

A SEARCH FOR ^{26}AlH IN THE SPECTRA OF TECHNETIUM STARS *

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The presence of unstable, long-lived ^{26}Al has been sought in the spectra of the long-period variable R Andromedae (S6, 6e) and the irregular variable carbon star 19 TX Piscium (C6, 2). The spectra of both stars show technetium. We find no isotope shift in the absorption lines of AlH and conclude that $^{26}\text{Al}/^{27}\text{Al} < 1/7$.

The atmospheres of some carbon and S-type stars contain technetium (presumably ^{99}Tc , half-life 2.1×10^5 years) (Merrill 1952, 1956), and probably ^{93}Zr (half-life 9.5×10^5 years) (Schadee and Davis 1968; Peery and Beebe 1970). The presence of these unstable nuclides suggests the possibility that other long-lived unstable nuclides may be present as well (Table I).

Absorption lines of AlH appear in the spectra of the long-period variable R Andromedae (S6, 6e) (Merrill and Greenstein 1956) and the irregular variable carbon star 19 TX Piscium (C6, 2) (Peery 1970). Therefore, the molecular isotope shift presents the possibility of distinguishing between the unstable isotope ^{26}Al and the stable isotope ^{27}Al . The spectra of both stars show absorption lines of technetium (Merrill 1952, 1956).

Table II describes the spectrograms that we have used in our search for ^{26}Al . We have taken laboratory wavelengths of ^{27}AlH from Nicollet (1937) and Eriksson and Hulthen (1925), and have calculated isotope shifts with the molecular constants and approximate formulas given by Herzberg (1950)

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vibrational shift: $\Delta\nu = 1/2(\rho - 1)(\omega'_e - \omega''_e)$

rotational shift: $\Delta\nu = (\rho^2 - 1)(B'_0 - B''_0)J(J + 1)$,

(with similar equations for the (1, 1) R(8) line). All symbols have their conventional meanings. The ratio of reduced masses, $\rho^2 = \mu(^{27}\text{AlH})/\mu(^{26}\text{AlH})$, is 1.00138.

TABLE I
LONG-LIVED UNSTABLE NUCLIDES OF ASTROPHYSICAL INTEREST*

Nuclide	Half-Life (years)	Nuclide	Half-Life (years)
¹⁰ Be	2.7×10^6	⁹⁹ Tc	2.1×10^5
²⁶ Al	7.4×10^5	¹⁰⁷ Pd	7×10^6
³⁶ Cl	3×10^5	¹²⁶ Sn	$\sim 10^5$
⁴¹ Ca	1.1×10^5	¹²⁹ I	1.6×10^7
⁵³ Mn	$\sim 10^6$	¹³⁵ Cs	2.0×10^6
⁶⁰ Fe	$\sim 3 \times 10^5$	¹³⁷ La	6×10^4
⁵⁹ Ni	8×10^4	¹⁴⁶ Sm	5×10^7
⁷⁹ Se	7×10^4	¹⁵⁰ Gd	$\sim 3 \times 10^5$
⁸¹ Kr	2×10^5	¹⁵⁴ Dy	$\sim 10^6$
⁹³ Zr	9.5×10^5	¹⁸² Hf	9×10^6
⁹⁴ Nb	2.0×10^4	²⁰² Pb	$\sim 3 \times 10^5$
⁹³ Mo	$\sim 10^4$	²⁰⁵ Pb	3×10^7
⁹⁷ Tc	2.6×10^6	²⁰⁸ Bi	$\sim 7.5 \times 10^5$
⁹⁸ Tc	1.5×10^6	²¹⁰ Bi	2.6×10^6

*From *Chart of the Nuclides*, Knolls Atomic Power Laboratory.

TABLE II
OBSERVATIONAL DATA

Star	Plate	Date	Dispersion (Å/mm)	Emulsion
R And	Palomar Pb1667	Aug. 18, 1954	4.5	Ila-O
19 TX Psc	Mount Wilson Ce3153	Aug. 17, 1943	10	Ila-O

We have selected four lines of AlH that appear the least seriously blended in the spectrum of R And (Figure 1), and six lines in the spectrum of 19 TX Psc. Wavelengths appear in Table III; those of R And were taken from Merrill and Greenstein (1956) and those of 19 TX Psc from Peery (1970).

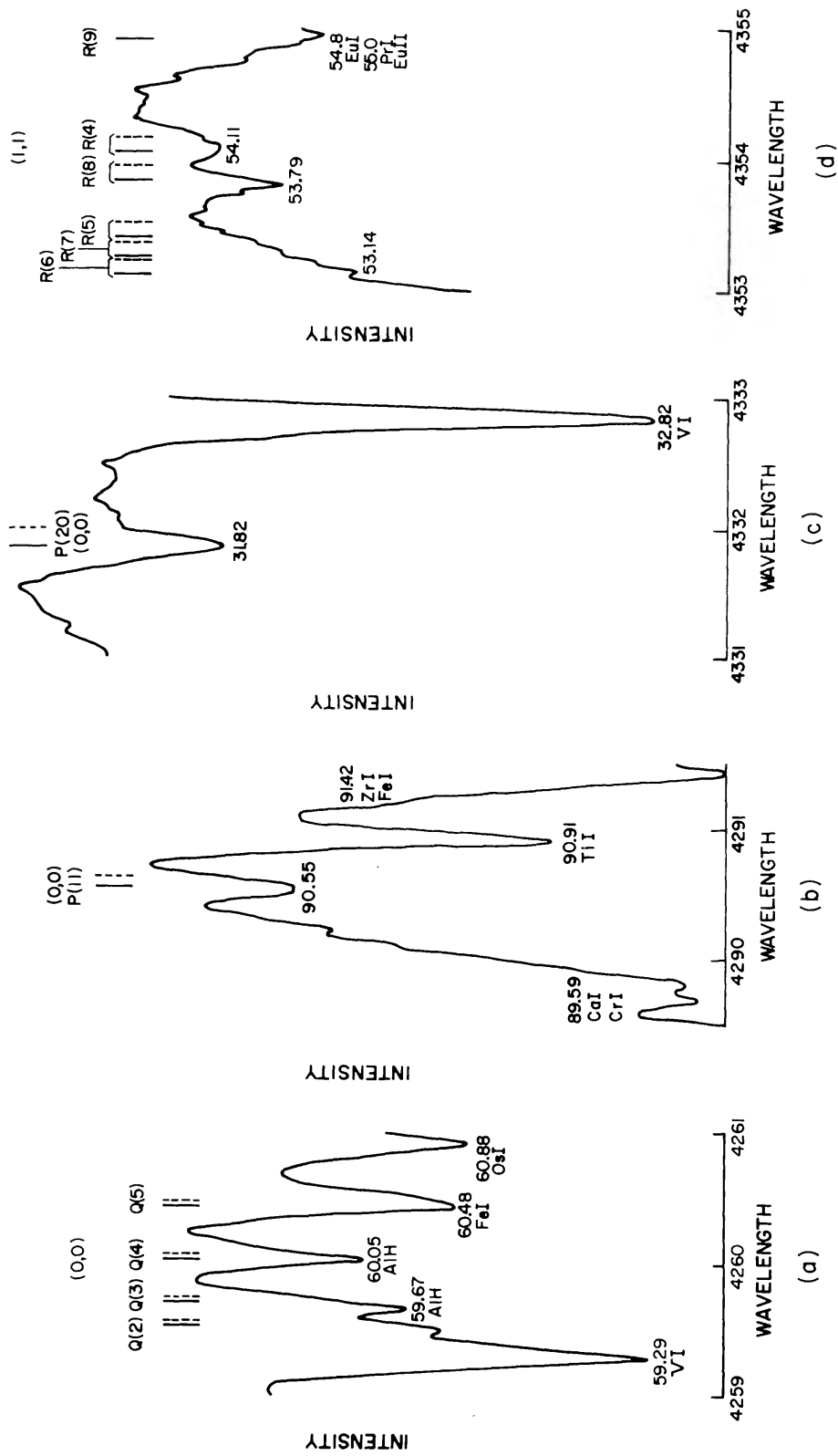


FIG. 1 — AlH absorption lines in R And. Solid lines: ^{26}AlH ; dashed lines: ^{27}AlH . (a) The displacement of the long-wavelength asymmetry from λ 4260.05 to λ 4290.58. (b) The contribution of ^{26}AlH to λ 4290.58 is estimated to be less than one-seventh that of ^{27}AlH . (c) λ 4331.82 does not appear to be broadened by ^{26}AlH . (d) No contribution of ^{26}AlH to λ 4353.79 is evident.

TABLE III
AlH WAVELENGTHS

Transition	$\lambda_{\text{lab}}(^{27}\text{AlH})$ (Å)	$\lambda(^{26}\text{AlH}) - \lambda(^{27}\text{AlH})$ (Å)	$\lambda_{\text{star}} - \lambda_{\text{lab}}(^{27}\text{AlH})$ (Å)		Excitation (eV)
			R And	19 TX Psc	
(0,0) Q(4)	4260.05	+0.04	0.00	+0.04	0.02
(0,0) P(11)	4290.58	+0.08	-0.03	-0.07	0.10
(0,0) P(16)	4310.68	+0.11	—	-0.08	0.21
(0,0) P(17)	4315.43	+0.12	—	-0.05	0.24
(0,0) P(20)	4331.80	+0.14	+0.02	0.00	0.33
(0,0) P(21)	4338.18	+0.15	—	+0.01	0.36
(1,1) R(8)	4353.83	+0.11	-0.04	—	0.26

Merrill and Greenstein report that wavelengths of atomic absorption lines shift positively with increasing excitation in the spectrum of R And. The fourth, fifth, and sixth columns of Table III appear to hint at the same behavior, particularly in 19 TX Psc. However, we conclude that the measures do not indicate shifts that could be attributed to ^{26}AlH .

Figure 1 shows microphotometer tracings of the four AlH lines in the spectrum of R And. Small amounts of ^{26}AlH should produce asymmetries on the long-wavelength sides of the lines; these do not appear. We estimate that a ratio of $^{26}\text{AlH}/^{27}\text{AlH} > 1/7$ should be discernible as such asymmetries, and we may take this value as a very coarse upper limit to the abundance ratio $^{26}\text{Al}/^{27}\text{Al}$ in these stars.

According to prevailing ideas of nucleosynthesis, the overabundances of heavy elements that characterize the S stars and many carbon stars have been produced in the stellar interiors by the s-process and subsequently brought out into the atmospheres. But while the s-process is commonly thought to occur at the temperature of helium burning, i.e., of the order of 10^8 K, the production of ^{26}Al is envisioned to take place during later stages of stellar evolution, at temperatures of billions of degrees. Therefore, ^{26}Al would not be expected to be brought into the stellar atmosphere along with the s-process nuclides.

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