THE A. C. GILBERT COMPANY

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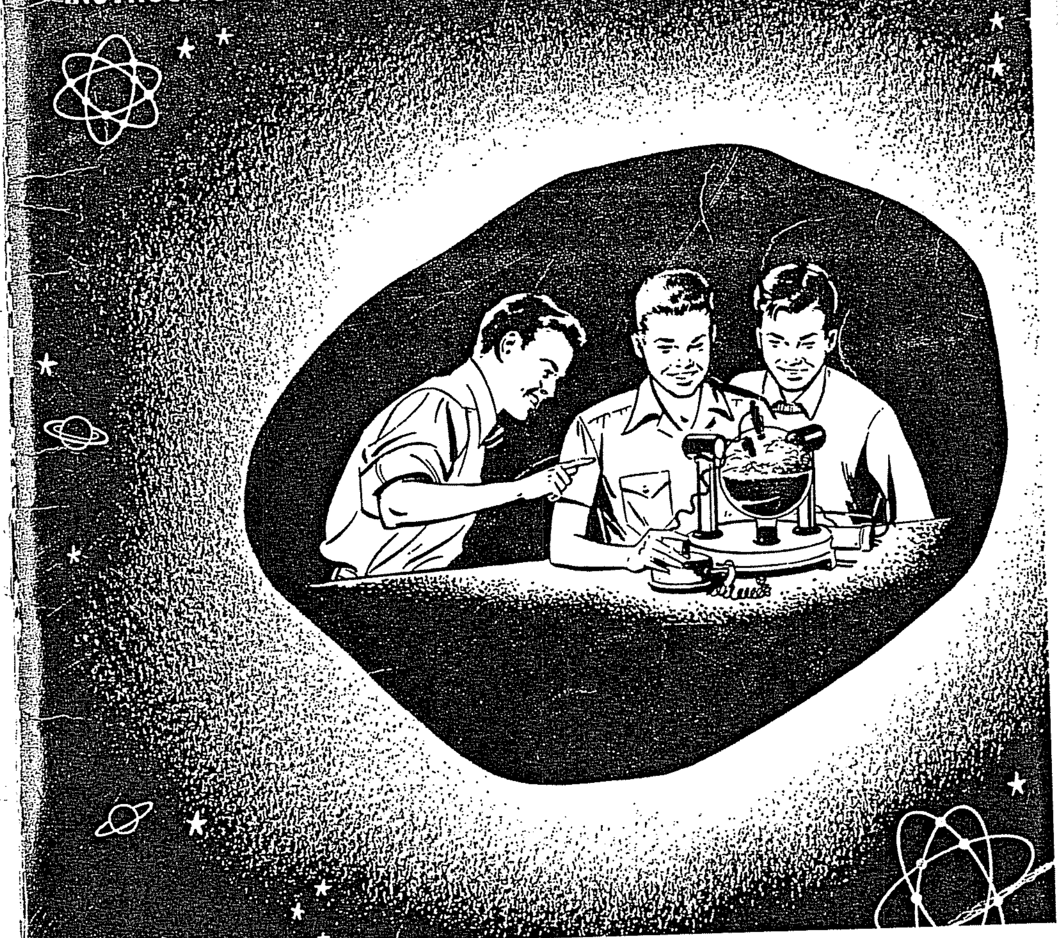
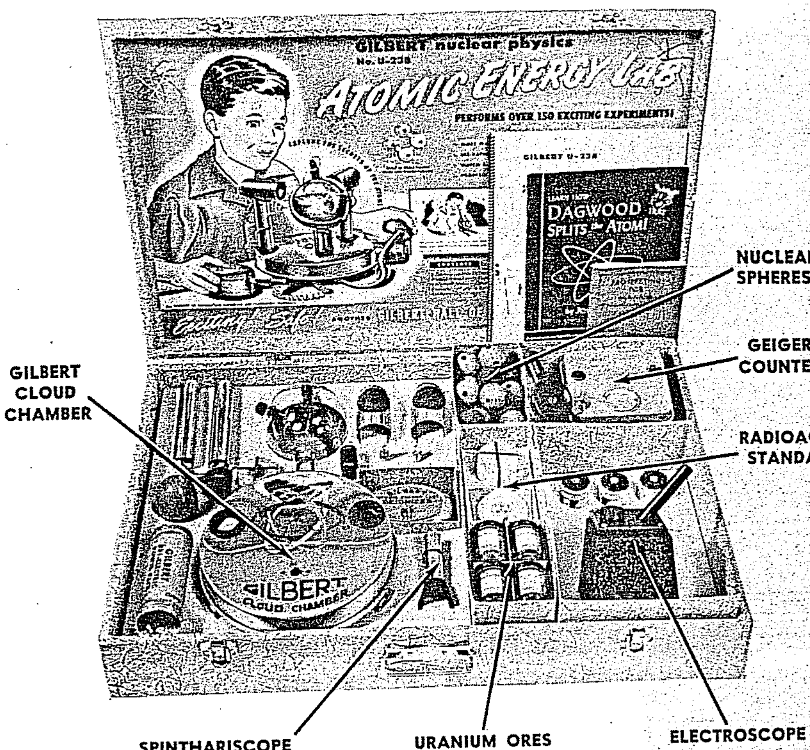
Form M2788

GILBERT Atomic Energy MANUAL

INSTRUCTIONS FOR OPERATING GILBERT ATOMIC ENERGY LAB



YOUR GILBERT ATOMIC ENERGY LAB AND ITS VARIOUS PARTS AND INSTRUMENTS



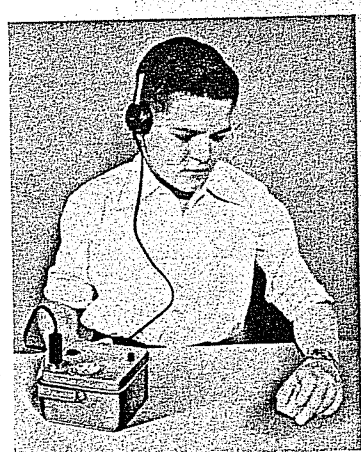


Figure 1-1. EXPERIMENTING WITH THE GILBERT GEIGER COUNTER.
Gilbert Radioactive Source is held near the Counter to produce a clicking in the headset. Neon tube flashes simultaneously with clicks.

SECTION I

EXPLORING WITH THE GEIGER COUNTER

One of the first things that will intrigue you when you open your Atomic Energy Laboratory is the Geiger Counter, which is located in the upper right hand corner of the box.

To operate your Geiger Counter, follow these steps. First, remove the circular cap on top of the counter for installation of the battery. Second, insert one of the flashlight batteries in this space, making sure that the positive terminal of the battery is pointing down. (The positive terminal can be distinguished by the small circular stud at the center of the end.) Now look for the on-off switch which is located on top of the box. Switch to the on position and allow your Geiger Counter to warm up. It is now ready to operate.

You can use your Geiger Counter in either of two ways; (a) You can count the number of flashes occurring in the neon lamp which is mounted flush with the rubber grommet in the lid of the box. (b) You can listen to the clicks in the earphone.

You will find several small plastic sources mounted inside your Atomic Energy Lab. One of these is marked Radioactive Standard-Gamma Source. Remove this source from the Lab and bring it close to the Geiger Counter. When you do this you will note that the number of flashes or clicks will increase rapidly until you can hardly count them. Removing the source will cause the clicking sound or the flashing light to slow down. Later on we will go into detail and explain what the clicks and flashes are and what they mean. Meanwhile, we will merely say that each click or flash corresponds to the detection of a radioactive ray going through the Geiger Counter.

One thing that you can immediately do with the Geiger Counter is to ferret out a hidden radioactive source. Let someone in your family hide the gamma source while you are in another room. Then, using the ferret, explore the room. Soon, by noting the increased number of flashes or clicks, you will be able to locate the hidden source.

If you have a luminescent dial wrist watch or pocket watch or any other luminescent material try bringing it close to your Geiger Counter. You will discover that your Geiger Counter will detect these things. In fact, there are a great many items that are in every day use which are radioactive. Some of them, indeed, have quite a powerful intensity.

There has been so much misinformation about radioactivity that we pause here to reassure you and your parents that the radioactive sources supplied to you are not dangerous in any way. They have been carefully designed by some of the nation's top scientists to be instructive and harmless. We assure you that no harm will come to you through daily contact with the radioactive sources supplied with your Atomic Energy Lab.

Figure 1-1 shows what is inside the Geiger Counter. You will note the long slender tube which is supported by two copper electrodes. This tube is the actual device which detects the penetrating rays and is known as a Geiger-Mueller Counter Tube. Now that you have an inside view of the Geiger Counter we can explain to you why the instrument hums when the switch is turned "On."

Although the Geiger-Mueller Counter Tube requires almost a thousand volts of electricity to operate satisfactorily, our only source of power is a 1-1/2 volt flashlight battery. Here is the way that we obtain the high voltage necessary from our low voltage source. First, we have a vibrator unit. This simple device chops up the direct current from the dry cell and converts it into pulsating current. You will notice that there are two coils wound on the vibrator and these together form a transformer. When the pulsating current feeds into the transformer it is boosted from a low voltage to a high voltage sufficient to operate the Geiger-Mueller Tube.

Anyone who uses a flashlight continuously knows that the battery will wear out. In the same way, your Geiger Counter will stop operating if you run it continuously for several hours. This does not mean that your instrument has burned out. It simply means that you must replace the flashlight battery. Any similar flashlight battery will be suitable. Just as a flashlight will work for weeks if it is used only for short periods of time, so, too, will the Geiger Counter run for a long time on a single battery if you use it for only a short time each day. You should remove the flashlight battery from the Counter if you are not going to use it for a long period of time. This will prevent battery leakage in the counter and insure longer life for your batteries.

The A. C. Gilbert Company has manufactured thousands of Geiger Counters and, while it has taken great pains to insure that each Geiger Counter will reach you in working condition and remain that way, it appreciates the fact

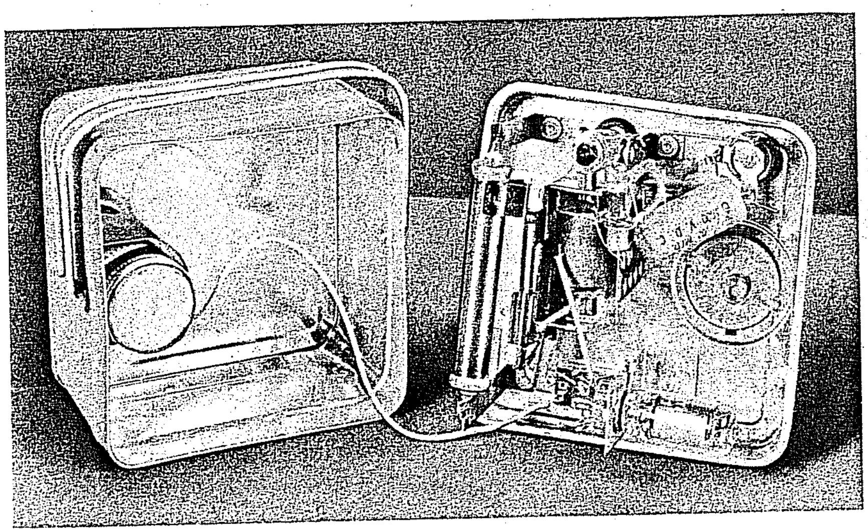


Figure 1-1. COMPONENTS OF YOUR GEIGER COUNTER

that out of the thousands of these sensitive instruments some will fail to function after a time. Here's what you should do in the event your instrument does not operate properly.

1) Make sure that the "On" switch is pushed to the "On" position.
2) Make sure that the battery has not worn out. Replace with a spare or a new battery in case you have any doubt.

If no hum from the vibrator is heard after these checks are made, the chances are that the vibrator has been damaged or has failed. However, it may happen that the vibrator will work properly but the instrument will not respond to the radioactive gamma source. Make sure that it is the gamma source that you are using. If the neon tube does not flash at all the Counter requires repair. If the neon tube flashes almost continuously in the absence of the radioactive source it also requires repair. Do not attempt to shake the box or otherwise fix the Geiger Counter. Return it to The A. C. Gilbert Company as per instructions given in the appendix.

MEASURING RADIATION WITH YOUR GEIGER COUNTER

While it is interesting to have fun with your Geiger Counter by hunting for hidden sources and showing the instrument off to your friends, it is far more interesting to make actual measurements as a scientist would. To go about this we first need a watch or a clock equipped with a sweep second hand. We start by seeing how our Geiger Counter behaves when there is no radioactive material around. The counting rate with no sources present is called the natural background of the instrument. It is very important for you to know the background count and to check this periodically to make sure that your instrument is performing properly. Record the number of counts for each 15 second period for an interval of five minutes. Your data should look something like that tabulated below:

	0-15 Seconds	15-30 Seconds	30-45 Seconds	46-60 Seconds	Total Seconds
1st Minute	3	4	2	3	12
2nd Minute	5	4	3	5	17
3rd Minute	4	4	3	3	14
4th Minute	3	3	5	3	14
5th Minute	5	3	5	4	17
				Total	74

To obtain the average counting rate, you must divide the total count 74 by the time interval, thus obtaining about 15 counts per minute. Note that in any one minute the counting rate may swing as high as 17 or as low as 12. This makes it clear that in order to obtain a reliable average figure we must take counts over a long enough time to iron out the variations which occur during any short time period.

You can do an interesting experiment by simply jotting down on a piece of paper the exact time (reading on a stop watch or a sweep second hand) when each count occurs. Take data for five one half minute intervals. The data you obtain should look something like that listed below:

1st Minute	2nd Minute	3rd Minute	4th Minute	5th Minute
5	3	2	4	1
9	7	5	6	7
13	11	11	16	14
19	18	13	24	21
24	23	21	29	27
30	25	23		
	30	27		
		30		

RANDOM OCCURRENCE OF COUNT

Note that the occurrence of a count is completely random; that is, there is no observable regularity to the time when a click occurs.

GRAPHICAL REPRESENTATION OF RANDOM COUNT

The random nature of the count can also be readily seen from a graph. This is what you do. On a piece of graph paper mark off a unit that is to represent a minute and divide this minute into smaller units which are to represent seconds. Now, by using your watch, time the occurrence of the counts of your Geiger Counter. As each count occurs make a line on your graph corresponding to the time that it occurred. When the minute has elapsed mark off another set of units and repeat the above procedure. When you have done this four or five times you will note by comparing the graphs that the pattern of counts on your graphs is not the same. This is what we call a "random count."

The background counting rate of your Geiger Counter should remain nearly constant even though you make the measurements on different days. You must make sure, however, that you always remove the radioactive sources from the vicinity of the counter when you make this measurement. It is also desirable to perform the experiment in the same place each time. The reason for this is that everything about us has some radioactivity and as we move to different places we are likely to encounter different amounts of radioactivity. Even the human body is slightly radioactive. The air we breathe contains small amounts of radioactive material. The earth and building materials contain more significant quantities of radioactive elements. No matter where we go we can never really be free from some small amount of radioactivity. We call this residual counting rate the radioactive background.

THE RADIOACTIVE SOURCES

Perhaps by now the user of the Atomic Energy Lab has been impatient to explore the properties of the radioactive sources marked alpha, beta, and gamma. First, bring the source labeled alpha up to the counter. Note that it has no recognizable effect on the counter. This should not disturb the user for there is nothing wrong with the source. It means that the type of ray emitted by this source is much different from the gamma ray. We call it the alpha ray. Alpha rays are easily absorbed in any solid substance or even in air and they are not able to penetrate the walls of the Geiger Counter.

The source marked beta does have an effect upon the Geiger Counter. In order to observe it, the source must be brought close to the Geiger Counter. Obviously the ray emitted from this source is more penetrating than the alpha ray, but it still is no match for the powerful gamma ray. We call these rays emitted from the beta source beta rays. We shall later learn that beta rays are simply high speed electrons. For the time being, however, we will concentrate our attentions solely upon the gamma rays.

One can have a great deal of fun playing hide and seek with the gamma ray source. Obviously, this game takes two or more people to play it. The person who is selected to find the gamma ray source is given the Geiger Counter and told to wait outside the room while the others hide the source. Then, after the source has been hidden, the outsider is invited in and told to look for it. Prizes can be awarded to the person who finds it in the shortest time.

HOW FAR AWAY CAN THE SOURCE BE DETECTED?

Let us see how far away from the source we can get with the Geiger Counter and still detect the presence of the source through an increased counting rate. To perform this experiment, place the source in the open, let's say in the center of a large room. Then lay a tape measure in a straight line away from the source. Starting at a distance of six feet away from the source, make a measurement of the counting rate. You will find that at this distance the rate is about that of the background count. Now, move the source a foot closer to the Geiger Counter. The Geiger Counter tube inside the Geiger Counter is located almost entirely under the words "Model U239" and this is an excellent spot to measure from. We can then speak of the source to counter distance in exact terms. Move the source in steps of a foot or a half foot closer to the Geiger Counter. Record the counts per minute for each distance. You should be able to take measurements up to six inches from the Geiger Counter.

At this point the counting rate will be very high. The count may be over 200 counts per minute. (Counts per minute is often abbreviated to read c.p.m.). You need to use a trick to count so rapidly. On one of your data sheets, make a large cross so that you can record data in four groups. In each quadrant, or section, of the cross make a pencil dot for all counts occurring in a 15 second interval. In this way you do not need to keep counting, but simply jab at the paper every time a click or a flash occurs. By dividing the data into four 15 second intervals, you can look at the consistency of your counting. At your leisure you can count up the number of dots in each quadrant and, with a little practice, you will be able to count 200 c.p.m. with fair accuracy.

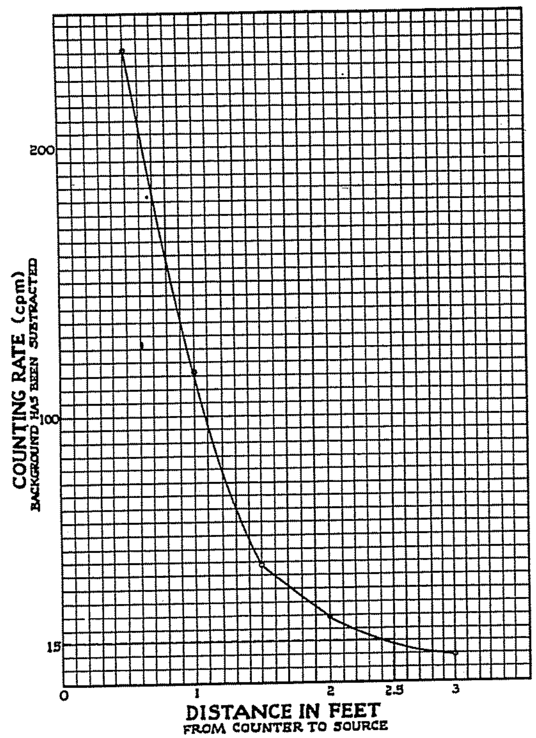


Figure 1-2.
COUNTING RATE AT VARIOUS DISTANCES FROM THE GAMMA SOURCE

From each reading, subtract the background counting rate. Your data should then appear as follows:

Distance	Counting Rate (C.P.M.)
6"	236
1 ft.	104
18"	43
2 ft.	23
3 ft.	10
Greater than 3 ft.	Close to Background Count

Since the counting rate really expresses the number of gamma rays at any one point we may call this the intensity. Thus, we have obtained experimental data on the intensity of gamma radiation (rays per minute) from a small source for various distances away from this source.

We have taken data for a number of distances. Now, we shall put this data on a chart or graph so that we can read off the intensity or counting rate at any distance. To do this we take a piece of graph paper, preferably one ruled with large squares. We mark off on the horizontal scale the distances in feet, which represent the distance separating the source from the counter in our experiment. Then on the vertical scale we mark off appropriate units for the

counting rate. If you are not familiar with the technique of plotting points on graph paper and if it is not readily apparent to you how this is done, you may check with your science teacher for some assistance.

To plot our data on the graph, we take a given set of readings, say 43 c.p.m. at 18". We run a pencil along the horizontal scale until we find 18" (1.5 feet). Here we make a mark. Then we run a pencil line upward (parallel to the vertical scale), stopping at a point which is opposite 43 on the vertical scale. Similarly we establish points for the other sets of data until all the data is plotted. Now we can sketch in by hand a smooth curve connecting all these points.

Now, you can estimate the intensity of gamma radiation at any point from six inches to thirty six inches. It is done like this. From some random distance on your horizontal scale draw a line upward until it intersects the curve. From this point draw a line parallel to the horizontal scale over to the vertical scale. At this point on the scale you can read off the counts per minute, which is the approximate count for your random distance. Thus one reads an intensity of 15 c.p.m. at a distance of 2.5 feet. Figure 1-2 illustrates the relationship between the distance from the Geiger Counter to the gamma source and the counts per minute (c.p.m.).

Relationship Between Intensity and Distance

The most obvious fact to learn from the curve in Figure 1-2, or the curve that you have drawn, is that the intensity (c.p.m.) of gamma radiation drops off very rapidly with increasing distance from the source. Let us look a little more closely at the exact way in which this intensity drops off and see if there is any rhyme or reason to it. The intensity at one foot is roughly 100. If we double the distance we find that at two feet the intensity drops to about 1/4th of its one foot value. Thus, by doubling the distance, we decrease the intensity by a factor of 4, or, to put it another way, the number of counts is 1/4th as many when the distance is doubled. There are only about 1/9th as many counts when the distance is tripled. Examine your curve or Figure 1-4 and you will see that this is true. Whenever a quantity behaves this way, it is said to obey the Inverse Square Law.

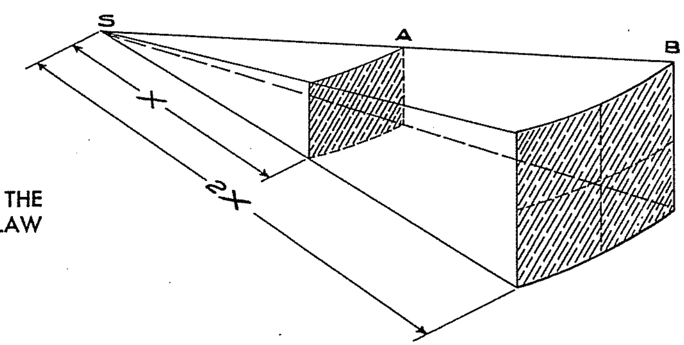


Figure 1-3.
UNDERSTANDING THE INVERSE SQUARE LAW

The Inverse Square Law is one which is good for more than just gamma rays. It applies to radiation emitted by an ordinary light. You can verify this fact by taking a light meter such as the direct reading type used by photographers and take readings of the light intensity at various distances from a lamp bulb. You should find that the observations will confirm your experience with gamma rays.

By glancing at Figure 1-3 you may be able to see a little more clearly how the Inverse Square Law works. We have a source located at S. At some arbitrary distance which we shall call X, we measure the counts or radiation intensity. Let us say that 100 rays pass through the area at X distance from the source. Now looking at the next area which is 2X, or twice as far from the source as the first area, we see that it has an area 4 times as large as the first area.

As the 100 rays are still radiating in the same direction, we find that the 100 rays are passing through 4 times the area, while in any small portion of that area there are only 1/4th as many rays as before. So it may be concluded that, as the distance is doubled, the intensity, or the number of rays passing through the same amount of space, is divided by four or 1/4th as much. The same situation would prevail if the distance were tripled, except that there would be 3 squared or 9 times the area and the intensity would be divided by 9 or be 1/9th of the original intensity.

More About Gamma Rays

The experiment which we have done with gamma rays may not yield the same data to all observers. To check this assertion, try making the same kind of measurements varying the local conditions. Perform the experiment first on a concrete floor. Then, prop your source and counter up on two cardboard boxes so that you make the experiment up in the air away from heavy materials such as concrete. You will observe differences and they will depend upon precisely what solid objects are close to the gamma source and to the Geiger Counter. Gamma rays can penetrate concrete and are also scattered by concrete.

Absorbing the Gamma Rays

So far we have investigated the effect which the distance from the source to the counter has upon the counting rate. Now, let us turn our attention to the problem of seeing what effect various materials have upon the counting rate. One of the most common materials that one usually has around the house is wood, so we shall use this for our first experiment of measuring the absorption of gamma rays.

For this experiment it will be most useful if one selects pieces of wood (if wood is not readily available, you may use books instead) one inch in thickness and larger than the width and depth of the Geiger Counter. Set up the equipment as shown in Figure 1-4. First, with no slabs of wood in between

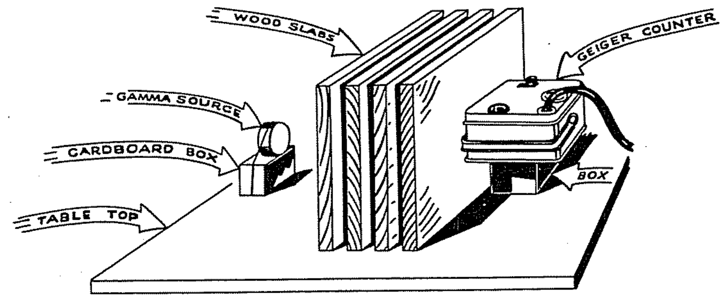


Figure 1-4.
HOW THE GAMMA RAY ABSORPTION EXPERIMENT IS SET UP

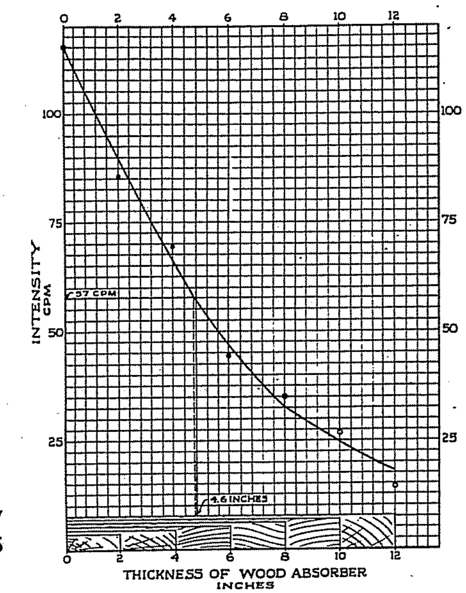


Figure 1-5.
GRAPH SHOWING HOW WOOD THICKNESS AFFECTS INTENSITY

the counter and source, measure the counting rate and put this value in your note book as shown below:

Thickness of Wood	Counting Rate* (C. P. M.)
0 Inches	115
3	86
4	69
6	44
8	35
10	27
12	14

*Counter to source distance = 12 inches

Then, insert one piece of wood and measure the counting rate carefully. Repeat this measurement for each piece of wood added until finally the counting rate is so low that it is almost the same as the background count.

By inspecting the various counting rates we can see that the intensity of the gamma rays drops off sharply. To be more scientific, we have to resort to graphical means of representing the data which we have thus obtained.

Figure 1-5 shows just how we construct a simple graph. The horizontal scale represents the thickness of wood used as an absorber. The vertical scale shows the counting rate. As before, we plot each set of points on the graph remembering that we must use the corrected counting rate; that is, the measured counts per minute minus the background count. When we have the string of points spotted on the graph, we draw a continuous line through them as shown in Figure 1-5.

You may find that your points if connected by a series of straight lines would make a rather ragged curve. This is due to the uncertainty in each measurement plus effects due to the scattering of the gamma rays. You may avoid this difficulty by drawing a smooth curve on the graph which seems to come closest to all the points.

Half Thickness

Now that we have a smooth curve we can pick off the graph the intensity for any thickness of wood or we can determine what thickness of wood is required to reduce the initial intensity (with no absorber) by a given amount. The thickness of absorbing material which just reduces the counts per minute by 1/2 is called the half thickness. Examine Figure 1-5 and you will note that the number of counts per minute is halved at a thickness of absorber material of about four and one half inches. Check the graph that you have made, and determine the half thickness of the material that you used as an absorber.

While you may not have realized it in doing the experiment on absorption, it is important to keep the source and the instrument at a fixed distance from each other. If one did the experiment by simply sandwiching the absorber between the counter and source then no simple relation between absorber thickness and intensity would be obtained. Every time a new absorber would be added to the sandwich the relative distance and therefore the counting rate would be changed. The size of the absorber itself has some influence on the observed intensity for some of the radiation is scattered and introduces a complicating effect.

As a gamma ray whizzes through matter it completely disregards the atoms of the matter through which it is passing; that is, until it finally makes one collision with a single atom. Then it hands over all of its energy to an electron in this atom. Thereupon, the electron is quickly stopped because it, unlike a gamma ray, does not disregard the influence of atoms around it. When a gamma ray is emitted from the gamma source, it may either travel through a fraction of an inch in the wood or it may travel through all twelve inches. On the average, considering the mass behavior of thousands of gamma rays, there is a higher probability, however, that the gamma ray will be stopped in the first few layers of the absorber.

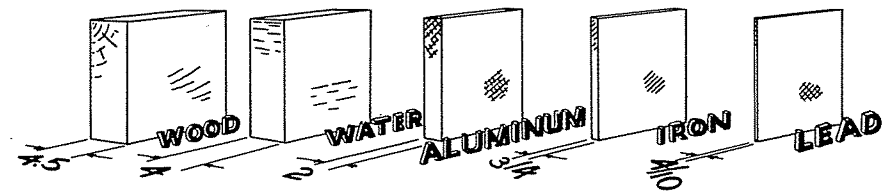


Figure 1-6. COMPARING DIFFERENT MATERIALS AS ABSORBERS
Shown above are the half-thicknesses of wood, water, aluminum, iron, and lead. Thus ¾ inch of iron will absorb as much gamma radiation as 4 inches of water.

Different Kinds of Absorbers

Let us now see how materials other than wood work as absorbers. Perhaps the easiest material to obtain is iron or, in some cases, aluminum may be readily available. Such objects as a frying pan or other kitchen utensils are good examples. Other obtainable materials with which you can experiment are tin, glass, crockery, rubber, plastic, cloth, paper, sand, brick, lead, brass, putty and so on.

Using absorbers of whatever material you can obtain repeat the absorption experiment. As before, plot your results on a graph. Note that the same kind of curve is obtained as we found for wood but that the half thickness value for iron or aluminum is much less than for wood. If you have sheets of lead available, you will be able to verify that the half thickness is still less for this heavy element. Our use of the half thickness is a convenient yardstick by means of which we can compare the gamma ray absorption in different materials. By it we can say that one inch of wood is equivalent to one-tenth of an inch of lead. In other words, lead absorbs gamma rays 10 times better than wood. Now, if you had access to all the different common elements and could carry on experiments with them, you would be able to obtain half thicknesses for these and make a graphical comparison such as is shown in Figure 1-6.

Physicists customarily use an abbreviated unit for measuring gamma ray energy. This unit is called the Electron Volt, and more often a larger unit, one million electron volts is used. This is abbreviated one MEV. This unit we shall use in talking about gamma rays. Our Atomic Energy Lab gamma source for example is found to emit a 1.14 MEV gamma ray.

The advantage of having a convenient unit for talking about gamma rays is that we no longer have to be so vague as to say, "In this experiment we use a soft gamma ray..." Rather we can be accurate and say "Here we use a 0.35 MEV gamma ray...." The larger the MEV of a gamma ray, the greater is its half thickness and the greater is its penetrating power. Gamma rays having energy above one MEV are usually thought of as being high energy rays.

RADIOACTIVE ORES

Included with your Atomic Energy Lab are four glass bottles containing samples of radioactive ore. Sample No. 100 contains some pieces of Carnotite taken from the Colorado plateau region. Carnotite is bright yellow in color. Your sample, however, may be of greyish or brownish cast due to the presence of iron. Consult your booklet, "Prospecting for Uranium," for more information about the occurrence of this ore.

To make a rough measurement of the radioactivity of your sample, place the glass bottle next to the Geiger Counter, locating it as close to the Geiger tube as possible. The counting rate that you will obtain will depend upon the strength of your particular sample. It should be somewhere between 35 and 100 counts per minute.

Make the same test to determine the radioactivity of the other samples and record the data in your note book. You will probably find that the Carnotite is the most active of the samples with the Autunite being the next most radioactive. The Torbernite and Uraninite will be quite weak and may only register about 50% over the background rate.

All these samples except the Autunite have been sealed in bottles so that you will not open them. The Autunite is not sealed and you can remove the pieces from the jar. The other samples have been sealed for they tend to flake and crumble and you would run the risk of having radioactive ore spread out in your laboratory. This will raise the level of the background count. The Autunite is sufficiently hard so that it does not crumble readily and you may handle it outside of the container. It is well, however, to place pieces of the ore in a thin paper sack so that small bits of the ore do not contaminate your laboratory.

Place the packaged Autunite next to the Geiger Counter and again record the counting rate. You should note a very decided increase in the count. Your counting rate should increase at about a factor of four or five. How do we account for this big increase? It is true that we have spread the old sample out more so that more of it is closer to the Geiger Counter. This, however, would not account for such a big increase. We must conclude that the ore emits some kind of radiation which is absorbed by the thick glass wall of our sample bottle. We can verify this by slipping a plate of glass in between our Geiger Counter and this Autunite and determining the counting rate again. This time we will find that it drops off, showing that we were correct in assuming that some other easily absorbable radiation is present. This type of radiation consists of beta rays which are also emitted by our beta source.

Introducing Beta Rays

Up until now our experiments have been mostly with the gamma rays. We deliberately refrained from introducing the beta source in order not to confuse you by meeting many new particles in the early part of your experimenting. Now we shall describe beta radiation very briefly, leaving until a later chapter the more detailed discussion of the subject.

Absorption of Beta Particles

Let us first measure the absorption of beta particles in some light material such as cardboard. Take some stiff cardboard, not of the corrugated variety and cut up a dozen or so pieces large enough to cover the beta source. Prop up the beta source by taping it to a little paper box and face it toward the side of the Geiger Counter which contains the Geiger Counter tube. Place the Geiger Counter about 12 inches or so from the source. At this distance you will get a counting rate of about 100 or more c.p.m. Now place one piece of cardboard after another between the source and the counter taking a reading for each absorber added. You will find that a one centimeter layer (a little larger than 1/3 of an inch) of cardboard absorbs most of the beta rays. Twice as many centimeters of cardboard absorbs the beta rays completely. Use the plastic rule supplied with your Atomic Energy Lab in order to change from inches to centimeters.

As another experiment you can substitute thin sheets of metal for the cardboard and note that the beta particles are completely stopped by as little as seven-tenths centimeters of aluminum or three-tenths centimeters of iron. From this we can conclude that our Geiger Counter would not be able to detect beta rays at all if the Geiger Counter tube were packaged in a heavy steel box.

In working with your Geiger Counter and beta source you may often find that an experiment will produce a puzzling result, or two experiments which you think should produce the same result will yield inconsistent data. For example, if you place the beta source a given distance from the Geiger Counter and have the beta source suspended in air so that nothing solid is close to it, you may find that the results with the Geiger Counter are considerably different from those obtained with the source placed upon a table top or backed with wood. Furthermore, even in air the course of a beta particle is not a straight line, but an irregular path. Thus, in making absorption measurements, it becomes important that you consider where you place your absorber in respect to the source and to the Geiger Counter. Furthermore, the size of the absorber becomes important since this will affect the scattering of the beta particles.

PROSPECTING FOR URANIUM

As a result of our war-time development of Atomic Energy the element uranium has assumed great importance in our national affairs. Uranium is a very heavy metallic element, but it does not occur in metallic form in nature. Nevertheless, there are over 100 minerals which are uranium bearing. These are widely distributed over the face of the earth. There are, however, only a very few deposits of uranium ore which are rich in uranium. Most of the uranium which has been mined has been taken from veins of pitchblende located as follows: Shinkolobwe in the Belgian Congo, Eldorado in Canada, and Joachimsthal in Bohemia. In these localities, especially in the Belgian Congo, uranium occurs in very rich deposits.

A prospector equipped with a Geiger Counter can use his instrument as an aid to discovering deposits of uranium ore. There are, however, some very definite difficulties in prospecting for uranium and you should not feel that you can dash out and discover new deposits of the precious ore. First, while uranium is a relatively abundant element (ranking with lead in terms of abundance) it is usually found in very little concentrations so that detection is difficult. Secondly, the ore may be covered over with non-radioactive rock in which case the radioactivity of the ore itself is smothered by absorption in this rock. The booklet entitled "Prospecting for Uranium" included in your Atomic Energy Lab contains details about uranium prospecting. The booklet is an official one prepared jointly by the Atomic Energy Commission and the U. S. Geological Survey. No matter where you go on the surface of the earth, you will find that your Geiger Counter never ceases to have a steady background counting rate. By and large this background rate does not vary much from one place to another, although, if you happen to be standing near a pitchblende deposit the rate would be increased. If we do not consider such a special case we know that the background is ordinarily fairly constant. It must be due to radiation in the immediate vicinity of the counter.

Suppose we list the various sources of radiation which may cause clicks in the Geiger Counter:

1) We know that radioactivity in the earth bombards the counter.

2) We know that building materials contain a small fraction of radioactive substances which also contribute to the counting rate.

3) We know that the materials in the Geiger Counter itself are very slightly radioactive and give rise to counts.

4) Finally we know that there is a slight amount of radioactive material in the air and human beings which might contribute to the counting rate.

SHIELDING

In order to eliminate some of these sources of radioactivity let us surround the Geiger Counter with layers of heavy substances on all sides. Allow the cord to the ear phones to come out one side of shielding material so that the counting rate may be measured. Lead is an ideal substance for you to use for this experiment, but since you may not have this in your home, you may substitute another material such as iron or copper. If you happen to be an apartment dweller with no such items at hand, then you may perform the experiment in your science laboratory at school. Shielding the counter on all sides with an inch or two of solid lead, or with a thicker layer of less dense material, would be expected to reduce the radiation from sources in the vicinity of the counter. It would not, of course, shield against the radioactive materials in the counter itself, but, we can easily show by using another Geiger Counter that the radioactivity of the instrument itself is very small.

Make a careful measurement of the counting rate with the shield in place. Count for at least 10 minutes in order to get a good average rate. Then, make a similar measurement of the counting rate with no shield around the counter. You should obtain a definite decrease in counting rate when the

shielding is in place. The exact amount of the decrease will depend upon the amount or type of shielding, but in general a thick shield on all sides should decrease the counting rate by about a third.

Since we have successfully reduced the effect of radiation from the surroundings we are justified in asking what the Geiger Counter registers when it is shielded. One might suspect that the radioactivity in the shielding material might be the culprit, but we know from experience that lead is not radioactive so we can eliminate this as a contributing factor. What then do we have left as the cause of the remaining clicks in the Geiger Counter?

Evidently the radiation which continues to cause the Geiger Counter to click even with very heavy layers of lead or iron around it is much more penetrating than the rays which are emitted from our radioactive sources. Scientists, such as Robert A. Milikan and Arthur H. Compton have devoted much of their life work to the study of these very penetrating rays which we shall call Cosmic Rays. These rays are quite different in their nature from gamma rays. They are actually sub-atomic particles traveling with very high speed. These new particles are called Mesons although the name Mesotron is sometimes used too.

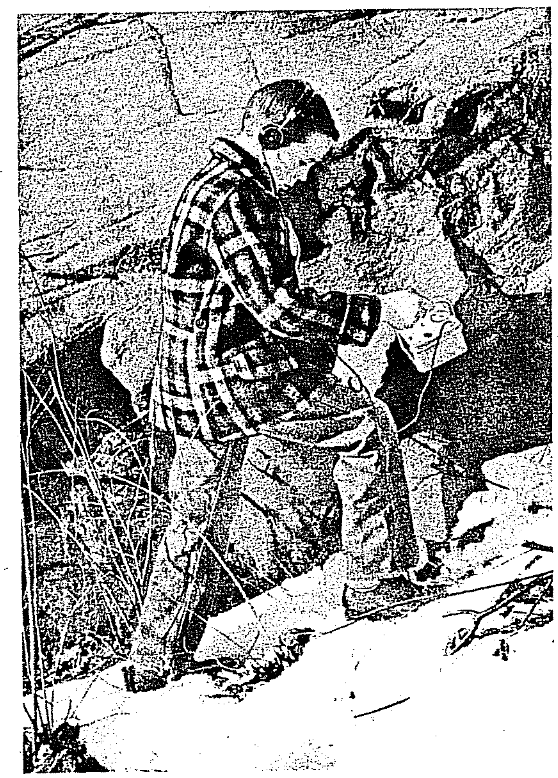


Figure 1-7.
YOUNG PROSPECTOR HOLDING THE GILBERT GEIGER COUNTER NEAR A ROCK FORMATION TO TEST FOR RADIOACTIVITY.