Preparation of Oxygen-15 for the Study of Pulmonary Function

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The use of radioactive gases is one of the important method of lung function research. A short-lived radioactive isotope, oxygen-15, has been used for studying physiological lung function and the diagnosis in safety. It enables us to observe the way of local intake of oxygen in lung and its clearance by the blood.

A method of preparation and use of oxygen-15 has been reported by N. A. Dyson, et al. in which a continuous flow of air containing oxygen-15 is produced by the $^{14}\text{N}(d,n)^{15}\text{O}$ reaction.

In the same way oxygen-15 has been prepared by using air and 20 μA deflected beam of 3.4 MeV deuteron from the 26 in cyclotron of the Institute of Physical and Chemical Research, Tokyo. Oxygen-15 thus obtained has high specific activity and contains sufficiently small amount of radioactive contaminants, so that it could satisfactorily be used for clinical purpose.

For the study of lung function, a radioisotope has now come into use with effect. In order not to harm the body, it is necessary to prevent it from remaining in any organ for a long period and therefore we must select an isotope with short effective half life. For this purpose, oxygen-15 was proved to be safe and ideal^{1),3)~7)}. This isotope is taken into the lung as inspiration gas, distributed all over the lung rapidly, perfused into lung vessels and washed out from there. So we can see the function of the various parts of the lung by measuring annihilation radiation from this isotope. A method of preparation of oxygen-15 by a cyclotron and its application to the lung function test was reported at first in 1958 by N. A. Dyson, P. Hugh-Jones, C. C. Newberry and J. B. West¹⁾. Later, it was described by D. D. Vonberg and J. F. Fowler²⁾ of Hammersmith Hospital that a cyclotron could be used also for other medical researches and in plant physiology.

The present paper describes the method of preparation, contents of radioactive contaminants and the yield of oxygen-15, in hopes of using it for the study of cardio-pulmonary function.

Preparation of Oxygen-15

The process employed was almost the same as that of N. A. Dyson et al.¹⁾, that is, oxygen-15 is produced by the (d,n) reaction of nitrogen-14. The air in a target box was bombarded through a thin aluminium or nickel foil window by 20 μA deflected beam of 3.4 MeV deuteron from the 26 in cyclotron of the Institute of Physical and Chemical Research. The bombarded air from the target box was circulated by a pump through polyethylene tube and back to the box, thus forming a closed circuit with a flow rate of 10 litres per minute. The pump for circulating the air through the closed circuit was arranged just in front of an experimental room. After eliminating ozone from the bombarded air with MnO_2 , the activity of oxygen-15 was monitored and measured. Then, transferred to the experimental room, it was diluted with air and used for the study of cardio-pulmonary function. According to a quantity of the bombarded air taken out from the tube for experiment, it is necessary to replenish fresh air from outside of the tube before monitoring the activity to compensate the pressure in the closed circuit (Fig. 1).

The activity of oxygen-15 in the bombarded

Fig. 1 Flow diagram for preparation of oxygen-15.

air was monitored in three ways as follows:

- 1) By means of a vibrating reed electrometer, observing the ion current due to β -rays in an ionization chamber intervening between polyethylene tubes.
- 2) By a G-M counter, measuring β -rays from outside of the tube.
- 3) By a scintillation counter or an ionization chamber, measuring the annihilation γ -rays from oxygen-15.

The beam current of the cyclotron was also recorded at the same time.

A quantitative measurement of the activity of the oxygen-15 was carried out, firstly, by measuring annihilation γ -rays using the ionization chamber and the vibrating reed electrometer, in which the activity was calculated assuming that the specific gamma-ray constant of oxygen-15 is 0.6 and, secondly, by measuring γ -ray spectrum with the aid of a TMC 402 multi-channel pulse height analyzer. In the latter case the counts of a peak at 0.51 MeV was measured. The results of these two measurements were almost identical

Result

Radioactive Contaminants

The γ -ray spectrum of the air bombarded

through 10μ aluminium foil window of the cyclotron showed two peaks at 0.51 and 1.78 MeV (Fig. 2). The half-life of these two peaks was about 2 minutes. The latter was proved to be of aluminium-28 produced by $^{27}\text{Al}(d, p)^{28}\text{Al}$ reaction, because, when the aluminium window of the cyclotron was replaced by a nickel foil, always the peak at 1.78 MeV disappeared. By analyzing the decay curve of the air bombarded through the nickel window of the cyclotron, some contaminants of small quantity were found. In case of the closed circuit, they were ^{41}Ar (0.9%) and ^{13}N (0.1%), but when the circuit was open, ^{41}Ar decreased to 0.03% and ^{13}N became less than 0.1% (Fig. 3).

Fig. 2 A scintillation γ -ray spectrogram of air bombarded with deuterons through 10μ aluminium foil window of the cyclotron.

Fig. 3 Decay curve of bombarded air.

Yield of Oxygen-15

The yield of oxygen-15 in this experiment was 22 mc per litre of air.

Conclusion

Oxygen-15 was prepared by the (d, n) reaction of nitrogen in the air bombarded by deuteron beam from the 26 in cyclotron. As it had very small amount of radioactive contaminants and its yield was sufficient, the gas could be used for the cardio-pulmonary function study. By using the nickel foil window of the cyclotron instead of the aluminium foil, production of aluminium-28 could be prevented which was always produced as a by-product when the aluminium foil window was used.

The yield of oxygen-15 depends on the total volume of the circuit system, the volume of the target box and the flow rate of the air. In view of the above conditions, we have taken the following two points into consideration. i) The bombardment time is not too long, and ii) the target box should be of proper size (200 ml) and the total space of the closed circuit system made as small as possible. In our experiment, the distance between the target box and the experimental room is 19 meters, so the polyethylene tube (0.8 cm in diameter) must be as much as 38 meters long to make a closed circuit.

As the deuteron energy from the 26 in cyclotron is rather low, oxygen-15 from it contained smaller amount of radioactive contaminants than the one produced by deuteron of higher energy from the larger cyclotron such as that of Hammersmith Hospital.

Summary

1) The method of preparation, contents of radioactive contaminants and the yield of oxygen-15 were studied.

2) A nickel foil window instead of an aluminium foil of a cyclotron was used to avoid the radioactive contamination with ^{28}Al .

3) This study was aimed at the application of oxygen-15 to cardio-pulmonary function research.

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要 旨

^{15}O の 製 造

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肺機能検査に放射性同位元素ガスを使用する方法は, 重要な1つの方法であり, ^{15}O は短寿命な放射性同位元素であるので, 肺の生理学的機能の研究および医学的診断などに安全に使用できる。 ^{15}O を使用すると肺の局所的な O_2 のはいり方およびその血液中への流入などが観察されるので,

その利用はたいへん価値のあることである。

^{15}O の製造およびその使用については、N. A. Dyson らによって、すでに報告され、 ^{15}O は ^{14}N (d, n) ^{15}O 反応によってつくられている。

われわれは理化学研究所の 26 in cyclotron の 3.4 MeV deuteron の $20\ \mu\text{A}$ beam で ^{15}O を製造した。 ^{15}O はよくでき、不純物も少ないので、これを安全に研究に使用できる。