PRODUCTION OF SHORT-LIVED RADIOACTIVE GASES BY AN IN-HOUSE SMALL CYCLOTRON AND ITS CLINICAL USE.

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Such short-lived positron emitting isotopes as 11-C, 13-N, 15-O and 18-F have been proven of inceasing importance in clinical diagnosis, assisted by the development of radioisotopes labeling techniques and the instrumentation for positron emission computed tomography (PET).

These short-lived radioisotopes must be produced by a cyclotron which is located at hospital, becauce of ultra short half-life. The small cyclotron for medical use, the CYPRIS was installed at Kyoto University Hospital, last March. This cyclotron is designed for the production of only four radionuclide, that is 11-C, 13-N, 15-O and 18-F for routine clinical use. The acceration energy of this cyclotron is fixed at 15 MeV and 8 MeV for proton and deuteron, respectively. Beam current is variable in the range of 0 - 50 μA. These energy and current are sufficient to produce the radioactivity for the routine clinical use. This is a machine with many desirable characteristics for use at hospital.

(1) This cyclotron is very compact, measuring only 1.56 m high, 1.71 m long and 1.53 m wide. This is able to be installed in a small space.
(2) Simple mechanism, for example a single 180 Dee, is adopted for reliability and simplicity of operation and ease of maintenance.
(3) A microprocessor is built in the control system. Cyclotron is automatically controlled through simple push buttom requiring only one operator.
(4) The target system is fo a rotary changeable type, consisting of 8 target position. Ensuring the purity of the compounds, a specific target is selected remotely for a specific compound.
(5) Operation status are monitored from a CRT equipped with a microprocessor. When the cyclotron become unoperational, fault is indicated on the CRT and instruction message can be read from it.

The radionuclides produced, such as 11-C, 13-N, 15-O and 18-F, passed through a chemical processing system for the production radioactive compounds like 11-CO_2, 11-CO, 13-N_2, 13-NH_3, 15-O_2, C15-O, C15-O_2, $H_2$15-O, 18-F_2, H18-F. These chemical processing is in a hot cell shielded by lead and remote-controlled by a microprocessor equipped with a CRT display, becauce large amount of radioactivity must be handled in routine.

At Kyoto University Hospital, the use of radioactive gases, such as 11-CO, 11-CO_2, 13-N_2, 15-O_2 and C15-O_2, are being considered at the first stage of its clinical use due to their usefulness for many dynanic physiological studies, practicularly in the investigation of pulmonary, cardiac and brain malfunction. At this time, our main objective is the production of those gases at high yield and constant radioactivity flow with suitable chemical and radiochemical purity for routine clinical use.

Nowdays, our purpose has been attained with great satisfaction.

Such radioactive gases as 11-CO, 11-CO_2, 15-O_2 and C15-O_2 are being produced at a constant rate of 30 - 40 mCi/min (varation is less than 2 %) at 20 - 30 uA in constant flow 100 - 200 ml/min. The chemical and radiochemical purity of these gases are sufficient for clinical use. These results are summerized in table 1.

Table 1. Performance of radioactive gases production

Nuclide	11-C		15-O	
Chemical Form	^{11}CO	$^{11}CO_2$	$^{15}O_2$	$C^{15}O_2$
Target	N_2		N_2+2%O_2	N_2+0.5%CO_2
Nuclear Reaction	$^{14}N\ (p,\alpha)\ ^{11}C$		$^{14}N\ (d,n)\ ^{15}O$	
Flow Rate	100 ml/min		200 ml/min	
Chemical Purification	Zn, 390	CuO, 850	Soda lime	Charcoal, 400
Purpose	$CO_2 \rightarrow CO+O_2$	$CO+O_2 \rightarrow CO_2$	-	$O_2+C \rightarrow CO_2$
Radioactive Cocentration	7.1 (μCi/ml/min)	7.1 (μCi/ml/min)	34 (μci/ml/min)	37 (μCi/ml/min)
Chemical Purity	$CO<20ppm$, $CO_2<30ppm$,	$CO<20ppm$ $CO_2<30ppm$	$CO_2<10ppm$ $N_2O<10ppm$	$CO<20ppm$ $CO_2<50ppm$
Radiochemical Purity	$^{11}CO>98.5\%$ $^{11}CO_2<0.03\%$ $^{13}N_2<1.5\%$	$^{11}CO_2>98.5\%$ $^{11}CO<0.03\%$ $^{13}N_2<1.5\%$	$^{15}O_2>99.7\ \%$ $^{13}N_2O<0.3\%$	$C^{15}O_2>99.0\%$ $C^{15}O<0.5\%$ $^{15}O_2<0.1\%$ $^{13}N_2<0.4\%$

Clinical trials of these gases are to be started along the installation of positron emission computed tomography (PET).