Activity of Radioactive Materials

The **activity** (how radioactive it is) of a radioactive material can be measured with a Geiger-Müller (GM) tube. The GM tube can be used to count how many atoms in the material experience a radioactive decay each second. Each of these decays is recorded in the **count rate** reported by the GM equipment.

The **activity** is a radioactive material **is the number of counts per second** it produces.

1 count per second (cps) = 1 Becquerel (Bq)

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If a radioactive sample is monitored
with a GM tube and a count rate of
1200 counts per second is obtained,
then we say that the activity of the
sample is 1200Bq.
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The activity of all radioactive materials decreases over time. Some materials lose their activity very quickly (in less than 1s) while others can remain radioactive for thousands of years.

If we had a piece of radioactive material, we would not be able to say which of the sample's atoms would be the next one to decay and produce radiation. However, plotting the decay of **any** radioactive material against time always produces the same shape of curve, see the graph below.
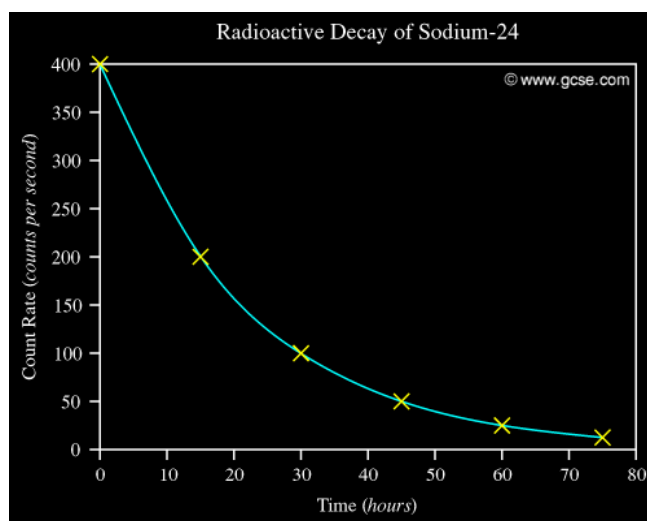
An example of a radioactive decay curve

Look again at the graph on the previous page. Each of the yellow crosses represents a halving of the count rate, e.g. from 400cps to 200cps, from 100cps to 50cps.

Now look at the time axis of the graph. Notice that the time period between each of the yellow crosses is 15 hours. This tells us that the count rate of Sodium-24 halves every 15 hours. In other words, the activity of Sodium-24 is halved every 15 hours.

We can summarise this by saying that Sodium-24 has a **half-life** of 15 hours.

The time it takes for the activity of a radioactive material to drop by half is called the half-life of the material.

Each different radioactive material has it's own individual half life. It doesn't matter if the half-life is short (<1s) or long (1,000 years). Every time a half-life passes, the activity of the material is halved.

We'll try an example now.

Example:

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A radioactive chemical has an activity of
10,000Bq.  What is the activity of this
chemical after 2 half-lives have passed?
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Solution:

	1 half-life		**2 half-lives**	
10,000	$\longrightarrow$	5,000	$\longrightarrow$	2,500
	activity ÷ 2		**activity ÷ 2**	

After 2 half-lives, the activity is 2,500Bq.

Notice that our example didn't even say how long the half-life was. We just used the fact that activity is halved each time a half-life passes!

Try these examples on your own (answers on last page).

1. A scientist finds a piece of radioactive rock with an activity of 800Bq. What will be the activity of this rock after 5 half-lives have passed?

2. The radioactive source used to sterilise medical equipment being manufactured in a factory has an activity of 200kBq (200,000Bq). Calculate the activity of this source 4 half-lives later.

Now we'll look at an example where we know the half-life.

Example

A radioactive sample in a laboratory has a half-life of 10 days. If the sample has an activity of 4800Bq when it is returned to the safe, what will be it's activity when it is next used 40 days later?

Solution:

$$\text{Number of half-lives} = \frac{\text{time}}{\text{half} - \text{life}}$$

$$= \frac{40 \, \text{days}}{10 \, \text{days}}$$

$$= \underline{4}.$$

So 4 half-lives have passed.

Now we calculate the activity 4 half-lives later.

Half-lives: **1**   **2**   **3**   **4**
4,800 ——→ 2,400 ——→ 1,200 ——→ 600 ——→ 300
   activity ÷ 2   activity ÷ 2   activity ÷ 2   activity ÷ 2

So after 40 days, the activity of the sample is <u>300Bq</u>.

Now try these questions: (answers at end)

3. A scientist prepares a radioactive solution with a half-life of 36 hours. Using a GM tube, the scientist says the liquid has a count rate of 72kBq. What will be the activity of the solution (in Becquerels) if it is measured again in 108 hours?

4. A radioactive material with a half-life of 2 days is found to have an activity of 1500Bq. What was the activity of this material 4 days ago?
(use the same method but work backwards)

Calculating the half-life

If you have a lot of information about the radioactive decay of a material, such as times and count rates, then it is possible to find the material's half-life by drawing a graph, similar to the Sodium-24 graph we saw earlier.

However, we normally don't have enough information to draw a graph and so we need another method to **calculate** the half-life.
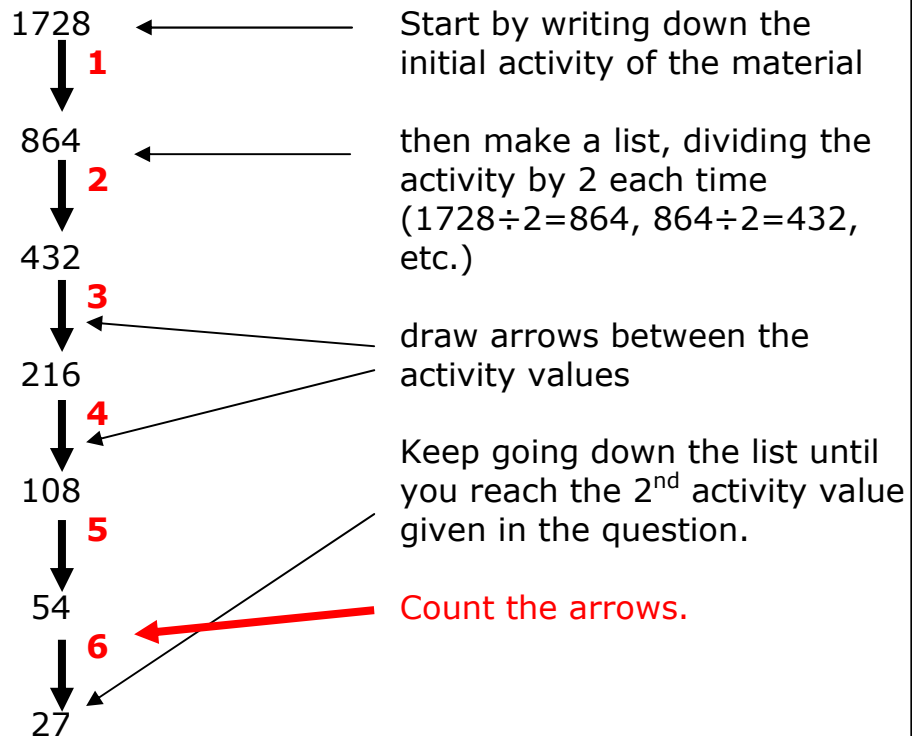
To see how it works, let's try an example (see next page)

Example:

    The activity of a radioactive material
    is 1728Bq. After 24 hours, the activity
    has fallen to 27Bq. Calculate the half-
    life of the radioactive material.

Solution: Comments:

        1728 ←─────────────────   Start by writing down the
          1   initial activity of the material

         864 ←─────────────────   then make a list, dividing the
          2   activity by 2 each time
                                      (1728÷2=864, 864÷2=432,
         432   etc.)
          3
                                      draw arrows between the
         216   activity values
          4

         108   Keep going down the list until
          5   you reach the 2nd activity value
                                      given in the question.
          54
          6 ←─────────────   Count the arrows.

          27

There are 6 arrows, so 6 half- ←──   **The number of arrows is**
lives have passed.   **the same as the number of**
                                      half-lives that have passed.

                         time
Half-life = ──────────────────────
            number of half −lives
                                      We know from the question it
                                      took 24 hours for the activity
              24   ←─────────────   to fall to 27Bq.
        =   ────
               6

So half-life = **4 hours**

Now see if you can work through these questions using the same steps.

5.   A radioactive chemical is prepared in a laboratory. The chemical has an initial activity of 272kBq. The activity of the chemical is rechecked 3 hours later and found to be 17kBq. What is the half-life of the chemical?

6.   The activity of a radioactive material is 344Bq. Two days later, the activity of the same material has fallen to 43Bq. Calculate the half-life of the material.

Answers to problems

1.   25Bq
2.   12,500Bq (or 12.5kBq)
3.   9kBq (or 9,000Bq)
4.   6000Bq (or 6kBq)
5.   45 minutes
6.   16 hours