CALCULATING THE OPTICAL PARAMETERS OF A HIGHLY CHARGED PLASMA BY THE HFS METHOD.

PART 2. AVERAGE AND GROUP-AVERAGE ABSORPTION COEFFICIENTS

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Published data on mean absorption coefficients for aluminum and air plasmas are compared with calculated ones.

A model has been described [1] for use in calculating optical characteristics of plasmas, which involves minimum effort and acceptable run times in deriving the properties of a plasma with any composition over a wide parameter range. There is good agreement with published data for the ionic compositions and spectral absorption coefficients for various substances.

When one simulates a plasma, one usually employs mean or mean-group absorption coefficients with Planck and Rosseland averaging functions. Those mean coefficients should be compared with published values. The fullest current data on plasma optical parameters for wide temperature and density ranges have been derived [2] for aluminum and air. Most of the calculations are based on measured spectroscopic data, which is particularly valuable in evaluating the models.

The mean and mean-group absorption coefficients for Planck and Rosseland averaging functions have been calculated from

$$\varkappa^P = \frac{\int_0^\infty \varkappa'_\varepsilon G(\varepsilon)\, d\varepsilon}{\int_0^\infty G(\varepsilon)\, d\varepsilon}; \quad \varkappa_k^P = \frac{\int_{\varepsilon_k^1}^{\varepsilon_k^2} \varkappa'_\varepsilon G(\varepsilon)\, d\varepsilon}{\int_{\varepsilon_k^1}^{\varepsilon_k^2} G(\varepsilon)\, d\varepsilon};$$

$$G(\varepsilon) = \frac{\varepsilon^3 \exp(-\varepsilon/T)}{1-\exp(-\varepsilon/T)};$$

$$(\varkappa^R)^{-1} = \frac{\int_0^\infty (\varkappa'_\varepsilon)^{-1} G_1(\varepsilon)\, d\varepsilon}{\int_0^\infty G_1(\varepsilon)\, d\varepsilon}; \quad (\varkappa_k^R)^{-1} = \frac{\int_{\varepsilon_k^1}^{\varepsilon_k^2} (\varkappa'_\varepsilon)^{-1} G_1(\varepsilon)\, d\varepsilon}{\int_{\varepsilon_k^1}^{\varepsilon_k^2} G_1(\varepsilon)\, d\varepsilon};$$

$$G_1(\varepsilon) = \frac{\varepsilon^4 \exp(-\varepsilon/T)}{(1-\exp(-\varepsilon/T))^2}.$$

Figure 1 shows the mean Planck coefficients for aluminum as functions of temperature for various densities, while Fig. 2 does the same for air; Figs. 3 and 4 give the temperature dependence of the Rosseland mean absorption coefficients for aluminum and air plasmas corre-

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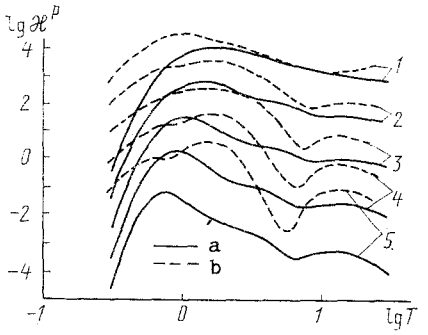

Fig. 1

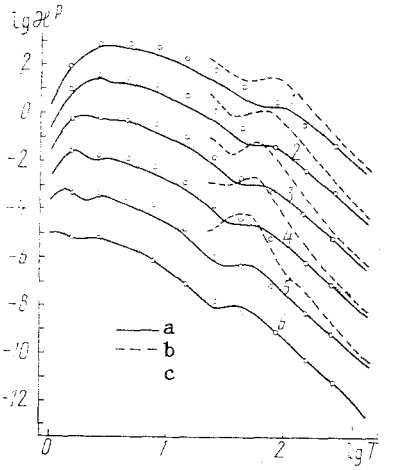

Fig. 2

Fig. 1. Planck mean absorption coefficients for an aluminum plasma: 1) $\rho = 0.1$ g/cm^3; 2) 10^{-2}; 3) 10^{-3}; 4) 10^{-4}; 5) 10^{-5}; a) this study; b) [3] data.

Fig. 2. Planck mean absorption coefficients for air plasmas: 1) $\rho = 10^{-2}$ g/cm^3; 2) 10^{-3}; 3) 10^{-4}; 4) 10^{-5}; 5) 10^{-6}; 6) 10^{-7}; a) this study; b) [4] data; c) [5].

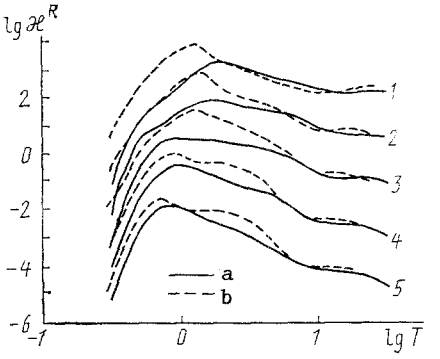

Fig. 3

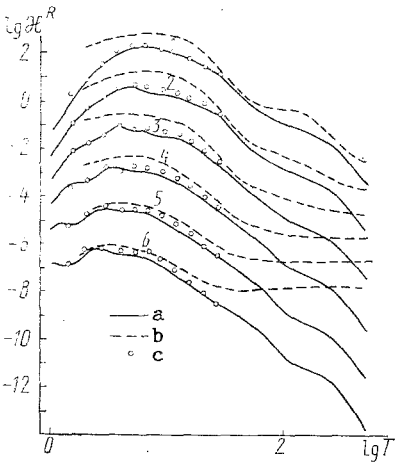

Fig. 4

Fig. 3. Rosseland mean absorption coefficients for aluminum plasmas: 1) $\rho = 0.1$ g/cm^3; 2) 10^{-2}; 3) 10^{-3}; 4) 10^{-4}; 5) 10^{-5}; a) this study; b) [3] data.

Fig. 4. Rosseland mean absorption coefficients for air plasmas: 1) $\rho = 10^{-2}$ g/cm^3; 2) 10^{-3}; 3) 10^{-4}; 4) 10^{-5}; 5) 10^{-6}; 6) 10^{-7}; a) this study; b) [4] data; c) [5].

spondingly. The solid lines show the absorption coefficients attained in our calculations. In [3, 4], the spectral lines contributed appreciably to the mean coefficients, and at low temperatures, there was also important absorption by the neutral atoms [3]. In [4], the absorption by the molecular components in air was incorporated for low temperatures, and the Rosseland means were given with correction for scattering at the plasma electrons. In [5], only the continuous absorption was incorporated in the mean absorption coefficients (as here). There was good agreement with [5] for the Planck and Rosseland coefficients. Similar values apply for the Planck coefficients for air from [4] at high temperatures, where the role of the lines in the mean coefficients is reduced. There are appreciable discrepancies in the Rosseland means at high temperatures from the [4] data because of the scattering correction there. The differences between our mean coefficients and the [3, 4]

data arise as follows. For an aluminum plasma at temperatures T < 1 eV, a neutral-atom absorption correction was applied in [3], as that absorption predominates at low temperatures. For T > 1 eV, there is good agreement for the Rosseland coefficients for an aluminum plasma. The marked differences for the Planck coefficients for T > 1 eV and the much smaller differences in the Rosseland ones are due to the considerable line contributions.

In ranges where there are virtually no lines, the mean group Planck and Rosseland coefficients from [3] fit very closely to ours.

This comparison of means shows that our model can be used for plasma properties, including mean absorption coefficients, and the values can be used to derive plasma dynamic features. The main advantages of the software suite are the minimum of effort, the promptness in obtaining the results, the arbitrary plasma composition, and the acceptable run times, e.g., 17 min for an air plasma with the ES 1061.

NOTATION

$\varkappa^P$, $\varkappa_k^P$ Planck mean and mean-group absorption coefficient; $\varkappa^R$, $\varkappa_k^R$ Rosseland mean and mean-group absorption coefficient; $\varkappa'_\varepsilon$ spectral absorption coefficient corrected for induced emission; ε photon energy; ε_k^1, ε_k^2 lower and upper bounds to spectral group k; T plasma temperature; ρ plasma density.

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