seven sectors combined. It is difficult to assess the statistical significance of such limited data.

The extent to which the structure in the "away" sectors resembles that in the "toward" sectors provides some estimate of this. It appears that in both the "away" and "toward" sectors the average field magnitude is greater than 6 gammas (1 gamma = 10^{-5} gauss) near the beginning of the sector, and decreases to less than 4 gammas as the sector sweeps past the earth.

We have investigated the effect on geomagnetic activity of the interplanetary sector structure sweeping past the earth, using the 24-hour sum values of the geomagnetic index Kp (6). In Fig. 3B, the gross structure of Kp in both the "away" and "toward" sectors appears to be similar, with a change of about a factor of three from maximum to minimum; Kp reaches a peak greater than 25 about 2 days after the sector boundary sweeps past the earth, and then decreases to less than 10 in the trailing portion of the average sector. The interplanetary field magnitude and geomagnetic activity tend to be large (or small) at the same positions within the sector.

The effect of the interplanetary sector structure on cosmic rays was investigated by means of the Deep River neutron monitor in a similar manner, as shown in Fig. 3C. The "away" sectors show a minimum at about the 3rd day while the "toward" sectors show a rather uniform increase with time. The counting rates obtained with the Deep River neutron monitor thus tend to be large at the positions within the sector where Kp and the interplanetary magnetic field are small and vice versa.

The orbital period of Imp-1 is 93.5 hours, while the 1/7 sectors sweep past the earth with an average interval of about 91.5 ± 2 hours. The sector boundaries usually sweep past while Imp-1 is near perigee and therefore the boundaries cannot be observed. We have carefully checked the possibility inherent in this situation that an artifact was introduced, but have obtained negative results.

The existence of a longitudinal structure in the interplanetary magnetic field has important implications in determining the structure of the sun. NORMAN F. NESS

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- 12 April 1965

Explosion of Burning Zirconium Droplets Caused by Nitrogen

Abstract. Single droplets of zirconium were photographed as they burned luminously in free fall. When the oxidizer was oxygen containing small amounts of nitrogen (less than 5 percent), the burning droplets exploded only when a threshold concentration of nitrogen was exceeded. Explosions also occurred when the zirconium was partially nitrided before being burned in pure oxygen. These experiments prove that the presence of nitrogen can cause the explosion of zirconium droplets burning in oxygen-rich atmospheres.

When metal droplets burn in gaseous oxidizers, they often glow brightly for a time, then explode violently (1, 2). Familiar examples of such explosions are the sparks formed when certain metals are ground (3) and in the pyrotechnic "sparkler." These explosions have been variously attributed to boiling of the metal (4), possibly aided by an alteration of the metal oxide by water vapor (5), to boiling of the metal oxide (6), to dissolved gas (7), and to the evolution of CO from the combustion of carbon alloyed with the metal (8).

I now report that the presence of small amounts of nitrogen can cause the explosion of zirconium droplets burning in oxygen-rich atmospheres.

Experiments were performed as fol-

lows. Single droplets were formed from small squares, 56 μ thick, of zirconium foil dropped through a flash-heating apparatus similar, except for slight improvements, to that described previously (2). The squares were melted and ignited in oxygen or in the mixedgas oxidizers by means of a helical flash lamp which was fired as the foil passed through. As they fell downward through the Pyrex combustion chamber, the droplets were photographed by their own luminosity (Polapan type 52 film at aperture f/45 from a distance of 1 meter). The camera's shutter was opened for 1 second by a solenoid about 25 msec after the scattered light from the heating flash had extinguished.

Droplets with diameters of 525 μ burned brilliantly but did not explode in oxygen flowing at 5.0 lit./min at an overall pressure of 625 torr; each droplet extinguished gradually to form a dense white sphere with a diameter of approximately 600 μ .

As small amounts of nitrogen were added to the streaming oxygen, neither the photographic images of the burning droplets nor the appearance of the products changed until the concentration of nitrogen reached 2.9 percent (measured with calibrated flowmeters). When the nitrogen concentration was increased gradually from 2.9 to 4.0 percent, a progressively greater fraction of the droplets showed fragmentations. At concentrations of 4.5 percent nitrogen, all droplets exploded. Photographs of droplets burning in pure oxygen and in 4.5 percent nitrogen and 95.5 percent oxygen are shown in Fig. 1.

In the threshold region between 2.9 and 4.0 percent nitrogen the droplets formed several types of products, each apparently caused by the release of a gas inside a partially molten sphere. Some droplets formed white spheres similar in diameter and appearance to those formed when the nitrogen concentration was below 2.9 percent, except that there were a few bulges on the outside.

Other droplets formed thin-walled semiopaque white sacs with thicker portions attached. A few formed complete thin-walled white sacs as large as 1.3 mm across. With nitrogen concentrations of 4.5 percent, each droplet formed approximately 10 to 30 thin-walled white sacs with dimensions between about 50 and 700 μ . The thinwalled white sacs appear to be identical to those obtained by Meyer (9) when granules of zirconium dioxide were dropped through a nitrogencontaining plasma torch.

The nitrogen need not be in gaseous form in the system to cause the explosion. A result similar to that shown



Fig. 1. The combustion of a freely falling zirconium droplet in oxygen (left) and in a mixture of 4.5 percent nitrogen and 95.5 percent oxygen (right). In each case, the droplets are burning in a 75-mm Pyrex tube containing the oxidizing gas at 625 torr flowing downward at 5.0 lit./min. Droplet diameter is 525 μ . The weak traces are reflections from the walls of the chamber.

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at the right of Fig. 1 also was obtained when the original squares of zirconium had been partially nitrided (by heating for 1 hour at 900°C in flowing nitrogen at 625 torr) before they were burned in pure oxygen.

It was reported earlier that zirconium reacts simultaneously with nitrogen and oxygen both during the low temperature oxidation of solid zirconium in air (10) and during the higher temperature combustion of molten zirconium droplets in air (11). The latter results were obtained by interrupting the combustion of the droplets at various stages by allowing them to fall into liquid argon. X-ray diffraction patterns from droplets quenched toward the end of the combustion in air (before explosion) contained strong lines arising from zirconium, zirconium nitride, zirconium dioxide and the recently characterized zirconium oxynitride, Zr_2ON_2 (12).

In the experiments reported here, where considerably lower concentrations of nitrogen were available to the droplets, x-ray diffraction patterns obtained in a similar manner contained strong lines arising from zirconium and zirconium dioxide, and faint lines, near the limit of detection, corresponding to the most intense lines of zirconium oxynitride.

A plausible explanation of the results cited here is that when gaseous nitrogen is present in the early stages of combustion, the molten zirconium will take up both oxygen and nitrogen to form a liquid phase that contains zirconium, oxygen, and nitrogen (similar to getter action). The same composition may also result if the zirconium is partially nitrided before being burned in pure oxygen. As the droplet burns further, its composition must eventually approach that of the thermodynamically favored zirconium dioxide so that nitrogen is subsequently liberated. When there is sufficient nitrogen present to exceed the solubility in the molten mixture, a high internal pressure of gas will form and the fragmentation will occur. Lesser concentrations of nitrogen will produce only a few inflated sacs or bulges.

This explanation is somewhat akin to that attributed to Gordon (7), in which the internal release of dissolved gases was considered to cause the explosions. The mechanism suggested here, however, includes but does not require the physical solution of gases in the metal before ignition. If there is insufficient gas in the metal before combustion, explosions may still occur, but now as a result of gas taken up during the initial stages of the burning reaction.

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- the experiments, and E. J. Graeber for per-forming the x-ray diffraction studies. Sup-ported by the AEC.

12 April 1965

Activation Energy of Direct-**Current Electrical Conductivity of** Ice with HF and NH₃ Added

Abstract. The activation energies of ice with varying amounts of impurities added were investigated with sintered platinum electrodes. For both types of impurities the activation energy was minimum at a concentration of 10⁻⁴M. The experimental arrangement and possible reasons for the existence of a minimum in activation energy are discussed.

The activation energy of the d-c electrical conductivity in pure ice has been investigated by many authors (1, 2). There seems to be some disagreement about the values of the activation energy owing to difficulties in the interpretation of the data and possible sources of error, as well as establishment of a good ohmic contact with the sample substance. The error that is hardest to identify stems