Gas Target Systems at Ghent University

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Gas target systems for the production of ^{15}O, ^{11}C and ^{81}Rb in routine use at Ghent University are described <1>.
Oxygen-15 is produced on-line as $^{15}O_2$ and $C^{15}O_2$ <2>.
Carbon-11 is produced in batch-mode as:

- $^{11}CO_2$ for the photosynthesis of glucose <3> and for the production of the precursor $^{11}CH_3I$, used for the methylation of radiopharmaceuticals <4>.
- $^{11}CH_4$ for the production of the precursor $H^{11}CN$, used for the synthesis of ^{11}C-1-aminocyclopetanecarboxylic acid <5> and 2-deoxy-D-1-^{11}C-glucose <6>.

For the production of ^{81m}Kr generators, ^{81}Rb is produced in batch mode <7>.
Nuclear and experimental data are summarised in Table 1.

Oxygen-15

The experimental set-up is shown in figure 1.

According to Clark <8> a gas mixture of nitrogen and oxygen for the $^{15}O_2$ production and of nitrogen and carbon dioxide for the $C^{15}O_2$ production is used. The irradiated gases pass through a small bore tube to a shielded area. For the production of $^{15}O_2$ the gas mixture passes through a soda lime trap and a charcoal trap at room temperature.

For the production of $C^{15}O_2$ a charcoal trap at 400°C is commonly used. We obtained better results using a mixture of copper oxide and iron oxide on a kaolin support at 400°C. The flow rate of the gas is set at 0.5 l/min with a needle valve at the place of use and monitored with a flow meter.

Table 1 : Nuclear and experimental data for the production of ^{15}O, ^{11}C and ^{81}Rb

	^{15}O	^{11}C	^{81}Rb
Reaction	$^{14}N(d,n)^{15}O$	$^{14}N(p,\alpha)^{11}C$	$^{82}Kr(p,2n)^{81}Rb$
Isotopic abundance	99.6 %	99.6 %	11.6 %
Threshold energy	Q > 0	3.1 MeV	14.2 MeV
Decay; half-life	β^+; 2.05 min	β^+; 20.4 min	^{81}Rb : β^+, EC; 4.58 h ^{81m}Kr: IT; 13 s
Particle energy	7.5 MeV	17.3 MeV	22.3 MeV
Target gas : composition (v/v)	N_2/O_2 (96/4)[a] N_2/CO_2 (97.5/2.5)[b]	N_2 (traces O_2)[d] N_2/H_2 (94.5/5.5)[e]	Kr (natural)
pressure (absolute)	1.5 x 10^5 Pa	9 to 10 x 10^5 Pa[f]	3.5 x 10^5 Pa
Production yield	2.9 GBq/min[a,c] 3.3 GBq/min[b,c]	7.4 GBq/μA[g]	0.67 GBq/μA[g]

a) for the production of $^{15}O_2$
b) for the production of $C^{15}O_2$
c) for 10 μA beam intensity (on line)
d) for the production of $^{11}CO_2$
e) for the production of $^{11}CH_4$
f) dependent on the beam intensity used
g) for saturation (batch mode)

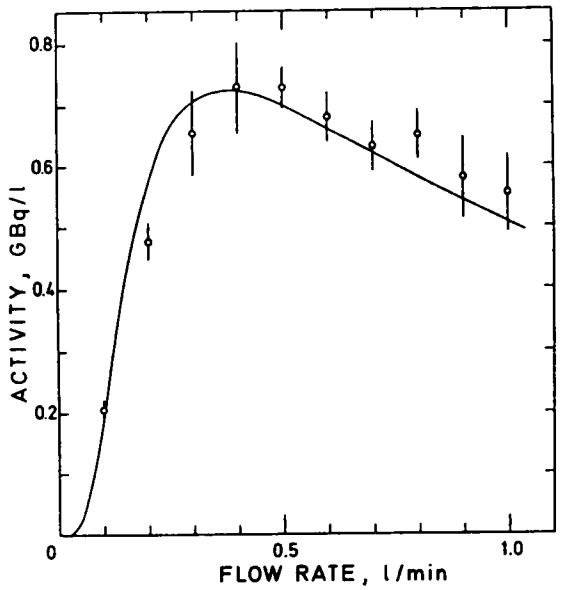

Figure 2 : Oxygen-15 activity (production of $^{15}O_2$) as a function of the flow rate. The initial increase can be explained by the shortening of the time required for the gas to flow from the target gas holder to the place of use, as the flow rate increase. At higher flow rates the activity per unit of volume decreases, since each unit of volume is irradiated for a shorter time.

Table 2 : Chemical and radiochemical purity of $^{15}O_2$ and $C^{15}O_2$

		$^{15}O_2$	$C^{15}O_2$	TLV[a]
Chemical purity (concentration in µl/l)	O_3	0.01	0.01	0.1
	NO_2	0.01	0.02	5
	CO	< 1	2 to 9	50
Radiochemical purity	$^{15}O_2$	100 %	< 0.2 %	
	$C^{15}O_2$	< 0.3 %	100 %	
	$^{13}N_2$	0.5 %	0.5 %	
	$N_2{}^{15}O$	0.5 %	< 0.6 %	
	$C^{15}O$	< 0.3 %	< 0.09 %	

[a] TLV : Threshold Limit Value

The gas passses through a shielded measuring cell containing a GM-tube to measure the activity per unit volume. The GM counter is coupled to a ratemeter, which allows the activity to be recorded during production. The experimental set-up is completely remotely controlled using solenoid valves. The vacuum pump is used to evacuate the target when switching from a $^{15}O_2$ production to a $C^{15}O_2$ production or vice versa. This can be done in less than 10 min without any radiation exposure to the operator. The $^{15}O_2$ activity as a function of the flow rate is given in figure 2. The chemical and radiochemical purity is summarised in Table 2.

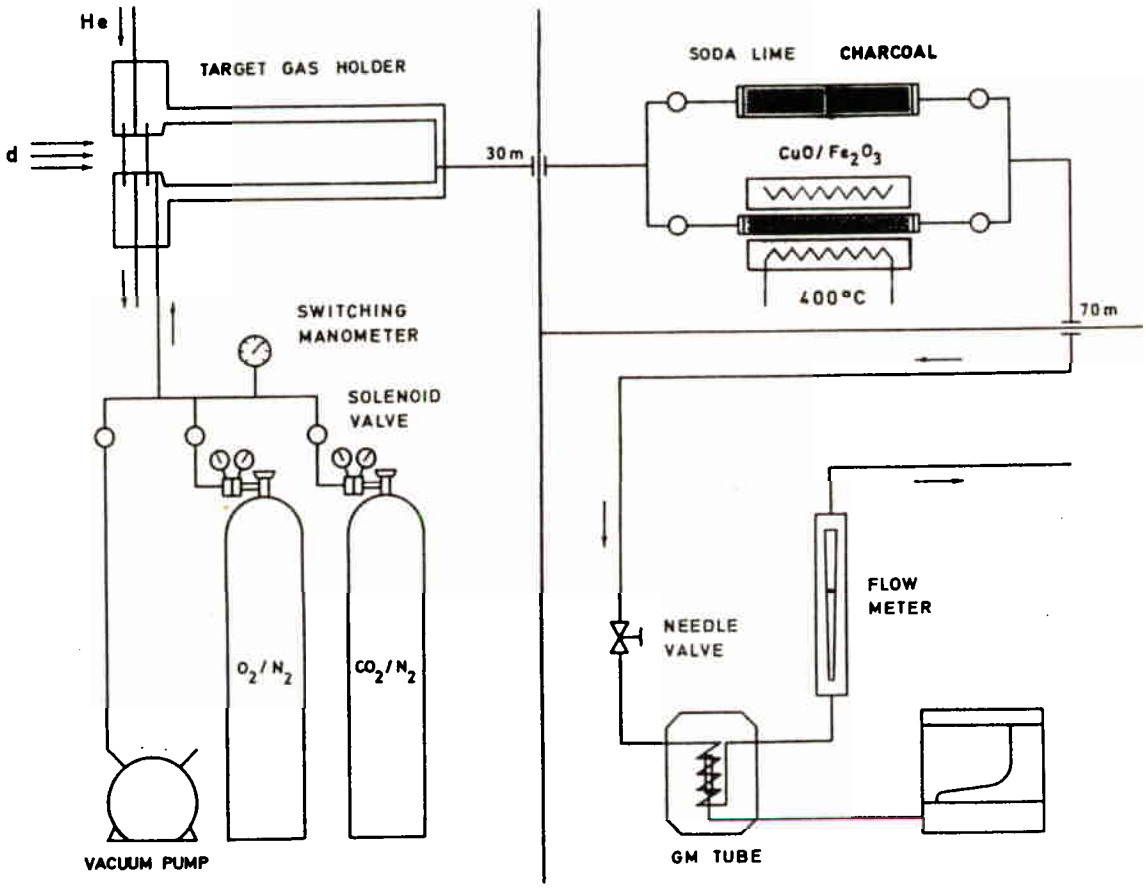

Figure 1
Experimental set-up for the production of $^{15}O_2$ and $C^{15}O_2$

Carbon-11

The target gas holder for the production of ^{11}C is given in figure 3. The flange at the back of the target gas holder (left) can be replaced by a 100 μm Ti-foil (no. 2) and an electrically insulated Faraday cup (right) mounted on the holder. The beam intensity on the Faraday cup can be measured.

To study scattering of the proton beam by the inlet foil (no. 1) and by the target gas, a copper foil was irradiated, placed directly behind foil no. 2. Measurement of the distribution of the induced activity yields the diameter of the scattered beam <9>.

The amount of gas in the target holder (or its pressure under cooling, no irradiation), required to ensure thick conditions, increase with the beam intensity. Indeed, heating by the charged particle beam reduces the density of the target gas in the path of the beam. To determine the required amount of gas in the target holder, for several starting pressures (no irradiation) above the one corresponding to the range of the incident 17.3 MeV protons in nitrogen (9×10^5 Pa), the beam intensity is increased and the intensity recorded at the breakpoint, i.e. the point where a 5 nA current is measured in the Faraday cup. The starting pressure (o) is plotted versus the beam intensity at the breakpoint in figure 4. The equilibrium pressure (•) under irradiation is higher due to heating of the target gas by the beam <9>.

Rubidium-81

The experimental set-up for the production of ^{81}Rb is given in figure 5.

After the irradiation the krypton gas escapes through the water in the reservoir, pressure is then used to push the water into the gas holder through a perforated stainless steel tube (figure 6). The water washes the ^{81}Rb from the target wall, is pushed out of the target, back into the reservoir and is transferred to the hot laboratory.

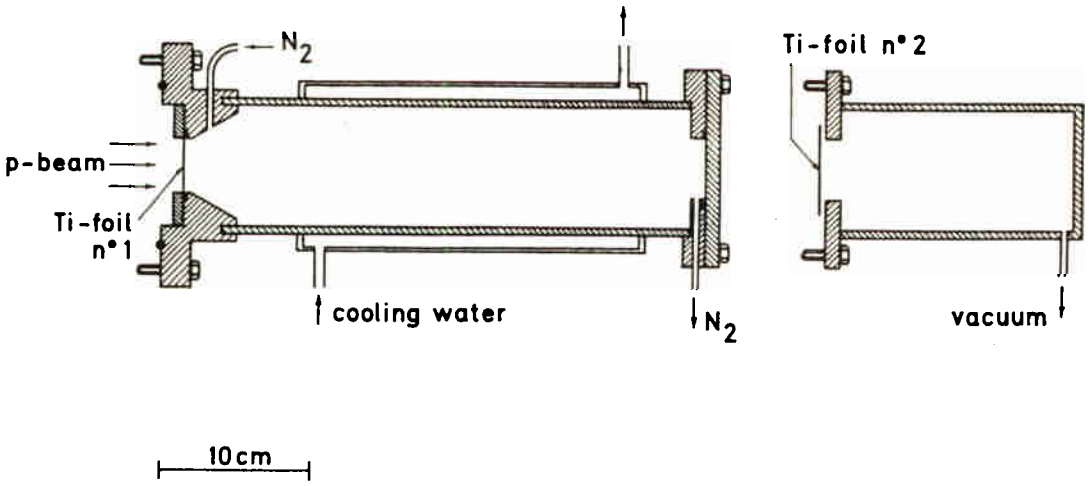

Figure 3 : Gas target holder for the production of ^{11}C

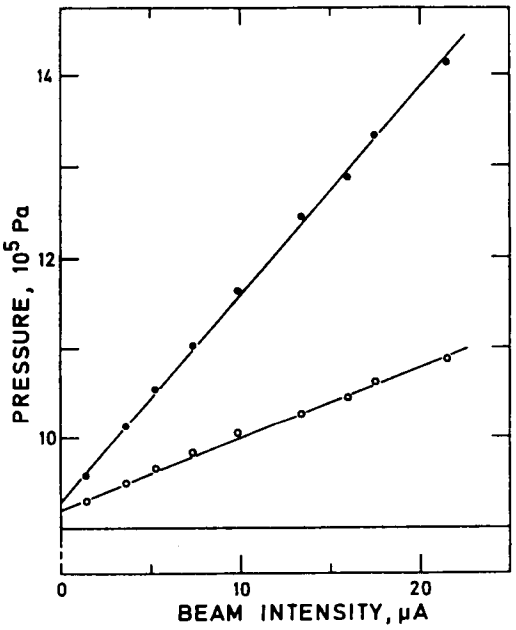

Figure 4 : Target gas pressure as a function of the beam intensity (see text)

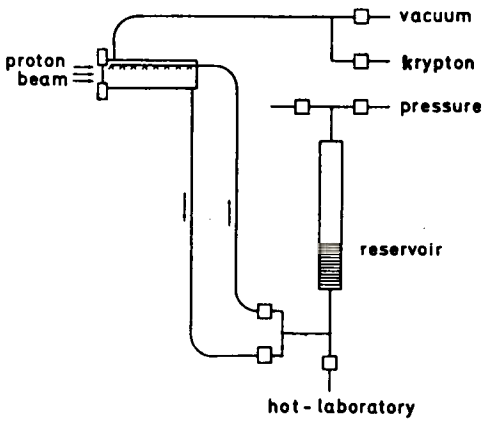

Figure 5 : Experimental set-up for the production of ^{81}Rb

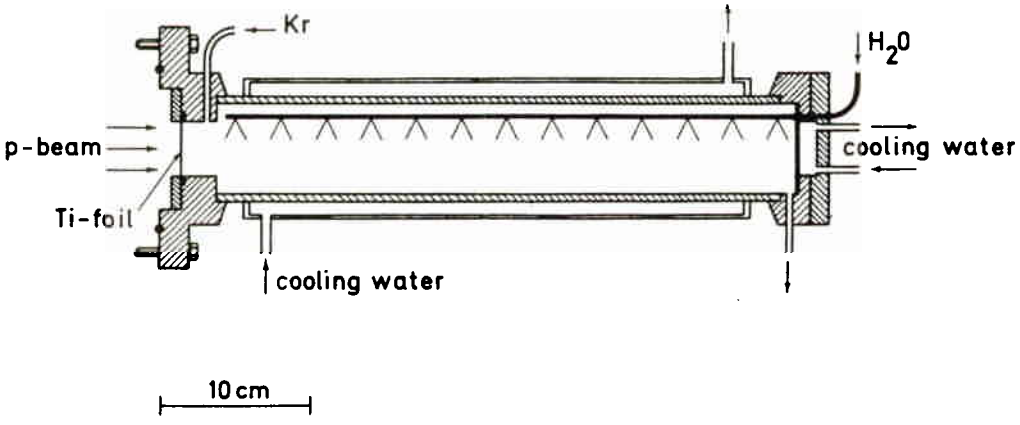

Figure 6 : Gas target holder for the production of ^{81}Rb

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