

again many times greater than those for protons. It is well established that the chemical shift of a ^{13}C frequency can be derived in terms of the nature of the carbon skeleton, with quantitatively defined values for the α -carbon, β -carbon and so on as far as the ϵ -position, when a proton on the α -carbon is replaced by a methyl group. By this means, and by comparison of the different amino-acids, Horsley *et al.* have made an essentially complete assignment of the entire spectrum. It has already been shown that there are small but measurable sequence-dependent differences in frequency in peptides, and Horsley *et al.* envisage the likelihood that peptide carbonyl resonances of proteins will reflect the local chain conformation. One now awaits ^{13}C resonance studies on enzymes.

A different use of an isotope in NMR has the aim of clearing the thicket of the proton magnetic resonance spectrum of proteins, so as to focus on selected residues only. If an enzyme is prepared from cells supplied with selected deuterated amino-acids, the number of proton resonances in the spectrum can be reduced at will. This method has been applied to staphylococcal nuclease by Putter *et al.* (*Proc. US Nat. Acad. Sci.*, **64**, 1396; 1969). Five derivatives, containing protons only in two, three or four species of amino-acid, were prepared. With the tryptophan residues deuterated, the aromatic region of the spectrum emerges starkly simple from the mush of overlapping bands present in the native enzyme. The tyrosine and histidine frequencies can be identified easily. The aliphatic region is also much simpler, and, for example, four peaks apparently corresponding to the methyl groups of the four methionine residues are resolved. The twenty-three lysines, with their many protons, remain difficult to disentangle, however, and it would require chemical synthesis or hybridization of non-covalently associating fragments from deuterated and undeuterated molecules to make any further impression. To the fertile mind many applications of selective deuteration will suggest themselves.

CHEMICAL SYNTHESIS

New Cyclization Reactions

from our Organic Chemistry Correspondent

THE formation of a new carbon-carbon bond by reaction between a Grignard reagent and a carbonyl compound is well known. But although this reaction can be utilized to bring about efficient coupling between two molecules, no effective intramolecular counterpart has been developed.

A practical solution to this problem has now been found which utilizes the organo-copper species di-*n*-butylcopperlithium (Corey *et al.*, *J. Amer. Chem. Soc.*, **92**, 395, 396; 1970). This reagent attacks a vinyl bromide or iodide more readily than it does an isolated

ketone function. The possibility of effecting cyclization when both functions are present in the same molecule is exemplified by the conversion, in high yield, of the bromodiketone (I) into the keto-alcohol (II), which has the carbon skeleton of the plant hormone gibberellic acid. Cyclization proceeds selectively to give the desired new five-membered ring; protection of the second carbonyl group is unnecessary.

Similar cyclizations can be carried out with saturated haloketones, but yields are disappointing (about 20–30 per cent). An alternative procedure, also reported by Corey *et al.*, however, overcomes this difficulty. The reagent of choice is now the dianion derived from nickel tetraphenylporphine and two equivalents of lithium naphthalene. With this, in tetrahydrofuran, 7-iodo-2-heptanone is cyclized to 1-methylcyclohexanol in 88 per cent yield. A detailed mechanistic picture of these valuable new transformations, however, is not yet clear.

MÖSSBAUER EFFECT

Liquid Crystals Join the Club

THE latest surprise to emerge from the select group of materials known as liquid crystals is an observation of the Mössbauer effect in a smectic liquid crystal. D. L. Ulrich, J. M. Wilson and W. A. Resch (*Phys. Rev. Lett.*, **24**, 355; 1970) have introduced atoms of ^{57}Fe into a smectic liquid crystal with a low solid to smectic transition temperature and have obtained the familiar shapes of Mössbauer spectra produced through the recoil-free emission of gamma rays from the unstable ion.

This experiment opens up a valuable new way of studying liquid crystals. The peculiarity of these materials is, of course, that the long rod-like molecules have some of the translational and rotational degrees of freedom of a liquid and yet retain a kind of crystalline order in the manner of a solid. What is interesting is that for the Mössbauer effect to occur there must be strong binding between atoms to provide the recoilless emission of low energy gamma rays, and it seems that the layered structure of the smectic liquid crystal is rigid enough for this to happen. In normal liquids the atomic binding is, of course, too weak, but the Mössbauer effect has been demonstrated in glycerine, the high viscosity of which is thought to be due to hydrogen bonding. There is no evidence, however, of hydrogen bonding in liquid crystal systems.

Ulrich *et al.* observed the changes in Mössbauer spectra as a sample was taken through two phase transitions, solid to smectic liquid crystal and smectic to nematic liquid crystal. An abrupt reduction in peak heights was seen at the first transition and at the second the Mössbauer effect vanished completely as the molecules gained an additional degree of translational freedom. The ^{57}Fe atoms had been introduced to the system through a small quantity of solute. The effect of the liquid crystal in aligning the solute molecules was evident from the changes in symmetry of the spectrum when the sample was shaken and then taken through a heating and cooling cycle.

The Mössbauer effect has been steadily finding new applications since its discovery in 1958. During the past six or seven years a mass of information has been accumulated on hyperfine interactions, and more

