Role of manganese in photosynthesis

If it were not for chloroplasts, human beings would not be able to breathe or at least they would be breathing something other than oxygen. As chloroplasts convert solar energy and use it to synthesize food for green plants, they generate a lot of oxygen. The present oxygen-rich condition of the earth's atmosphere is credited to their activity.

The oxygen comes from the photosynthetic splitting of water. The chloroplast uses solar energy to pull water molecules apart. The end products are molecular oxygen and various reduced substances in which the hydrogen from the water has become bound. This reaction is not only a fundamental one for producing free oxygen and for liberating hydrogen from water, it gains more interest because the chloroplast does it in a way that is so efficient in energy as to be almost unbelievable.

It has been suspected for some time that manganese ions, which are present in the chloroplasts, play a catalytic role in this water splitting. At the meeting of the American Physical Society in Phoenix last week David Goodman of the University of California at Berkeley reported what was called "a first view of the manganese sites in the photosynthetic apparatus." This first look was made possible by the new synchrotron radiation laboratories (in this particular case the Stanford Synchrotron Radiation Laboratory at Stanford University).

Synchrotron radiation is given off by electrically charged particles (electrons or positrons are ones used in practice) as they pass through a magnetic field. It is an unavoidable by-product of any apparatus in which these particles move in circular paths, such as an electron-positron storage ring. Modern storage rings like Stanford's SPEAR yield X-rays in such copious intensity that they can be used for materials-science investigations that were not possible before. In this case synchrotron radiation enabled Melvin Klein of UCB, Goodman and co-workers to locate manganese ions in chloroplasts.

The main thing that this sort of study of these enzymatic and quasi-enzymatic processes is trying to find out is the stereochemistry, the locations of the various ions and the numbers and orientations of the bonds that connect them to their neighbors. As the chemical reaction of interest proceeds, these locations and linkages will generally experience some alteration. The nature and sequence of these changes is the key to a physical chemical understanding of what happens.

There are a number of techniques for gaining information about stereochemistry. The one used here is called EXAFS (Extended X-ray Absorption Fine Structure). In it, the sample is irradiated with X-rays to determine what wavelengths it absorbs and how much of each. A very complex analysis of these data can locate a lot of ions and bonds. Manganese will show up in an EXAFS investigation. It has been called a "spectroscopically silent" element, because it does not manifest itself to other spectroscopic probes. There is too little signal going in or coming out or both.

The chloroplasts investigated were taken from spinach. Their membranes were ruptured and the inactive chlorophyll washed out. Then, with the active chlorophyll still in them, they were prepared for irradiation by a technique that basically imposes a symmetry of order on what may be a disorderly array of membranes. This technique has caused some comment, but investigators who use it maintain that it does not falsify the processes of interest.

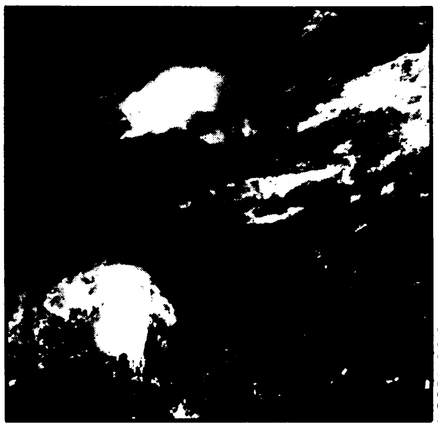
Results so far indicate that the action takes place at sites where two oxygens and possibly two manganese are bound together in a diamond-shaped structure with each manganese bonded to two oxygens and each oxygen to two manganese (a μ-dioxo bridge). It is not yet clear that manganese is the catalyst of interest. There are indications that another metal may be located at the manganese sites. That metal could be iron. "There's a lot of iron in chloroplasts," Goodman says, "and iron looks a lot like manganese in this spectroscopy." Investigation continues. □

A different look at thunderstorms

When you're drenched in a sudden thunderstorm this summer, it may be of interest — though probably of no comfort — to know that meteorologists are beginning to see such storms as part of a larger, and possibly more predictable, beast. In fact, these previously unidentified systems, which have been dubbed Mesoscale Convective Complexes (MCC's), may represent "a type of weather system not recognized in the meteorological literature before."

"They function differently than other systems," says J. Michael Fritsch, who has studied the systems with Robert A. Maddox of the National Oceanic and Atmospheric Administration in Boulder, Colo. "In terms of the structure of their winds, the source of energy, the way atmospheric circulation is affected and the internal cloud structure, they are put together and behave differently than any other system. And more surprising, they are all over the damn place."

An MCC, explains Maddox in a recent paper (BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY 61:11), is identified from infrared satellite photos as a circular, continuous shield of cold (less than −32°C) cloud top that may cover more than 100,000 square kilometers. It occurs primarily in the middle of the continent during summer months, says Fritsch. Maddox and Fritsch speculate that the huge systems originate, usually in the Rocky Mountains or the plains, as a few thunderstorms that "somehow interact and amalgamate" until they have become a highly organized system that in turn helps to strengthen the dozen or so component storms. This is quite different, says Fritsch, from the traditional view of thunderstorms as unrelated, random storms scattered across an area. Although isolated storms do occur, "we found that more often than not, in the mid-continent, they are not random," says Fritsch. "The thunderstorms act together to produce an original circulation larger than any individual storm." MCC's are not linear as are



NOSS/NCC/SDSD

Satellite photo shows large organized mass of thunderstorms over Illinois (top center). Researchers suggest that these storms may represent a previously unidentified type of weather system.

squall lines and they are much larger than other circular storm systems such as hurricanes, he explains. While they stress that the physics of the systems are not well understood, Fritsch and Maddox believe that MCC's may be a major means of releasing the heat that drives the earth's "weather machine." Individual storms have been thought to be a chief means by which heat is carried from the earth's surface into the atmosphere, but because they are so well organized, MCC's release more heat than would their component thunderstorms separately.

All of these characteristics imply that MCC's — and therefore thunderstorms — should be fairly predictable, says Fritsch. Thunderstorms are too small in scale to be handled by predictive computer models, he explains, but when they are viewed as part of a nonrandom, larger-scale phenomenon, it becomes a question "not of if it will rain, but how much." In the Midwest, he estimates, between 60 and 100 MCC's occur each year, "probably accounting for most of the warm season rainfall." If the prediction models can be "geared up to handle MCC's, it may help predict a large