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SOLID CHEMICAL RADIATION DOSIMETER

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EFFECTS OF PHYSICAL STATES ON ACID PRODUCTION AND COLOR CHANGE IN THE HAP SYSTEM*

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INTRODUCTION

This report is concerned with further investigations into certain physical and chemical aspects of the HAP solid chemical dosimeter, which records the spatial distribution of radiation. The HAP system (Halogenated compound - Azo dye - Paraffin matrix) allows changes in the concentration of the various components thereby making possible formulations closely equivalent to soft tissue in terms of electron density and the effective atomic number (Z).

The following series of experiments are reported:

1. Effect of temperature and physical state.
2. Correlation of acid production with electron density and Z.
3. Factors influencing the peak response.

MATERIALS AND METHOD

For the acid production studies a liquid paraffin (e.g. heavy mineral oil) instead of solid paraffin at room temperature was found to be the matrix of choice because acid extraction was more complete and reproducible. Chloroform was the halogenated compound used and the dye was dimethylaminoazobenzene. The solid state of the mixture was obtained by cooling in a deep freeze capable of temperatures down to 82° C. Extraction of acid was done with deionized distilled water. Measurements of pH were with a Beckman Model No GS meter.

For the light transmittance measurement studies paraffin was blended with chloroform and the dye at 65 to 70° C in making the translucent solid slabs. As stated in previous reports, the base or matrix was considered as the solvent in the concentration calculations of molality.

RESULTS

1. Effects of Temperature and Physical State

   A. Acid production

   The same formulations of the mineral oil HAP dosimeter were irradiated with X-rays in their liquid as well as their solid states and the acid production determined. There was much more acid produced in the liquid state as compared to the same formulation irradiated as a solid. This difference is clearly illustrated by Figures 1 and 2.

   B. Transmittance measurements of color response

   The same formulations of the paraffin base HAP dosimeter were irradiated at different temperatures and allowed to equilibrate at room temperature for the light transmittance measurements. Figure 3 shows that there was less color change at the lower temperatures.

2. Correlation of Acid Production with Electron Density and Effective Atomic Number

   A. Acid production

   The frozen solid mineral oil HAP dosimeter with chloroform concentrations ranging from 0.5 to 3.0 molal were irradiated with X-rays having effective energies of 25 keV and 100 keV as well as gamma rays from Coblat 60, which is considered to have an effective energy of 1.25 MeV. The absorbed dose (rads) and the G values for the various formulations exposed to the different radiation sources were correlated with acid produced.

These data are plotted in Figure 4 and show that there is more acid produced in the higher concentrations of chloroform irradiated with higher radiation energies.

B. Transmittance measurements of color response

Color changes were measured as the amount of light transmitted through the dosimeter before and after irradiation of 0.8 cm solid paraffin base slabs within a phantom of the same chloroform concentration. The change of color was greater with the higher chloroform concentrations and greater with the higher radiation energies as seen in Figure 5.

3. Factors Influencing the Peak Response in the HAP System

It was previously reported that relatively low concentrations of halogenated organic compound (chloroform or bromoform) gave the most color change with radiation. This effect was considered as due to the physical state of the paraffin and/or plastic matrix. Upon further examination it was found that this response was not consistent. Paraffin alone as the matrix seems to show a continually increasing sensitivity with higher concentrations of halogenated hydrocarbon whereas the small addition of other substances such as microcrystalline wax or plastics can produce the peak response. It also appears that trace amounts of water may be responsible for the peak response in some instances. More work needs to be done to elucidate this phenomenon.

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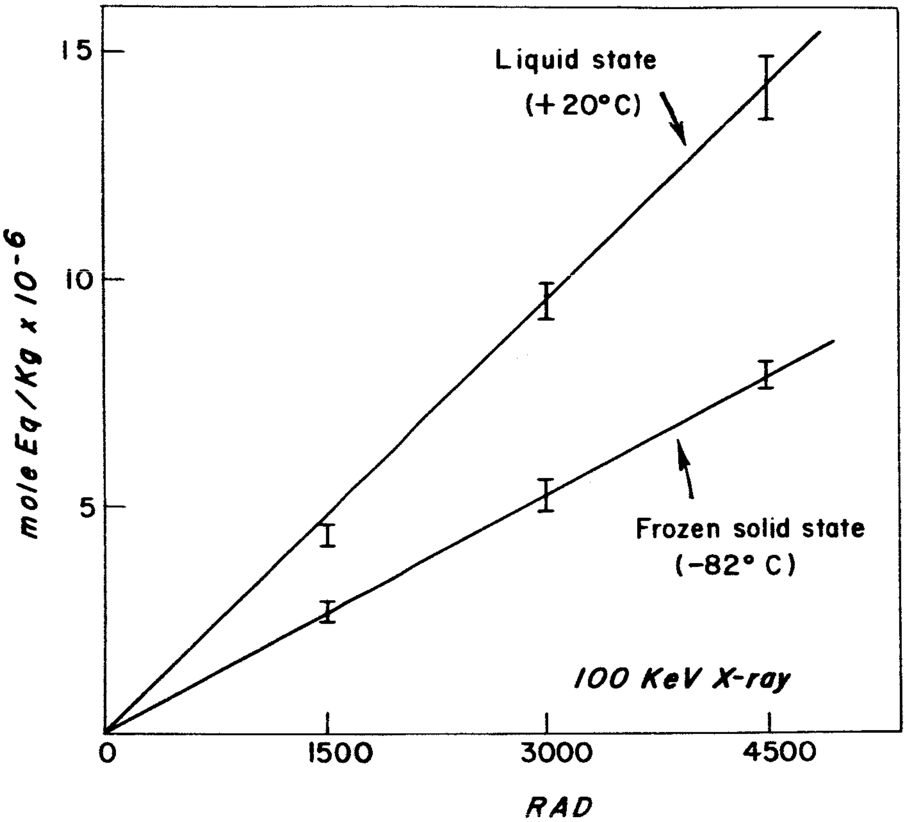

FIGURE 1

Effect of Physical State (during irradiation) and X-ray Photon Energy on Acid Production.

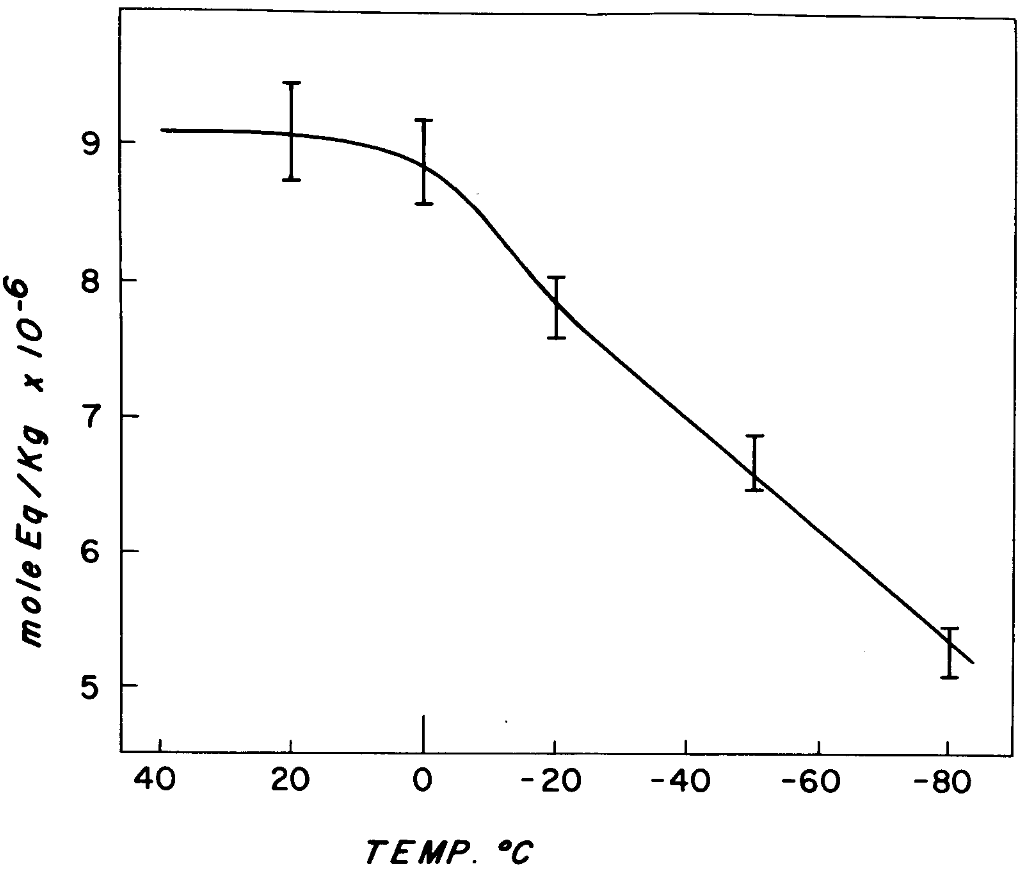

FIGURE 2

Effect of Temperature at the Time of Irradiation on the Quantity of Acid Produced by X-rays with an Effective Energy of 100 keV.

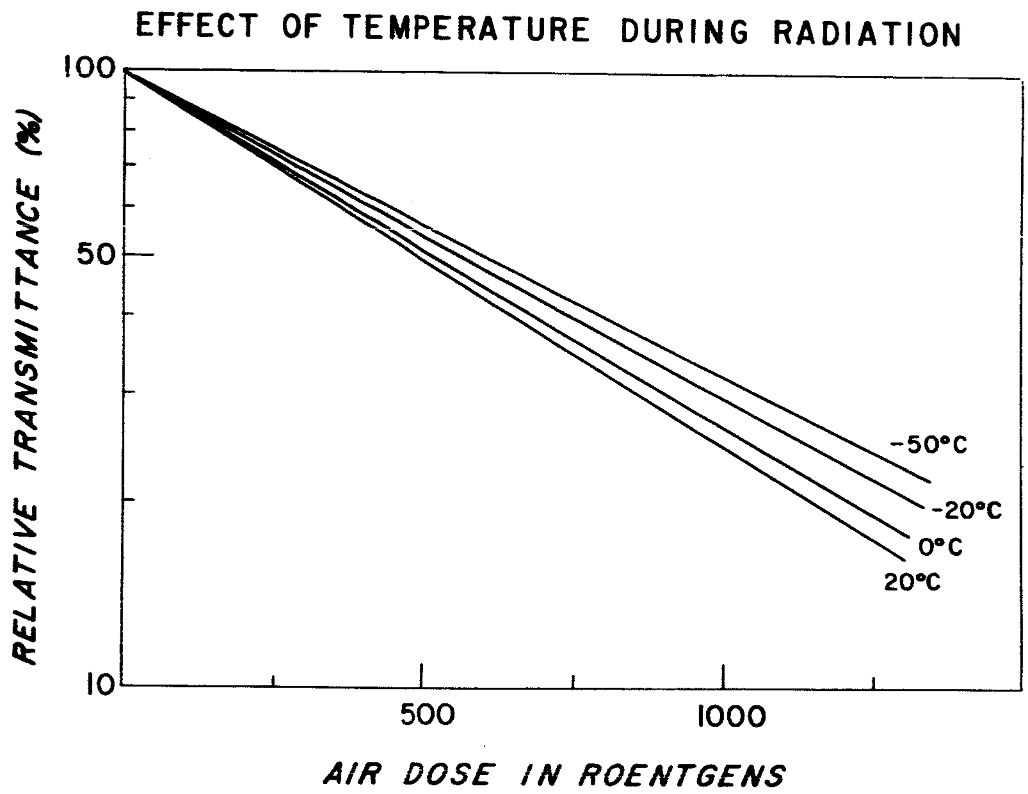

FIGURE 3

Effect of Temperature on Sensitivity (color change as measured by transmitted light) of the Paraffin-Based HAP Dosimeter.

EFFECT OF RADIATION ENERGY AND CONCENTRATION ON ACID PRODUCTION

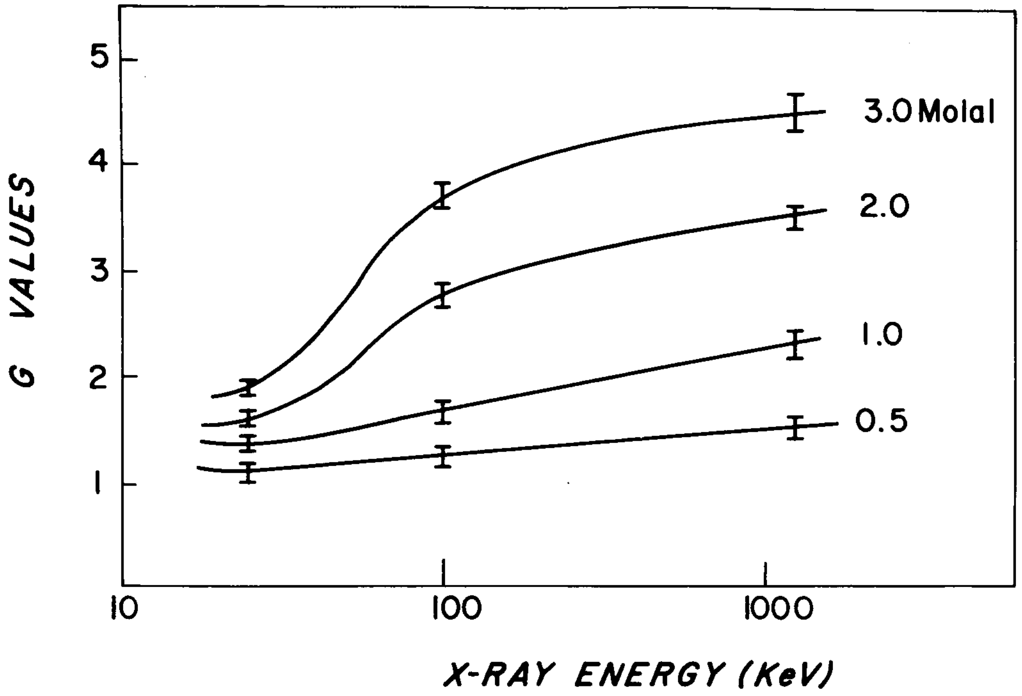

FIGURE 4

Effect of Photon Energy and Chloroform Concentration on the G Value (amount of acid resulting from every 100 ev of energy absorbed).

EFFECT OF RADIATION ENERGY AND CONCENTRATION ON SENSITIVITY

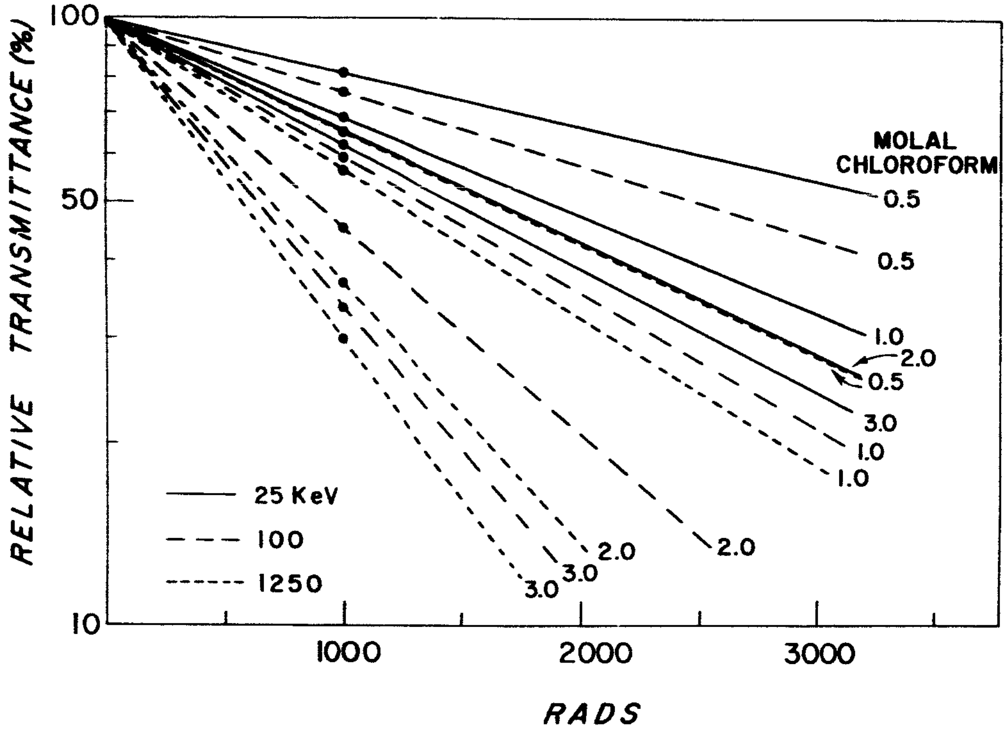

FIGURE 5

Effect of Photon Energy and Chloroform Concentration on Sensitivity (color change) of Solid Paraffin Base Slabs.