SSRP NEWS

SSR"P" GOES TO "L"

Because of the growth of SSRP and the expansion program that is to begin in November, Stanford University is establishing the project as an independent research laboratory reporting to the Vice Provost for Research. Hence the Stanford Synchrotron Radiation Project (SSRP) will become the Stanford Synchrotron Radiation Laboratory (SSRL), effective 1 September 1977.

Mr. Ronald Gould has been appointed Associate Director of SSRL, effective 1 July 1977; he will be responsible for all SSRL administration at the facility site. Ron comes from the W. W. Hansen Laboratories of Physics where SSRP has been administered since its inception in 1972-3.

SYNCHROTRON RADIATION PROBES NITROGEN FIXATION

PREFACE

The technique known as Extended X-ray Absorption Fine Structure (EXAFS), which has been used in the study described below, was developed at SSRP starting in 1974. It has almost a unique capability of giving information about the local environment around specific elements in complex materials. Thus it is a natural tool for studies of catalysts, whose effectiveness depends on the configuration of particular elements and in small changes in position of these critical elements. Enzymes are biological catalysts that control many biological processes. The nitrogenase enzyme, the particular subject of the study, catalyzes the fixation of nitrogen into forms that can be used by plants as food (fertilizer). At present there is a poor understanding of the mechanism by which nitrogenase performs this function. Improved understanding of this process, such as provided by studies made by chemist Steve Cramer in his thesis work at Stanford, could lead to the development of better ways of making fertilizer. This could have a profound effect on agricultural productivity particularly since present techniques of producing fertilizer consume large quantities of energy and the cost of such commercial fertilizer has approximately tripled in price in the past 3 - 4 years.

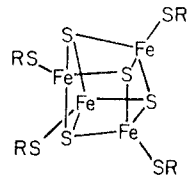
--H. Winick

Nitrogen is an element that is essential for life, but it can enter into the food chain only after it has been "fixed"--that is, combined with other elements such as oxygen or hydrogen. In nature, nitrogen fixation is accomplished by a few different kinds of bacteria, which live in the soil, in the oceans, and even in the guts of termites.

The first step in nitrogen fixation occurs when these micro-organisms convert atmospheric nitrogen (which exists as a diatomic gas: N_2) into ammonia: NH_3. The ammonia is then incorporated into amino acids, the building blocks out of which proteins are constructed:

$$N_2 \rightarrow NH_3 \rightarrow \text{amino acids} \rightarrow \text{proteins}$$

The catalyst at the heart of the nitrogen-fixing process is an enzyme called "nitrogenase." Nitrogenase itself is composed of two smaller components, the iron (Fe) protein, and the molybdenum-iron (Mo-Fe) protein. The Fe protein is thought to contain a cubical arrangement of 4 iron atoms and 4 sulfur atoms called a "cluster," which probably looks something like this:



The electrons that are needed for the reduction of nitrogen are transferred from other proteins to the Fe protein cluster, which then reduces the Mo-Fe protein cluster, which then in turn reduces N :

$$\text{other proteins} \xrightarrow{e^-} \text{Fe protein} \xrightarrow{e^-} \text{Mo-Fe protein} \xrightarrow{e^-} N_2$$

The Mo-Fe protein contains two molybdenum atoms and about 24 iron atoms. Until recently, very little was known about how these metal atoms were arranged in the protein. It was generally thought that the iron atoms were present as Fe-S clusters, but nothing could be stated with certainty about the molybdenum. The difficulty was that there was no spectroscopic method for observing the Mo atoms--they were invisible to the conventional techniques. Recently, however, it has become possible to detect the molybdenum in nitrogenase through the use at SSRP of the so-called X-ray absorption fine structure (EXAFS) method. (In fact, SSRP is presently the only place in the world where the EXAFS spectroscopic method of experimentation is practical.)

The X-ray absorption spectra that we collect in these studies* are essentially records of how the absorption of X-rays by nitrogenase varies as the energy of the X-rays is changed. A typical spectrum has the appearance shown in the following figure.

*The work described here is a collaborative effort of K. O. Hodgson of Stanford, Len Mortensen of Purdue, Ed Stiefel of the Charles Kettering Institute, and a number of others. The author is a graduate student at Stanford working under the supervision of Professor Hodgson.