The significance of the cross-section theorem is best understood from the viewpoint of a multiple scattering problem. A distribution of scatterers can be replaced by a medium with a modified index of refraction and an attenuation. For a random distribution of scatterers the equation of the coherent wave $\langle\psi\rangle$ in the medium is:[3]

$$(E-H-\bar{T})\langle\psi\rangle=0, \quad \bar{T}_{ba}=nT_{aa}\delta_{ba},\qquad(7)$$

where $\bar{T}$ has only diagonal matrix elements and n is the density of scatterers. Thus the phase velocity is determined primarily by the real part of T_{aa} and the attenuation by the imaginary part.

It is also possible to interpret (9) in the language of a decay problem. Since T_{aa} represents the energy shift of state a, $|\Psi_a|^2$ has the time dependence $\exp[-2ImT_{aa}/\hbar]$. Thus (9) states that the rate of decay of state a is equal to the total transition probability from state a to all other states *including* a.

In a true decay problem, the right-hand side of (4) would include transitions only to states $b\neq a$. To prove the theorem appropriate to decay problems, we note that there is no incident wave. Thus the Schrödinger equation takes the integral form

$$\Psi_a=(E-H)^{-1}V\Psi_a.\qquad(8)$$

Introducing the projection operator P_a associated with state Φ_a and $Q_a=1-P_a$, the corresponding annihilation operator we can separate the term associated with state Φ_a by multiplying (8) by (P_a+Q_a). Since

$$(E-H)^{-1}P_aV\Psi_a=(E-H)^{-1}P_aT\Phi_a=(E_a-E_a{}^0)T_{aa}\Phi_a$$

and T_{aa} represents the energy shift we obtain:

$$\Psi_a=\Phi_a+(E-H)^{-1}Q_aV\Psi_a.\qquad(9)$$

This differs from the collision case (A2) by the factor Q_a which suppresses state a. Equation (2) becomes:

$$ImT_{aa}=Im(\Psi_a,\ V\Psi_a)-\pi(\Phi_aT\dagger Q_a\delta(E-H)T\Phi_a)\qquad(10)$$

and the sum in (4) is over $b\neq a$.

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Comparison of the Isotopic Constitution of Terrestrial and Meteoritic Sulfur

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THE isotopic content of elements in meteorites and a comparison of the meteoritic and terrestrial values are of considerable interest. Recently results have been reported for gallium,[1] copper,[2] iron,[3] and sulfur.[4] Although in most cases only 1 or 2 samples of each were investigated, the results show no variation in isotopic ratios. In the case of carbon where variations in the isotopic ratios up to 5 percent occur in terrestrial sources, Murphey and Nier[5] have reported variations up to 2.5 percent between samples of meteoritic carbon. Recent results of Trafimov[4] indicated little or no variation in the isotopic content of terrestrial and meteoritic sulfur with the exception of sea water sulfate, which was found to be slightly enriched in S^{34}.

However, in view of the marked variation in the S^{32}/S^{34} ratio found by Thode, Macnamara, and Collins[6] for different terrestrial compounds of sulfur, it seemed important to study the isotopic composition of meteoritic sulfur and to establish the relation between the isotopic composition of terrestrial and meteoritic sulfur. Ten samples of troilite from four siderite and two stony meteorites have been analyzed with a 180-degree direction focusing mass spectrometer of the Nier type.[7] The S^{32}/S^{34} ratios obtained for these samples a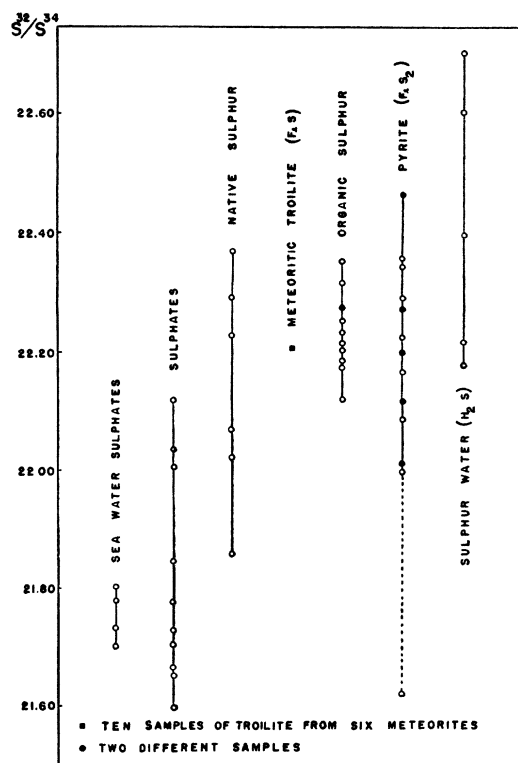re given in Table I. All the samples were compared with the same standard used in our previous work, and the relative ratios are probably good to 0.1 percent or better. It is seen that the S^{32}/S^{34} ratios for meteoritic samples are constant within the probable limits of error and that the value coincides approximately with the average value found for terrestrial sulfur[6] (see Fig. 1).

FIG. 1. Isotopic distribution of S^{34} in terrestrial and meteoritic sulfur.

TABLE I. Isotopic distribution of S^{34} in meteoritic sulfur.

Type of meteorite	Name and location	S^{32}/S^{34} ratio
Siderite	Canyon Diablo, Arizona	22.21 ±0.01
Siderite	Canyon Diablo, Arizona	22.22 ±0.01
Siderite	Canyon Diablo, Arizona	22.21 ±0.01
Siderite	Canyon Diablo, Arizona	22.21 ±0.01
Siderite	Waterville	22.20 ±0.01
Siderite	Duchesne, Duchesne Co., Utah	22.23 ±0.01
Siderite	Duchesne, Duchesne Co., Utah	22.24 ±0.01
Siderite	El Toba, Argentine	22.22 ±0.01
Aerolite	"Beenham," Union Co., New Mexico	22.20 ±0.01
Siderolite	Brenham, Kiowa Co., Kansas	22.23 ±0.01

Since the abundance of the sulfur isotopes vary markedly in samples of terrestrial sulfur, it is important that the source of sulfur be stated where absolute abundances are involved. In this regard, it would be well to quote absolute abundances on the basis of meteoritic sulfur in view of the remarkably constant values found in these samples. The absolute abundances of the sulfur isotopes found in this laboratory for a representative sample of meteoritic sulfur are given in Table II. The chemical atomic

TABLE II. Absolute isotopic abundances of meteoritic sulfur.

Mass	Percentage
32	95.018
33	0.750
34	4.215
36	0.017

weight of meteoritic sulfur was calculated from these results to be 32.064.

It is most interesting that the isotopic content of sulfur samples from a single meteorite and from different meteorites should be constant to better than 0.1 percent. This is in striking contrast to the fairly large variations (2.5 percent) found by Murphey and Nier[5] for the isotopes of carbon in meteorite samples. Relatively large variations in isotopic ratios occur for both the carbon and sulfur isotopes in terrestrial sources.

It is clear from theoretical and experimental evidence that these variations in terrestrial samples are due to fractionation that occurs in biological and geological processes because of differences in the chemical properties of isotopic molecules. A comparison of the isotopic ratios obtained for meteoritic and terrestrial sulfur illustrated in Fig. 1 suggests that at the time the earth was formed the isotopic content of sulfur was the same as that now found for meteoritic sulfur, but that fractionation has occurred since, thereby spreading out the ratios above and below the base value. The remarkably constant isotopic ratios found for meteorites, however, indicate that meteoritic sulfur has not been subjected to the same fractionation processes.

There is a great deal of evidence to show that meteorites originated from within the solar system. Work on the isotopic content of various elements in meteorites, including our results for sulfur, bears this out. If we accept the view that meteorites resulted from the disintegration of a planet by some celestial catastrophe then we might expect sulfur from stony meteorites, which probably originated from the crust of the ancestral planet to show variations in isotopic content as do sulfur samples from the earth's crust. The stony meteorites examined to date, however, show no variation in the isotopic content of sulfur, which was found to be the same in all meteorites.

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Thermoelectromotive Force of Superconducting versus Normal Junctions of the Same Metal

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MEASUREMENTS of temperature variation of the thermoelectromotive force of superconducting versus normal junctions of the same metal have been made for tin and lead. The experimental technique differs from that of Keesom and Matthijs[1] in that they employed magnetic shielding and several circuits of the metal in series, whereas the present work required no magnetic shielding and only one circuit. A wire of the metal to be studied was connected to a d.c. voltage amplifier (breaker type) by copper leads. The temperature of the two points of contact with the leads was adjusted to have one portion of the specimen superconducting and the remainder normal. By applying appropriate magnetic field strengths over the entire length of the wire the temperature of the superconducting-normal junction can then be varied. If the two points of contact are maintained at constant temperature throughout the course of the experiment, the voltage differences observed can be attributed to the temperature variation of the thermoelectromotive force of the superconducting-normal junction. If the contact temperatures do change during the experiment, the observed voltages have to be corrected from data obtained by calibrating the circuit with varying contact temperatures (usually only one contact need be made variable) in the absence of magnetic fields. Taking the voltage of the superconducting-normal junction as zero at T_c (where T_c is the superconducting transition temperature for zero magnetic field) the observed voltage differences can be summed to give the desired absolute voltage for temperatures below T_c. Using this procedure data were obtained from 2.30°K to 3.72°K for tin and from 4.22°K to 7.26°K for lead.

Figure 1 shows a log-log plot of E/E_0 versus $1-(T/T_c)^2$ for the data obtained with tin and lead. E is the thermoelectromotive force of the superconducting-normal junction; E_0 is the value of E at 0°K (obtained by extrapolation); T is the temperature ($T \leq T_c$). It is seen that the data for both these elements can be represented by the reduced equation

$$E/E_0 = 1 - (T/T_c)^2, \tag{1}$$

where $T_c = 3.72°K$, $E_0 = 5.5 \times 10^{-8}$ volts for tin, and $T_c = 7.26°K$, $E_0 = 59 \times 10^{-8}$ volts for lead. The parabolic relation given by Eq. (1) can be derived from the Fermi gas model[2] if it is assumed that the Thomson coefficient, σ, of a superconductor is zero. This assumption is supported in the case of lead, by the experiments of Daunt and Mendelssohn.[3]
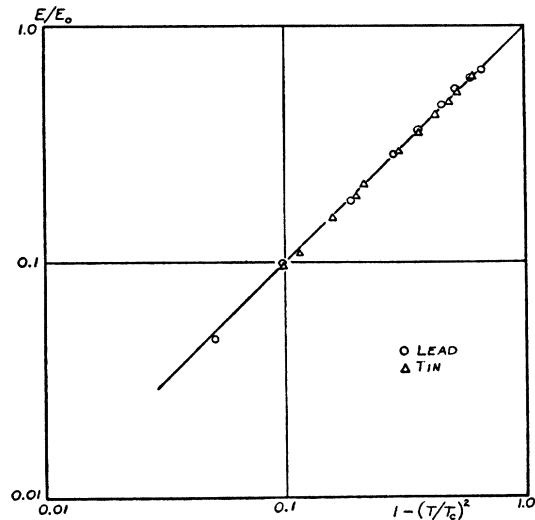

FIG. 1. Logarithmic plot of E/E_0 as a function of $1-(T/T_c)^2$.

These results can be used to calculate the value of γ, where γT is the electron contribution to the specific heat, by combining Eq. (1) with the free electron theory expression for the Thomson coefficient. The relation found is

$$\gamma = 3eE_0/T_c^2, \tag{2}$$

where e is the electronic charge and γ is expressed per atom of material. Using the values of E_0 and T_c given above, and converting to a mole basis, it is found that γ is 2.7×10^{-4} and 7.7×10^{-4} cal. per mole per (deg. K)^2 for tin and lead respectively.

Preliminary experiments with lead having small amounts of impurity (total impurity $\sim$1.5 percent) have shown that not only does E decrease by as much as a factor of 5, but also Eq. (1) no longer represents the data adequately.

A detailed account of the work reported above, as well as the results of experiments in progress at this date, will be given in the near future. The author wishes to thank Dr. R. T. Webber for having suggested the subject of this investigation.

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