DOSIMETRY PT 3

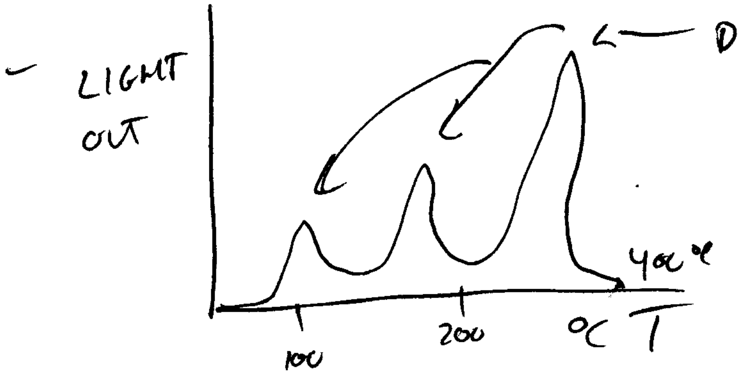
TLD

RECALL

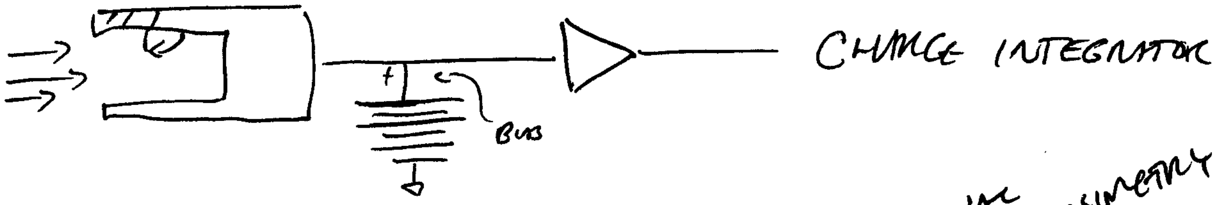
IONIZING RADIATION PRODUCE e^--HOLE PAIRS IN INORGANIC CRYSTALS

↳ LEADS TO FORMATION OF EXCITED STATES W/ ENERGIES THAT ARE IN THE FORBIDDEN GAP W/ ACTIVATOR IMPURITIES ARE ADDED.

- IN SCINT DET, DESIRABLE FOR EXCITED STATES TO DECAY QUICKLY
- IN TLD IMPURITIES ARE CHOSEN SO e^- + HOLES REMAIN TRAPPED AT ACTIVATOR SITES AT ROOM TEMP.
- PLACED IN A RADIATION FIELD IT BECOMES AN INTEGRATOR
- POST EXPOSURE TLD IS HEATED + EMITTES photons of a few eV
-



FINISH UP CHARGED PARTICLE DOSIMETRY



INTERNAL RAD. DOSIMETRY →

CHEMICAL DOSIMETRY

- IN CHEMICAL DOSIMETRY THE ABSORBED DOSE IS DETERMINED FROM THE CHEMICAL CHANGE PRODUCED IN AN ~~A~~ SUITABLE SUBSTRATE

- REQUIRES KNOWLEDGE OF THE RADIATION-CHEMICAL YIELD (G) WHICH IS PREVIOUSLY CALIBRATED AGAINST ANOTHER "PRIMARY" DOSIMETER

  ⇒ CHEMICAL DOSIMETERS ARE THEN "SECONDARY DOSIMETERS"

- DESIRABLE FEATURES:
  - PROPORTIONAL YIELD OVER A LARGE RANGE OF DOSE : $1 \rightarrow 1\times10^6$ Gy
  - INDEPENDANT OF DOSE RATE $\dot{D}$ ~ Gy/min → 10^6 Gy/s
  - INDEPENDANT OF ENERGY & L.E.T.
  - TEMPERATURE INDEPENDANT &
  - REPRODUCIBILITY ~ 1→5%

1.3

$$D_M = \bar{E} \int_0^t C \, dt \ [Gy]$$

of corse $C(t) = C_0 e^{-\lambda t}$

$$D_M = \bar{E} \int_0^t e^{-\lambda t} \, dt \ [Gy]$$

INTEGRATING

$$D_M = \frac{\bar{E} C_0 (1 - e^{-\lambda t})}{\lambda}$$

WHEN $t \to \infty$ + ALL DECAY HAS OCCURRED

$$D_M = \frac{\bar{E} C_0}{\lambda} \ [Gy]$$

DOSIMETRY OF INTERNAL RADIATION SOURCES

- SHORT RANGE OF α + β LIMITS VOLUME THAT CAN BE IRRADIATED.

- CONVENIENT TO THEN TO MIX ISOTOPE W/ MATERIAL TO BE IRRADIATED

MEAN ENERGY RELEASED

$$\dot{D}_M = C\left[\frac{Bq}{kg}\right] \times \bar{E}\,[J]\left[\frac{Gy}{s}\right]$$

CONCENTRATION OF ISOTOPE PRESENT

$C\ [mCi]$ + $\bar{E}\ [MeV]$

$$\dot{D}_M = 5.928\times10^{-3}\, C\left(\frac{mCi}{g}\right)\times \bar{E}\,(MeV)\ \left[Gy/s\right]$$

ACCOUNTING FOR RADIOACTIVE DECAY

ACTUAL ABSORBED DOSE $$D_M = \int_0^t \dot{D}_M\, dt\ [Gy]$$

TLD MATERIALS

MAGNESIUM ACTIVATED CALCIUM SULFATE

$CaSO_4:Mn$ ~ RESOLUTION 10 μRAD

ITS TRAPS ARE SHALLOW + WILL "FADE" w/ 24hrs

$CaSO_4:Dy$

LiF ⟹ negligible FADING, close to T.E.

GAMMA 0.01 → 1,000 RADS

^6Li GOOD FOR SLOW n

OTHER

$CaF_2:Mn$

$CaF_2:Dy$

$Li_2B_4O_7:Mn$

- STABLE UNDER NORMAL CONDITIONS, AIR & WATER (BEFORE & AFTER IRRADIATION)
- SHELF LIFE AFTER PREPARATION

NO ONE DOSIMETER' ACCURACY MEETS ALL OF THE REQUIREMENTS.

"FRICKE" OR Ferrous sulfate is the closest.

→ 2.2

FOR ANY DOSIMETER IN WHICH RADIATION INDUCES A CHEMICAL CHANGE, THE MEAN ABSORBED DOSE OVER THE VOLUME OCCUPIED BY THE DOSIMETER IS

$$D_D = \frac{\text{YIELD OF RADIATION INDUCED PRODUCT}}{\text{RADIATION CHEMICAL YIELD}} \left[\frac{\text{mol/kg}}{\text{mol/J}}\right]$$

RADIATION CHEMICAL YIELDS ARE REPRESENTED BY SYMBOL

$G \qquad G(Fe^{3+})$

UNITS CAN BE EXPRESSED AS mol/J, $\mu\text{mol}/J$ OR

$\text{molecules}/100\,\text{eV}$ WE WILL USE $\mu\text{mol}/J$

FRICKE DOSIMETRY

FERROUS IONS IN A SULFATE SOLUTION ARE OXIDIZED BY THE ACTION OF RADIATION.

ALL AQUEOUS CHEMICAL DOSIMETERS INTERACT W/ WATER TO PRODUCE FREE RADICALS

H + OH, WHICH ARE VERY REACTIVE

OH RADICAL CAN OXIDIZE THE FERROUS ION DIRECTLY.

$$Fe^{2+} + OH \rightarrow Fe^{3+} + OH^{-}$$

POST IRRADIATION, CHEMICAL DOSIMETERS ARE ANALYZED BY LIGHT ABSORPTION.

- FRICKE RANGE 4×10^3 TO 4×10^4 RAD
- DOSE MEASUMENTS ARE ABSOLUTE
- AQUEOUS SYSTEM APPROXIMATES SOFT TISSUE

OTHER CHEMICAL DOSIMETERS ARE BASED ON CERIC SULFATE, OXALIC ACID, FERROUS SULFATE, CUPRIC SULFATE

RADIATION-CHEMICAL YIELDS IN LOOK UP TABLES etc ARE REPORTED AS THE NUMBER OF MOLECULES OF 'PRODUCT' FORMED / OR CHANGED PER 100eV ENERGY ABSORBED

THEN WE CAN EXPRESS MEAN ABSORBED DOSE AS

\# of moles of product formed per kilogram

$$D_D = m_p\left[\frac{mol}{kg}\right]\times\frac{100}{G(P)}\left[\frac{eV}{molecule}\right]\times 6.022\times10^{23}\left[\frac{molecules}{mol}\right]\times 1.602\times10^{-19}\left[\frac{J}{eV}\right]\times 1\left[\frac{Gy}{J/kg}\right]$$

\# of molecules of product formed per 100eV energy absorbed

$$= 9.648\times10^{6}\,\frac{m_p}{G(P)}\;[Gy]$$

NOTE WE CAN ALSO EXPRESS PRODUCT YIELD IN UNITS OF mol/m3 WHEN C_p ρ = kg/m3

$$D_D = \frac{9.648\times10^{6}\,C_p}{\rho\,G(P)}\;[Gy]$$

Q: HOW DO WE DETERMINE PRODUCT YIELD?

ABSORPTION SPECTROPHOTOMETRY IS FREQUENTLY USED TO DETERMINE PRODUCT YIELD, ASSUMING BEER'S LAW

$$\text{moles product formed per } m^3 = \frac{\Delta A}{\Delta\varepsilon\, l}$$

ΔA ≡ DIFFERENCE IN ABSORBANCE OPTICAL DENSITY BETWEEN IRRADIATED + UN-IRRADIATED SOLUTIONS

$\Delta\varepsilon$ ≡ DIFFERENCE IN MOLAR EXTINCTION (OR ABSORPTION) COEFF $\left[\frac{m^2}{mol}\right]$ BETWEEN REACTANT + PRODUCT AT THE GIVEN λ

l ≡ OPTICAL PATH LENGTH

COMBINE EQUATIONS WE GET

$$D_D = \frac{\Delta A}{\Delta \epsilon \, l \rho \, G(P)} \, [Gy] \quad \longleftarrow 10^6 \text{ of radiation chemical yield } \mu mol/J$$

WHERE CAREFUL TO KEEP UNITS OF

$G(P) \; [mol^{-1}]$

$\rho \; [kg/m^3]$

← SKIP →

EXAMPLE

A SOLUTION CONTAINING ^{32}P COUNTED ~~on~~ A $t=0$ ~~[illegible]~~ WAS FOUND TO CONTAIN ~~[illegible]~~ 1,34 mCi of ^{32}P. & ~~48 hrs after the solution~~ was added to a solution of ferrous sulfate in sulfuric acid SUCH THAT THE MIXED SOLUTION WAS 0.001 M WITH RESPECT TO $FeSO_4$ + 0.4 M TO H_2SO_4. FINAL VOLUME WAS 10 ml

48 hrs later the optical density was measured at 304 nm, & A ~~BLANK~~ "BKG" CONTROL WAS MEASURED TO HAVE AN OPTICAL DENSITY OF 0.003

5/

1. CALCULATE G(FERRIC) FOR ^{32}P β's

A: MOLAR EXTINCTION COEFFICIENT FOR FERRIC ION @ TEMP 24°C 324nm IS 2175

ρ OF 0.4M H_2SO_4 @ 24°C = 1.024g/cm3

^{32}P $T_{1/2}$ = 14.22

AVERAGE ENERGY OF β ~~RAY~~ IS 0.7 MeV

ABSORBED DOSE

AVG β-ENERGY

ACTIVITY AT START $\frac{mCi}{g}$ of solute

$$D_m = \frac{5.121\times10^4 \times \bar{E} \times C_0}{\lambda}\left(1-e^{-\lambda t}\right) \text{ RAD}$$

AFTER 2 DAYS / 48HRS

$$\lambda = 0.04873 \text{ day}^{-1}$$

$$C_0 = \frac{1.361\,mCi}{10.24\,g} = 0.1329\ mCi/g$$

$$D_m = \frac{(5.121\times10^4)(0.70\,MeV)(0.1329)}{0.04873}\left(1-e^{-0.04873\cdot 2}\right) = 9079 \text{ rad}$$

FOR FERRIC SULFATE

$$D_m = \frac{0.965\times10^9\,(OD_i - OD_b)}{\varepsilon\, d\, \rho\, G(Fe^{3+})}$$

$$G(Fe^{3+}) =$$

BEER'S LAW

BEER'S LAW STATES THAT MOLAR ABSORPTIVITY IS CONSTANT (+ THE ABSORBANCE IS PROPORTIONAL TO CONCENTRATION) FOR A GIVEN SUBSTANCE DISSOLVED IN A GIVEN SOLUTE AND MEASURED AT A GIVEN λ.

FOR THIS REASON, MOLAR ABSORPTIVITIES ARE CALLED "MOLAR ABSORBTIVE COEFFICIENTS" OR "MOLAR EXTINCTION COEFFICIENTS. BECAUSE TRANSMITTANCE + ABSORBANCE ARE UNITLESS, THE UNITS FOR MOLAR ABSORPTIVITY MUST CANCEL WITH UNITS OF MEASURE IN CONCENTRATION + LIGHT PATH