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NOTES ON CARBON-13

1. Carbon-13 is unique among the known isotopes of carbon. It has a low natural abundance (1.11% with carbon-12 having 98.89%) and is not radioactive thus permitting routine human, industrial and laboratory uses without problems of radiation hazard. Carbon-13 possesses a nuclear spin of one-half whereas carbon-12 and -14 both have zero spin. Carbon-13 may therefore be used in nuclear magnetic resonance studies and can create fine structure in electron spin spectroscopy. Carbon-13 labeled macromolecules are heavier and thus can be separated by ultra-centrifugation from their lighter equivalents. The above characteristics indicate a potential large scale utilization of carbon-13 in medicine, science, and industry.

2. A fundamental question arises: Is there a need to accelerate the rate of development of this isotope in terms of production, synthesis into useful compounds and beneficial utilization?

To answer this question preliminary studies are needed to:

(1) Identify present and potential uses of carbon-13;

(2) Explore production processes and costs;

(3) Review problems of a synthesis program for converting primary material into useful compounds; and

(4) Evaluate toxicity problems of carbon-13; if any.

3. Carbon-13 is not a substitute tracer for carbon-14 and it is doubtful if enriched carbon-13 would reduce utilization of carbon-14

at all. Rather, abundant supplies of carbon-13 could open new applications based upon the isotope's greater mass, the availability of macro quantities of material, and on the ability of the nuclear spin to perturb nuclear magnetic, electron spin, and optical spectra.

4. In the past ten years rapid development of older techniques and new analytical procedures have increased the apparent potential usefulness of enriched carbon-13. Some key developments include:

(1) The mass spectrometer has been greatly improved and its utilization extended, especially for organic compounds. Mass spectroscopy currently has wide applications in identifying complex organic molecules and mixtures by fragmentation patterns. Such instruments are now commonplace in industrial and research laboratories;

(2) The nuclear magnetic resonance spectroscopy (NMR) of protons and other isotopes with nuclear spin has taken a position of prime importance in structural studies of organic molecules. Recent development of the 220 M Hertz superconducting solenoid NMR has further extended the sensitivity of this technique so that the spin of enriched carbon-13 is an important factor in NMR spectra;

(3) Density gradient separation of macromolecules labeled with carbon-13 is a powerful tool of the molecular biologists, and can be used in many ways, especially in separating newly or specifically synthesized macromolecules.

These techniques should be extended to industrial macromolecular research;

(4) Enriched carbon-13 may contribute to the fine structure of electron spin resonance spectra;

(5) In clinical studies of inborn errors of metabolism or of those induced by disease, the use of carbon-13 would present no radiological hazard and could have widespread utilization;

(6) Carbon-13 could be presumably used as a tracer in chemical and engineering studies of factories and pilot plants when some of the ultimate product would get into the hands of the general public. Economies should be realized in clean-up and shut-down times as compared to the radioactive tracer method.

5. Present effort in carbon-13 production is as follows: A British firm, 20th Century Limited, produces 60% carbon-13 by CO distillation in a plant with 0.6 - 0.7/g per day output. The product is sold in the U. S. by Isomet, Inc. Mound Laboratory has enriched about 30g of this material to approximately 90%. This enriched carbon-13 is for sale at a cost of $3,800/g. Mound Laboratory is producing 5 to 10 grams per year of carbon-13 from natural abundance methane. A distillation column for CO has been installed and will produce 100-250 grams per year of carbon-13 at > 90% enrichment beginning in FY 1969 at a cost of $500 to $1,000 a gram.

6. The synthesis of carbon-13 labeled compounds should present no technical problems, especially on the gram to kilogram scale possible if carbon-13 production is accelerated.

7. We know of no data on the toxicity of carbon-13 in high concentrations. One can argue from theoretical considerations that there should be negligible toxicity in higher animals from high levels of carbon-13. However, insufficient enriched material has been available to study effects in animals.