SILICON IN THE SOLAR CORONA

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Résumé. — *Dans les régions spectrales* 40-62 Å *et* 256-356 Å, *les raies de résonance des ions de Si sont particulièrement visibles dans la Couronne. La faiblesse ou l'absence totale des raies de résonance du fer d'état d'ionisation compris entre XI et XV dans le spectre des rayons X mous coronaux est inattendue. On peut remarquer aussi l'importance des raies de type* ($3d \rightarrow 2p$) *par rapport aux transitions de résonance* ($3p \rightarrow 2s$) *dans les spectres du genre de Li ou de Be. On suggère que les niveaux supérieurs* (3d) *sont excités par collisions quadripolaires à partir des états fondamentaux* $2s$ *ou* $2s^2$.

L'intensité relative des raies X par rapport aux raies de résonance dans la région 300 Å *semble plus conciliable avec des températures bien supérieures à* 10^6 *K qu'avec des températures aussi basses que* 700000 °*K* ; *mais les données disponibles ne permettent pas une comparaison précise. L'intensité relative de l'émission dans les raies issues de différents états d'ionisation de Si peut signifier que l'ionisation de Si passe par un maximum pour les états IX et X. Les abondances de C, Mg, S et Al* relativement *à Si ne semblent pas très différentes des abondances chromosphériques données par* Pottasch, *ni des abondances photosphériques.*

Abstract. — *Resonance lines of coronal ions of silicon are prominent in the spectral ranges* 40-62 Å *and* 254-356 Å.

An unexpected feature of the soft X-ray spectrum is the weakness or absence of the resonance lines of iron in ionization stages XI through XV.

A second feature is the prominence of lines of the type ($3d \rightarrow 2p$) *relative to the resonance transitions* ($3p \rightarrow 2s$) *in Li-like and Beryllium-like spectra. It is suggested that the upper levels* (3d) *are excited by quadrupole collisions from the ground* $2s$ *or* $2s^2$ *levels.*

The intensity of the soft X-ray lines relative to the resonance lines in the 300 Å *region seems to be more consistent with temperatures well above one million degrees than with temperatures as low as* 700000 °*K, but the data are not adequate for a precise comparison. The relative intensity of the line emission from the various stages of silicon ionization may be interpreted as indicating that the ionization of silicon peaks in stages IX and X.*

The abundances of C, Mg, S, and Al relative *to silicon do not seem to be greatly different from the chromospheric abundances reported by* Pottasch *or with the photospheric abundances.*

Резюме. — В спектральных областях 40-62 Å и 256-356 Å резонансные линии ионов Si особенно видимы в короне. Слабость или полное отсутствие резонансных линий железа в ионизированном состоянии, заключенном между XI и XV, в спектре лучей X менее корональных — неожиданы. Можно также отметить значительность линий типа (3d —- 2p) по отношению к резонансным переходам (3p —- 25) в спектрах ряда Li или Be. Выдвинута мысль, что верхние уровни (3d) возбуждены четырехполюсными соударениями с основных состояний 2s или $2s^2$.

Относительная интенсивность линий X по отношению к резонансным линиями в области 300 Å повидимому более согласуема с температурами намного превышающими 10^6 к°, чем с такими низкими температурами как 700.00 к° ; но имеющиеся данные не позволяют точное сравнение. Относительная интенсивность эмиссии в линиях, происшедших, из разных ионизационных состояний Si, может означать, что ионизация Si проходит через максимум для состояний IX и X. Обилия C, Mg, S и Al по отношению к Si повидимому не очень отличны от хромосрефных обилий приведенных Потташем, ни от фотосферных обилий.

Data

The discussion in this paper is limited to the well identified coronal lines which appear in two widely separated spectral regions : 250-370 Å and 33-70 Å. Since silicon is represented in these two regions by a wide range of ions and also accounts for the strongest lines in the soft X-ray spectrum, the discussion largely centers around silicon.

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Spectra obtained on May 10, 1963, by Tousey, Austin and Purcell showing the spectral region 250-370 Å may be seen in the accompanying paper by Tousey, Austin, Purcell and Widing (1965). For this region a reliable H and D curve was available to calibrate photographic density into relative intensity. The relative intensities so obtained agreed well with the counting rates recorded in the same region in a rocket flight by HINTEREGGER on May 2, 1963. For an absolute calibration the photon fluxes in the May 2 spectrum were used (HINTEREGGER, HALL and SCHWEIZER, 1964).

The lines principally identified in this region are screening transitions of the type

$$\Delta n = 0$$

$$s^2\, p^k \rightarrow sp^{k+1}$$

In the spectrum obtained on September 20, 1963, by TOUSEY, AUSTIN, and PURCELL (see Fig. 6 in TOUSEY, AUSTIN, PURCELL and WIDING) many of the same ions observed in the 250-370 Å region are again seen via transitions of the type

$$\Delta n = 1$$

$$\Delta l = \pm 1.$$

Unfortunately, no laboratory calibration curve to convert photographic densities into relative intensities for the spectral region 33-80 Å was available. Instead an attempt was made to convert eye-estimates of photographic density into relative intensity by comparing the photographic spectrum with the photoelectric scan of HINTEREGGER on May 2, 1963, in the region 150-170 Å where the two spectra overlapped. But the resulting relative intensities must be considered uncertain.

For an absolute calibration we adopted a flux of 0.05 ergs cm^{-2} s^{-1} for the energy in the 44-60 Å band which is smaller than the Geiger counter measurement in July, 1963, of approximately 0.07 ergs cm^{-2} s^{-1} (ACCARDO, 1964) but larger than the ion chamber measurements of approximately 0.025 ergs cm^{-2} s^{-1} recorded in early 1964 by the NRL Solar Radiation Monitoring Satellite (KREPLIN, 1964).

At this point it is appropriate to note that the ion chamber currents in the 44-60 Å band have been reduced to fluxes by assuming that the incident solar energy can be represented by a gray temperature of 0.5×10^6 °K (KREPLIN, 1961). When we put in the observed line distribution and the known efficiency as a function of wavelength of the ion chamber, the measured currents lead to the same fluxes.

It is also noteworthy that the ion chamber essentially monitors the line radiation of Si IX, X, XI, and XII. Of these the strongest lines are from Si IX and X, ions which should be typical of the radiation from the quiet corona. As a result we should not expect a slowly varying component of very large amplitude in the 44-60 Å band. Using a model for a typical plage in which Si XI and Si XII enhance by factors similar to those observed in Fe XV and XVI, and Si IX and X by considerably smaller factors as inferred from OSO-I observations (NEUPERT, BEHRING, and LINDSAY, 1964), we estimate a total flux increase in the 44-60 Å band by a factor of 3.7 when the relative area of the disk occupied by plages is 10 %. In addition, the radiation from the disk should increase by a factor of about 3 during the solar cycle corresponding to the increase of electron density (ALLEN, 1963). So the total range in the 44-60 Å flux between solar maximum and solar minimum should be approximately an order of magnitude.

INTERPRETATION

a) *Introduction.*

In predicting spectra to compare with the observed coronal spectra it is essential to include dielectronic recombination, and computations are under way using the convenient formulae given by BURGESS (1964). We should just like to make some remarks regarding a comparison of the soft X-ray spectrum with the computations of ELWERT (1954, 1961).

Adopting a flux of 0.05 ergs cm^{-2} s^{-1} in the 44-60 Å band the total line energy between 33 and 70 Å is about 0.1 erg cm^{-2} s^{-1} in close agreement with ELWERT. However, the distribution of the line energy in the observed and computed soft X-ray spectra is rather different. As may be seen, the dominating features of the observed spectrum are the C VI and C V resonance lines and transitions in Si VIII, IX, X, XI, and XII. The lines of Mg, S and Fe XVI (the only iron ion identified) are relatively much weaker. In the ELWERT spectra, on the other hand, the resonance lines of Fe XI, XII, XIII, XIV, and XV, which are found principally between 53 Å and 88 Å, and Ne VIII at 88 Å make a relatively large contribution to the total line energy. ELWERT took Fe as abundant as Si, but even if we adopt a lower Fe : Si ratio more consistent with abundances in the photosphere we should still expect detectable lines from Fe XII, XIII, XIV, and XV between 55 Å and 80 Å. Part of the difficulty is associated with the obvious decrease in instrumental sensitivity toward longer wavelengths. However, the Fe XIV lines at 58.96 and 59.58 Å and the Fe XV line at 52.91 Å are still in a favorable position to be detected, but do not appear to be present.

Of the theoretical spectra computed by ELWERT for 600,000, 700,000, and 1,000,000 °K the one for 1,000,000 °K comes closest to matching the relative distribution among the silicon ions except that then C V is predicted too strong relative to both C VI and the silicon lines. However, it seems best to defer further discussion until the dielectronic rates are included.

b) *Excitation.*

Figure 1 illustrates a further unexpected feature of the soft X-ray spectrum : the lines from the $3d$ levels are stronger than the lines from the $3p$ levels. Especially striking (see Fig. 6 in TOUSEY, AUSTIN, PURCELL and WIDING) is the great strength of the $2s3d$ $^1D_2 \rightarrow 2s2p$ $^1P_1^0$ transition in Si XI at 49.2 Å relative to the resonance transition $2s3p$ $^1P_1^0 \rightarrow 2s^2$ $^1S_0$ transition at 43.8 Å. Since appreciable collisional excitation of the upper levels can take place only from the ground $2s$ or $2s^2$ levels this implies that near threshold energies the quadrupole cross-section for ($2s$-$3d$) is somewhat larger than the dipole cross-section for ($2s$-$3p$).

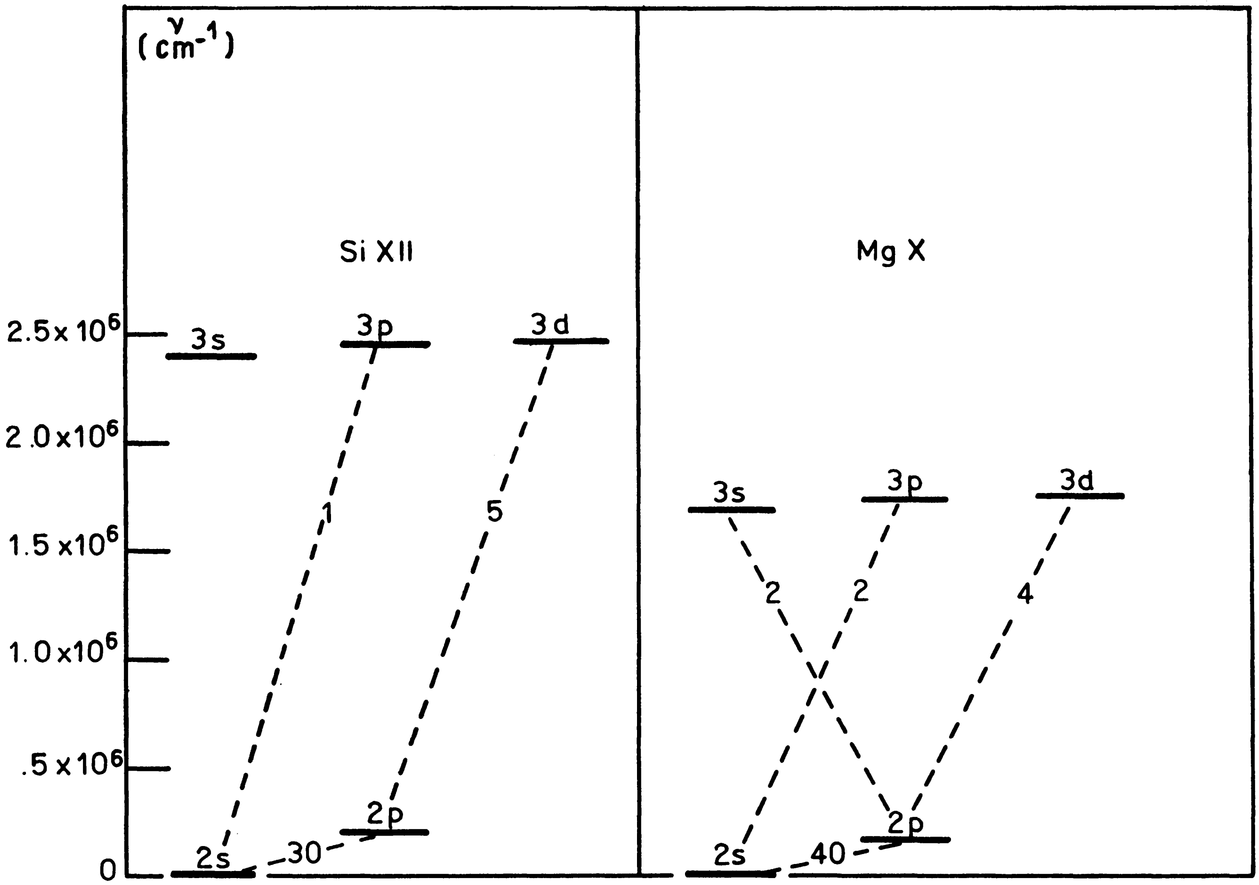

FIG. 1. — Observed line intensities in Mg X and Si XII. Line intensities in units of 10^{-3} erg cm^{-2} s^{-1}.

To investigate further the populating mechanism for the $n = 3$ levels in a Li-like atom we have tabulated in Table I the collisional and spontaneous rates as well as the hydrogenic recombination rates for Mg X. This ion was chosen since WEISS (1963) has computed f-values for many of the transitions involved ([1]). F-values for the $2s$-$4p$, $3s$-$4p$, and $3d$-$4p$ transitions were computed with the tables of BATES and DAMGAARD (1949) Collision rates were estimated using the formulae given by VAN REGEMORTER (1962). The recombination coefficients were taken from the data of BOARDMAN (1964) using the scaling procedure for hydrogenic ions. Dielectronic recombination should not be a significant factor in populating any of the levels shown in the model atom (Fig. 2) since the dielectronic rate to form Mg X is smaller than the total radiative recombination rate.

([1]) To obtain the data for Z = 12, a short extrapolation was required.

TABLE I

TRANSITION RATES IN Mg X.

COLLISION RATES C_{LU}.

TRANSITION	$T = 1 \times 10^6$ °K	$T = 2 \times 10^6$ °K
$2s \to 2p$	$3.4 \times 10^{-9}\, n_e$	$3.6 \times 10^{-9}\, n_e$
$2s \to 3p$	4.4×10^{-11}	1.5×10^{-10}
$2s \to 4p$	4.1×10^{-12}	1.5×10^{-11}
$2s \to i$	2.1×10^{-12}	2.5×10^{-11}

RECOMBINATION COEFFICIENTS $\dfrac{\alpha_{n1}}{\sum_{n=2}^{12} \alpha_{n1}}$

$i \to 2s$	.09	.10
$i \to 2p$	.20	.22
$i \to 3s$	.03	.03
$i \to 3p$	.08	.08
$i \to 3d$	.06	.07
$i \to 4p$	.04	.04

SPONTANEOUS RATES A_{UL}.

TRANSITION	A_{UL}
$2p \to 2s$	7.6×10^8
$3d \to 2p$	6.7×10^{11}
$3p \to 2s$	2.0×10^{11}
$3s \to 2p$	9.2×10^{10}
$3d \to 3p$	4.2×10^6
$3p \to 3s$	9.6×10^7
$4p \to 2s$	9.9×10^{10}
$4p \to 3s$	2.8×10^{10}
$4p \to 3d$	3.7×10^9
$P_6 = \Sigma A_{4PL} =$	13.1×10^{10}

In the notation of Figure 2 the photon emission rates can be written as :

$$N_2 A_{21} = N_1 \left[(C_{12} + C_{13} + C_{15}) + C_{16} \frac{A_{63} + A_{65}}{P_6} + C_{1i} \frac{\left(\alpha_{i2} + \alpha_{i3} + \alpha_{i5} + \alpha_{i6} \dfrac{A_{63} + A_{65}}{P_6} \right)}{\Sigma \alpha_{ij}} \right]$$

$$N_3 A_{32} = N_1 \left[C_{13} + C_{16} \frac{A_{63}}{P_6} + C_{1i} \frac{\left(\alpha_{i3} + \alpha_{i6} \dfrac{A_{63}}{P_6} \right)}{\Sigma \alpha_{ij}} \right].$$

$$N_4 A_{41} = N_1 \left[C_{14} + C_{1i} \frac{\alpha_{i4}}{\Sigma \alpha_{ij}} \right]$$

$$N_5 A_{52} = N_1 \left[C_{15} + C_{16} \frac{A_{65}}{P_6} + C_{1i} \frac{\left(\alpha_{i5} + \alpha_{i6} \dfrac{A_{65}}{P_6} \right)}{\Sigma \alpha_{ij}} \right],$$

with

$$P_6 = A_{61} + A_{63} + A_{65}.$$

To get the relative line energies to compare with Figure 1 we must multiply these emission rates by $h\nu$. The $3s$, $3p$, $3d$ levels are isolated from each other by the smallness of the inter-term collisional and spontaneous rates relative to the spontaneous rate to the $n = 2$ terms.

Looking first at the populating rates for the $3p$ level we see that

$$\frac{C_{14}}{C_{1i} \dfrac{\alpha_{i4}}{\Sigma \alpha}} \simeq 75.$$

Even if C_{14} should be lowered by a factor of 3 and the precise value of $\dfrac{\alpha_{i4}}{\Sigma_\alpha}$ is uncertain, it seems clear that direct collisional excitations to the $3p$ level will be the dominant rate, as noted by ELWERT (1954). If we now assume that quadrupole transitions are unimportant (i. e. $C_{13} = C_{15} \sim 0$) we can predict the emission rates from the $3d$ and $3s$ levels relative to the emission rate from the $3p$ level. Cascade from the $4p$ level and direct recapture into $3s$ and $3d$ will then be about equally important, but it may be seen that the resulting emission rates from $3s$ and $3d$ relative to $3p$ will be too small, since

$$\frac{C_{14}}{C_{16} \dfrac{A_{65}}{P_6}} \sim 300.$$

The predicted relative line intensities are given in Table II.

TABLE II

TRANSITION	RELATIVE INTENSITY at $T = 2 \times 10^6$
$N_2 A_{21} h\nu$	98
$N_3 A_{32} h\nu$	0.7
$N_4 A_{41} h\nu$	26
$N_5 A_{52} h\nu$	0.4

To obtain the observed relative intensities it seems necessary to include a collisional rate for $(2s\text{-}3d) = C_{15}$ that is 2 to 4 times larger then the collision rate for $(2s\text{-}3p)$.

HINTEREGGER (1964) has noted that the flux ratio $\dfrac{(2s\text{-}3p)}{(2s\text{-}2p)}$ in Mg X may in principle be used to

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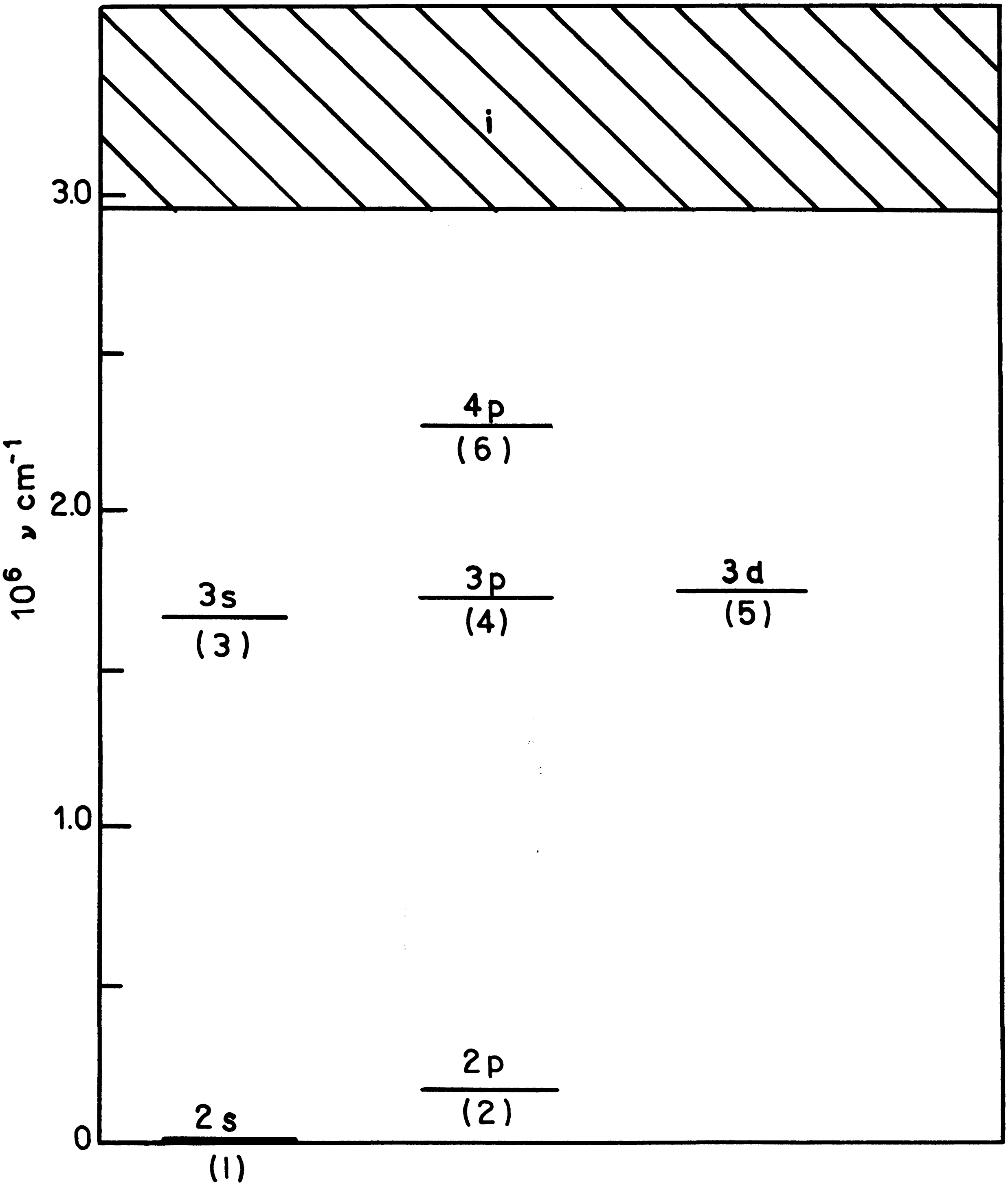

FIG. 2. — Term diagram for MG X.

check the coronal temperature, but that in practice the observational accuracy is not yet sufficient. This is certainly the case with the data used in the present discussion, where the calibration of the line intensities in the soft X-ray region is uncertain, and where we have adopted a flux for the $2s$-$2p$ transition from 1961 data, when solar conditions may have been quite different.

Part of the difficulty may be illustrated by noting that in the theoretical equation (2) for the line

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flux we seek to determine T through the exponential factor for 2 lines of a given ion with widely different values of excitation potential W.

(2)

$$\frac{F}{f} = 2.4 \times 10^{-20} \frac{1}{T_e^{1/2}} P_i \, e^{-W/kT} \frac{n_i}{N_{EL}} \frac{N_{EL}}{N_H} \int_{T_R} n_e^2 \, dh.$$

Table III shows that the flux ratio of lines at 50 Å to those at 300 Å is sufficiently sensitive to temperature only if the lines are formed in the lower range of coronal temperatures. The soft X-ray lines on the other hand, appear to be stronger than would be the case if the temperature were as low as 0.7×10^6. The evidence from the new recombination rates also points to temperatures in the vicinity of 2×10^6 °K where the line ratios are no longer sensitive to temperature.

TABLE III

VALUES OF $e^{-W/kT}$

λ	$T = 0.7 \times 10^6$ °K	2.0×10^6 °K
50 Å	.02	.24
300 Å	.50	.79

The best data from the present spectra for a study of line ratios in the 50 Å and 300 Å region are the lines of Si IX and Si X, since these ions produce multiplets of the same intensity in the 44-60 Å band accounting for roughly 2/3 of the observed flux of 0.025 to 0.06 ergs cm^{-2} s^{-1}. Curves giving the theoretical flux ratio

$$\frac{F\,(\lambda \sim 50\text{ Å})}{F\,(\lambda \sim 300\text{ Å})}$$

were computed for Si IX and Si X. These show that if the temperature is to be determined with an accuracy of ± 50%, the value of

$$\frac{\frac{F}{f}\,(50\text{ Å})}{\frac{F}{f}\,(300\text{ Å})}$$

must be known to within a factor of 2.5 at T = 700,000 °K but to within 50% at 2×10^6 °K. The uncertainty in the observed fluxes alone probably exceeds these requirements. In addition, recent work on cross-sections in the Li sequence (BURGESS, 1965) indicates that the formula for collisional excitation rates that goes into the formation of equation (2) may give results accurate only to within a factor of 3. We conclude simply by noting that with a flux of 0.05 ergs cm^{-2} s^{-1} in the 44-60 Å band, the observed flux ratio for Si IX exceeds the theoretical values at 0.8×10^6 °K and 2×10^6 °K by factors of 6 and 2, respectively. The observed ratios for Si X similarly are too large at the same temperatures by factors of 18 and 5, respectively.

c) *Ionization.*

We may still obtain information on the corona from the distribution of ionization i. e. by looking at the factor $\frac{n_i}{N_{EL}}$ in equation (2).

This is an attractive problem to consider since we observe lines from silicon in stages VIII through XII in the relatively narrow wavelength range of 40 to 61 Å on the soft X-ray spectrum of September 20, 1963 and lines from stages VIII through XI in the wavelength range 254-320 Å in the spectrum of May 10, 1963.

Under the assumption of emission in an approximately iso-thermal corona, we may evaluate $e^{-W/kT}$ for an assumed temperature for each line. Then all other quantities in (2) are constant for ions of a given element, and the relative abundance $\frac{n_i}{N_{Si}}$ are essentially proportional to $\frac{F}{f}\,e^{W/kT}$. In this case, the slow variation of $e^{W/kT}$ for $T \gtrsim 1 \times 10^6$ °K is a help. For lines in the 250-320 Å region $e^{W/kT}$ is essentially the same factor for all ions. Even for the $\Delta n = 1$ transitions, $e^{W/kT}$ varies only by a factor of 3 between 40 Å and 60 Å at $T = 1 \times 10^6$, and no essential change in the derived ionization curve resulted when other temperatures were used. In practice, the analysis was carried out with an assumed temperature of 2×10^6 °K.

The resulting plots are shown in Figure 3. The total abundance N_{Si} was estimated by summing over the observed relative abundances, so that each point in the plot essentially represents

$$\frac{\left(\frac{F}{f}\,e^{W/kT}\right)_i}{\sum\limits_{\text{obs. ions}} \left(\frac{F}{f}\,e^{W/kT}\right)_i}.$$

We again emphasize that the data for the $\Delta n = 0$ transitions were based on a calibrated tracing while the data for the other plot were based

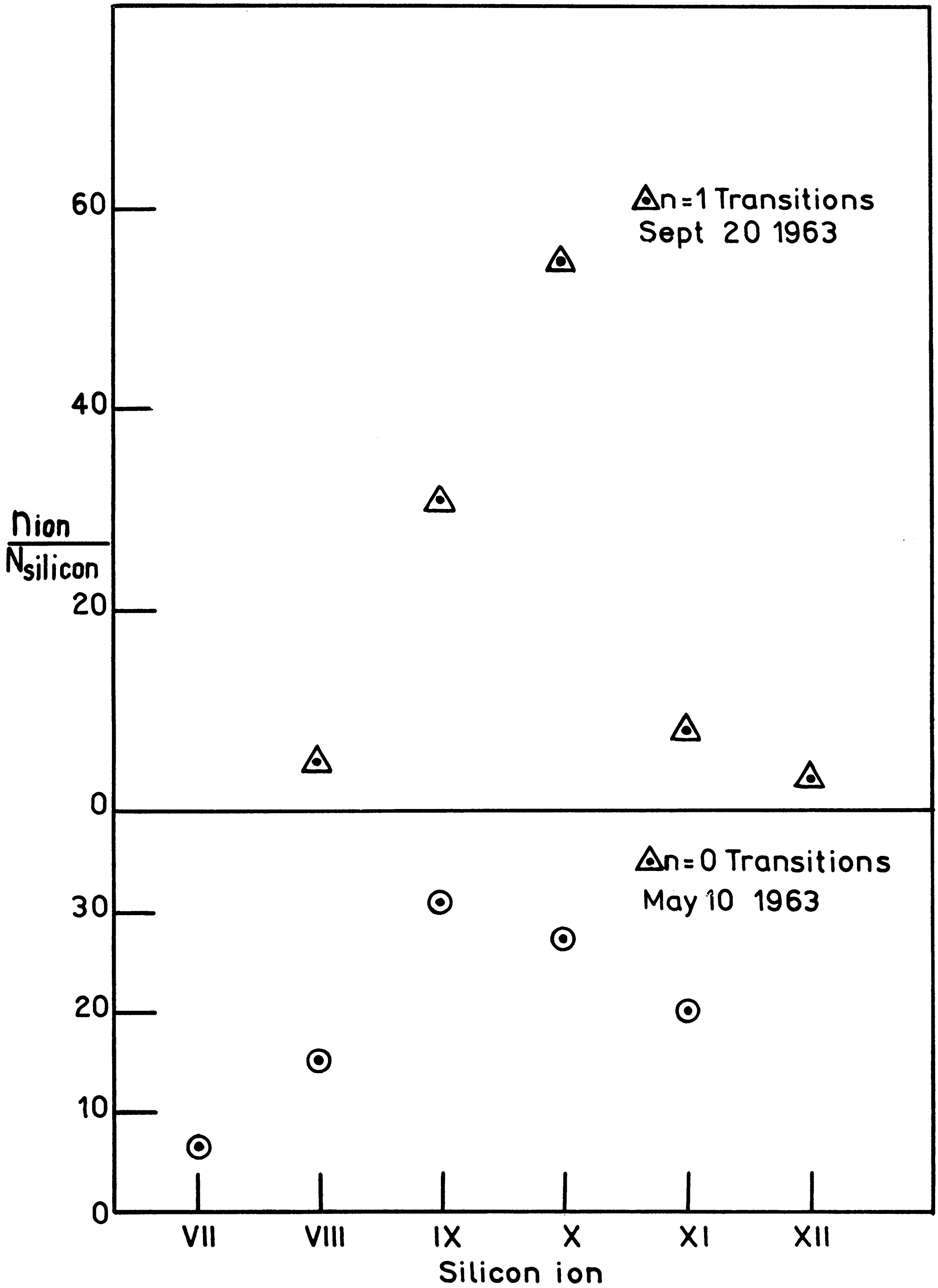

FIG. 3. — Observed ionization of silicon.

only on eye estimates. This may explain the difference in the vertical scale of the two plots. Also, the strongest lines of Si XI and Si XII in the soft X-ray region could not be used because they (presumably) involve the unknown quadrupole cross-sections ; rather we were forced to use the weaker $2s^2 - 2s3p$ and $2s$-$3p$ resonance transitions. The intensities used for both plots refer to integrated radiation from the Sun. Si XI and XII may show flux variations exceeding a factor of 2 ; the lower stage ions should be less variable and more or less characteristic of the undisturbed corona.

The flatness of the distribution obtained from the $\Delta n = 0$ transitions is remarkable. It should be noted that (as previously mentioned) the uncertainty in the formula for estimating excitation rates exceeds the total range in the relative abundances, so that the entire character of the $\Delta n = 0$ plot could be altered. Whether this would also be the case for the $\Delta n = 1$ plot is less certain.

Despite differences in scale and detail the two plots agree with the following relative ordering of abundances :

$$(\mathrm{IX} \simeq \mathrm{X}) > \mathrm{XI} > (\mathrm{VIII} \simeq \mathrm{XII}).$$

On the interpretation we have advanced, the ionization of silicon peaks in stages IX and X. If the relative intensities, on the other hand, reflect primarily the structure of the corona through the factor $\int_{T_R} n_e^2\, dh$ rather than the variation of $\frac{n_i}{N_{Si}}$, then the alternative interpretation is that most of the mass of the corona is associated with temperature regions favoring the emission of stages IX and X.

The relative prominence of Si IX and Si X with ionization potentials of 352 and 401 eV, respectively is reminiscent of the relative prominence of forbidden line emission from Fe XIII and Fe XIV with ionization potentials of 355 and 390 eV. The present results for silicon depend on spectra taken in 1963 when the solar cycle was approaching a minimum. The analysis of forbidden lines by Pottasch (1964) in which the data were weighted heavily by data from the 1952 eclipse (approximately two years before solar minimum), indicates that even near minimum Fe XIII and Fe XIV may remain the most abundant ions of iron.

Preliminary computations using the general formula for estimating dielectronic rates (Burgess, 1964) indicate that the $\Delta n = 0$ transitions can be fitted by a single ionization curve computed for $T = 1.6 \times 10^6$ °K while the $\Delta n = 1$ transitions are better fitted by $T = 1.8 \times 10^6$ °K (1). The data of Figure 3 and, therefore, these temperatures should be more or less characteristic of the undisturbed corona, since probably only the lines of Si XI and Si XII were appreciably enhanced by the moderate activity present on May 10 and September 20, 1963. These temperatures compare favorably with the coronal " support " temperatures derived by Unsöld (1955) :

$T = 1.62 \times 10^6$ equator, at solar minimum,
$T = 1.15 \times 10^6$ pole, at » »

although allowance for the coronal fine structure would raise these temperatures by about 0.5 to 0.6×10^6 °K (Brandt, Michie, and Cassenelli, 1964).

Abundances

The calibrated intensities for ions of silicon, magnesium, sulfur, and aluminum observed in the wavelength range 250-370 Å may be applied to the

TABLE IV

Abundances Relative to Silicon.

Element	Ions Used	Present Analysis	(Pottasch, 1963) U. V. Spectrum	(Goldberg, Muller, Aller, 1960) Photospheric
—	—	—	—	—
Silicon	VIII-XI	1.0	1.0	1.0
Magnesium	VIII,IX	.9	.5	0.8
Aluminum	X	.09	...	.05
Sulfur	X	.3	.2	.6
Iron	XV XVI	.2	.3	.1

(1) This material added January 1965.

problem of the relative abundances of the elements in the corona. The results, using the method of POTTASCH (1963) are given in Table IV along with a comparison with other determinations.

No discrepancy exceeding a factor of 2 with either the chromospheric or photospheric abundances is apparent.

The data below 80 Å may be used for a rough check on the carbon to silicon ratio, since we need only note that the lines of the most abundant silicon ions (IX and X) have an intensity comparable to C VI. From equation (2) the ion densities in an isothermal corona are proportional to $\frac{F}{f} e^{W/kT}$. The exponential factor is evaluated for an assumed temperature of 1.8×10^6 °K. The $\frac{\text{C VII}}{\text{C VI}}$ ratio at the same temperature is $\simeq 8$. With these data the carbon to silicon ratio estimated from the relative intensities in the soft X-ray region is approximately 5. In view of the uncertain nature of the intensities and assumptions, this may be considered satisfactory agreement with either the ratio 8 determined by POTTASCH from the chromospheric lines or the ratio 17 determined in the photosphere.

ACKNOWLEDGMENT

We would like to thank Professor L. GOLDBERG for several valuable remarks.

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Discussion

W. M. NEUPERT. — I would suggest that anyone using the ultraviolet observations of the Fe XV and Fe XVI lines in a discussion of coronal temperature take note that these lines originate primarily in localized regions, in which coronal conditions may be different from those in the remainder of the corona.

G. ELWERT. — I should like to mention that the measured line spectrum should be compared with the computed spectrum for a lower temperature since a temperature of 10^6 °K is very high on the basis of cross-sections for photorecombination which I used 12 years ago. With decreasing temperature, the wavelengths of the lines of high intensity are shifted to larger values. For a temperature of $7\ 10^5$ °K which was also considered at that time, the wavelength of the line of maximum intensity was above 80 Å. On the basis of the old recombination cross-sections the measured spectrum seems therefore to correspond to a temperature between 7×10^5 and 10^6 °K.