PUERTO RICO NUCLEAR CENTER RESONANCE IN RADIATION EFFECTS Progress Summary Report No. 1 prepared by the UNIVERSITY OF PUERTO RICO UNDER CONTRACT No. AT W0-1-1833 FOR U.S. ATOMIC ENERGY COMMISSION PRNC 14 RESONANCE IN RADIATION EFFECTS Progress Summary Report #1 March 1963 Hency J. Gonberg - Principal Investigator Robert A. Luse Florencio Vazquez Martinez Puerto Rico Nuclear Center operated by the University of Puerto Rico for the U.S. Atomic Energy Commission under Contract No. AT-(40-1) 1833 INTRODUCTION. To answer the question "what are the unique effects of ionizing radiation on matter?", our research program continues a study started at the University of Michigan under the principal investigator. The Michigan program is now under the direction of Prof. Hoyt Whipple, while in Puerto Rico a new project has been created. The first objective of the Puerto Rico Program is to provide an independent test of the original results reported from Ann Arbor. The second is the extension of the investigation to new problems in biological, chemical, and physical effects produced by monochromatic X-rays in the less than 20 kilovolt energy range. Below is a summary of the results obtained during the first year of operation of the Puerto Rico project. Section 1. Resonance Radiation Effects of Low-Energy Monochromatic Rays on Catalase (by R.A. Luse) Dilute solutions of the iron metalloenzyme catalase were irradiated with a beam of monochromatic X-rays having photon energies in the 6-9 keV range and with a high purity (4.50 eV). Irradiation was carried out in a sample holder constructed of methacrylate plastic with a thin Mylar film window. Approximately 0.2 ml of sample could be irradiated in the chamber (6 x 9 x 4 cm). A chamber of similar size, shielded from radiation, contained control solution. Masking of solution under the conditions of complete absorption was avoided by mechanical stirring with a fine glass rod. To minimize evaporation and inactivation of the sample, solutions were covered and maintained at 5°C by placing

water from a constant temperature, refrigerated bath through the sample holder. ---Page Break--- In conjunction with this irradiation system, a ferrous-ferric micro-dosimetry technique was developed. The primary requirement specified for the dosimeter system was the ability of direct substitution for the sample, to ensure that values of radiation intensity measured with the dosimeter correspond directly to those absorbed by the biological sample. Other considerations were simplicity of use and reliability in the low dose ranges involved in this work. The Fricke ferrous-ferric dosimeter was chosen, since it is the best characterized secondary standard available. It relies on the oxidation, by ionizing radiation, of ferrous ion to ferric ion, and on determination of the concentration of ferric ion formed by its light absorption at 304 nm (cf. Schuler and Allen). Application of this dosimeter is primarily limited by the methods for ferric ion analysis. A considerably more sensitive assay of ferric ion concentration is the measurement of the absorption of the red-orange ferric-thiocyanate complex; the solar absorptivity of this complex is 10,000 - 14,000 liter mole■$^{1}$ cm■$^{1}$ at 480 nm. Pribicevic, Gal, and Draganic have characterized this complex formation and proposed its use as a dosimetry system in the 300 - 100 rad dose range. Not all their results could be confirmed, so that further characterization and modification of the system were undertaken; these changes were incorporated in the procedure developed. To avoid dilution of the irradiated solution, optical measurements were taken with the Beckman DU spectrophotometer in cuvettes of 3 mm x 10 mm x 25 mm chamber dimensions; as little as 0.22 ml of solution may be used in such cuvettes. X-radiation intensities of 2 x 10■ photons per hour in the sample holder have been determined by this method (6-hour irradiation periods were required). The results of this chemical dosimetry ---Page Break--- ety x 10■ Beam intensity absorbed in sample (photons) Photon energy,

Figure 1. Monochromatic X-ray beam intensity as a function of photon energy ---Page Break--- Percent catalase inactivation 20 - 60 65 70 75 80 85 Photon energy, Kev Figure 2. Resonance

radiation effect of monochromatic X-rays on catalase Total dose absorbed by sample = 1.4 x 10^3 photons. (except for starred point, where dose = 0.2% 10^ ---Page Break--- -5- in the photon energy range of current interest are given in Figure 1. There is no resonance radiation effect in the ferrous dosimeter at the K-absorption edge of iron; this is expected, since the ferrous to ferric oxidation is due to “indirect” effects. The extent of enzyme inactivation was determined using essentially the standard assay for catalase developed by Beers and Sizer in which titrated hydrogen peroxide is followed spectrophotometrically at 240 nm. The results of such irradiation experiments using monochromatic x-rays in the energy range 6.4 - 8.3 Kev are given in Figure 2. Here, enzyme inactivation of the iron enzyme at or near the K-absorption edge of iron (7-11 Kev) is obvious. This is taken to confirm the resonance radiation hypothesis of Gosberg and previous experimental work of Benons and Paraskevoudakis. Section II, Characterization of a High Intensity Monochromatic X-Irradiation System in the 5-20 Kev Region (by F. Vasquez Martinez) The x-ray emission system utilized for the present resonance radiation study was characterized quantitatively as to intensity and photon energy distribution, and second harmonic contamination. The monochromatic x-ray beam resulting from crystal diffraction and collimation was analyzed horizontally across its front for (a) intensity distribution, utilizing a special moving slit device; and (b) photon energy distribution, using double diffraction by a second analyzer crystal. The results of this work are shown as Figures 3 and 4, ---Page Break--- 2 laa My |x? 2 i 3 len? ans? DISTRIBUTION WITH [oz* SLIT | DISTRIBUTION WITH [oz? SLT te [We 084nm | 4 We 084mm 2 ' 2 [sx10* | [sxio# 8 i 3 i LS axiot | 2x0 2 1 3 1 5

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