Tables of Mie Scattering Cross Sections and Amplitudes

D. Deirmendjian

January 1963

R-407-PR

A REPORT PREPARED FOR

UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation

1700 MAIN ST. • SANTA MONICA • CALIFORNIA

This research is sponsored by the United States Air Force under Project RAND — Contract No. AF 49(638)-700 — monitored by the Directorate of Development Planning, Deputy Chief of Staff, Research and Technology, Hq USAF. Views or conclusions contained in this Report should not be interpreted as representing the official opinion or policy of the United States Air Force. Permission to quote from or reproduce portions of this Report must be obtained from The RAND Corporation.

Tables of Mie Scattering Cross Sections and Amplitudes

D. Deirmendjian

January 1963

R-407-PR

A REPORT PREPARED FOR

UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation

1700 MAIN ST. • SANTA MONICA • CALIFORNIA

SUMMARY

THIS REPORT tabulates selected values of the scattering cross sections and amplitudes in the forward and backward direction for various sizes of dielectric and absorbing spheres irradiated by plane electromagnetic waves. For a number of physical substances in the visible, infrared, and microwave regions of the spectrum, the reader can obtain from the tables such other useful quantities as the extinction and absorption cross sections and the specific intensity of the scattered field at 0° and 180°.

Since a more general description of the theory and its use in studying all the scattering and polarization properties of various spheres was incorporated in RAND Report R-393-PR,[1] the present work should be considered as its companion and extension.

ACKNOWLEDGMENT

MRS. E. O. JOHNSON ably assisted in preparing and checking the tables, as specified, from the original IBM printout sheets.

CONTENTS

I. INTRODUCTION

DURING OUR INVESTIGATION of the scattering, absorption, and polarization properties of homogeneous spheres irradiated by electromagnetic waves, we have accumulated a large number of scattering functions corresponding to various values of the dielectric and conducting properties of the scattering media. Some of the results were described in a previous RAND report,[1] which particularly emphasized the dependence of various aspects of the scattering process on the sphere's physical properties and its size in relation to wavelength.

The continuing purpose of this program is to derive the integrated scattering properties of aggregates of particles with a given continuous size distribution. A few selected size spectra corresponding to atmospheric haze and cloud droplets have already been used, and the results discussed in another recent study.[2]

All of the above work is based on the classical electromagnetic field theory and G. Mie's particular application of it to homogeneous finite spheres of arbitrary complex index of refraction.[3] As made evident in the recent Interdisciplinary Conference on Electromagnetic Scattering held in Potsdam, New York, August 13–15, 1962, a number of individual workers and organizations have computed, or are in the process of computing, the Mie scattering functions, thereby extending the range of already existing tabulations. Clearly, the continued publication of extended tables of all such computations cannot always be justified in terms of scientific usefulness. The existence of the modern computer has made the tabulation of many functions practically unnecessary, since these machines can reproduce them in a matter of minutes and at little cost. On the other hand, not everyone has access to these machines, and a judicious tabulation of *selected values* may often be useful, lending itself to unforeseen problems.

To economize in space while maintaining a sufficient sampling of parameters with greatest usefulness, we have decided to tabulate only the following basic quantities: the complex amplitudes of the electric vector wave scattered in exactly the forward and backward directions, and the total scattering cross section. As Section II shows, the reader can easily obtain from these basic quantities several other parameters.

Thus the present tables have three main objectives:

1. To display exact values for the complex amplitudes of the far field produced by scattering on homogeneous spheres of different sizes and of different dielectric and conducting properties. The amplitudes, especially for back scattering, may be useful in further research on applications of the newly developed coherent sources, such as "masers," "irasers," and "lasers."
2. To provide values of the total scattering and absorption cross sections for such spheres.
3. To provide check values of scattering parameters for other workers interested in writing their own computer programs, as well as for extensions of the theory to non-spherical or nonhomogeneous scatterers.

II. DESCRIPTION AND USE OF THE TABLES

SINCE ANOTHER RAND REPORT[1] fully describes the Mie expressions, computational technique, symbols, and their interpretation pertinent to the following tables, the present report should be considered the companion and extension of the first one. The format of the tables is essentially the same as that in Appendix C of the previous report, with an additional column for the total scattering cross section, whenever necessary. All tabulated numbers are dimensionless.

The first column in each table lists the usual Mie size parameter $x = 2\pi r/\lambda$, where r is the geometric radius of the sphere, and λ the free-space wavelength of the incident radiation. Whenever the index of refraction m is complex, the second column lists the corresponding normalized scattering cross section $K_{sc}(m, x)$. The third and fourth columns list the complex amplitude functions for scattering angles θ that equal, respectively, 0° and 180°; the functions are in the form $S_1(m, x, \theta) = a + bi$, where S_1 is the Mie function exactly as defined by van de Hulst[3] and in our previous report.[1]

The heading of each table shows, in the form $m = c - di$, the real or complex index of refraction for the scattering medium inside the sphere with respect to the external medium. Also, most tables indicate the appropriate wavelength and substance as available from laboratory measurements or as deduced by theory. These indications should not be taken too literally, since new data may reveal errors in accepted values of the index of refraction. However, as far as the theory of electromagnetic scattering is concerned, *the computed functions are exact for the indices shown.*

From the tables the reader may obtain directly or by simple arithmetic the following useful quantities:

1. *The true extinction cross section* σ_{ext} *of the sphere.* This represents the effective cross-sectional area of the sphere for scattering *and* absorption of the incident plane-wave flux of radiation. It is given by the product of the normalized Mie extinction cross section, K_{ext}, and the geometrical cross section, that is,

$$\sigma_{ext}(m, r, \lambda) = \pi r^2 K_{ext}(m, x), \qquad (1)$$

where K_{ext} can be obtained from the tables by the formula,

$$K_{ext}(m,x) = \frac{4}{x^2}\,\mathrm{Re}\,\{S(m,x,0)\}, \tag{2}$$

representing the well-known cross-section theorem. Replacing this in Eq. (1) and eliminating x and r we obtain the alternate form

$$\sigma_{ext}(m,r,\lambda) = \frac{\lambda^2}{\pi}\,\mathrm{Re}\,\{S(m,x,0)\} \tag{3}$$

in units of the square of the wavelength.

2. *The scattering cross section* σ_{sc}. For spheres with a complex index (that is, spheres that absorb some of the incident energy, which is therefore lost to the scattered field), we have necessarily $\sigma_{ext} > \sigma_{sc}$. The normalized scattering cross section K_{sc}, which is tabulated, gives σ_{sc} by means of the formula

$$\sigma_{sc}(m,r,\lambda) = \pi r^2 K_{sc}(m,x)\,. \tag{4}$$

However, in the case of nonabsorbing spheres, where $\mathrm{Im}\{m\} = 0$, the scattering cross section is not tabulated, since $K_{ext} \equiv K_{sc}$ and Eqs. (1) or (3) can be used.

3. *The absorption cross section* σ_{abs}. This is obviously the difference between the cross sections given by Eqs. (1) and (4). Hence,

$$\sigma_{abs}(m,r,\lambda) = \pi r^2\,[K_{ext} - K_{sc}]\,. \tag{5}$$

Both terms on the right can be obtained from the tables.

4. *Transmission through a medium.* The transmission of a collimated monochromatic beam of electromagnetic energy through a homogeneous monodisperse medium containing $n(r)$ spheres of radius r per cubic centimeter is given by the expression

$$T_\lambda = \exp\{-Ln(r)\,\sigma_{ext}(m,r,\lambda)\}, \tag{6}$$

where L is the length in centimeters of the geometrical path, and $n(r)\sigma_{ext} = \beta_{ext}$ is the corresponding monochromatic extinction coefficient or *extinction cross section per unit volume.* The equivalent quantity for any *heterodisperse* medium or mixture containing spheres of various sizes and indices of refraction can also be computed by the reader by a proper summation of the cross sections with respect to the partial concentrations of particles of each size and index.

5. *Forward and backward scattering intensities.* For a given sphere, the *normalized intensity* or *phase function* at any scattering angle θ is generally defined as

$$P(m,x,\theta) = 2\,\frac{|S_1(m,x,\theta)|^2 + |S_2(m,x,\theta)|^2}{x^2 K_{sc}(m,x)}, \tag{7}$$

such that its integral with respect to all solid angles is equal to 4π. S_1 and S_2 are related to the electric vector amplitudes, which are, respectively, perpendicular and parallel to the scattering plane when the incident radiation is unpolarized. In the particular case of exact forward and backward scattering, we have

$$P(m, x, 0°) = 4\frac{|S_1(m, x, 0°)|^2}{x^2 K_{sc}(m, x)} \tag{8}$$

and

$$P(m, x, 180°) = 4\frac{|S_1(m, x, 180°)|^2}{x^2 K_{sc}(m, x)}, \tag{9}$$

since for homogeneous spheres

$$S_1(0) = S_2(0), \qquad S_1(180°) = -S_2(180°).$$

The quantities defined by Eqs. (7), (8), and (9) are expressed in terms of nondimensional fluxes per unit solid angle or steradian. To get the specific intensity in terms of physical units, one introduces the incident flux and the scattering cross section mentioned above. Thus, when a small volume element of a monodisperse medium is illuminated by a parallel unpolarized flux of F units, it scatters an amount

$$I_\lambda(\theta) = F\beta_{sc}\frac{P(\theta)}{4\pi} \quad (\text{sterad})^{-1}\,\text{cm}^{-3} \tag{10}$$

in the direction θ, expressed in the same energy units as for the flux F, where, for the particular cases $\theta = 0°$ and 180°, all the quantities on the right-hand side can be obtained from the tables, and

$$\beta_{sc} = n(r)\sigma_{sc}(m, r, \lambda). \tag{11}$$

By appropriate summations, the reader can easily derive expressions equivalent to Eqs. (8), (9), and (10) for heterodisperse scattering media.

In the literature on radar meteorology one often encounters the term *radar cross section* or *back scattering cross section* σ_b per particle. This is somewhat confusing, because the correct units here are those of an area *per unit solid angle*.* Nevertheless, this quantity is also obtainable from the present tables by means of the formula

$$\sigma_b(m, r, \lambda) = \frac{\lambda^2}{\pi}|S_1(m, x, 180°)|^2. \tag{12}$$

This is related to the normalized intensity function of Eq. (9) by means of the expression

$$\sigma_b(m, r, \lambda) = \sigma_{sc}(m, r, \lambda)P(m, x, 180°). \tag{13}$$

---

*Ref. 3, p. 284.

In problems of radiative transfer in scattering media, the general phase function given by Eq. (7) is clearly to be preferred, since it is necessary to know the field in any direction. The particular case of back scattering toward the source has only limited significance, and its use may lead to erroneous conclusions. A comparison of Eqs. (13) and (10) shows that one can also write

$$I_\lambda(180°) = Fn(r)\,\frac{\sigma_b(m, r, \lambda)}{4\pi}. \tag{14}$$

However, the form of Eq. (10) is to be preferred because of its generality and use in the problem of *diffuse reflection and transmission in extended plane stratified scattering media*, where the angle between the incident and reflected (or transmitted) radiation may assume any value.

III. ACCURACY AND EXTENT OF THE TABLES

THE IBM-7090 PROGRAM described elsewhere[1] produces an accuracy of five significant figures. In tabulating the scattering cross sections we have rounded off to four significant figures. For the complex amplitudes, we have retained four figures in either the real or the imaginary part, *whichever is the larger in absolute value*; we have then rounded off the other part to the *same number of decimal places*. This saves space and allows the reader to obtain the absolute value of the amplitude with an accuracy of four significant figures.

The tables of refractive indices display a good sampling of our results. They include water spheres illuminated by infrared, certain minerals and metals in the visible, and water and ice in the microwave. Not included are water spheres in the visible, with $m = 1.33$, since these have been thoroughly tabulated by others.* Size parameters are here limited to moderate values of x, depending on the material and wavelengths considered. Hopefully, they will indicate the effect that changes in the complex index have on the scattering and absorption properties in the same range. For obvious reasons, the increments Δx are not uniform for all the tables. For highly absorbing small spheres, we have used very small increments, when available, to display the rapid increase of the cross sections in this range. (Compare Tables 21, 22, and 23.)

Tables 6 and 8 show the scattering cross sections only, since the corresponding amplitudes have been tabulated in Appendix C of Ref. 1.

*Ref. 3, for example, lists tables available as of the date of publication.

REFERENCES

1. DEIRMENDJIAN, D., AND R. J. CLASEN, *Light Scattering on Partially Absorbing Homogeneous Spheres of Finite Size*, The RAND Corporation, Report R-393-PR, February 1962.
2. DEIRMENDJIAN, D., *Scattering and Polarization Properties of Polydispersed Suspensions with Partial Absorption*, The RAND Corporation, RAND Memorandum RM-3228-PR, July, 1962. To appear in *Proceedings of the Interdisciplinary Conference on Electromagnetic Scattering*, Pergamon Press, Inc., New York, 1963.
3. VAN DE HULST, H. C., *Light Scattering by Small Particles*, John Wiley & Sons, Inc., New York, 1957.

TABLES OF MIE SCATTERING CROSS SECTIONS AND AMPLITUDES

Table 1

COMPLEX AMPLITUDES

$m = 1.29$ (liquid water, 20°C, at λ2.25μ)

x:0 5(0.5)15.0

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00033 + 0.02350i	0.00033 + 0.02108i
1.0	0.0181 + 0.2002i	0.0173 + 0.1269i
1.5	0.1392 + 0.6874i	0.1002 + 0.1740i
2.0	0.535 + 1.636i	0.0266 — 0.1464i
2.5	1.475 + 2.978i	—0.4717 — 0.2733i
3.0	3.066 + 4.780i	—0.2502 + 0.3099i
3.5	5.621 + 6.690i	0.8677 + 0.0537i
4.0	9.195 + 8.739i	0.3334 — 0.8398i
4.5	13.72 + 10.37i	—0.9845 + 0.3555i
5.0	19.54 + 11.48i	0.166 + 1.409i
5.5	25.73 + 11.92i	0.8076 — 0.6703i
6.0	33.06 + 10.75i	—1.085 — 1.296i
6.5	40.16 + 9.43i	—0.4855 + 0.7786i
7.0	47.16 + 5.44i	1.537 + 0.266i
7.5	54.32 + 2.00i	0.0645 — 0.6037i
8.0	58.93 — 3.60i	—0.7658 + 0.9367i
8.5	64.83 — 9.33i	0.2386 — 0.0632i
9.0	66.59 — 13.79i	—1.102 — 1.161i
9.5	69.24 — 20.92i	0.044 + 1.087i
10.0	70.29 — 22.30i	3.073 — 0.491i
10.5	68.18 — 27.65i	—1.096 — 2.040i
11.0	70.86 — 26.99i	—3.116 + 3.927i
11.5	65.97 — 25.55i	3.131 + 2.567i
12.0	69.91 — 24.93i	—0.005 — 6.295i
12.5	69.47 — 14.76i	—6.537 — 1.301i
13.0	72.29 — 14.02i	3.423 + 5.388i
13.5	82.76 — 1.48i	8.400 — 4.495i
14.0	84.03 + 3.96i	—4.783 — 3.538i
14.5	103.1 + 10.2i	—2.829 + 9.940i
15.0	110.6 + 23.2i	6.666 + 2.646i

Table 2

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.29 - 0.0472i$ (liquid water, 20°C, at λ8.15μ)

x:0.5(0.5)15.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.005419	0.00399 + 0.02343i	0.00358 + 0.02101i
1.0	0.07177	0.0507 + 0.1942i	0.0369 + 0.1215i
1.5	0.2338	0.2490 + 0.6416i	0.1115 + 0.1481i
2.0	0.4781	0.777 + 1.451i	−0.0315 − 0.1095i
2.5	0.7914	1.812 + 2.534i	−0.4181 − 0.1434i
3.0	1.106	3.483 + 3.887i	−0.1185 + 0.1655i
3.5	1.421	5.893 + 5.268i	0.5836 − 0.1534i
4.0	1.716	9.120 + 6.586i	0.1849 − 0.4543i
4.5	1.958	13.04 + 7.63i	−0.3778 + 0.4364i
5.0	2.166	17.71 + 8.16i	0.1231 + 0.7435i
5.5	2.303	22.82 + 8.27i	0.0312 − 0.3648i
6.0	2.389	28.29 + 7.51i	−0.6536 − 0.5725i
6.5	2.419	33.97 + 6.36i	0.04149 + 0.03988i
7.0	2.387	39.37 + 4.39i	0.8010 − 0.1167i
7.5	2.327	44.87 + 2.07i	0.1982 + 0.1107i
8.0	2.212	49.64 − 0.49i	−0.1810 + 0.6946i
8.5	2.090	54.31 − 3.43i	−0.3446 + 0.0702i
9.0	1.939	58.38 − 5.80i	−0.7567 − 0.4236i
9.5	1.788	62.02 − 8.41i	0.1376 − 0.2005i
10.0	1.645	65.79 − 10.02i	1.034 − 0.631i
10.5	1.501	68.89 − 11.32i	0.0537 − 0.1053i
11.0	1.389	72.85 − 11.96i	−0.220 + 1.482i
11.5	1.282	76.50 − 11.53i	0.3464 + 0.5227i
12.0	1.211	81.11 − 11.14i	−0.966 − 1.258i
12.5	1.155	86.42 − 9.42i	−1.176 − 0.233i
13.0	1.121	92.20 − 8.08i	1.424 + 0.217i
13.5	1.111	99.65 − 6.12i	1.425 − 0.960i
14.0	1.108	107.2 − 4.3i	−0.9313 + 0.5869i
14.5	1.127	116.4 − 3.0i	−0.369 + 2.080i
15.0	1.146	125.9 − 1.5i	0.2977 − 0.5869i

Table 3

Scattering Cross Sections and Complex Amplitudes

$m = 1.29 - 0.0645i$

$x:0.5(0.5)15.0$

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.005535	0.00533 + 0.02342i	0.00477 + 0.02100i
1.0	0.07250	0.0624 + 0.1920i	0.0439 + 0.1196i
1.5	0.2320	0.2874 + 0.6249i	0.1152 + 0.1402i
2.0	0.4654	0.856 + 1.386i	−0.04722 − 0.09535i
2.5	0.7551	1.923 + 2.387i	−0.4013 − 0.1085i
3.0	1.042	3.610 + 3.601i	−0.0941 + 0.1235i
3.5	1.320	5.982 + 4.820i	0.5074 − 0.1960i
4.0	1.575	9.098 + 5.938i	0.1695 − 0.3696i
4.5	1.778	12.84 + 6.80i	−0.2429 + 0.4294i
5.0	1.945	17.22 + 7.20i	0.0967 + 0.6248i
5.5	2.051	22.01 + 7.21i	−0.0972 − 0.2705i
6.0	2.111	27.07 + 6.55i	−0.5650 − 0.4653i
6.5	2.124	32.34 + 5.50i	0.0798 − 0.1003i
7.0	2.089	37.43 + 3.91i	0.6781 − 0.1488i
7.5	2.029	42.57 + 1.98i	0.2654 + 0.1890i
8.0	1.933	47.29 − 0.06i	−0.1143 + 0.6240i
8.5	1.829	51.88 − 2.35i	−0.4314 + 0.1359i
9.0	1.710	56.21 − 4.25i	−0.6622 − 0.3238i
9.5	1.592	60.24 − 6.17i	0.1223 − 0.3951i
10.0	1.482	64.46 − 7.52i	0.7742 − 0.5918i
10.5	1.376	68.41 − 8.49i	0.2496 + 0.1226i
11.0	1.292	72.90 − 9.09i	0.043 + 1.180i
11.5	1.218	77.50 − 8.97i	−0.0384 + 0.3958i
12.0	1.165	82.69 − 8.79i	−1.011 − 0.745i
12.5	1.126	88.55 − 7.94i	−0.6919 − 0.3441i
13.0	1.103	94.84 − 7.17i	1.130 − 0.299i
13.5	1.094	102.2 − 6.2i	1.032 − 0.561i
14.0	1.093	109.8 − 5.3i	−0.3483 + 0.8593i
14.5	1.102	118.5 − 4.7i	−0.254 + 1.495i
15.0	1.114	127.5 − 4.1i	−0.3525 − 0.4471i

Table 4

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.29 - 0.4720i$

x:0.5(0.5)15.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.01965	0.03697 + 0.02600i	0.03293 + 0.02381i
1.0	0.2018	0.3101 + 0.1419i	0.1876 + 0.0893i
1.5	0.4479	0.9542 + 0.2794i	0.1861 + 0.0918i
2.0	0.6480	1.993 + 0.374i	−0.1384 + 0.1669i
2.5	0.8031	3.395 + 0.377i	−0.3394 + 0.1690i
3.0	0.9086	5.129 + 0.285i	−0.2160 − 0.1770i
3.5	0.9801	7.159 + 0.095i	0.0425 − 0.4931i
4.0	1.027	9.469 − 0.174i	0.3363 − 0.2594i
4.5	1.059	12.04 − 0.51i	0.4863 + 0.2985i
5.0	1.080	14.87 − 0.89i	0.1489 + 0.5787i
5.5	1.095	17.96 − 1.32i	−0.5123 + 0.3737i
6.0	1.106	21.31 − 1.78i	−0.7393 − 0.1629i
6.5	1.115	24.92 − 2.27i	−0.1991 − 0.6935i
7.0	1.121	28.79 − 2.79i	0.5634 − 0.6804i
7.5	1.127	32.93 − 3.33i	0.8454 + 0.0735i
8.0	1.132	37.33 − 3.89i	0.4049 + 0.8907i
8.5	1.136	41.99 − 4.48i	−0.4741 + 0.8803i
9.0	1.140	46.92 − 5.09i	−1.062 + 0.005i
9.5	1.143	52.11 − 5.72i	−0.6843 − 0.9218i
10.0	1.146	57.56 − 6.37i	0.448 − 1.068i
10.5	1.149	63.28 − 7.04i	1.252 − 0.242i
11.0	1.151	69.26 − 7.73i	0.8910 + 0.9184i
11.5	1.153	75.50 − 8.44i	−0.340 + 1.338i
12.0	1.155	82.00 − 9.17i	−1.330 + 0.489i
12.5	1.157	88.77 − 9.91i	−1.154 − 0.925i
13.0	1.158	95.79 − 10.68i	0.123 − 1.548i
13.5	1.160	103.1 − 11.5i	1.407 − 0.729i
14.0	1.161	110.6 − 12.3i	1.458 + 0.826i
14.5	1.162	118.4 − 13.1i	0.103 + 1.703i
15.0	1.163	126.5 − 13.9i	−1.451 + 1.041i

Table 5

COMPLEX AMPLITUDES

$m = 1.315$ (liquid water, 20°C, at λ1.61μ)

x: 0.5(0.5)15.0

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00039 + 0.02543*i*	0.00039 + 0.02279*i*
1.0	0.0214 + 0.2177*i*	0.0204 + 0.1375*i*
1.5	0.1647 + 0.7475*i*	0.1161 + 0.1795*i*
2.0	0.642 + 1.772*i*	0.0040 − 0.1849*i*
2.5	1.735 + 3.159*i*	−0.5554 − 0.2318*i*
3.0	3.605 + 5.006*i*	−0.1394 + 0.4048*i*
3.5	6.463 + 6.794*i*	1.002 − 0.164*i*
4.0	10.51 + 8.59*i*	0.0090 − 0.9251*i*
4.5	15.34 + 9.82*i*	−1.005 + 0.846*i*
5.0	21.47 + 10.07*i*	0.725 + 1.273*i*
5.5	27.84 + 9.88*i*	0.454 − 1.329*i*
6.0	34.57 + 7.37*i*	−1.650 − 0.782*i*
6.5	41.69 + 5.12*i*	0.339 + 1.176*i*
7.0	46.69 + 0.35*i*	1.790 − 0.508*i*
7.5	53.17 − 4.54*i*	−0.6727 − 0.2995*i*
8.0	55.43 − 8.92*i*	−0.459 + 1.601*i*
8.5	58.72 − 15.87*i*	0.0129 − 0.5437*i*
9.0	60.27 − 17.72*i*	−1.929 − 0.787*i*
9.5	58.22 − 23.18*i*	1.040 + 0.678*i*
10.0	61.20 − 23.76*i*	2.504 − 2.837*i*
10.5	56.13 − 21.82*i*	−2.268 − 0.612*i*
11.0	59.41 − 22.78*i*	1.063 + 5.492*i*
11.5	60.05 − 12.28*i*	4.938 − 0.778*i*
12.0	60.88 − 11.99*i*	−5.063 − 4.186*i*
12.5	72.41 − 1.66*i*	−5.042 + 6.764*i*
13.0	72.95 + 6.47*i*	6.911 + 1.750*i*
13.5	90.79 + 8.90*i*	−1.530 − 9.329*i*
14.0	102.6 + 23.8*i*	−10.05 + 1.33*i*
14.5	116.5 + 16.8*i*	5.596 + 6.022*i*
15.0	141.5 + 23.1*i*	7.39 − 12.01*i*

Table 6

SCATTERING CROSS SECTIONS

$m = 1.315 - 0.0143i$ (liquid water, 20°C, at $\lambda 5.30\mu$)
$m = 1.315 - 0.1370i$ (liquid water, 20°C, at $\lambda 6.05\mu$)
$m = 1.315 - 0.4298i$ (liquid water, 18°C, at $\lambda 15.0\mu$)
x:0.5(0.5)15.0

x	K_{sc} $m = 1.315 - 0.0143i$	K_{sc} $m = 1.315 - 0.1370i$	K_{sc} $m = 1.315 - 0.4298i$
0.5	0.006207	0.007318	0.01789
1.0	0.08479	0.09253	0.1902
1.5	0.2860	0.2760	0.4367
2.0	0.6158	0.5147	0.6453
2.5	1.044	0.7699	0.8094
3.0	1.490	1.001	0.9207
3.5	1.935	1.194	0.9950
4.0	2.377	1.347	1.042
4.5	2.717	1.449	1.072
5.0	3.035	1.511	1.091
5.5	3.224	1.535	1.103
6.0	3.325	1.527	1:111
6.5	3.372	1.499	1.116
7.0	3.247	1.453	1.121
7.5	3.158	1.402	1.125
8.0	2.903	1.347	1.128
8.5	2.683	1.294	1.132
9.0	2.434	1.247	1.134
9.5	2.128	1.206	1.137
10.0	1.954	1.173	1.140
10.5	1.678	1.148	1.142
11.0	1.564	1.130	1.144
11.5	1.440	1.118	1.146
12.0	1.357	1.111	1.147
12.5	1.397	1.108	1.149
13.0	1.364	1.108	1.150
13.5	1.482	1.109	1.151
14.0	1.541	1.111	1.152
14.5	1.634	1.113	1.153
15.0	1.757	1.115	1.154

Table 7

COMPLEX AMPLITUDES

$m = 1.525$

$x: 1(1)25$

x	$S_1(0°)$	$S_1(180°)$
1	0.0592 + 0.3633*i*	0.0558 + 0.2188*i*
2	1.980 + 2.502*i*	−0.5276 − 0.2668*i*
3	8.043 + 4.023*i*	0.9545 − 0.7599*i*
4	16.37 + 2.08*i*	0.574 + 2.277*i*
5	23.99 − 4.66*i*	−4.543 + 0.017*i*
6	22.73 − 11.17*i*	1.274 − 5.368*i*
7	20.42 − 5.96*i*	3.632 + 5.128*i*
8	34.43 + 3.81*i*	−13.09 + 2.81*i*
9	53.15 + 10.30*i*	−1.31 − 11.91*i*
10	71.85 − 1.63*i*	4.822 + 5.453*i*
11	83.65 − 21.18*i*	−12.11 + 7.44*i*
12	88.13 − 15.44*i*	−2.97 − 16.68*i*
13	82.31 − 17.64*i*	4.680 + 6.232*i*
14	93.57 − 0.61*i*	−7.321 + 3.507*i*
15	136.9 + 6.7*i*	−3.718 − 0.990*i*
16	176.1 − 16.8*i*	9.641 − 9.956*i*
17	181.2 − 30.4*i*	−2.474 + 2.998*i*
18	182.1 − 33.6*i*	−4.844 − 8.025*i*
19	182.4 − 30.8*i*	−1.05 − 11.14*i*
20	201.9 − 9.9*i*	3.177 − 2.291*i*
21	252.9 + 16.6*i*	−11.63 − 8.08*i*
22	295.9 − 2.4*i*	−4.18 − 18.53*i*
23	324.4 − 46.8*i*	7.051 − 2.955*i*
24	337.5 − 61.9*i*	−27.66 + 3.61*i*
25	308.4 − 31.3*i*	−6.11 − 19.51*i*

Table 8

SCATTERING CROSS SECTIONS

$m = 1.525 - 0.0682i$ (liquid water, 20°C, at $\lambda 3.07\mu$), x: 1(1)25; and $m = 1.353 - 0.0059i$ (liquid water, 20°C, at $\lambda 3.90\mu$), x: 1(1)20

x	K_{sc} $m = 1.525 - 0.0682i$	K_{sc} $m = 1.353 - 0.0059i$
1	0.2295	0.1071
2	1.538	0.8140
3	2.544	1.931
4	2.699	2.970
5	2.212	3.587
6	1.526	3.676
7	1.131	3.359
8	1.135	2.834
9	1.306	2.212
10	1.397	1.692
11	1.348	1.490
12	1.236	1.680
13	1.160	2.058
14	1.160	2.319
15	1.201	2.382
16	1.226	2.281
17	1.213	2.132
18	1.178	1.870
19	1.155	1.663
20	1.154	1.541
21	1.167	
22	1.176	
23	1.173	
24	1.162	
25	1.155	

Table 9

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES
$m = 1.212 - 0.0601i$ (liquid water, 18°C, at λ10.0μ)
x: 0.5(0.5)10.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.003117	0.00496 + 0.01731i	0.00445 + 0.01556i
1.0	0.03967	0.0508 + 0.1399i	0.03471 + 0.08826i
1.5	0.1271	0.2124 + 0.4568i	0.0823 + 0.1180i
2.0	0.2503	0.591 + 1.033i	−0.00183 − 0.03612i
2.5	0.4188	1.310 + 1.860i	−0.2517 − 0.1401i
3.0	0.5941	2.439 + 2.932i	−0.1924 + 0.0127i
3.5	0.7810	4.094 + 4.190i	0.2796 + 0.0131i
4.0	0.9652	6.318 + 5.566i	0.3639 − 0.1958i
4.5	1.141	9.152 + 6.966i	−0.09565 + 0.03500i
5.0	1.304	12.63 + 8.31i	−0.2385 + 0.4522i
5.5	1.449	16.69 + 9.48i	−0.0492 + 0.1449i
6.0	1.574	21.36 + 10.42i	−0.1384 − 0.4324i
6.5	1.675	26.51 + 11.03i	−0.1007 − 0.3307i
7.0	1.755	32.13 + 11.27i	0.3608 + 0.0395i
7.5	1.810	38.06 + 11.13i	0.3924 + 0.1659i
8.0	1.844	44.28 + 10.53i	−0.1444 + 0.3496i
8.5	1.856	50.65 + 9.59i	−0.3679 + 0.3162i
9.0	1.850	57.09 + 8.22i	−0.2554 − 0.2940i
9.5	1.828	63.57 + 6.60i	−0.1433 − 0.6004i
10.0	1.791	69.94 + 4.68i	0.2980 − 0.1237i

Table 10

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.111 - 0.1831i$ (liquid water, 18°C, at λ11.5μ)

x:0.5(0.5)10.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.003011	0.01502 + 0.00932*i*	0.01350 + 0.00845*i*
1.0	0.03406	0.1223 + 0.0645*i*	0.07754 + 0.04071*i*
1.5	0.09631	0.4036 + 0.1818*i*	0.1113 + 0.0520*i*
2.0	0.1695	0.9241 + 0.3599*i*	−0.01145 + 0.04097*i*
2.5	0.2536	1.726 + 0.580*i*	−0.1751 + 0.0421*i*
3.0	0.3383	2.835 + 0.828*i*	−0.1501 − 0.0232*i*
3.5	0.4188	4.271 + 1.087*i*	0.0309 − 0.1642*i*
4.0	0.4940	6.043 + 1.337*i*	0.1686 − 0.1641*i*
4.5	0.5628	8.150 + 1.565*i*	0.1852 + 0.0696*i*
5.0	0.6244	10.59 + 1.76*i*	0.0710 + 0.2730*i*
5.5	0.6793	13.36 + 1.90*i*	−0.1609 + 0.1980*i*
6.0	0.7277	16.45 + 2.00*i*	−0.3161 − 0.0671*i*
6.5	0.7699	19.85 + 2.03*i*	−0.1570 − 0.2811*i*
7.0	0.8065	23.56 + 2.01*i*	0.2107 − 0.2813*i*
7.5	0.8383	27.56 + 1.92*i*	0.3958 − 0.0254*i*
8.0	0.8656	31.84 + 1.78*i*	0.2015 + 0.3239*i*
8.5	0.8890	36.40 + 1.57*i*	−0.1837 + 0.4162*i*
9.0	0.9091	41.24 + 1.31*i*	−0.4281 + 0.0830*i*
9.5	0.9263	46.34 + 1.00*i*	−0.3158 − 0.3768*i*
10.0	0.9411	51.71 + 0.64*i*	0.1108 − 0.4936*i*

Table 11

COMPLEX AMPLITUDES

$m = 1.44$

$x: 0.5(0.5)7.0$

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00072 + 0.03478*i*	0.00072 + 0.03104*i*
1.0	0.0418 + 0.3048*i*	0.0397 + 0.1877*i*
1.5	0.325 + 1.047*i*	0.1984 + 0.1703*i*
2.0	1.367 + 2.336*i*	−0.2572 − 0.3310*i*
2.5	3.174 + 3.783*i*	−0.7480 + 0.2497*i*
3.0	6.559 + 5.014*i*	0.7924 + 0.1679*i*
3.5	10.57 + 6.04*i*	0.307 − 1.518*i*
4.0	15.42 + 5.05*i*	−1.058 + 0.764*i*
4.5	21.35 + 3.64*i*	1.897 + 1.486*i*
5.0	24.93 + 1.04*i*	0.136 − 2.026*i*
5.5	29.17 − 4.31*i*	−2.819 + 1.177*i*
6.0	32.50 − 6.40*i*	2.716 + 1.647*i*
6.5	30.54 − 11.09*i*	0.975 − 3.696*i*
7.0	33.01 − 14.53*i*	−2.629 + 2.251*i*

Table 12

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.44 - 0.4000i$ (liquid water, 18°C, at λ16.6μ)

$x: 0.5(0.5)7.0$

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.02105	0.02963 + 0.03638*i*	0.02606 + 0.03284*i*
1.0	0.2395	0.2905 + 0.2351*i*	0.1734 + 0.1405*i*
1.5	0.5637	0.9959 + 0.5172*i*	0.1707 + 0.1104*i*
2.0	0.8292	2.167 + 0.751*i*	−0.2087 + 0.1256*i*
2.5	1.014	3.758 + 0.838*i*	−0.3755 + 0.1136*i*
3.0	1.117	5.680 + 0.774*i*	−0.1446 − 0.2274*i*
3.5	1.168	7.867 + 0.550*i*	0.1644 − 0.4988*i*
4.0	1.185	10.29 + 0.23*i*	0.3686 − 0.1789*i*
4.5	1.186	12.92 − 0.16*i*	0.4031 + 0.4438*i*
5.0	1.180	15.79 − 0.59*i*	0.0425 + 0.6043*i*
5.5	1.172	18.89 − 1.03*i*	−0.6072 + 0.2056*i*
6.0	1.166	22.24 − 1.49*i*	−0.7252 − 0.3186*i*
6.5	1.162	25.86 − 1.94*i*	0.0024 − 0.7021*i*
7.0	1.160	29.74 − 2.42*i*	0.7415 − 0.5698*i*

Table 13

COMPLEX AMPLITUDES

$m = 2.20$

x: 0.5(0.5)10.0; 12(4)40

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00369 + 0.08009*i*	0.00366 + 0.06841*i*
1.0	0.2797 + 0.8213*i*	0.2213 + 0.3146*i*
1.5	2.539 + 0.732*i*	−0.2167 + 0.9230*i*
2.0	5.374 − 0.802*i*	0.872 − 2.098*i*
2.5	6.902 − 2.680*i*	−4.381 + 2.456*i*
3.0	5.148 − 0.237*i*	2.849 − 0.921*i*
3.5	6.453 + 0.781*i*	−1.189 + 2.388*i*
4.0	13.70 + 1.70*i*	4.023 − 4.567*i*
4.5	17.08 + 4.41*i*	−1.388 + 0.412*i*
5.0	15.56 − 3.30*i*	−3.067 − 0.966*i*
5.5	14.21 − 6.19*i*	4.391 + 3.273*i*
6.0	17.45 − 2.85*i*	−8.201 − 6.442*i*
6.5	25.89 + 1.55*i*	8.441 + 6.537*i*
7.0	34.41 − 2.40*i*	−4.909 − 6.491*i*
7.5	39.22 − 10.90*i*	6.987 + 4.632*i*
8.0	40.00 − 14.80*i*	−6.267 + 0.289*i*
8.5	41.83 + 0.29*i*	6.61 − 10.61*i*
9.0	48.94 + 7.25*i*	−13.55 + 6.24*i*
9.5	55.48 + 4.68*i*	8.380 − 9.236*i*
10.0	63.76 − 13.93*i*	−1.420 + 7.093*i*
12.0	88.23 − 4.84*i*	10.70 + 7.81*i*
16.0	135.5 − 29.1*i*	7.45 − 14.18*i*
20.0	240.3 − 3.9*i*	−17.82 − 12.55*i*
24.0	306.4 − 42.4*i*	−7.35 + 36.32*i*
28.0	440.1 − 28.5*i*	29.71 − 11.00*i*
32.0	518.2 − 23.4*i*	−34.61 − 21.96*i*
36.0	749.9 − 56.2*i*	8.33 + 71.47*i*
40.0	848.4 − 93.6*i*	68.00 − 39.25*i*

Table 14

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 2.20 - 0.0220i$

$x: 0.5(0.5)10.0; 12(4)40$

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.05901	0.00474 + 0.08001*i*	0.00444 + 0.06832*i*
1.0	1.105	0.2961 + 0.8112*i*	0.2182 + 0.3103*i*
1.5	4.213	2.482 + 0.750*i*	−0.1733 + 0.8539*i*
2.0	4.744	5.162 − 0.559*i*	0.669 − 1.772*i*
2.5	3.282	6.158 − 2.120*i*	−3.425 + 1.932*i*
3.0	1.756	5.421 − 0.979*i*	2.699 − 1.477*i*
3.5	1.705	6.964 + 0.656*i*	−1.412 + 1.430*i*
4.0	2.480	12.79 + 2.09*i*	3.090 − 2.023*i*
4.5	2.645	16.75 + 1.49*i*	−0.795 + 1.471*i*
5.0	2.151	16.63 − 3.05*i*	−2.169 − 0.321*i*
5.5	1.599	15.95 − 4.96*i*	2.597 + 2.001*i*
6.0	1.570	18.89 − 2.34*i*	−5.583 − 4.477*i*
6.5	1.922	26.29 + 0.66*i*	5.575 + 3.950*i*
7.0	2.164	33.77 − 1.90*i*	−1.959 − 4.814*i*
7.5	2.101	38.11 − 7.80*i*	3.055 + 3.608*i*
8.0	1.794	39.04 − 9.33*i*	−2.486 + 1.801*i*
8.5	1.583	41.14 − 4.48*i*	1.256 − 2.778*i*
9.0	1.663	48.30 + 0.73*i*	−5.102 + 3.521*i*
9.5	1.832	57.43 − 0.54*i*	4.567 − 7.255*i*
10.0	1.806	62.85 − 7.82*i*	−2.543 + 5.316*i*
12.0	1.694	86.70 − 4.80*i*	2.560 + 0.963*i*
16.0	1.413	142.1 − 19.4*i*	4.058 − 9.362*i*
20.0	1.471	230.5 − 16.8*i*	−4.284 − 0.432*i*
24.0	1.334	314.7 − 32.7*i*	−5.579 + 7.691*i*
28.0	1.362	437.3 − 35.1*i*	−1.073 − 4.579*i*
32.0	1.281	553.4 − 46.6*i*	3.058 − 1.588*i*
36.0	1.308	710.2 − 55.2*i*	3.14 + 10.30*i*
40.0	1.262	859.3 − 64.7*i*	−4.063 − 0.079*i*

Table 15

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 2.20 - 0.2200i$

x: 0.5(0.5)10.0; 12(4)40

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.06036	0.01416 + 0.07981i	0.01143 + 0.06830i
1.0	1.014	0.4272 + 0.7116i	0.2039 + 0.2927i
1.5	2.576	2.100 + 0.716i	0.0927 + 0.4949i
2.0	2.402	3.964 + 0.156i	−0.2580 − 0.5156i
2.5	1.547	4.853 − 0.550i	−1.086 + 0.590i
3.0	1.143	5.917 − 0.717i	0.6999 − 0.8924i
3.5	1.173	8.040 − 0.220i	−0.1678 − 0.5875i
4.0	1.353	10.94 − 0.13i	1.007 + 0.371i
4.5	1.434	13.94 − 0.86i	0.3335 + 0.5943i
5.0	1.372	16.61 − 1.71i	−0.5993 + 0.9951i
5.5	1.289	19.29 − 2.08i	−0.7870 − 0.1442i
6.0	1.270	22.59 − 2.12i	−1.038 − 0.998i
6.5	1.294	26.57 − 2.29i	0.7489 − 0.8341i
7.0	1.312	30.78 − 2.88i	1.348 − 0.580i
7.5	1.306	34.96 − 3.63i	0.776 + 1.187i
8.0	1.290	39.23 − 4.18i	−0.212 + 1.514i
8.5	1.283	43.87 − 4.54i	−1.600 + 0.466i
9.0	1.287	48.98 − 4.93i	−1.294 − 0.995i
9.5	1.291	54.39 − 5.52i	0.135 − 1.917i
10.0	1.290	59.95 − 6.22i	1.613 − 0.764i
12.0	1.283	84.67 − 8.63i	−2.086 − 0.833i
16.0	1.275	146.7 − 14.4i	1.485 − 2.673i
20.0	1.269	225.4 − 21.1i	3.058 + 2.275i
24.0	1.265	320.6 − 28.5i	−3.219 + 3.226i
28.0	1.261	432.3 − 36.7i	−3.194 − 4.266i
32.0	1.258	560.3 − 45.5i	5.342 − 2.920i
36.0	1.255	704.8 − 54.8i	2.382 + 6.417i
40.0	1.252	865.5 − 64.7i	−7.441 + 1.591i

Table 16

COMPLEX AMPLITUDES
$m = 1.54$ (silicates, visible light)
x:0.5(0.5)10.0

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00104 + 0.04188i	0.00104 + 0.03722i
1.0	0.0625 + 0.3735i	0.0589 + 0.2239i
1.5	0.499 + 1.286i	0.2486 + 0.1126i
2.0	2.087 + 2.508i	−0.5719 − 0.2354i
2.5	4.568 + 3.975i	−0.3618 + 0.7001i
3.0	8.222 + 3.824i	0.8925 − 0.9374i
3.5	13.44 + 3.27i	−1.432 − 0.629i
4.0	16.47 + 1.64i	1.097 + 2.365i
4.5	19.89 − 3.21i	1.346 − 2.011i
5.0	23.28 − 5.85i	−4.761 + 1.376i
5.5	20.75 − 7.48i	1.976 + 3.830i
6.0	20.94 − 10.60i	0.000 − 5.774i
6.5	22.80 − 8.27i	−7.522 + 3.487i
7.0	20.04 − 2.97i	5.328 + 5.144i
7.5	26.74 − 0.37i	−1.460 − 7.033i
8.0	33.86 + 3.60i	−10.56 + 8.70i
8.5	40.37 + 8.57i	5.012 + 6.187i
9.0	58.12 + 6.91i	−5.584 − 9.870i
9.5	62.64 + 1.60i	−9.785 + 8.630i
10.0	71.71 − 2.90i	7.787 + 6.700i

Table 17

COMPLEX AMPLITUDES

$m = 1.55$ (silicates, visible light)

x: 0.5(0.5)10.0

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00108 + 0.04257i	0.00107 + 0.03782i
1.0	0.0648 + 0.3803i	0.0610 + 0.2274i
1.5	0.519 + 1.310i	0.2517 + 0.1042i
2.0	2.157 + 2.509i	—0.5996 — 0.2114i
2.5	4.728 + 3.968i	—0.2889 + 0.7263i
3.0	8.330 + 3.693i	0.836 — 1.052i
3.5	13.60 + 2.86i	—1.509 — 0.385i
4.0	16.54 + 1.36i	1.481 + 2.367i
4.5	19.44 — 3.67i	1.010 — 2.236i
5.0	22.63 — 6.57i	—4.635 + 2.301i
5.5	20.14 — 7.16i	2.839 + 3.712i
6.0	19.86 — 10.08i	—0.852 — 5.872i
6.5	21.52 — 7.78i	—6.380 + 5.379i
7.0	20.39 — 0.85i	6.803 + 4.993i
7.5	27.26 + 0.57i	—2.748 — 6.400i
8.0	33.89 + 5.22i	—8.04 + 10.92i
8.5	42.98 + 10.32i	7.304 + 6.354i
9.0	59.25 + 3.63i	—6.778 — 7.738i
9.5	63.23 + 2.23i	—7.44 + 10.79i
10.0	73.73 — 2.56i	12.48 + 7.44i

Table 18

COMPLEX AMPLITUDES
$m = 1.56$ (silicates, visible light)
x: 0.5(0.5)10.0

x	$S_1(0°)$	$S_1(180°)$
0.5	0.00111 + 0.04326i	0.00111 + 0.03841i
1.0	0.0671 + 0.3871i	0.0631 + 0.2307i
1.5	0.540 + 1.334i	0.2543 + 0.0953i
2.0	2.226 + 2.507i	−0.6256 − 0.1850i
2.5	4.893 + 3.955i	−0.2100 + 0.7458i
3.0	8.429 + 3.565i	0.768 − 1.163i
3.5	13.71 + 2.43i	−1.548 − 0.128i
4.0	16.63 + 1.07i	1.890 + 2.314i
4.5	18.96 − 4.07i	0.646 − 2.420i
5.0	21.87 − 7.17i	−4.308 + 3.167i
5.5	19.70 − 6.79i	3.809 + 3.429i
6.0	18.86 − 9.47i	−1.686 − 5.850i
6.5	20.41 − 6.80i	−4.863 + 6.784i
7.0	21.46 + 1.17i	8.723 + 4.490i
7.5	27.70 + 1.44i	−3.744 − 5.657i
8.0	35.06 + 7.14i	−5.43 + 12.50i
8.5	47.51 + 11.35i	11.34 + 5.57i
9.0	58.99 + 1.14i	−7.041 − 6.308i
9.5	65.07 + 2.42i	−4.41 + 13.19i
10.0	80.20 − 10.22i	21.59 − 1.06i

Table 19

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.55 - 0.0155i$

x:2(2)12(4)40

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
2	2.020	$2.158 + 2.405i$	$-0.5625 - 0.1724i$
4	3.707	$16.08 + 1.24i$	$1.419 + 1.815i$
6	1.885	$20.64 - 8.59i$	$-0.921 - 4.695i$
8	1.689	$35.85 + 4.02i$	$-5.451 + 7.702i$
10	2.220	$70.58 - 5.68i$	$9.094 + 1.301i$
12	1.586	$79.92 - 17.66i$	$-5.653 - 4.741i$
16	1.801	$158.9 - 18.7i$	$2.711 - 4.836i$
20	1.503	$226.8 - 5.1i$	$7.239 + 0.883i$
24	1.325	$308.2 - 30.7i$	$0.387 + 4.370i$
28	1.415	$443.5 - 49.4i$	$-1.112 + 2.211i$
32	1.359	$571.4 - 32.4i$	$-2.769 - 1.187i$
36	1.238	$690.7 - 48.6i$	$-0.070 - 1.310i$
40	1.256	$867.1 - 79.1i$	$0.256 - 2.236i$

Table 20

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.55 - 0.1550i$

x:2(2)12(4)40

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
2	1.338	$2.235 + 1.664i$	$-0.3538 + 0.0223i$
4	1.885	$12.74 + 0.64i$	$0.6463 + 0.0290i$
6	1.217	$22.93 - 2.60i$	$-0.9147 - 0.8228i$
8	1.149	$38.99 - 2.35i$	$-0.261 + 1.481i$
10	1.202	$60.75 - 5.10i$	$1.297 - 0.604i$
12	1.170	$84.74 - 7.96i$	$-1.310 - 0.497i$
16	1.172	$147.1 - 13.4i$	$0.695 - 1.601i$
20	1.166	$225.5 - 20.0i$	$1.944 + 1.128i$
24	1.164	$320.6 - 27.5i$	$-1.699 + 2.083i$
28	1.162	$432.2 - 35.8i$	$-2.119 - 2.307i$
32	1.160	$560.1 - 44.6i$	$2.950 - 2.027i$
36	1.158	$704.4 - 54.1i$	$1.775 + 3.613i$
40	1.157	$865.0 - 64.2i$	$-4.259 + 1.373i$

Table 21

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.28 - 1.37i$ (iron at $\lambda 0.441\mu$)

x:0.1(0.1)1.0(0.25)2.00(0.50)10.00

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.1	0.0002408	0.0006905 + 0.0006549*i*	0.0006872 + 0.0006545*i*
0.2	0.003901	0.005700 + 0.005167*i*	0.005592 + 0.005153*i*
0.3	0.01995	0.02017 + 0.01686*i*	0.01936 + 0.01676*i*
0.4	0.06289	0.05052 + 0.03742*i*	0.04718 + 0.03705*i*
0.5	0.1490	0.1038 + 0.0653*i*	0.09387 + 0.06431*i*
0.6	0.2876	0.1853 + 0.0945*i*	0.1614 + 0.0926*i*
0.7	0.4704	0.2951 + 0.1167*i*	0.2454 + 0.1136*i*
0.8	0.6700	0.4273 + 0.1254*i*	0.3347 + 0.1210*i*
0.9	0.8532	0.5732 + 0.1202*i*	0.4148 + 0.1148*i*
1.0	0.9984	0.7269 + 0.1064*i*	0.4731 + 0.1006*i*
1.25	1.195	1.152 + 0.073*i*	0.4799 + 0.0772*i*
1.50	1.291	1.688 + 0.044*i*	0.2727 + 0.1438*i*
1.75	1.381	2.326 — 0.038*i*	—0.0577 + 0.3382*i*
2.00	1.440	3.012 — 0.148*i*	—0.3500 + 0.5571*i*
2.5	1.490	4.633 — 0.372*i*	—0.5552 + 0.4023*i*
3.0	1.520	6.532 — 0.679*i*	—0.5064 — 0.5944*i*
3.5	1.532	8.737 — 1.022*i*	—0.116 — 1.040*i*
4.0	1.537	11.21 — 1.41*i*	0.8402 — 0.4048*i*
4.5	1.539	13.97 — 1.84*i*	1.244 + 0.524*i*
5.0	1.538	17.00 — 2.30*i*	0.194 + 1.162*i*
5.5	1.537	20.31 — 2.80*i*	—1.217 + 1.009*i*
6.0	1.534	23.90 — 3.33*i*	—1.478 — 0.292*i*
6.5	1.531	27.75 — 3.89*i*	—0.440 — 1.703*i*
7.0	1.528	31.88 — 4.48*i*	1.077 — 1.517*i*
7.5	1.525	36.27 — 5.10*i*	1.913 + 0.286*i*
8.0	1.522	40.93 — 5.74*i*	1.050 + 1.917*i*
8.5	1.519	45.86 — 6.42*i*	—1.097 + 1.857*i*
9.0	1.516	51.05 — 7.11*i*	—2.451 + 0.114*i*
9.5	1.513	56.52 — 7.83*i*	—1.461 — 1.955*i*
10.0	1.510	62.24 — 8.57*i*	1.027 — 2.468*i*

Table 22

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.51 - 1.63i$ (iron at $\lambda 0.589\mu$)

x: 0.1(0.1)1.0(0.25)2.00(0.50)10.00

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.1	0.0002615	0.0005581 + 0.0008197i	0.0005540 + 0.0008191i
0.2	0.004274	0.004674 + 0.006555i	0.004545 + 0.006539i
0.3	0.02224	0.01699 + 0.02192i	0.01602 + 0.02181i
0.4	0.07191	0.04426 + 0.05044i	0.04029 + 0.05007i
0.5	0.1761	0.09560 + 0.09225i	0.08393 + 0.09143i
0.6	0.3523	0.1803 + 0.1413i	0.1526 + 0.1400i
0.7	0.5943	0.3020 + 0.1847i	0.2457 + 0.1835i
0.8	0.8621	0.4539 + 0.2093i	0.3516 + 0.2088i
0.9	1.100	0.6207 + 0.2108i	0.4507 + 0.2110i
1.0	1.272	0.7899 + 0.1965i	0.5245 + 0.1958i
1.25	1.438	1.222 + 0.167i	0.5399 + 0.1417i
1.50	1.489	1.764 + 0.175i	0.2850 + 0.1525i
1.75	1.568	2.431 + 0.120i	−0.1432 + 0.3144i
2.00	1.610	3.125 + 0.022i	−0.5118 + 0.5446i
2.5	1.624	4.761 − 0.126i	−0.6453 + 0.4041i
3.0	1.635	6.676 − 0.376i	−0.4025 − 0.7383i
3.5	1.634	8.913 − 0.637i	−0.005 − 1.182i
4.0	1.629	11.40 − 0.95i	0.9225 − 0.2652i
4.5	1.625	14.20 − 1.30i	1.312 + 0.779i
5.0	1.618	17.26 − 1.67i	0.057 + 1.220i
5.5	1.613	20.61 − 2.09i	−1.518 + 0.893i
6.0	1.606	24.23 − 2.53i	−1.545 − 0.472i
6.5	1.600	28.12 − 3.01i	−0.162 − 1.907i
7.0	1.595	32.29 − 3.50i	1.363 − 1.526i
7.5	1.589	36.72 − 4.03i	1.965 + 0.619i
8.0	1.584	41.44 − 4.59i	0.880 + 2.259i
8.5	1.579	46.41 − 5.17i	−1.419 + 1.794i
9.0	1.575	51.66 − 5.77i	−2.696 − 0.269i
9.5	1.570	57.17 − 6.40i	−1.302 − 2.273i
10.0	1.566	62.95 − 7.05i	1.516 − 2.489i

Table 23

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES

$m = 1.70 - 1.84i$ (iron at λ0.668μ)

x: 0.1(0.1)1.0(0.25)2.00(0.50)10.00

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.1	0.0002691	0.0004617 + 0.0008936i	0.0004569 + 0.0008931i
0.2	0.004418	0.003909 + 0.007190i	0.003757 + 0.007174i
0.3	0.02319	0.01449 + 0.02431i	0.01336 + 0.02422i
0.4	0.07608	0.03884 + 0.05692i	0.03422 + 0.05669i
0.5	0.1901	0.0870 + 0.1067i	0.0735 + 0.1064i
0.6	0.3897	0.1709 + 0.1681i	0.1395 + 0.1687i
0.7	0.6729	0.2979 + 0.2264i	0.2353 + 0.2296i
0.8	0.9918	0.4617 + 0.2626i	0.3512 + 0.2708i
0.9	1.271	0.6427 + 0.2680i	0.4642 + 0.2820i
1.0	1.460	0.8217 + 0.2509i	0.5506 + 0.2680i
1.25	1.592	1.250 + 0.217i	0.5787 + 0.1944i
1.50	1.604	1.783 + 0.248i	0.3015 + 0.1622i
1.75	1.677	2.463 + 0.215i	−0.1894 + 0.2892i
2.00	1.710	3.157 + 0.123i	−0.6155 + 0.5174i
2.5	1.701	4.784 + 0.028i	−0.7198 + 0.4019i
3.0	1.705	6.700 − 0.184i	−0.3218 − 0.8115i
3.5	1.697	8.941 − 0.384i	0.092 − 1.283i
4.0	1.687	11.43 − 0.64i	0.9537 − 0.1839i
4.5	1.679	14.24 − 0.93i	1.334 + 0.973i
5.0	1.669	17.30 − 1.24i	−0.012 + 1.258i
5.5	1.662	20.65 − 1.60i	−1.711 + 0.778i
6.0	1.653	24.28 − 1.97i	−1.607 − 0.590i
6.5	1.646	28.19 − 2.39i	0.042 − 2.004i
7.0	1.639	32.37 − 2.81i	1.575 − 1.534i
7.5	1.632	36.82 − 3.27i	1.965 + 0.823i
8.0	1.626	41.55 − 3.76i	0.736 + 2.501i
8.5	1.621	46.54 − 4.26i	−1.604 + 1.749i
9.0	1.615	51.81 − 4.79i	−2.834 − 0.560i
9.5	1.610	57.34 − 5.34i	−1.210 − 2.478i
10.0	1.605	63.14 − 5.92i	1.843 − 2.454i

Table 24

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES
$m = 1.78 - 0.0024i$ (H_2O ice, at λ0.2 to λ5.0 cm)
x: 0.5(0.5)4.0(2.0)16.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.03112	0.002091 + 0.05745i	0.002058 + 0.05046i
1.0	0.5037	0.1277 + 0.5335i	0.1160 + 0.2911i
1.5	2.177	1.237 + 1.813i	0.0905 — 0.1596i
2.0	3.272	3.296 + 2.241i	—0.5678 + 0.5858i
2.5	4.641	7.311 + 1.089i	0.590 — 1.187i
3.0	4.834	11.01 + 0.42i	—2.926 — 0.235i
3.5	3.216	10.01 — 2.43i	2.960 + 1.524i
4.0	2.653	10.84 — 5.71i	—1.988 — 3.809i
6.0	2.810	26.23 + 5.64i	8.849 + 5.454i
8.0	2.642	45.30 — 10.04i	—13.14 + 1.51i
10.0	2.283	59.92 + 1.43i	0.67 — 15.83i
12.0	2.367	90.43 — 20.60i	15.71 + 18.53i
14.0	2.237	117.9 + 6.1i	—26.58 — 5.27i
16.0	2.241	155.8 — 26.1i	19.90 — 22.73i

Table 25

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES
$m = 2.5604 - 0.8947i$ (liquid water, 0°C, at λ0.2 cm)
x: 0.5(0.5)4.0(2.0)16.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.5	0.1034	0.03855 + 0.09936i	0.02598 + 0.08624i
1.0	1.367	0.7752 + 0.4793i	0.2907 + 0.3993i
1.5	1.518	1.772 + 0.301i	0.2862 + 0.2058i
2.0	1.454	3.031 + 0.133i	—0.6567 + 0.1967i
2.5	1.411	4.495 + 0.058i	—0.6597 + 0.1209i
3.0	1.428	6.312 — 0.126i	—0.0594 — 0.6844i
3.5	1.428	8.404 — 0.333i	0.4650 — 0.9326i
4.0	1.426	10.75 — 0.59i	0.7934 + 0.0465i
6.0	1.413	22.92 — 1.85i	—1.115 — 0.956i
8.0	1.402	39.40 — 3.51i	—0.181 + 2.075i
10.0	1.394	60.15 — 5.49i	1.985 — 1.386i
12.0	1.386	85.12 — 7.76i	—2.838 — 0.544i
14.0	1.380	114.3 — 10.3i	1.733 + 3.020i
16.0	1.375	147.6 — 13.1i	1.355 — 3.688i

Table 26

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES
$m = 3.1918 - 1.7657i$ (liquid water, 0°C, at λ0.5 cm)
x: 0.25(0.25)1.00(1.00)7.00

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.25	0.008652	0.00325 + 0.01419i	0.00245 + 0.01370i
0.50	0.1614	0.0513 + 0.1212i	0.0225 + 0.1120i
0.75	0.8701	0.3245 + 0.3371i	0.1451 + 0.3608i
1.0	1.671	0.8345 + 0.3498i	0.4517 + 0.5010i
2.0	1.657	2.971 + 0.255i	−0.7527 + 0.2583i
3.0	1.635	6.276 + 0.063i	−0.0568 − 0.8136i
4.0	1.614	10.72 − 0.24i	0.9655 + 0.0309i
5.0	1.598	16.27 − 0.63i	−0.362 + 1.326i
6.0	1.584	22.92 − 1.12i	−1.472 − 1.194i
7.0	1.573	30.66 − 1.69i	2.174 − 0.915i

Table 27

SCATTERING CROSS SECTIONS AND COMPLEX AMPLITUDES
$m = 5.8368 - 3.0046i$ (liquid water, 0°C, at λ2.0 cm)
x: 0.1(0.1)1.0(0.5)2.0

x	K_{sc}	$S_1(0°)$	$S_1(180°)$
0.1	0.0002487	0.0000673 + 0.0009726i	0.0000428 + 0.0009554i
0.2	0.004131	0.000942 + 0.008081i	0.000055 + 0.007601i
0.3	0.02251	0.00612 + 0.02826i	−0.00167 + 0.02613i
0.4	0.07959	0.02439 + 0.06512i	−0.00815 + 0.06826i
0.5	0.2153	0.0611 + 0.1156i	−0.0082 + 0.1521i
0.6	0.4625	0.1221 + 0.1837i	0.0243 + 0.2734i
0.7	0.8109	0.2246 + 0.2613i	0.0995 + 0.4067i
0.8	1.203	0.3717 + 0.3259i	0.2091 + 0.5261i
0.9	1.556	0.5497 + 0.3586i	0.3342 + 0.6109i
1.0	1.793	0.7334 + 0.3545i	0.4474 + 0.6499i
1.5	1.792	1.531 + 0.336i	0.2854 + 0.4150i
2.0	1.865	2.750 + 0.378i	−0.8973 + 0.1505i