RADIO-CARBON DATING

IT is well known that the phenomenon of radioactivity can be successfully applied to fix the age of materials, such as rocks and minerals, which contain radioactive elements. The method is based on the fact that the radioactive disintegration of nuclei follows strictly the laws of statistical probability and is wholly unaffected by external factors such as temperature, pressure, physical state, chemical combination, etc. The characteristic factor used in this age-determination is the 'half-life' period of the radioactive nucleus. It represents the time it will take for the amount of the radioactive material present at any instant to be reduced to one-half by radioactive decay. These 'half-lives' are widely different for different radioactive materials. For some they are small fractions of a second, and for others they are several thousands of millions of years. To tell the age of an object which contains some particular radioactive element, it is only necessary to measure what fraction of its original content has decayed away, whereupon a knowledge of the 'half-life' of the radioactive element concerned will enable one to calculate the age of the object.

In practice, it is necessary to choose an atomic nucleus whose 'half-life' bears some correspondence to the age it is intended to measure. Thus radioactive decay carbon, C 14, which has a 'half-life' of 5,570 years, can only conveniently be used, with all the recent refinements of measuring techniques, to measure ages up to about 50,000 years, for after a greater interval so much of the original material would have disappeared that the accurate measurement of what was left would be difficult. Uranium, on the other hand, has a 'half-life' of 4,500 million years. This makes it suitable as a means of measuring the ages of rocks formed at the beginning of the earth's geological history. It also follows that of the radioactive elements which may have been in existence when the earth was formed only those with the longest 'half-lives' will still remain in existence. This fact explains why plutonium whose 'half-life' is a few thousand years only, is now such a minute constituent of uranium-bearing ores. At first sight this would seem to imply that radioactive dating would have to depend entirely on longlived radioactive materials and thus it would only be suitable for the measurement of ages measured in hundreds of millions of years. Fortunately this is not so. It turns out that some radioactive materials occur naturally on the earth because they are being created as quickly as they can disappear by spontaneous decay. One is radioactive carbon, C 14, and another is tritium, H 3.

Carbon 14, which has, as mentioned above, a 'half-life' of 5,570 years, is formed by the interaction of secondary cosmic ray neutrons on nitrogen atoms in the high atmosphere of the earth, at a height of 40,000 feet. From there the material is carried as carbon dioxide throughout the atmosphere until it becomes distributed more or less uniformly and indistinguishably from ordinary carbon in the oceans, and becomes incorporated in the structure of all living things.

This uniform mixing of radioactive carbon through the "Biosphere" of the earth provides one of the essential qualities which make it possible to use the substance as a means of dating. It has been calculated that there are something like 80 metric tons of radioactive carbon on the surface of the earth. This means that every gram of ordinary carbon taken from the atmosphere or from living materials should contain such an amount of C 14, that 16 atoms of it should break up by radioactive decay every minute. The products of this decay are an electron and a nitrogen atom.

The uniform distribution of radio-carbon only takes place within living matter however. Trees which have died no longer continue to absorb it and so the radio-carbon which they may have contained just before death continues to decay away according to the well established disintegration law. After 5,570 years only half of the original amount will be left. This leads directly to the method of measuring the ages of such things as archæological or geological specimens of organic materials. One has to measure the content of radio-carbon in them and to compare this with the amount that would have been present if the material were still alive.

It is worth remarking at this point that the above argument in the calculation depends on the assumption that the intensity of cosmic rays has remained more or less constant during the last 10,000 years or so. In this connection it may be mentioned that as a result of the explosion of hydrogen bombs the radio-carbon concentration of the

atmosphere has been increased by as much as 10% in the last few years.

The practical difficulties of measuring ages by radioactive means are many. The chief difficulty is that the amount of radioactivity in a sample of rock or organic material is so small that it is very difficult to record the rate of radioactive decay without ambiguity—especially that arising from the presence of radioactive substances in laboratory atmosphere and apparatus. For radio-carbon dating special geiger counters have been devised to reduce these errors. The usual procedure in the dating of a material is to extract the carbon in the form of a gas (either carbon dioxide or acetylene) and to convert this either into solid carbon which may be incorporated into the walls of a radiation measuring device such as a geiger counter or to fill such a counter with the gas.

The ages of materials three or four thousand years-old can be measured with an accuracy of one or two hundred years, for ages up to 20,000 years the error may be a thousand years or so. Even here it is possible to tell with considerable accuracy the difference in the ages of similar samples. Radioactive carbon dating has now become a routine procedure in archæology and geology and the National Physical Laboratory has established a unit at Teddington in the Applied Physics Division.

Apart from the archæological applications, the radio-carbon dating method has been used to determine with accuracy the time at which the last Ice Age started to melt away. Thus examination of the remnants of mosses and lichens taken from glacial deposits in North America and Northern Europe has shown that the final retreat of the glacial ice started 10,300 years ago.—ISLO *Science Newsletter.*

FALL-OUT SINCE TESTS BEGAN

INFORMATION has been presented officially by the Ministry of Defence (U.K.) about the amounts of fission poisons released into the atmosphere by the explosion of nuclear bombs of one kind or another by U.S., U.K. and U.S.S.R.

This information has been made available so that those who are concerned with the making of estimates relating to redioactive fall-out can base their calculations upon actual figures.

In the tables the sizes of bombs have been given in units of a kiloton—the explosive equivalent of 1,000 tons of chemical explosive.

U.S. and U.K. Nuclear Events

(Yield in kilotons)

Year	Total fission yield
1945	60
1946	40
1948	100
1951	500
1952-54	37,000
1955	200
1956	9,000
1957-58	19,000

Soviet Nuclear Events

(Yield in kilotons)

Inclusive years	Total fission
1945-51	60
1952-54	500
1955-56	4,000
1957-58	21,000

U.S., U.K. and Soviet Events

(Yield in kilotons)

Inclusive years	Fission yield			Total yield	
	Air burst	Ground surface burst	Water surface burst	Air burst	Surface burst
1945–51 ..	190	550	20	190	570
1952–54 ..	1,000	15,000	22,000	1,000	59,000
1955–56 ..	5,600	1,500	6,000	11,000	17,000
1957–58 ..	31,000	4,400	4,600	57,000	28,000

The "Fission yield" of a bomb is an estimate of the amount of its explosive power derived from fission as opposed to thermonuclear fusion. It is directly a measure of the amount of fall-out poisons released into the atmosphere.

It is significant that the first great increase of world radiation was accounted for in the period 1952-54. Most of this is probably due to the bomb exploded at Bikini at the beginning of March, 1955.

The Ministry says that the yield of British and American thermonuclear bombs is on the average roughly half derived from fission and half from fusion. It has used this assumption about Russian bombs to calculate the amount of radioactivity released by them from the measured total yields of the explosions.