



## First results on radiometric dating of metals by alpha spectrometry☆

J. Cruz<sup>a,b,\*</sup>, E. Figueiredo<sup>c</sup>, V. Correigidor<sup>d</sup>, P.J. Girginova<sup>b</sup>, L.C. Alves<sup>e</sup>, C. Cruz<sup>d</sup>, R.J.C. Silva<sup>c</sup>, I. Liritzis<sup>f</sup><sup>a</sup> LUMMA-SPE, DE FCT, Universidade NOVA de Lisboa, 2825-166 Monte de Caparia, Portugal<sup>b</sup> Centro de Física Nuclear da Universidade de Lisboa, Av. Prof. Gama Pires, 1649-016 Lisboa, Portugal<sup>c</sup> CERNMADON, INCT, FCT, Universidade NOVA de Lisboa, 2825-126 Monte de Caparia, Portugal<sup>d</sup> SPN, IST-UL, Campus Universidade de Lisboa, E.N. 30, 2650-066 Sacavém, Portugal<sup>e</sup> CFN, IST-UL, Campus Universidade de Lisboa, E.N. 30, 2650-066 Sacavém, Portugal<sup>f</sup> King Saud University, Kingdom of Saudi Arabia, and, Laboratory of Archaeometry, Dept of Mathematics Studies, University of the Aegean, 1 Demetrias Ave, Rhodes 81102, Greece

## ARTICLE INFO

## Article history:

Received 13 August 2015

Received in revised form 1 October 2015

Accepted 1 October 2015

Available online 13 October 2015

## Keywords:

Uranium

Dating metals

Alpha spectrometry

<sup>238</sup>U

Ores

Slags

## ABSTRACT

A new TSAC (Thin-Source Alpha Particle-Counting spectrometry) setup of high geometrical efficiency and low intrinsic background was built to measure the alpha particles coming from the <sup>238</sup>U and <sup>232</sup>Th decay chain radionuclides with concentration as down to five ppm level. It was designed to test the <sup>226</sup>Ra/<sup>238</sup>U method, which is the only direct metal dating method proposed to date. Micro-PDCL, micro-RBS and SEM-EDS were used as complementary analytical techniques in order to search for heterogeneities and/or impurities that could bias the TSAC data. Ores, resulting slags and metallic profile from two recent smelting experiments that reproduced ancient techniques and two ancient ores were studied to determine how radionuclides fractionation occurs during smelting. With this TSAC setup the background signal was extremely low, but comparable to the signal from the measured metals. Preliminary results show no evidence of a preferential depletion of <sup>226</sup>Ra in archaeological with respect to the other radionuclides.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

Archaeo-metallurgical research focuses in the reconstruction of early trade routes in terms of location of metal sources (ore deposits) and in the study of metallic artifacts and metallurgical remains through various analytical and examination techniques. Important information can be derived from these studies, like ore provenance, contact between different ancient societies and their technological development.

It's not an overstatement to say that the Holy Grail of archaeo-metallurgists is to achieve a method that can directly give the date of the manufacture of a metallic artifact.

Until now, the dating of metallurgical processes is made indirectly, under favorable conditions, by [1]: a) thermoluminescence (TL) and optical stimulated luminescence (OSL) of burnt soil in kilns and crucibles, or of remaining core material in the metal artifact and slag products [2]; b) radiocarbon (<sup>14</sup>C) applied on carbon found in trapped slag inclusions (mainly from artifacts); c) association with other archaeological artifacts found in the same archaeological context; and d) some aging or degradation specificities that may differentiate an old from a new object (e.g. intergranular corrosion is a slower corrosion process).

In 2005 [1] I. Liritzis proposed a radiometric dating method for metals that are produced from ores (native metals excluded), based on the isotopic fractionation that may occur during ore smelting. This fractionation disrupts the secular equilibrium in the <sup>238</sup>U series. In this sense, <sup>226</sup>Ra, a radionuclide that occurs naturally in the decay chain of <sup>238</sup>U with a half-life of 1602 years, tends to be withdrawn by slag products away of the melted metal, as a result of its low specific gravity, 5–6 g/cm<sup>3</sup>, and its lower melting point (700 °C) when compared to some metals, as for example copper (8.9 g/cm<sup>3</sup>; 1083 °C).

As a consequence, in a metal, <sup>226</sup>Ra would appear from the decay of its parent, <sup>238</sup>Th (half-life,  $t_{1/2} = 80000$  years). Assuming that initially in the metal <sup>226</sup>Ra is not present, then at time  $t$ , the ratio between the activities of <sup>226</sup>Ra and <sup>238</sup>Th is given by Eq. (1) [1]

$$\frac{A_{226Ra}}{A_{238Th}} = \frac{\lambda_{238Th}}{\lambda_{226Ra} - \lambda_{238Th}} \left[ 1 - e^{-(\lambda_{226Ra} - \lambda_{238Th})t} \right], \quad (1)$$

where  $\lambda_{226Ra}$  and  $\lambda_{238Th}$  are the decay constants ( $\lambda = \ln(2)/t_{1/2}$ ) of <sup>226</sup>Ra and <sup>238</sup>Th, respectively. As  $\lambda_{226Ra} \gg \lambda_{238Th}$  ( $4.33 \times 10^{-4} \text{ yr}^{-1} \gg 8.66 \times 10^{-6} \text{ yr}^{-1}$ ) the ratio of activities tend to the value  $\lambda_{226Ra} / (\lambda_{226Ra} - \lambda_{238Th}) \approx 1$ , and the secular equilibrium is attained after around 5000 years. This period is comparable to the elapsed time since the onset of metallurgy in some areas of the globe. Therefore, this growth of <sup>226</sup>Ra back to secular equilibrium with its parent <sup>238</sup>Th is the basis of this method. This model, known as the <sup>226</sup>Ra/<sup>238</sup>Th Liritzis method,

☆ ScienceDirect paper presented at TECHNET 2015 Conference, Catania (Italy), April 27–30, 2015.

\* Corresponding author.

E-mail address: jmc@fmn.unl.pt (J. Cruz).

# Radiometric Dating By Alpha Spectrometry

**JE Gale**



## **Radiometric Dating By Alpha Spectrometry:**

Thank you for downloading **Radiometric Dating By Alpha Spectrometry**. Maybe you have knowledge that, people have look hundreds times for their chosen books like this Radiometric Dating By Alpha Spectrometry, but end up in infectious downloads.

Rather than enjoying a good book with a cup of tea in the afternoon, instead they are facing with some harmful virus inside their laptop.

Radiometric Dating By Alpha Spectrometry is available in our digital library an online access to it is set as public so you can get it instantly.

Our book servers saves in multiple locations, allowing you to get the most less latency time to download any of our books like this one.

Kindly say, the Radiometric Dating By Alpha Spectrometry is universally compatible with any devices to read

<https://pinsupreme.com/public/book-search/index.jsp/out%20of%20the%20box%20for%20life%20being%20free%20is%20just%20a%20choice.pdf>

## **Table of Contents Radiometric Dating By Alpha Spectrometry**

1. Understanding the eBook Radiometric Dating By Alpha Spectrometry
  - The Rise of Digital Reading Radiometric Dating By Alpha Spectrometry
  - Advantages of eBooks Over Traditional Books
2. Identifying Radiometric Dating By Alpha Spectrometry
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Radiometric Dating By Alpha Spectrometry
  - User-Friendly Interface

4. Exploring eBook Recommendations from Radiometric Dating By Alpha Spectrometry
  - Personalized Recommendations
  - Radiometric Dating By Alpha Spectrometry User Reviews and Ratings
  - Radiometric Dating By Alpha Spectrometry and Bestseller Lists
5. Accessing Radiometric Dating By Alpha Spectrometry Free and Paid eBooks
  - Radiometric Dating By Alpha Spectrometry Public Domain eBooks
  - Radiometric Dating By Alpha Spectrometry eBook Subscription Services
  - Radiometric Dating By Alpha Spectrometry Budget-Friendly Options
6. Navigating Radiometric Dating By Alpha Spectrometry eBook Formats
  - ePub, PDF, MOBI, and More
  - Radiometric Dating By Alpha Spectrometry Compatibility with Devices
  - Radiometric Dating By Alpha Spectrometry Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Radiometric Dating By Alpha Spectrometry
  - Highlighting and Note-Taking Radiometric Dating By Alpha Spectrometry
  - Interactive Elements Radiometric Dating By Alpha Spectrometry
8. Staying Engaged with Radiometric Dating By Alpha Spectrometry
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Radiometric Dating By Alpha Spectrometry
9. Balancing eBooks and Physical Books Radiometric Dating By Alpha Spectrometry
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Radiometric Dating By Alpha Spectrometry
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Radiometric Dating By Alpha Spectrometry
  - Setting Reading Goals Radiometric Dating By Alpha Spectrometry
  - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Radiometric Dating By Alpha Spectrometry
  - Fact-Checking eBook Content of Radiometric Dating By Alpha Spectrometry
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

### **Radiometric Dating By Alpha Spectrometry Introduction**

In the digital age, access to information has become easier than ever before. The ability to download Radiometric Dating By Alpha Spectrometry has revolutionized the way we consume written content. Whether you are a student looking for course material, an avid reader searching for your next favorite book, or a professional seeking research papers, the option to download Radiometric Dating By Alpha Spectrometry has opened up a world of possibilities. Downloading Radiometric Dating By Alpha Spectrometry provides numerous advantages over physical copies of books and documents. Firstly, it is incredibly convenient. Gone are the days of carrying around heavy textbooks or bulky folders filled with papers. With the click of a button, you can gain immediate access to valuable resources on any device. This convenience allows for efficient studying, researching, and reading on the go. Moreover, the cost-effective nature of downloading Radiometric Dating By Alpha Spectrometry has democratized knowledge. Traditional books and academic journals can be expensive, making it difficult for individuals with limited financial resources to access information. By offering free PDF downloads, publishers and authors are enabling a wider audience to benefit from their work. This inclusivity promotes equal opportunities for learning and personal growth. There are numerous websites and platforms where individuals can download Radiometric Dating By Alpha Spectrometry. These websites range from academic databases offering research papers and journals to online libraries with an expansive collection of books from various genres. Many authors and publishers also upload their work to specific websites, granting readers access to their content without any charge. These platforms not only provide access to existing literature but also serve as an excellent platform for undiscovered authors to share their work with the world. However, it is essential to be cautious while downloading Radiometric Dating By Alpha Spectrometry. Some websites may offer pirated or illegally obtained copies of copyrighted material. Engaging in such activities not only violates copyright laws but also undermines the efforts of authors, publishers, and researchers. To ensure ethical downloading, it is advisable to utilize

reputable websites that prioritize the legal distribution of content. When downloading Radiometric Dating By Alpha Spectrometry, users should also consider the potential security risks associated with online platforms. Malicious actors may exploit vulnerabilities in unprotected websites to distribute malware or steal personal information. To protect themselves, individuals should ensure their devices have reliable antivirus software installed and validate the legitimacy of the websites they are downloading from. In conclusion, the ability to download Radiometric Dating By Alpha Spectrometry has transformed the way we access information. With the convenience, cost-effectiveness, and accessibility it offers, free PDF downloads have become a popular choice for students, researchers, and book lovers worldwide. However, it is crucial to engage in ethical downloading practices and prioritize personal security when utilizing online platforms. By doing so, individuals can make the most of the vast array of free PDF resources available and embark on a journey of continuous learning and intellectual growth.

### **FAQs About Radiometric Dating By Alpha Spectrometry Books**

How do I know which eBook platform is the best for me? Finding the best eBook platform depends on your reading preferences and device compatibility. Research different platforms, read user reviews, and explore their features before making a choice. Are free eBooks of good quality? Yes, many reputable platforms offer high-quality free eBooks, including classics and public domain works. However, make sure to verify the source to ensure the eBook credibility. Can I read eBooks without an eReader? Absolutely! Most eBook platforms offer web-based readers or mobile apps that allow you to read eBooks on your computer, tablet, or smartphone. How do I avoid digital eye strain while reading eBooks? To prevent digital eye strain, take regular breaks, adjust the font size and background color, and ensure proper lighting while reading eBooks. What the advantage of interactive eBooks? Interactive eBooks incorporate multimedia elements, quizzes, and activities, enhancing the reader engagement and providing a more immersive learning experience. Radiometric Dating By Alpha Spectrometry is one of the best book in our library for free trial. We provide copy of Radiometric Dating By Alpha Spectrometry in digital format, so the resources that you find are reliable. There are also many Ebooks of related with Radiometric Dating By Alpha Spectrometry. Where to download Radiometric Dating By Alpha Spectrometry online for free? Are you looking for Radiometric Dating By Alpha Spectrometry PDF? This is definitely going to save you time and cash in something you should think about.

**Find Radiometric Dating By Alpha Spectrometry :**

*out of the box for life being free is just a choice*

**our rifles**

outer and inner space

~~outside and inside killer bees~~

**our soviet sister**

**outdoor living skills program manual**

*out and about with tom and pippo*

**outcast of ute bend curley large prints**

**our worlds story/grade 6 & 7**

**outdoor education**

**outsider notes feminist approaches to nation state ideology writersreaders and publishing**

**our wonder world 10vol**

~~outta sight~~

outdoor first care

out of the shadow the story of charles edison

**Radiometric Dating By Alpha Spectrometry :**

A Disassembly Manual for the Winchester Models 62 and ... This book is illustrated with many photos and very detailed directions about how to takedown your Winchester 62 or 62A firearm. It will first outline the ... Winchester Model 62 Owners Manual Reproduction Made with high quality scans of original. Great information and a nice addition to your rifle. Good information but just the basics. Winchester Model 62A (Owners Manual) Winchester Model 62A (Owners Manual) The Smithy. Owners Manuals | Winchester Repeating Arms If you have misplaced the owner's manual originally provided with your firearm or safe, you can — in many cases — can find a digital copy here. Winchester 62A Rifle Service Manuals, Cleaning, Repair ... Feb 5, 2015 — Here are the full Disassembly Service Manuals of the Winchester Model 62A Rifle. You get step by step Pictures packed along with all the ... Winchester Model 62 Important Instructions Originally given with the purchase of any Model 62, this booklet provides instructions on how to put the gun together, assemble the bolt, fire the gun, ... 62a feeding/jamming/quality/reliability May 13, 2018 — You need to do a complete cleaning of the action, and since you are a novice at this you need a Service Manuals of the Winchester Model 62A ... products manuals PRODUCTS



MANUALS. Here are the files (PDF) of the original Owner's Manuals : OVER/UNDER SHOTGUNS. CHOOSE, Supreme.pdf · Select.pdf. SEMI-AUTO SHOTGUNS. CHOOSE ... model 62 manual | Rimfire Central Firearm Forum Sep 30, 2020 — Went on the Winchester website for manuals and they do not show one for the model 62. Where can I find one? I am relatively new with guns, ... Solutions To Case 17 Healthcare Finance Gapenski Solutions To Case 17 Healthcare Finance. Gapenski. 3. 3. Dr. Samuel Myers and. Dr. Howard Frumkin, in mid-August. 2020.Together with. Planetary Health Case. Solutions To Case 17 Healthcare Finance Gapenski Welcome to our system where you can conveniently access a riches of resources in PDF style, all at your fingertips, anytime and anywhere. Gapenski's Cases in Healthcare Finance Sixth Editi... 105 CASE 17 Southeastern Homecare was founded in 1992 in Miami, Florida, as a taxable partnership by Maria Gonzalez, MD; Ramon Garcia, RN; and Ron Sparks, ... Cases in Healthcare Finance, Seventh Edition The book's 33 cases explore financial management and accounting in a variety of healthcare settings, such as hospitals, clinics, medical practices, home health ... Chapter 17 Solutions | Gapenski's Healthcare Finance: An ... Access Gapenski's Healthcare Finance: An Introduction to Accounting and Financial Management, Seventh Edition 1st Edition Chapter 17 solutions now. Chapter 17.pdf - Healthcare Finance: An Introduction to... Healthcare Finance: An Introduction to Accounting & Financial Management, Sixth Edition by Louis C. Gapenski and Kristin L. Reiter Health Administration Press. Gapenski's Cases in Healthcare Finance, Sixth Edition The cases are supported by an extensive array of ancillary resources—including spreadsheet models for both instructors and students, case questions and ... Healthcare Finance 6th Edition Textbook Solutions Access Healthcare Finance 6th Edition solutions now. Our solutions are written by Chegg experts so you can be assured of the highest quality! Gapenski's Cases in Healthcare Finance Dec 1, 2017 — Case Solution 1 - 1. CASE 1 SOLUTION. NEW ENGLAND HEALTHCARE. Premium Development. Case Information. This case requires students to develop a ... Finance Case Presentations Gapenski, Healthcare Finance: An Introduction to Accounting and Financial ... Student Health at Shands offers a variety of clinical services. The clinic is ... Press Release - 8th Edition of the European Pharmacopoeia ... Medicines are indispensable for ensuring patients' health and access to good-quality medicines and healthcare is a basic human right. The European ... European pharmacopoeia 8.0 : published in accordance ... Edition: 8th ed ; Publisher: European Directorate for the Quality of Medicines & Healthcare, Council of Europe, Strasbourg, 2013-14. European Pharmacopoeia: Books European Pharmacopoeia 8th Edition 2014 -2016 Print. by European Pharmacopoeia. Hardcover. THE 8TH EDITION OF THE EUROPEAN PHARMACOPOEIA ... Jul 12, 2013 — pharmacopoeial standards. The upcoming 8th Edition of the European Pharmacopoeia contains more than 2220 monographs and. 340 general chapters ... European Pharmacopoeia 8th Edition 2014 Print (Volume ... European Pharmacopoeia 8th Edition 2014 Print (Volume 8.0 ,8.1 and 8.2) - ISBN 10: 9287175276 - ISBN 13: 9789287175274 - Hardcover. Technical Guide for the elaboration of monographs Apr 2, 2022 — 8th Edition. 2022. European Directorate for the Quality of ... Elaboration of a European Pharmacopoeia (hereinafter the “European Pharmacopoeia.

European Pharmacopoeia 8 0 : Free Download, Borrow ... Feb 17, 2017 — Volumes 1 and 2 of this publication 8.0 constitute the 8 th Edition of the European Pharmacopoeia. They will be complemented by non-cumulative ... European Pharmacopoeia 8th Edition Jan 15, 2014 — European Pharmacopoeia 8th Edition · Identification A: requirement for elasticity deleted since test cannot be performed on all types of rubber ... European Pharmacopoeia 8th ed (8.0 + supp 8.1 & 8.2 ... European Pharmacopoeia 8th ed (8.0 + supp 8.1 & 8.2) (PUB200093). Language: English. Approximative price 450.00 €. Subject to availability at the publisher. European Pharmacopoeia (Ph. Eur.) The Ph. Eur. Commission · Groups of experts and working parties · European Pharmacopoeia 11th Edition. Focus. Biotherapeutics · Alternatives to animal testing ( ...