Radioactive aerosols produced in AP0 target station


1. Correlation between the particle size distribution of radioactive aerosols and their half-lives

2. Activity of P-32

Shun Sekimoto
(Kyoto University Research Reactor Institute)

JASMIN collaboration meeting, February 16, 2012
Introduction

In target area of accelerator facility, "High-energy proton beams" traveling in air and beam sprays from the interaction of the beam with the target and related target station components produce radioactive aerosols.”

Motivation

To investigate those radio-nuclides composition and their amount
→ The shielding in an accelerator facility (by evaluating a residual radioactivity)
→ Cosmo- and geo- science (by simulating high-energy nuclear (spallation) reaction

To know particle size of those radioactive aerosols
→ For the radiation control purposes, especially for evaluating the internal exposure of the workers.
**Introduction**

In target area of accelerator facility, "**High-energy proton beams** traveling in air and **beam sprays** from the interaction of the beam with the target and related target station components produce **radioactive aerosols**."

- **Concrete shielding**
- **Air gap**
- **Iron shielding**
- **Inconel target**

Ave. beam current: 250-290 nA

**This work**

- # Collection of **radioactive aerosols** from the AP0 target vault
- # Separation of **radioactive aerosols** into several samples according to particulate size ranging from 0.056 to 10 µm
- # **Impactor** method

Anti-proton target station (AP0) @Fermilab
Experimental (Aerosol-sampling) (2/15, 10:20-3h sampling)

- Target room
- 120 GeV proton target
- Concrete shielding
- Iron shielding
- Impactor
- Flow meter
- Pump
- Gas/aerosol-sampling device
- Filter holder
- Experimental (Aerosol-sampling)
Results: Particle size distribution

Particle diameter \( (d_p, m) \) (\( dA_0/d\ln d_p \))

Be aerosol fitted
GMD 1.6 \( \mu m \)
GSD 2.3

Be-7 (T\(_{1/2}\): 53.3 d)

GMD: Geometric mean diameter
Discussion: Half life vs. particle size distribution

<table>
<thead>
<tr>
<th></th>
<th>Half-life (day)</th>
<th>GMD (μm)</th>
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<tbody>
<tr>
<td>Na-24</td>
<td>10</td>
<td>10^-1</td>
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<tr>
<td>Au-198</td>
<td>10</td>
<td>10^-1</td>
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<tr>
<td>Sc-47</td>
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<tr>
<td>Au-196</td>
<td>10</td>
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<tr>
<td>V-48</td>
<td>100</td>
<td>10^0</td>
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<td>Cr-51</td>
<td>100</td>
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<tr>
<td>Be-7</td>
<td>100</td>
<td>10^0</td>
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<tr>
<td>Co-58</td>
<td>1000</td>
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<tr>
<td>Co-56</td>
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<tr>
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<tr>
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<td>10^2</td>
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<tr>
<td>Na-22</td>
<td>1000</td>
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<tr>
<td>Co-60</td>
<td>1000</td>
<td>10^2</td>
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### Discussion: Half life vs. particle size distribution

Restart of AP0-operation → **6 month** → Aerosol-sampling

Growing up of aerosols

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Motivation (Why we focus on P-32)

The pure beta emitters such as P-32 as well as gamma rays emitting nuclides are also important.

$^{32}\text{P}$ ($T_{1/2} = 14.26$ d, no-γ)
- pure beta emitter
→ cannot be determined by conventional method used in radiation control
- from argon (Ar) in air
→ close to Ar
→ P-32 from Ar >> trace

In spite of target materials, it is essential to determine activity levels of $^{32}\text{P}$ for the radiation control purposes, especially for evaluating the internal exposure of the workers.

Production of $^{32}\text{P}$ in target area have not been studied previously, because of difficulties in detecting and characterizing pure beta-emitters compared to gamma-ray emitters.
Motivation (Why we focus on P-32)

The pure beta emitters such as P-32 as well as gamma rays emitting nuclides are also important.

\[ ^{32}\text{P} \quad (T_{1/2} = 14.26 \text{ d}, \text{ no-}\gamma) \]
- pure beta emitter
- cannot be determined by conventional method used in radiation control

- from argon (Ar) in air
  - close to Ar
  - P-32 from Ar >> trace

This work

# Determination of the activity levels of the beta emitting radio-nuclide \(^{32}\text{P}\)
  in the radioactive aerosols produced in Anti-proton target station.
# Is \(^{32}\text{P}\) mainly produced from
  Ar in air, target, or the instruments around the target?
Experimental (Aerosol-sampling)

The radioactive aerosols, (which were produced from Ar in air, target, or the other instruments,) were withdrawn by a pump and collected on filter paper.

gamma-ray spectrometry

chemical treatment (to separate P)

Sampling condition:
# 9.5 L of air / min
# 26 h-sampling
(≈ 15 m³ of air in total)
Results “Beta-ray counting and spectrum”

**Beta-ray counting** by Geiger-Mueller counter

MgNH$_4$PO$_4$•6H$_2$O

**Beta-ray spectra** from liquid scintillation counter

- **Beta-ray spectra** from liquid scintillation counter
  - 91000 cnts @600-1500 keV
  - 53000 cnts @600-1500 keV

**Decay curve** for T$_{1/2}$: 14.3 d (P-32)

![Graph showing decay curve for T$_{1/2}$: 14.3 d (P-32)](image-url)
Discussion  “Target materials in detail”

(cross-section drawing of target parts)

To cool down the Inconel target, Cu container and Cu balls are installed in the Inconel-target-hole.

Inconel: Ni, Fe, Cr, Nb, Mo etc.,

Anti-proton target station (AP0) @Fermilab

Inconel target

Concrete shielding

Iron shielding

Air gap

Target room

120 GeV proton

Ave. beam current: 250-290 nA

Cu balls with Au-coating
Discussion

“Which contribute to P-32 production, air, target, etc.?”

$^{32}\text{P}$: $<^{22}\text{Na}$, $\approx^{46}\text{Sc}$, $^{48}\text{V}$, $^{52}\text{Mn}$

→mainly produced from target materials or Ar in air?
Summary

# Determination of the activity levels of the beta emitting radionuclide $^{32}\text{P}$ in the radioactive aerosols produced in Anti-proton target station.

→Aerosol-sampling, chemical separation, LSC

# Discussion about source material of $^{32}\text{P}$, air or target components.

→Comparing other nuclides obtained by gamma-ray spectrometry