mitochondria are the enzymatic sites of intense glycolytic activity and also the view (*3, 7*) that hormonal regulation of glucose phosphorylation in living cells takes place at the mitochondrial level of organization.

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Analysis of Standard Granite and Standard Diabase for Trace Elements

The standard granite (sample G-1) and the standard diabase (sample W-1) have been used as interlaboratory calibration standards for analysis for major constituents of silicate rocks (*1*). In the course of this study, three sets of spectrochemical analyses of the trace elements were performed by R. L. Mitchell, K. J. Murata, and L. G. Gorfinkle and L. H. Ahrens. Partial trace-element analyses have been subsequently reported by other authors (*2*). The techniques used were neutron activation, stable-isotope dilution, and spectrochemical analysis.

Most of the trace-element data reported for standard granite and standard diabase have been obtained by direct-current-arc spectrochemical procedures. Although these techniques can give results reproducible to better than ±5 percent, the accuracy is frequently off by as much as a factor of 2, because of large matrix effects, selective volatility of the elements, and so forth. The analyses reported here were performed by x-ray fluorescence techniques. The elements determined were copper, nickel, rubidium, zinc, strontium, zirconium, and manganese. The results are shown in Table 1, where they are recorded as parts per million (ppm).

X-ray fluorescence methods offer the advantages of excellent reproducibility and an exact method of accounting for matrix effects. The analyses were made with a North American Phillips x-ray fluorescence unit, using a tungsten target x-ray tube, a scintillation detector, and a helium atmosphere. Standards consisted of oxides of the elements in an aluminum oxide matrix. Selenium was used as the internal standard for elements below the absorption edge of iron (Zr, Sr, Rb, Zn, Cu, and Ni). The titanium already present in samples G-1 (1500 ppm) and W-1 (6530 ppm) was used as the internal standard for manganese.

The precision of the determinations of elements with concentrations higher than 25 ppm averaged ±5 percent; the precision for elements with concentrations below 25 ppm averaged ±10 percent. With the proper selection of an internal standard, the absorption corrections for the matrix should be accurate within a few percent. Therefore, the accuracy of the determinations reported here should lie within the combined errors of sample preparation, precision of counting, and the error of the matrix. The accuracy of the determinations for elements with concentrations greater than 25 ppm should be about ±10 percent; for those below 25 ppm, about ±15 percent. However, the accuracy of the Cu determinations is probably not this good because the CuKα radiation is partially interfered with by WLα_1 radiation originating from the x-ray tube, making a background correction difficult.

Since samples G-1 and W-1 are to be used by many laboratories as calibration samples for future analyses, every effort should be made to determine the trace elements in the best possible manner. Most trace-element analyses thus far have been performed by the frequently inaccurate spectrographic technique. This report is an attempt to contribute more accurate information on the trace elements in these important standards.

Table 1. Results of trace-element analysis of the standard granite (sample G-1) and standard diabase (sample W-1).

Element	Concentration (ppm)	
	G-1	W-1
Manganese	212	1400
Nickel	3	68
Copper	18	171
Zinc	26	78
Rubidium	248	25
Strontium	263	197
Zirconium	268	94

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Gravity Shields

In a recent paper D. C. Peaslee pointed out that so-called "antiparticles"—that is, particles that are related to normal particles by the *charge conjugation* operator of quantum theory—have positive mass and, hence, would be useless for employment in gravity shields (*1*). This argument is, of course, unexceptionable; however, it does not exclude the possibility of elementary particles with negative mass (whose antiparticles would possess negative mass as well), although such particles have not yet been discovered. There are some arguments tending to indicate that such particles may not be capable of existence at all (Pauli's derivation of the connection between spin and statistics), but they are not yet to be regarded as conclusive. In this contribution (*2*), I should like to describe briefly the behavior pattern of such particles if they should exist; I shall also demonstrate that such particles would be of very dubious value in "gravity shields."

For a particle of negative mass, according to Newton's second law ($f = ma$), force and acceleration point in opposite directions. Particles having masses of the same sign will attract each other gravitationally—that is, the *forces* will point toward each other—whereas particles of opposite masses will repel each other. Hence, all *accelerations* of particles of whatever mass will point toward particles of positive mass and away from particles of negative masses. If two particles having masses of opposite sign and equal magnitude act on each other purely gravitationally, then the particle of negative mass will chase the particle of positive mass, both their accelerations pointing in the same direction.

Let us now consider a particle of negative mass which also carries an electric charge. Under the influence of an applied electromagnetic field, such a particle will move according to the value of e/m—that is to say, a particle of negative mass and positive charge will move just like a particle of positive mass and negative charge. However, it will give rise to an electromagnetic field of its own, which is determined entirely by its charge and velocity and is independent of the sign of its mass; hence two such hypothetical particles can be distinguished by the effects they have on other particles, even though they cannot be separated by a mass spectrograph (which determines only the ratio of charge and mass).

Suppose that particles with negative mass should be discovered one day, and suppose that we should succeed in incorporating them into macroscopic matter. Then such matter would not be polarized gravitationally under the influence of an external gravitational field, and therefore it would not exhibit the kind of shielding properties that a dielectric does with respect to electrostatic forces. Only if the negative-mass particles possess an electric charge is it conceivable that such matter would be polarized gravitationally by means of an applied electric field. Even then, if the negative mass of these hypothetical particles should be of the same order of magnitude as the positive mass of particles now known (protons, neutrons, and the like), the shielding effect will be negligibly small.

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2. This work was supported by the Air Force Office of Scientific Research.

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Primary Quantum Conversion Process in Photosynthesis: Electron Spin Resonance

Some years ago, on the basis of a study of the kinetics of the Hill reaction in flashing light (*1*), together with a variety of independent observations involving both chemical and kinetic studies of photosynthesis as well as the kinetics of some experiments on luminescence (*2*), a proposal was made concerning the nature of the early processes in the transformation of electromagnetic energy into chemical potential. This proposal involved an ordered array of chlorophyll and collateral molecules, suggested by the structural detail, which has been provided for the photosynthetic organelles of green plants.

The sequence of events was to be an absorption leading to the first excited singlet state of chlorophyll, which then was converted into a triplet excitation, followed by an ionization process that would lead to a trapped electron and a hole, these two entities being the reducing and the oxidizing components which must be simultaneously generated. A part of the process involved the extremely rapid neutralization of the hole by capture of an electron from water, or a product formed from it (*3*). The resultant material would then ultimately appear as molecular oxygen. The electron, on the other hand, would pass through a series of carriers (hydrogen carriers) such as are well known in biochemical processes (thioctic acid, pyridine nucleotide, flavin, and so forth) ultimately leading to the reduction of carbon dioxide.

Table 1. Electron-spin resonance observations on various samples from photosynthetic material. The *g* value of the resonance was 2.00; at room temperature, the width between points of maximum slope was approximately 10 oersteds; at – 140°C, the width between points of maximum slope was approximately 15 oersteds; Light quality: $5800 < \lambda < 8000$ A.

Substance	Light intensity	Temperature (°C)	Signal growth time	Signal decay time
Dried leaves	Low*	25	Minutes	Hours
Dried whole chloroplasts (*8*)	Low*	25	Minutes	Hours
		60	Seconds	Seconds
Wet whole chloroplasts (*9*)	Low*	25	Seconds	Minutes
		– 140	Seconds	Hours
Wet small chloroplast fragments (*9*)	Low*	25	Seconds	Hours
Wet large chloroplast fragments (*9*)	Low*	25	~ 30 sec	~ 30 sec
Wet large chloroplast fragments	High†	25	~ 6 sec	~ 30 sec
Wet large chloroplast fragments	High†	– 140	~ 10 sec	Hours

* Low light intensity: approximately 10^{15} quanta/sec into cavity; the number of free electrons at equilibrium was approximately 10^{16}.

† High light intensity: approximately 10^{16} quanta/sec into cavity; the number of free electrons at equilibrium was approximately 10^{16}.

Although the observation of transient changes in the absorption spectrum of these particles during such a process has been pointed out (*4*), it has been difficult to identify the species responsible from such absorption changes in this complex of pigments. In such a sequence, one might expect another physical property, more characteristic of at least two of these species, to be observable—namely, the magnetism of the triplet state of chlorophyll and the magnetism which would be associated with the trapped, unpaired electrons.

Although the direct observation of the total changes in magnetic susceptibility under illumination would be extremely difficult, it seemed likely to us that the sensitivity of the method of electron-spin resonance might provide the means of making such a direct observation, and work was undertaken toward this end at that time (*5*). Early observations on various kinds of leaves and other plant materials gave indications that such an electron spin signal would appear under illumination, and in the middle of last year a report of the existence of such a light-induced signal in chloroplasts appeared (*6*). From the data presented then, as well as our own at that time, it was not possible to decide on the nature of the material responsible for the signal. This material not only could have been the chlorophyll triplet, as proposed, or the trapped electron, but it may also have been radicals of the semiquinone type among the hydrogen carriers on the path between the trapped electron and carbon dioxide.

One possible way of eliminating secondary chemical reactions as a potential source of the signal is to reduce the temperature at which the illumination is carried out and determine the effect of this on the rate at which the signal appears. A further variable that seemed important to us in the determination of the growth time of the signal was the rate at which quanta of light are actually impinging upon the sample. This we have also varied. And, finally, the nature of the green sample that is being examined may be expected to determine the growth and decay times of all the various magnetic species we have mentioned. The electron-spin resonance spectra of various samples under a variety of conditions were observed at a frequency of 9.3 kMcy/sec (7), and the results are given in Table 1.

It is thus clear that the shortest growth times that we have so far observed are definitely limited by the rate at which quanta arrive at the sample. Second, it is clear that cooling to – 140°C— at this temperature we may expect that none of the ordinary enzymatic reactions will proceed at measurable rates—does not significantly lengthen the time required for the full signal to appear, while it does very materially lengthen the time required for the signal to disappear after the light is turned off. These facts are consistent with the idea that the signal