Exp. 1 Radiation Safety

In Chapter 16, we discuss various aspects of the safe handling of radioactivity. The purpose of this first laboratory exercise is to demonstrate experimentally some of the factors involved in evaluating the hazards due to external exposure to radiation. In order to evaluate possible external radiation hazards, one must measure the radiation exposure in a given area. As pointed out in Chapters 5 and 16, this is accomplished by measuring the ionization produced in a fixed volume of gas, converting that to an electrical current which in turn drives a meter previously calibrated to read radiation exposure rate for a particular type of radiation (usually β^- or γ) directly in milliroentgen/hour or roentgen/hour*. Instruments that make such measurements are called survey meters and several types of this instrument are shown in Figure 16-2. With these few words of introduction, let us begin a quantitative investigation of the factors involved in external radiation exposure.

A. Distance

Imagine a point source of radiation is emitting particles uniformly in all directions (isotropic emission) as shown in Figure I-1. Now imagine placing the point source at the center of a hollow sphere of radius R. If the source is emitting N particles per second, then the number of particles striking each cm^2 of the surface of the sphere is N/A where A is the surface area of the sphere in cm^2. Since we know from geometry that $A = 4\pi R^2$, we can write that

$$\frac{\text{the number of particles hitting the sphere}}{cm^2} = \frac{N}{4\pi R^2} \qquad \text{(I-1)}$$

But the number of particles emitted per cm^2 is the radiation intensity of the source by definition so that we can say that

$$\text{(radiation intensity)} \propto \frac{1}{R^2} \qquad \text{(I-2)}$$

*As pointed out in Chapter 16, the roentgen is a unit of radiation energy dissipation and specifically represents the dissipation of 87.6 ergs/gm of dry air at STP by X or γ-radiation.

where R is the distance between the source and the object being struck. This is called the inverse square law and has important consequences for evaluating external radiation exposure. Clearly the radiation exposure will increase inversely as the square of the distance between the radiation source and the experimenter. Let us see if we can verify this experimentally.

Procedure

1) Using the survey meter provided, make quantitative measurements of the radiation exposure rate (as read on the meter) as function of the distance from a ^{60}Co source (a mixed β-γ emitter) to the face of the survey meter. Take readings at each distance with the beta shield* open and closed. Record the data in tabular form as given below in Table I-1.

Distance from meter face to source	Meter Reading (β- Shield Open)	Meter Reading (β-Shield Closed)

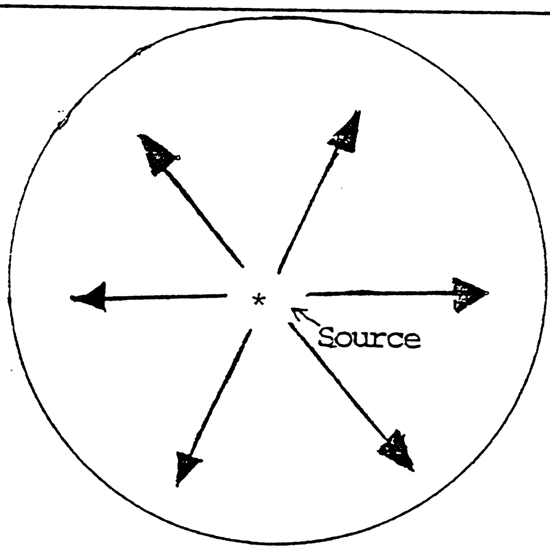

Figure I-1. Schematic diagram of isotropic particle emission.

*The beta shield of the survey meter is a cover fitting over the detector portion of the meter which prevents low energy β^- particles from entering the gas volume. Readings taken with the beta shield "open" or "closed" can give a measurement of the relative number of low energy beta particles vs. the number of high energy beta particle and γ-rays coming from the radiation source. The correct evaluation of the total radiation dosage depends on accounting for the dose rate due to both types of radiation separately. Usually a calibration system is pasted on the side of a survey meter telling how to convert the open shield and closed shield meter readings to a correct radiation dosage.

2) Calculate for each measurement in Table I-1, the reciprocal of the square root of the meter reading. Enter the result in your lab book. The tabular format shown below is appropriate:

Distance from source to meter	β-Shield Open Reading, O	$\frac{1}{\sqrt{O}}$	β-Shield Closed Reading, C	$\frac{1}{\sqrt{C}}$

3) Plot on the same linear graph, a) $(1/\sqrt{o})$ vs. distance, b) $(1/\sqrt{c})$ vs. distance as shown in Figure I-2.

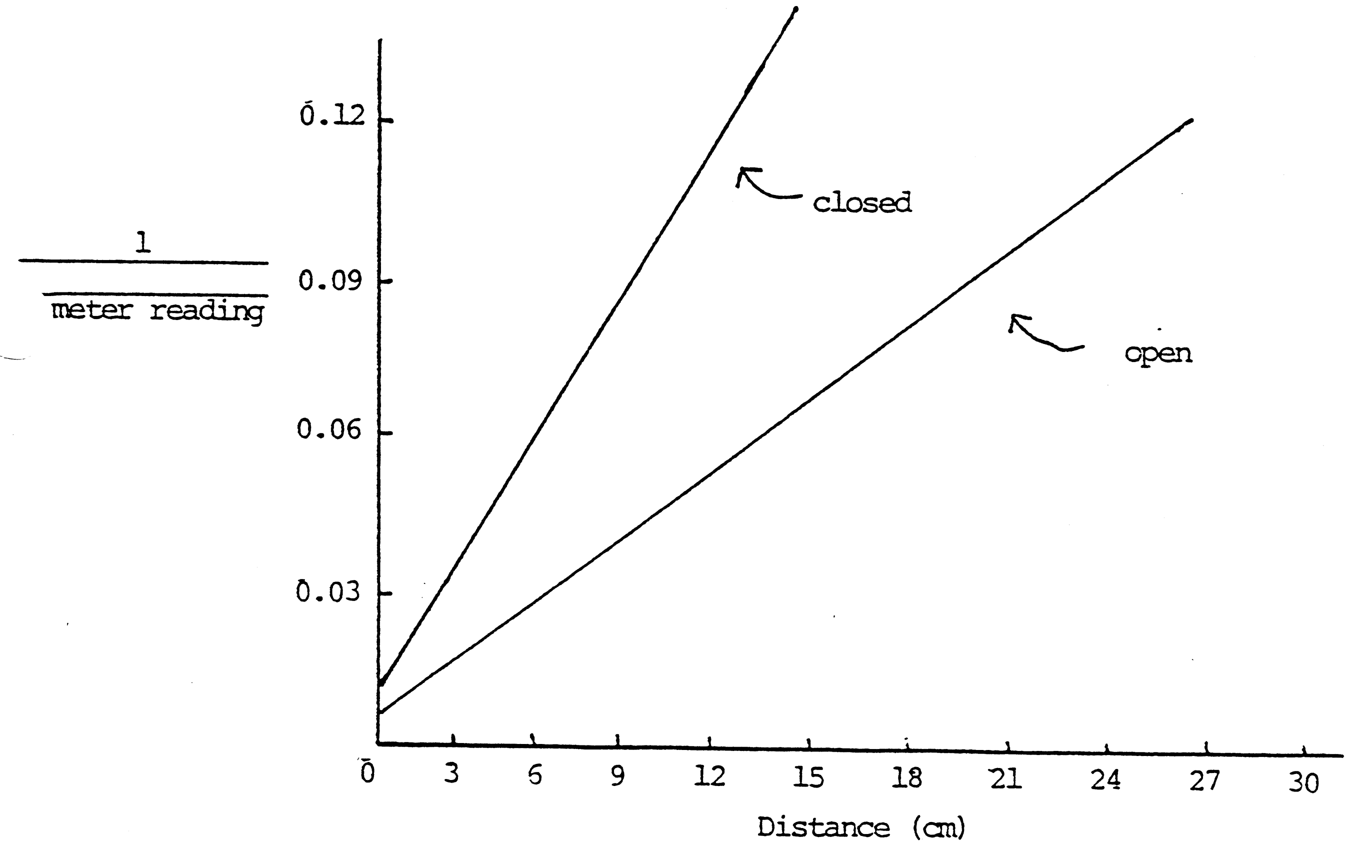

Figure I-2 Typical results of plotting $1/\sqrt{\text{meter reading}}$ vs. distance.

4) Are the intercepts on the distance axis non-zero? If so, why does this happen?

B. Time

A pocket dosimeter is a personnel radiation monitoring device that indicates the total radiation exposure a person has received. It is simply a charged capacitor that is discharged by the passage of ionizing radiaiton through it. By reading the charge on the capacitor at any moment one has a measure of the total integrated exposure (usually expressed in mR on the dosimeter scale). Let us use this device to explore another parameter of external radiation exposure, the time. Clearly the longer you remain in a radiation field the greater exposure you will receive.

Procedure

1) Place a fully charged pocket dosimeter at a distance from the ^{60}Co source corresponding to one of the distances used in part A of this experiment. Record the dosimeter readings as a function of time during the laboratory period.

2) In Table I-3 below, plot the dosimeter reading vs. elapsed time as in Figure I-3 (presented on the following page.)

Table I-3

Time	Dosimeter Reading

3) For an elapsed time of 1 hour, compare the dosimeter reading and that observed with the survey meter in Part A.

Dosimeter Reading (mr/1 hr. elapsed time) = ______________

Survey Meter Reading (mr/hr.) = __________________________

4) Comment on any discrepancies between the two readings.

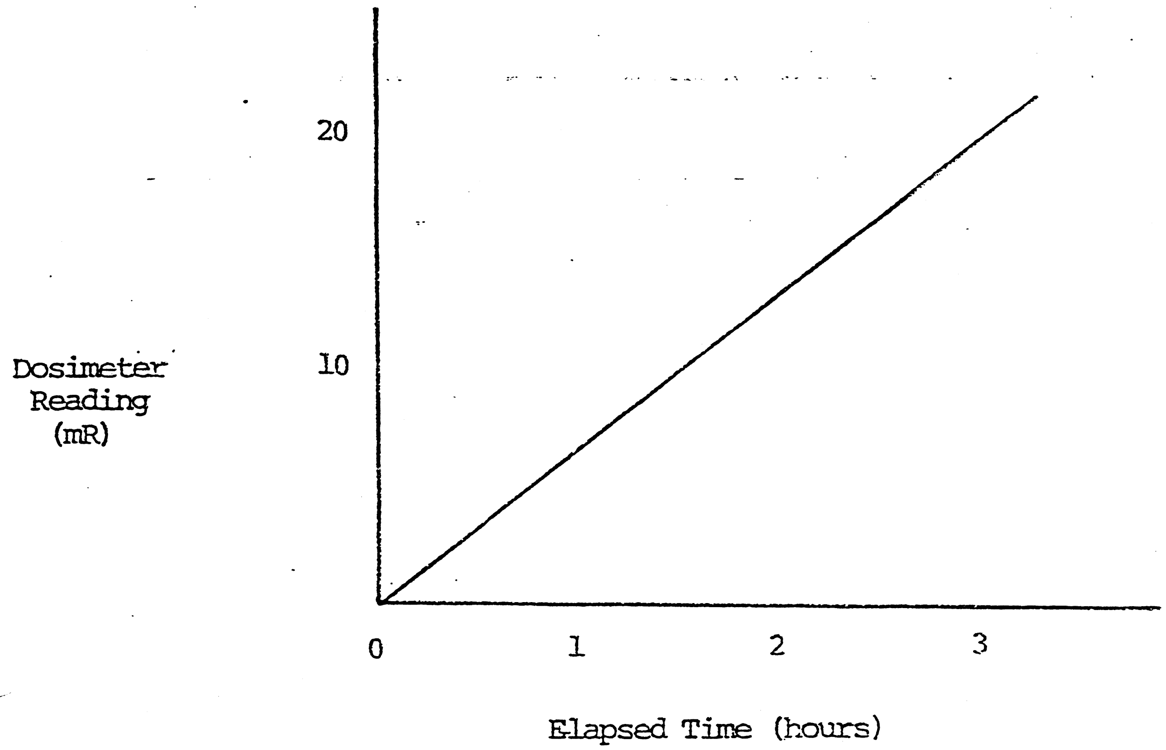

Figure I-3 Pocket dosimeter reading vs. time.

C. Shielding

As shown in Chapter 3, when γ-radiation passes through matter, it is attenuated according to the relationship

$$I = I_o \exp(-\mu x) \qquad \text{(I-3)}$$

where I_o is initial γ-ray intensity coming from the source, I is the intensity after passing through an absorber of thickness x cm and μ is the linear absorption coefficient of the absorber. One can show (as is done in Chapter 3) that

$$\mu = \frac{0.693}{x_{1/2}} \qquad \text{(I-4)}$$

where $x_{1/2}$ is the thickness of absorber required to reduce the γ-ray intensity by 1/2. Clearly, from examining equation I-4, one can see that the larger μ is, the more the γ-ray intensity will be attenuated, i.e., the better the shielding material. Let us try to verify some of these ideas concerning shielding external radiation experimentally.

Procedure

1) Set the survey meter some fixed distance from the source and measure the radiation intensity with the β-shield closed, recording the data in your lab notebook. The tabular format shown below is appropriate.

Absorber Thickness (cm)	Meter Reading

2) Place a 1/16" sheet of lead approximately 1/2 way in between the source and meter. Measure the radiation intensity and record it.

3) Place a second sheet next to the first and make another measurement. Continue adding lead sheets and recording data until the radiation intensity is ∿1/4 that with no absorber added.

4) Plot on semilog paper the log (meter reading) vs. absorber thickness as shown in Figure I-4.

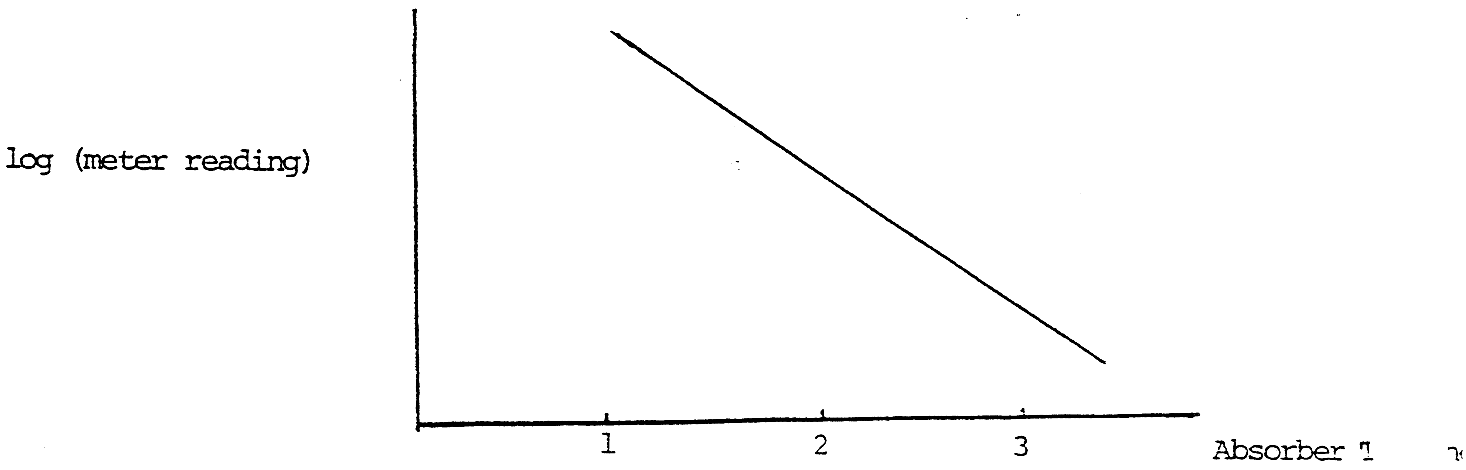

Figure I-4 Semilog plot of meter reading vs. absorber thickness.

How much absorber does it take to reduce the meter reading by 1/2?

$x_{1/2}$ = ______________________ cm

Calculate $\mu_{1/2}$

$\mu_{1/2}$ = ______________________ cm^{-1}

(The literature value of $\mu_{1/2} \sim 0.7cm^{-1}$).

Let us put all this information together. Three principles should have emerged from your laboratory investigation. They are:

1. Radiation intensity decreases with distance between source and detector. Specifically intensity decreases as ______________________________ ____.
2. Radiation exposure increases with the length of time, i.e., exposure increases ____.
3. Radiation intensity decreases with increasing shielding thickness. Specifically, the fraction of γ-radiation passing through an absorber of thickness x is ______________________________.

Thus to minimize radiation exposure, you put distance and shielding between you and the radiation source and work fast.