radiographs showed that only 15 percent of the C14 was still chemically in proline, or an absolute pool size of 2.36  $\mu M/g$  dry cells. The contribution of endogenously produced proline is not greater than 0.17  $\mu M/g$  dry cells (5). The concentrations of arginine and glutamic acid in the pool are 22.7 and 82.5  $\mu M/g$  dry cells respectively (5). If we use the radioactivity distributions mentioned before, then 10,000 count/ min of  $C^{14}/g$  dry cells in the pool would lead to the specific activities shown in Table 1.

Since these molecules are the precursors of proteins (1, 2), the specific activity of the protein residues will approach the pool levels after several generations. At that time, the radioactivity distribution of the protein will be as shown in Table 2.

The distribution of radioactivity in the proteins alone would indicate that most of the added proline remained as that residue. As is seen from this example, very little of the C14-proline taken up by the cells remained in that form. Because of the large pool sizes of the products, the specific activities of arginine and glutamic acid were low and do not contribute as much C<sup>14</sup> to the protein as the high specific-activity proline.

Accumulation of exogenous proline

Table 1. Pool levels.

Pool content $(\mu M/g$ dry cells)	Radioactivity (count/min per gram dry cells)	Specific activity (count/min per $\mu M$ )
2.36	Proline 1500 (15%)	636
22.7	<i>Arginine</i> 1000 (10%)	44
82.5	Glutamic acid 5000 (50%)	61
	Other compounds 2500 (25%)	

	Table	2.	Protein 1	levels.
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Pro- tein	Specific	Total radioactivity			
tent ( $\mu M/g$ dry cells)*	$(count/min \mu M)$	Count/ min	Calc. (%)	Found (%)	
735 5	636	Proline	75	59	
247.5	44	<i>Arginine</i> 11,000	5	6	
648.8	61 G	lutamic acia 40,000	20	21	
* See 5.					

by cells of *Candida utilis* has been followed. Incorporation of material in the TCA-soluble fraction of the cells has been found to be similar to that already found for other amino acids. These results indicate the existence of two pools within the cell (2, 3) termed the "expandable" and "internal" pools. In contrast with the studies on threonine (2), the expandable pool of proline was found to be osmotically stable, and therefore could not be removed by extraction in distilled water.

Pathways of proline synthesis in Candida utilis have been described by Abelson et al. (6, 7) in the following schema:



The results of the experiments reported here are in agreement with this plan. Although proline is an "end product" in amino acid biosynthesis (7), most of the exogenous proline was converted in the pool to other compounds, principally arginine and glutamic acid. Because of the small pool size of proline, the unconverted radioactivity led to a high specific activity of proline in the pool. However, the very large concentrations of C12-arginine and C12-glutamic acid greatly diluted the radioactive molecules derived from C<sup>14</sup>-proline, resulting in low specific activities of these compounds.

The amino acid composition of the proteins differs from that of the pool (1, 2, 5), requiring different rates of turnover of the individual amino acid pools in protein synthesis. Under conditions of the experiments reported here, a doubling of protein would require the proline pool to turn over 100 times, arginine 11 times, and glutamic acid 8 times. The effects of different specific activities and different rates of turnover are multiplicative, resulting in a protein radioactivity distribution concentrated in proline. An analysis of the radioactivity in protein alone would therefore indicate little conversion of the exogenous labeled material to other products (6, 7).

The radioactivity distribution of proteins calculated from known pool sizes and specific activities is in reasonable agreement with the observed values. One source of error lies in the labeled ornithine and citrulline in the internal pool which was ignored in these calcu-

lations. If these compounds contribute most of their radioactivity to protein proline, the calculated figures would more closely approach the observed protein values. The principal conversion of ornithine and citrulline to proline has already been shown by Abelson et al. (7).

It is therefore concluded that two pools of proline may be found in Candida utilis, supplying the demands of cellular protein synthesis. Most of the exogenous proline is converted to other amino acids in the glutamic acid family when the external concentration is  $10^{-5}M$  or greater. Because the pool concentrations of these compounds vary widely, the specific activity of these precursors also differs greatly. This leads to a distribution of radioactivity in protein which is concentrated in proline, in spite of the fact that most of the exogenous material was converted to other compounds.

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12 December 1962

## Xenon Tetrafluoride: **Crystal Structure**

Abstract. On the basis of a threedimensional x-ray analysis, the xenon tetrafluoride molecule in the solid is planar; the approximate symmetry is  $D_{4h}$ . The average distance between the xenon and the fluorine is  $1.92 \pm 0.03$  Å.

The structure of xenon tetrafluoride is of great interest as a basis for the theoretical explanation of its existence. The present report describes the crystal structure of this substance.

Xenon tetrafluoride was prepared in these laboratories in the manner described by Claassen et al. (1). The ma-



Fig. 1. The structure of the  $XeF_4$  molecule in the solid.

terial was sublimed into a quartz tube and purified by alternate heating, cooling, and pumping. Crystals suitable for x-ray photography were grown directly in the sealed-off quartz tube by providing a thermal gradient along the tube. There was no evidence of decomposition of the crystals during the x-ray photography.

Xenon tetrafluoride crystallizes in the monoclinic system with cell constants a = 5.03 Å, b = 5.90 Å, c = 5.75 Å (all  $\pm 0.03$  Å),  $\beta = 100^{\circ} \pm 1^{\circ}$ . On the basis of the observed extinctions (h0l, h + l odd; 0k0, k odd) the space group is probably  $C^{5_{2h}} - P2_1/n$ . From elementary packing considerations (van der Waals radius of F = 1.35 Å) it is evident that only two molecules of XeF<sub>4</sub> can be accommodated in this unit cell of volume 168 Å<sup>3</sup>. The calculated density is 4.10 g/cm<sup>3</sup>.

Data suitable for structure analysis were collected at room temperature with MoK $\alpha$  radiation from a plate-like crystal of dimensions 1 by 1 by 0.3 mm. The precession method was used to record the three nets h, h - l + n, l with n = 0,2,4. For each net the normal to the 1- by 1-mm face of the crystal was at a constant angle to the x-ray beam, and thus all intensities on a given net should be equally affected by absorption. Since separate scale factors were used for the three nets, absorption errors should be small in spite of the high linear absorption coefficient of 104 cm<sup>-1</sup>. The intensities from these photographs correlate well with intensities of the h, h + l, l net obtained from a second, much smaller crystal. The intensities of 268 independent reflections were estimated visually, corrected for Lorentz and polarization effects, and converted to structure amplitudes.

As there are only two molecules in the unit cell, Xe may be placed at 11 JANUARY 1963 the origin and at the body-centered position. After a least-squares refinement of scale factors and the Xe thermal parameter, a three-dimensional difference Fourier, with coefficients  $(F_{obs} - F_{xe})$  for those reflections for which (h + k + l) is even, was calculated. This difference Fourier necessarily has extra symmetry, and two structures equally compatible with the x-ray data can be derived from it. Least-squares refinements of these structures led to the following x-,y-,z-parameters for the two independent fluorine atoms;  $F^1$ , -0.225,  $\pm 0.027$ , -0.306; F<sub>2</sub>, 0.242, 0.165, -0.162 (all approximately  $\pm$  0.008).

The thermal parameter of Xe is 1.3  $\pm$  0.1 Å<sup>3</sup>, that of the two fluorines is 3.5  $\pm$  1.0 Å<sup>2</sup>. The conventional crystallographic *R* factor for these parameters is 0.11 against that of 0.16 based on Xe alone. In order to resolve the ambiguity in the sign of *y* (F<sub>1</sub>), structure factors calculated for both signs were compared with structure amplitudes for the nine reflections observed on the *h*, *h* - *l* + *l*, *l* net. Since only the fluorine atoms contribute to these structure amplitudes, even this limited comparison enables us to conclude that *y* (F<sub>1</sub>) = -0.027.

The molecule has symmetry  $D_{4h}$  within the limits of error of this study, although such symmetry is not required by the space group. The angle F<sub>1</sub>-Xe-F<sub>2</sub> is  $86 \pm 3^{\circ}$  and the two independent distances Xe to F do not differ significantly and have an average value of  $1.92 \pm 0.03$  Å (Fig. 1). The shortest intermolecular F...F contact is 2.95 Å. This and all other intermolecular distances are reasonable; the molecule fills space well, providing further confirmation of the formula XeF4. Since all of the intermolecular F...F contacts in this structure exceed slightly the expected van der Waals contact of 2.7 Å it is not surprising that a second phase of XeF<sub>4</sub>, with a density some 10 percent higher than that of the present structure. exists (2). The structure of this denser phase is at present unknown.

Although a neutron diffraction study would enable us to refine the structure further, the geometry of the molecule is well defined in the present x-ray study, and we plan no further work on the structure (3).

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## **References** and Notes

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   Research performed under the auspices of the U.S. Atomic Energy Commission. The molecular structure described above was initially found by refinement in a body-centered space group, and disorder in the stacking of the molecules had to be postulated in order to obtain agreement with the data. We are indebted to S. Siegel of Argonne National Laboratory for generously pointing out an error in our space group determination; the error arose because our data were initially collected in such a way that no reflections for which (h + k + l) is odd were observed. We are indebted to D. R. Mackenzie and R. H. J. Wiswall for the preparation of the sample.

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## Tertiary Lake Deposits in Western Coterminous United States

Strata deposited by long-vanished lakes in the western coterminous United States have been subjects of interest since the middle of the 19th century. They are the repositories of large numbers of fossils which range in size from remains of one-celled plants to bones of dinosaurs. In some, the details of minute insects and the vein structure of leaves are most delicately and perfectly preserved.

The lake deposits provide important clues to the paleogeography of the continent, to past climates, and to the development of modern landforms and climates. The lake deposits of Tertiary age provide virtually the only commercial sources of borate minerals and of trona and are important contributors of many other saline minerals to the economy. Locally, the lacustrine deposits yield petroleum and natural gas. In many areas they are the sources of clay used in the ceramic industry, of diatomite, and of sand and gravel used in construction. The interlayering of lacustrine and fluvial deposits furnishes the physical framework for artesian water supplies in many western basins. For these and other reasons, the distribution of lacustrine deposits is of immediate and lasting interest to many people.

The accompanying map (Fig. 1) shows the reported occurrence of lakedeposited materials in 11 of the western states in Paleocene and Eocene time (red overprint) and in Oligocene, Miocene, and Pliocene time (black), respectively. An earlier map (1) showed the distribution of lakes of Pleistocene age in the same region.

Figure 1 suggests that in earlier