, the lines are quite strong, but the general richness of the line spectrum prevented statistical support for the identification. We think Pt I may also be present in HR 7575, but this needs further work. In HR 4816, Pt II is weak or absent altogether. (This conclusion is unchanged since the work of Paper II.) There is even less indication that Pt II is present in HD 216533 and HR 6958.

TABLE 4

COEFFICIENTS OF POLYNOMINAL APPROXIMATIONS OF PARTITION FUNCTIONS

Ion	g_0	a_0	a_1	a_2	a_3	a_4
Pt I	7.0	2.550131	−0.614545	−0.280669	−0.602178	−0.174494
Pt II	6.0	1.329317	−1.924455	−0.396040	−0.107157	0.000000

TABLE 5

A Comparison of Platinum and Mercury Abundances

	Log (Abundance Excesses)	Log Abundances (log H = 12.0)
Pt.........	4 –5.5	5.8–7.3
Hg........	4.4–5.4	5.5–6.5

In Paper I, we argued that Pt II was probably present in the rare-earth maximum spectrum of HR 465(*a*). Paper II reached similar conclusions regarding 73 Dra and 78 Vir. In all three cases, the identifications had been proposed earlier by Bidelman (1976), Jaschek and Malaroda (1970), Guthrie (1972), and Adelman (1972). Pyper and Hartoog (1975) have confirmed the identification by Jaschek and Brandi (1972) of Pt II in HD 25254. Other identifications have been proposed (cf. the reviews by Kuchowicz 1973, 1976), but we shall not discuss them here, since we have not had direct experience with the spectra. Table 6 is a summary of the Pt II detection. For all stars for which Pt II is listed as present, there is either statistical support for the identification, a confirmation by other workers, or both. HD 221568 is listed inside parentheses; λ*4046.450 is definitely present, but it appears to be blended.

Only stars with sharp spectral lines, where there was some hope of detecting a trace element, have been listed in column (2).

We have argued elsewhere (Paper I, Paper III) that the presence of Hg and Pt in the magnetic Ap stars suggested a relationship with the manganese stars. This is not to dispute the *overall* distinction (Preston 1974) between the manganese stars (CP3) and magnetic Ap stars (CP2), which is clear. The question is whether, as with the R and S stars, there are intermediate objects. From a theoretical point of view, the existence of intermediate cases is a sign that a theory that will work for one kind of CP star may, with some degree of modification, work for the other. Clearly such an idea has been implicit in much of the work of Michaud (1970, 1976) and Havnes (1974, 1976). If there is a real hiatus in the chemical properties of the different types, there is less hope that one general idea (e.g., diffusion or accretion) would work for all of these objects.

TABLE 6

Pt II Identifications in Magnetic Ap Stars

Pt II Present	Pt II Weak or Absent
HD 200311	HR 6958
HR 4854	HD 216533
HR 465(*b*)	HR 4816
HD 25354	(HD 221568)
78 Vir	γ Equ
73 Dra	10 Aql
HR 7575	β CrB

Three of the stars in column (1), HR 4854, HR 465(*b*), and HR 7575, are rich in manganese. The first is quite weak in rare earths; the strongest Eu II line, λ4205.05, is weak, <40 mÅ, and the region around this line is dominated by strong Mn II. In HR 465(*b*), the rare-earth elements are somewhat stronger, but Mn II still dominates the λ4205 region. This star is quite different at rare-earth maximum (HR 465[*a*]), where a huge Eu II λ4205 appears; and Mn II λ4206.36 is not even measured for a wavelength!

Bidelman (1966) has remarked on the outstanding strength of Mn II in HR 7575. We find both neutral and first ionized Mn lines enhanced in HR 7575 when we compare it with either cooler Ap stars, like β CrB and γ Equ, or hotter ones, like HR 4816 or HR 4854; thus there can be no doubt that HR 7575 is, in some sense, "a manganese star." Yet there is also no doubt that this is a strong rare-earth star. Eu II λ4205 is too large to measure accurately. We estimate $\sim$250 mÅ, comparable in strength with that in any Ap star. The pattern of the rare-earth elements in HR 7575 is similar to that in β CrB: strong Ce, Eu, and Gd, with weak or moderate Nd and Sm; but the behavior of manganese is quite different.

HR 7575 is the coolest Ap star for which we feel confident of the Pt II identification. Allen (1976) has recently adopted $T_e = 8000$ K $\log g = 4.0$ for this star for JD 2442350.63.

We must refer to the literature for a discussion of 78 Vir, 73 Dra (cf. Paper II; Guthrie 1972, and references therein), and HD 25354 (see Pyper and Hartoog 1975).

Adelman (1974*b*) has given an excellent description of HD 200311, and has summarized its spectral similarities to the manganese stars. However, strong manganese is *not* one of the points of similarity. Moreover, HD 200311 is properly described as a silicon star; strong silicon and manganese are rarely, if ever, associated. The colors and hydrogen lines of HD 200311 are very similar to those of the manganese star κ Cnc, and both have enhanced gallium, platinum, and mercury. But while HD 200311 has strong S II, Si II, Co I, and Co II, and rare earths, κ Cnc has strong P II and Mn II. We note that platinum has not been found in any manganese star as blue as κ Cnc.

VI. CONCLUSIONS

It is clear that any interrelationship that may exist between the abundance peculiarities of the manganese and magnetic Ap stars is a very loose one. It remains for the theoretician to say whether or not the obvious similarities between HR 4854 and HR 7575 and the manganese stars can be exploited.

For the present, we conclude that a platinum excess can occur in both the magnetic and nonmagnetic sequences of Ap stars, and should not be thought of as an anomaly that is primarily characteristic of one sequence rather than the other.

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REFERENCES

Adelman, S. J. 1972, Ph.D. thesis, California Institute of Technology.
———. 1974*a*, private communication.
———. 1974*b*, *Ap. J. Suppl.*, **28**, 51.
Allen, M. S. 1976, Ph.D. thesis, University of Michigan.
Bidelman, W. P. 1966, in *IAU Symposium No. 26, Abundance Determinations in Stellar Spectra*, ed. H. Hubenet (London: Academic Press).
———. 1976, private communication.
Bolton, C. T. 1970, *Ap. J.*, **161**, 1187.
Cowley, C. R. 1975, *Ap. J.*, **198**, 379.
———. 1976*a*, in *IAU Colloquium No. 32, Physics of Ap Stars*, ed. W. W. Weiss (Universitaetssternwarte Wien) (Paper III), p. 275.
———. 1976*b*, *Ap. J. Suppl.*, **32**, 631.
Cowley, C. R., and Aikman, G. C. L. 1975, *Pub. A.S.P.*, **87**, 513.
Cowley, C. R., Hartoog, M. R., and Cowley, A. P. 1974, *Ap. J.*, **194**, 343 (Paper II).
Dworetsky, M. M. 1969, *Ap. J. (Letters)*, **156**, L101.
Dworetsky, M. M., Ross, J. E., and Aller, L. H. 1970, *Bull. AAS*, **2**, 311.
Dworetsky, M. M., and Vaughan, A. H., Jr. 1973, *Ap. J.*, **181**, 811.
Guthrie, B. N. G. 1972, *Ap. Space Sci.*, **15**, 214.
Hartoog, M. R., Cowley, C. R., and Cowley, A. P. 1973, *Ap. J.*, **182**, 847 (Paper I).
Havnes, O. 1974, *Astr. Ap.*, **32**, 161.
———. 1976, in *IAU Colloquium No. 32, Physics of Ap Stars*, ed. W. W. Weiss (Universitaetssternwarte Wien), p. 135.
Jaschek, M., and Brandi, E. 1972, *Astr. Ap.*, **20**, 233.
Jaschek, M., and Jaschek, C. 1974, *Vistas in Astronomy*, Vol. **16**, ed. A. Beer (Oxford: Pergamon), p. 131.
Jaschek, M., and Malaroda, S. 1970, *Nature*, **225**, 246.
Kiess, C. C. 1953, *J. Res. NBS*, **51**, 247.
Kuchowicz, B. 1973, *Quart. J.R.A.S.*, **14**, 121.
———. 1976, in *IAU Colloquium No. 32, Physics of Ap Stars*, ed. W. W. Weiss (Universitaetssternwarte Wien), p. 169.
Michaud, G. 1970, *Ap. J.*, **160**, 641.
———. 1976, in *IAU Colloquium No. 32, Physics of Ap Stars*, ed. W. W. Weiss (Universitaetssternwarte Wien), p. 81.
Moore, C. H. 1945, "A Multiplet Table of Astrophysical Interest" (Contr. Princeton Obs., No. 20).
———. 1958, *Atomic Energy Levels*, Vol. **3**, *NBS Circ.*, No. 467 (Washington: Government Printing Office).
Preston, G. W. 1974, *Ann. Rev. Astr. Ap.*, **12**, 257.
Pyper, D. M., and Hartoog, M. R. 1975, *Ap. J.*, **198**, 555.
Russell, H. N., and Bowen, I. S. 1929, *Ap. J.*, **69**, 196.
Shenstone, A. G. 1938, *Phil. Trans. Roy. Soc. London*, **A237**, 453.

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