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OUTLINE

1. Context and Objectives
   1. MERARG
   2. Its near future

2. Qualification of device
   1. Description of the analyzer
   2. Operating principle

3. Experimental qualification
   1. Static mode
   2. Dynamic mode
1.1 MERARG currently

- MERARG (Moyen d’Etude par Recuit et Analyse des Relâchements Gazeux)
  - Anealing test device
  - Kinetics of fission gas release
  - Gamma Spectrometry: $^{85}$Kr
  - On line micro-gas chromatography: He

Y.P and al, JNM, 2008 and JNM 2009
Currently

- Kinetics measurement of fission gas release: $^{85}$Kr
- Elementary detection by micro GC
  - He, H$_2$ sometimes Kr, Xe
  - Detection of few ppm
- Outline analysis of gas with MS @ LMRO CEA Saclay

Near future

- Kinetics measurement of fission gas release:
  - Kr, Xe
- Measurement of isotopic ratios evolution
  - Kr, Xe
- Elementary detection:
  - Kr, Xe, He and H$_2$
  - ~ 1 ppm
- Outline analysis of gas (same device) in back area

Choice: RGA type Analyzer
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Residual Gas Analyzer (RGA)

- 1 u mass separation over 1-200 u range
- Sensitivity increase with pre- et post-filters
- Easy and strong
2.1 Description of the analyzer

- **EI Source**
- **Linear quadrupole Mass filter**
- **Détector**

Distance: 50 cm
2.2 Operating principle

\[ (U + V \cos \omega t) \]

3D representation

- \((U + V \cos \omega t)\)
- \(-(U + V \cos \omega t)\)

OX strength

OY strength

\(t\)
2.2 Operating principle

- On the radial plane, quadrupole potential for infinite electrodes
  \[ \varphi(x, y, t) = \alpha \frac{V(t)}{r_0^2} \left( x^2 - y^2 \right) \]

- General equation of ion motion:
  \[ \vec{m} \gamma = \vec{F} = q \vec{E} = -q \nabla \varphi(x, y, t) \]

- No electrical strength applied to Oz axis

- Ion motion equations:
  \[
  \begin{align*}
  \frac{d^2 x}{dt^2} + \frac{2Ze(U_0 + V_0 \cos(\Omega t))}{mr_0^2} x &= 0 \\
  \frac{d^2 y}{dt^2} - \frac{2Ze(U_0 + V_0 \cos(\Omega t))}{mr_0^2} y &= 0 \\
  \frac{d^2 z}{dt^2} &= 0
  \end{align*}
  \]

*R.E. March, JFJ. Todd, Quadrupole Ion Trap Mass Spectrometry, 2nd ed, Wiley, 2005*
2.2 Operating principle

- Change of variables:
  - $a, q$ reduced parameters

Depending upon the physical parameters $U$ and $V$

The ion passes through the filter if:

- Its motion is stable and
- Its radial amplitude does not exceed the electrode position according to its position and velocity initial conditions

\[ a_x = -a_y = \frac{8ZeU_0}{mr_0^2 \Omega^2} \]
\[ q_x = -q_y = -\frac{4ZeV_0}{mr_0^2 \Omega^2} \]
\[ 2\xi = \Omega t \]

R.E. March, JFJ. Todd, Quadrupole Ion Trap Mass Spectrometry, 2nd ed, Wiley, 2005
2.2 Operating principle

- Stable number of ions
- Scanline at cst resolution
  - Width with mass
  - Quantity with mass
  - Peak center shifted towards lower masses

\[ R = \frac{m}{\Delta m} \]

- Linear Scanning
  - On a small mass range
  - With a negative DC offset

- Non linear scanning
  - Technically difficult to obtain a curve
  - With DC offset

- \( A \Delta m = \text{cst} \)
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With 2 axis

- Static mode
- Dynamic mode
  - Sampling device

Resolution
Sensitivity
3.1 Static Mode

- Operating conditions
  - Standard bottles with 100 ppm for each product in Ar carrier gas
- Micro leak valve => control pressure
3.1 Static Mode

<table>
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<tr>
<th>Mass</th>
<th>Experimental</th>
<th>Theoretical</th>
<th>Error between exp and theo</th>
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<td>8.90</td>
<td>2.52</td>
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</table>

Percentage comparison

Xenon spectrum

1.91 ppm
3.2 Dynamic Mode

- Pressure adaptation between MERARG and MS
- Pressure ratio = $10^{-9}$ torr
- 2 pressure stages
- 2 gas flow
- Differential pumping
- Capillary and molecular leak
- Two roughing pumps
3. Experimental qualification

3.2 Dynamic Mode

<table>
<thead>
<tr>
<th>Masses (u)</th>
<th>Experimental</th>
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<th>Error between exp and theo</th>
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<td>8.90</td>
<td>5.91</td>
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</table>

Percentages comparison

Xenon spectrum

On-Line Mass Spectrometry Measurement of Fission Gas Release from Nuclear Fuels
Submitted to Thermal Transients
Accepted, IEEE Transactions on Nuclear Sciences (2014)
CONCLUSION

- RGA choice is good choice
  - Compact and robust for on-line implementation

- Performances agree with the objectives
  - Lower threshold less than few ppm
  - With a mass resolution of 1 u

- Implementation on MERARG replica, autumn 2014
Thank you for your attention