Development of a UK primary standard for positron emitters in gas

Maria Marouli
• PET and production of positron emitting radionuclides

• The airborne Radioactivity

• First approach and results

• Summary
PET and production of positron emitting radionuclides
PET and production of positron emitting radionuclides

<table>
<thead>
<tr>
<th>Description</th>
<th>C-11</th>
<th>N-13</th>
<th>O-15</th>
<th>F-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum energy of $\beta^+(\text{keV})$</td>
<td>960.5</td>
<td>1198.45</td>
<td>1735.0</td>
<td>633.5</td>
</tr>
<tr>
<td>Half life (min)</td>
<td>20.37</td>
<td>9.967</td>
<td>2.041</td>
<td>109.728</td>
</tr>
</tbody>
</table>
Future of PET

UK Department of Health (Oct. 2005)

Framework for the development of PET services in England

15 units ➔ 23 units
The Airborne Radioactivity

Exhaust Duct

"hot" cells for radiopharmaceutical synthesis

~ 1-100mCi

~ Ci

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The Airborne Radioactivity

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Why monitor?

Table. Percentage contribution of positrons to the total D.E. rates for the skin.

<table>
<thead>
<tr>
<th>Cloud radius (m)</th>
<th>$^{14}$C</th>
<th>$^{13}$N</th>
<th>$^{15}$O</th>
<th>$^{18}$F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>98.8%</td>
<td>99.1%</td>
<td>99.4%</td>
<td>98.0%</td>
</tr>
<tr>
<td>5</td>
<td>94.1%</td>
<td>95.5%</td>
<td>97.1%</td>
<td>90.8%</td>
</tr>
<tr>
<td>10</td>
<td>88.8%</td>
<td>91.4%</td>
<td>94.4%</td>
<td>83.2%</td>
</tr>
<tr>
<td>20</td>
<td>79.9%</td>
<td>84.3%</td>
<td>89.4%</td>
<td>71.3%</td>
</tr>
<tr>
<td>50</td>
<td>61.6%</td>
<td>68.2%</td>
<td>77.3%</td>
<td>50.0%</td>
</tr>
<tr>
<td>100</td>
<td>45.4%</td>
<td>52.7%</td>
<td>63.8%</td>
<td>34.0%</td>
</tr>
<tr>
<td>200</td>
<td>32.1%</td>
<td>38.8%</td>
<td>50.0%</td>
<td>22.6%</td>
</tr>
<tr>
<td>1000</td>
<td>24.5%</td>
<td>30.0%</td>
<td>40.3%</td>
<td>16.8%</td>
</tr>
<tr>
<td>2000</td>
<td>23.6%</td>
<td>29.2%</td>
<td>39.4%</td>
<td>15.9%</td>
</tr>
<tr>
<td>4000</td>
<td>23.6%</td>
<td>29.2%</td>
<td>39.4%</td>
<td>15.9%</td>
</tr>
</tbody>
</table>
### Why monitor?

#### Table. Quantities for notification (IRR99)

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>Concentration for notification. Regulation 6 and Schedule 1 (Bq/g)</th>
<th>Quantity for notification. Regulation 6 and Schedule 1 (Bq)</th>
<th>Quantity for notification of occurrences. Regulation 30(1) (Bq)</th>
<th>Quantity for notification of occurrences. Regulation 30(3) (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>$^{11}\text{C}$</td>
<td>$10$</td>
<td>$10^6$</td>
<td>$10^{13}$</td>
</tr>
<tr>
<td></td>
<td>$^{11}\text{CO}$</td>
<td>$10$</td>
<td>$10^9$</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td></td>
<td>$^{11}\text{CO}_2$</td>
<td>$10$</td>
<td>$10^9$</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>$^{13}\text{N}$</td>
<td>$10^2$</td>
<td>$10^9$</td>
<td>$10^9$</td>
</tr>
<tr>
<td>Oxygen</td>
<td>$^{15}\text{O}$</td>
<td>$10^2$</td>
<td>$10^9$</td>
<td>$10^{10}$</td>
</tr>
<tr>
<td>Fluorine</td>
<td>$^{18}\text{F}$</td>
<td>$10$</td>
<td>$10^6$</td>
<td>$10^{13}$</td>
</tr>
</tbody>
</table>
A primary standard for positron emitters is essential to ensure the accuracy of the measurements.
How is airborne radioactivity measured?

Methods

- Kind of particle: annihilation photons, positron
- Place of measurement: lab, duct, by-pass loop, no by-pass loop
How is airborne radioactivity measured?

Examples

- Flow through ionization chamber for monitoring airborne radioactivity from PET/cyclotron facilities.
- Scintillation probe in the air stream of a duct.
How is airborne radioactivity measured?

Multiwire proportional counter

Scintillation detectors
First approach and results
First approach and results

The cross-talk...

Path length distribution of absorbed primary particles

Simulation time ...................... 1.559233E+04 sec
Simulation speed ...................... 2.024313E+02 shower

Simulated primary particles .......... 3.156375E+06
Transmitted primary particles ....... 0.000000E+00
Absorbed primary particles .......... 8.357910E+05

\textbf{Fractional transmission} ........ \textbf{0.000000E+00} \pm 0.0E+00

Fractional backscattering ............ 7.352054E-01 \pm 7.5E-04
Fractional absorption ................. 2.647946E-01 \pm 7.5E-04

Positrons of 960.5 keV in brass
First approach and results

Photons of 511keV in brass

Depth dose distribution

Average final energy:
- Transmitted particles .......... $4.441110E+05 \pm 2.2E+02$ eV
- Backscattered particles ......... $4.658630E+05 \pm 1.5E+02$ eV

Depth dose distribution

'psddose.dat' u 1:2:3

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511keV photons

Average incoming energies (impact detectors):
Medium ... 6.675328E+02 ± 3.5E+01 eV
Large ... 0.000000E+00 ± 0.0E+00 eV

First approach and results

Energy distribution of particles entering the medium detector

Energy distribution of particles entering the long detector

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First approach and results

C-11 positrons of 960.3keV in brass-lead(1.8cm)-brass

Energy distribution of transmitted photons through brass-lead-brass

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First approach and results

$^{85}\text{Sr}$

($T_{1/2} = 64.85\text{ d}$)
First approach and results
First approach and results

Without lead

Response of short counter to Sr-85

Response of Medium counter to Sr-85

Response of long counter to gammas
First approach and results

With lead shot  →  Background
First approach and results

Energy deposition to the walls of the counters in comparison to the gas: El. vs. Pos.

Ratio of av. deposited energies to wall vs. gas for elec. over pos.

- short
- medium
- long

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First approach and results

Energy deposition of positron emitting sources in the counters...

![Graph showing energy deposition ratio of different radionuclides.](image)
Next Steps...

- Convert liquid positron emitting source to a gas by acidification of a known mass of NaHCO₃ solution.

- First experiment to measure C-11 in a gas form using the proportional counters

  Count a $^{11}\text{CO}_2$ sample generated by acidification of a known mass of NaH$^{11}\text{CO}_3$ solution

  Simultaneously standardise as a liquid by ion-chamber counting

  response factor (cps Bq$^{-1}$) of the brass gas counters to $^{11}\text{C}$ in gaseous form
First experiment to measure C-11 in a gas form using the proportional counters

evelop a transfer instrument calibrated against the primary standard
Summary

Where is it produced?

How is it measured?

First and next steps...
Thank you!