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An ^{241}Am Plasma Desorption Ionization (AmDI) Source for Medical Applications

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ABSTRACT

Plasma Desorption Ionization (PDI) stands as a robust analytical technique facilitating the identification and quantification of a diverse array of compounds, including drugs, metabolites, and biomolecules within biological specimens. This study delves into the exploration of efficient and cost-effective ionization methodologies geared towards medical applications. Introducing an innovative avenue known as Americium-241 Plasma Desorption Ionization (AmDI), leveraging the radioactive element Americium-241 found in smoke detectors, boasting a lengthy half-life of 432.2 years. Desorption ionization experiments were executed employing an ion chamber extracted from a smoke detector, accompanied by sample tablets (ibuprofen and paracetamol) positioned in close proximity to a Tesla coil, serving as the plasma ionization source. The findings acquired affirm the viability and efficacy of the AmDI approach in characterizing this specific category of samples. This development represents a significant stride in medical diagnostics, offering a pragmatic and budget-friendly resolution for comprehensive analysis.

This research undertakes a practical and preliminary exploration, where desorption ionization assessments are conducted utilizing a smoke detector-extracted ion chamber and sample tablets (ibuprofen and paracetamol), strategically positioned in proximity to a Tesla coil functioning as the plasma ionization source. The results unearth the viability and efficacy of the AmDI technique, showcasing its prowess in characterizing these specific types of samples. As a pioneering stride, this advancement contributes significantly to the field of medical diagnostics, furnishing an accessible and cost-effective solution for comprehensive analytical pursuits. As the demand for effective and economical ionization methods for medical applications escalates, this study delves into the realm of innovation, proposing a novel approach named Americium-241 Plasma Desorption Ionization (AmDI).

Abbreviations: PDI: Plasma Desorption Ionization; AmDI: The Americium Desorption Ionization; FTIR: Fourier Transform Infrared Spectroscopy; XRD: X-Ray Diffraction

Introduction

The development of new ionization methods has been a field of constant research in mass spectrometry, with the aim of improving efficiency and applicability in various areas [1]. Among the pivotal attributes pursued, high sampling rates, peak performance, user-friendliness, seamless ionization, molecular specificity, and heightened sensitivity stand out as critical objectives [2]. In this line of advances, environ- mental ionization methods have emerged as a promising option, since they allow samples to be analyzed directly in their environment without the need for prior preparation [3]. Currently, more than 40 types of ambient ionization methods have been developed, and many of them have shown phenomenal success in various applications [4]. These methods can be grouped into categories according to their ionization mechanism, where those that use electrospray stand out, as well as various discharge methods and photoionization or laser ablation with photons of different wavelengths [5]. Likewise, other techniques such as microwave plasma ionization and ultra- sonic desorption have found their place in this diversity of approaches [6].

The key to understanding the diversity of these methods lies in how they provide the energy necessary to ionize the analytes present in the samples [7-9]. The mechanisms used include high-voltage discharge, the use of fast-moving droplets, interaction with photons, and

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the use of ultrasound or heat input, depending on the specific methodology [10-13]. In the present study, it has been possible to develop an innovative method of ionization by environmental desorption, which is based on the use of the radioactive element americium-241 (^{241}Am) [14,15]. This approach eliminates the need for low-pressure gas, high voltage, heat, or other forms of external power. Americium-241 is a by-product generated in nuclear reactors and has a half-life of 432.2 years, making it a practically perpetual energy source for mass spectrometry sampling [16]. Its most common form is $^{241}AmO_2$ and small amounts of this element (0.2 mm thick and 2 mm in diameter) are found in the smoke detectors that equip most homes today [17,18]. This novel approach, AmDI, promises to overcome many of the limitations associated with traditional ionization methods, providing an effective and sustainable alternative for future applications in the field of mass spectrometry and practical applications in various areas such as medicine [19].

Material and Methods

A disassembled ionization chamber from a smoke detector, widely available online at low cost, was used as the basis for the Americium-241 Plasma Desorption Ionization Source (AmDI). In smoke detectors, the radiation emitted by ^{241}Am is used to ionize air molecules, generating electrical currents. The $^{241}AmO_2$ discs present in these detectors are generally coated with a 2 μm thick layer of gold as shown in Figure 1. In order to reduce the radiation from α decay, which releases a ^{237}Np atom, an α particle and a γ photon [20].

$$^{241}_{95}Am \rightarrow ^{237}_{93}Np + ^{4}_{2}\alpha^{2+} + \gamma \quad (1)$$

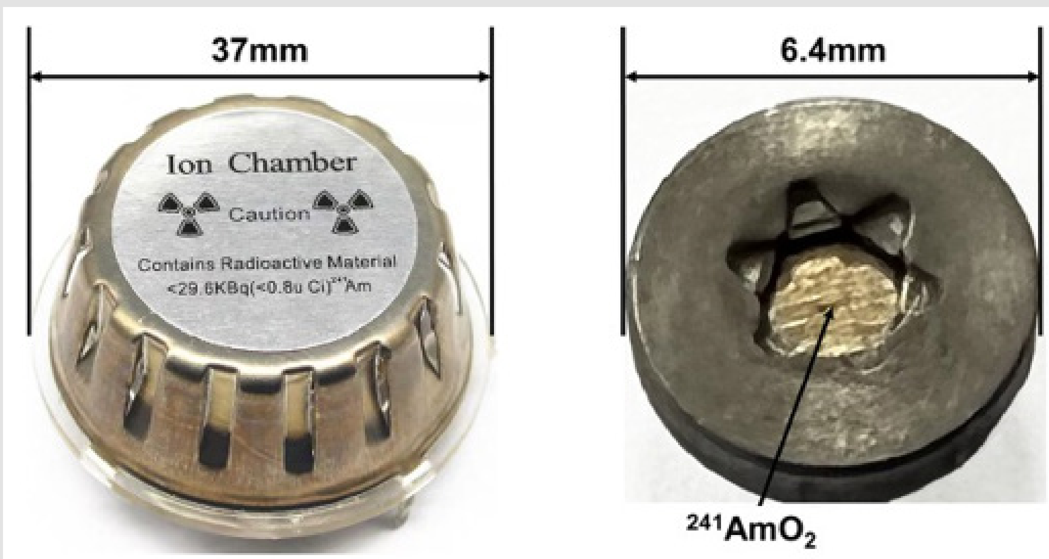

Figure 1: Smoke detector with $^{241}AmO_2$ covered in gold sheet.

The high mass and charge of alpha particles give them considerable ionizing power, although their ability to penetrate matter is limited. In air, these particles can travel a distance of about 4 cm, while in water their range is reduced to about 48 μm [21]. This translates into a significant level of safety for home or laboratory use of ^{241}Am since its ability to penetrate the human body is limited. The risks associated with this radiation are mainly relevant when the radioactive material is ingested or found inside the body [22]. It is important to note that the ^{241}Am disk in smoke detectors has a total mass of about 7 mg [23], which constitutes a relatively small and controlled amount of this radioactive element. Safety and precautionary measures in its handling are essential to guarantee its proper use in domestic and laboratory environments, minimizing any potential health risk. In this study, medication pills, such as paracetamol and ibuprofen, were mainly used as samples for analysis because they are widely used drugs in medicine [24]. However, it should be noted that this method can be easily extended and applied to other materials of interest. The approach used in the study demonstrates its versatility and potential to analyze a wide range of samples, beyond the mentioned drugs. The adaptability of the method allows its use in different fields, opening the door to future research in various areas of interest, such as the analysis of biological, environmental, or industrial samples. With this extension capacity, the scope of the re- search is significantly expanded and the foundations are laid for possible applications in fields as diverse as medicine, ecology, or chemistry. This represents a promising opportunity to advance scientific knowledge and problem-solving in various disciplines.

Plasma Generation

To achieve plasma generation in this study, a flyback was implemented as the main power source [25,26] However, instead of using a conventional high voltage, an innovative approach based on the radioactive element americium was taken. The americium desorption ionization (AmDI) process was carried out by the interaction of americium with the plasma arc generated by the flyback. By positioning the americium within the arc, ionization of the surrounding air molecules occurs, which causes the desorption of the ions from the surface and their subsequent ionization in the generated plasma. The choice to use americium instead of a traditional high voltage provided several advantages, including the elimination of the need for external power sources, which significantly simplified the experimental setup. In addition, the alpha particles of americium interact with the sample molecules, giving off electrons and generating positive ions, which proved to be highly efficient for the ionization of the samples, allowing to obtain precise and reliable results. It is important to mention that all the appropriate security measures were taken during the handling and manipulation of the americium, ensuring a safe working environment for all the team involved in the experiment. In Figure 2, the assembly diagram used is shown: The samples used in this study were paracetamol and ibuprofen tablets, which played a fundamental role in the Americium Desorption Ionization (AmDI) process. These samples were strategically placed between the two flyback terminals, allowing them to be in direct contact with the plasma arc generated from the ionization of americium. By placing the pills in this position, the interaction of the drug molecules with the plasma was facilitated, which allowed the desorption and ionization of the analytes present in the samples. This experimental setup ensured that the charged particles generated by the plasma would impact the pills, releasing ions and pro- viding valuable information on the molecular composition of the drugs. The proximity of the samples to the plasma arc generated by the ionization of americium ensured higher ionization efficiency and higher detection sensitivity, resulting in accurate and meaningful analytical data for analyses, as shown in Figure 3.

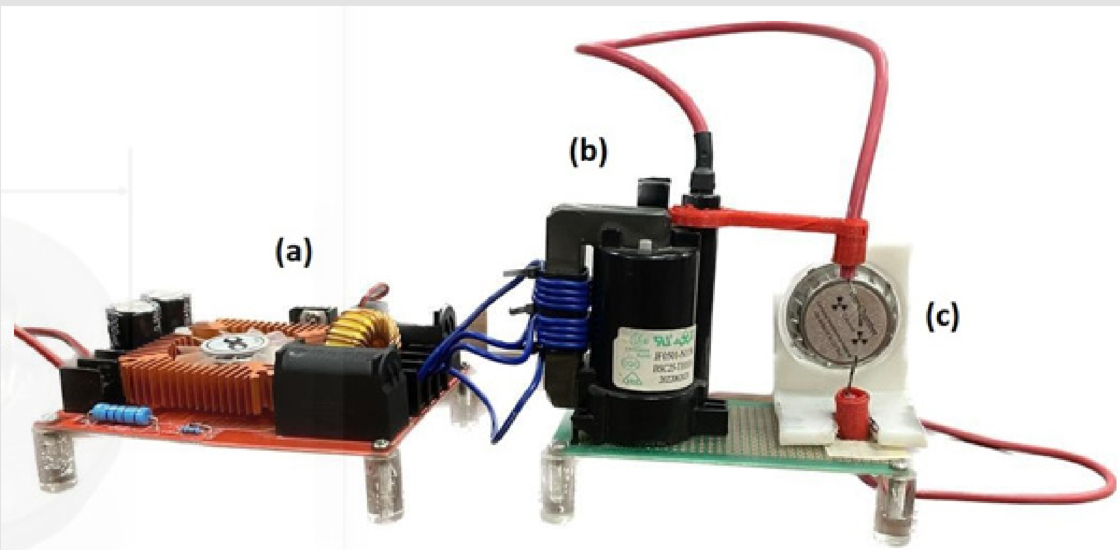

Figure 2: Assembly diagram of the AmDI system.
a) Drive plate,
b) Flyback, and
c) Americium-241

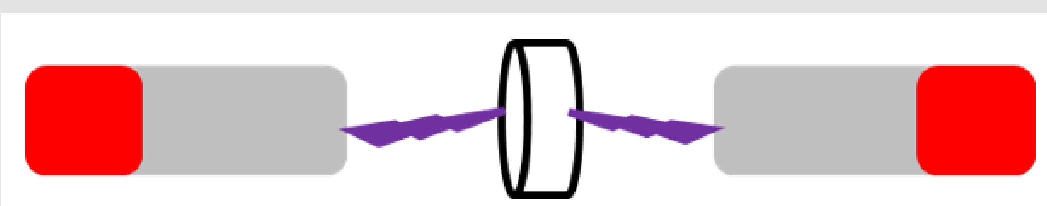

Figure 3: Sample placement in horizontal direction.

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Results

The results obtained after exposing ibuprofen and paracetamol to the plasma source with americium-241 were analyzed using the Fourier Transform Infrared Spectroscopy (FTIR) technique [27]. This technique made it possible to compare the infrared spectra of the samples before and after contact with the plasma, providing valuable information on the composition and structure of the drugs. Each chemical compound has a unique set of molecular vibrations that are reflected in its FTIR spectrum. By analyzing the FTIR spectra of paracetamol and ibuprofen, the main absorption bands were identified, which were related to the structural characteristics of the drugs. The FTIR spectrum of paracetamol showed typical absorption bands around 3, 328 cm^{-1}, corresponding to hydroxyl (OH) groups, and an intense band at 1, 650 cm^{-1}, due to the presence of the amide group (C = O). In addition, a mean band of 1, 580 cm^{-1} was observed, associated with a benzene ring in the paracetamol molecule [28,29]. In Figure 4, the sample irradiated with plasma is presented. These results indicate that paracetamol did not undergo major structural changes due to exposure to plasma generated by americium-241. These findings are relevant, as they support the safety of the AmDI method and suggest that this ionization technique does not affect the molecular structure of paracetamol during analysis. In Figure 5, the FTIR spectrum of ibuprofen reveals distinctive features in its absorption bands. At approximately 3, 468 cm^{-1}, a broadband corresponding to the presence of hydroxyl (OH) groups is observed. At a frequency of 1, 700 cm^{-1}, an intense band stands out, which is attributed to the existence of a carboxyl group (C = O). In addition, at 1, 537 cm^{-1}, a band of medium intensity is identified, indicative of the presence of an aromatic ring in the ibuprofen molecule [28].

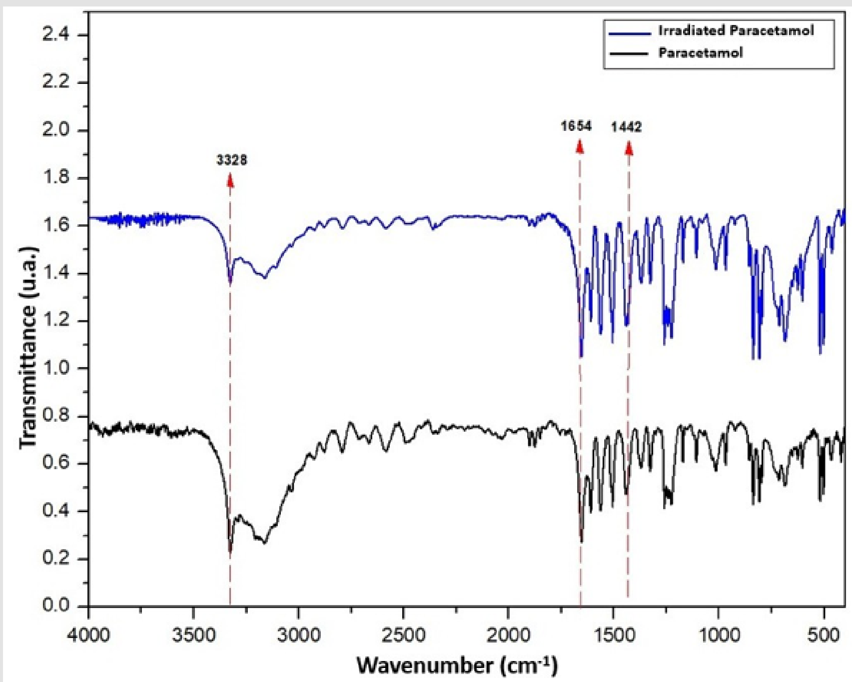

Figure 4: FTIR of irradiated and normal paracetamol.

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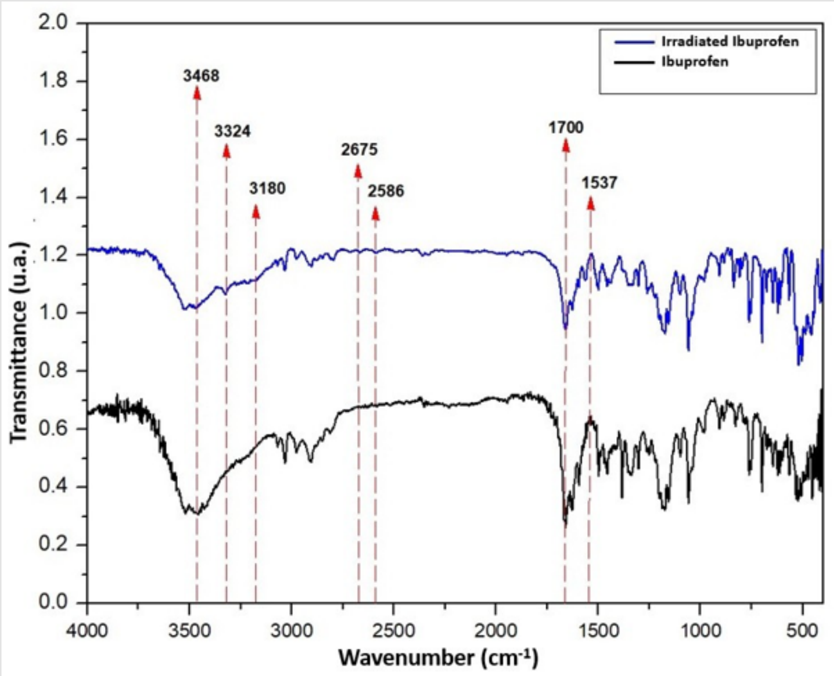

Figure 5: FTIR of irradiated and normal ibuprofen.

These observations are consistent with the known molecular structure of ibuprofen and allow confirmation of its identification using FTIR spectroscopy. Each of these absorption bands is characteristic and specific to the molecular vibrations of ibuprofen, providing additional evidence for the effectiveness of the AmDI method in accurately analyzing this drug. The results obtained after FTIR analysis of plasma-irradiated ibuprofen indicate that there was no significant alteration in its molecular structure due to exposure to plasma generated by americium-241. This information is valuable in supporting the reliability of the AmDI method in drug characterization and its potential application in various fields of research and clinical analysis. In addition to the observations on paracetamol and ibuprofen mentioned above, more detailed and comparative analyzes were carried out between the samples before and after their exposure to plasma generated by the ionization of americium. Both samples were found to retain their main structural features after contact with the plasma, suggesting that the AmDI method did not cause significant changes in the molecules of the drugs tested. The preservation of the molecular structure of the samples is a relevant finding, as it highlights the feasibility and safety of the AmDI approach for the analysis of pharmaceutical compounds and other materials. Furthermore, this result opens up promising prospects for its application in future research and clinical applications. It is important to mention that, together with the FTIR analysis, it is intended to complete the characterization with X-ray diffraction techniques to examine the crystalline structure of the samples, mass spectroscopy to identify the mass and composition of ionized molecules, and nuclear magnetic resonance spectroscopy. to characterize structural changes and molecular interactions of drugs in solution.

Conclusion

In this research, the Americium-241 Plasma Desorption Ionization (AmDI) method has been shown to be a valuable alternative for plasma generation and sample ionization, with an innovative approach using americium-241 as a source. of energy. The results obtained using the Fourier Transform Infrared Spectroscopy (FTIR) technique have made it possible to accurately characterize the paracetamol and ibuprofen samples, revealing the effectiveness of the method in identifying key molecular characteristics of the drugs. It is encouraging to note that the analyzed samples retained their essential molecular structure after contact with the plasma generated by the ionization of americium. These results underscore the safety and reliability of the AmDI method, suggesting its potential application in clinical assays and in a wide variety of research fields. As future work, it is intended to complement the characterization of the samples with other advanced techniques, such as X-Ray Diffraction (XRD), to examine the crystalline structure of the compounds. In addition, Mass Spectroscopy (MS) will be used to identify the mass and composition of the ionized molecules, providing additional information on the composition of the samples and their relationship with the obtained FTIR spectrum. Nu- clear Magnetic Resonance (NMR) Spectroscopy is also being considered to characterize possible structural changes and

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molecular interactions of drugs in solution. These additional techniques will allow for a deeper and more complete understanding of the samples, further strengthening the validity and utility of the AmDI method. In summary, the AmDI approach offers a promising outlook for future research and applications in the field of mass spectrometry and ambient ionization. The combination of various analytical techniques will allow further progress in the under- standing and application of this method, fostering significant advances in medical diagnostics, materials studies and other relevant scientific areas.

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Data Availability Statement

Data sharing not applicable - no new data generated.

References

1. Z Takats, JM Wiseman, B Gologan, RG Cooks (2004) Mass spec- trometry sampling under ambient conditions with desorption electrospray ionization. Science 306(5695): 471-473.
2. RB Cody, JA Laramée, HD Durst (2005) Versatile new ion source for the analysis of materials in open air under ambient conditions. Analytical chemistry 77(8): 2297-2302.
3. CL Feider, A Krieger, RJ DeHoog, LS Eberlin (2019) Ambientioniza-tion mass spectrometry: recent developments and application." Analytical chemistry 91: 4266-4290.
4. CL Feider, A Krieger, RJ DeHoog, LS Eberlin (2019) Ambientionization mass spectrometry today and tomorrow: embracing challenges and opportunities. Analytical chemistry 92(3): 2353-2363.
5. X Zhan, Z Zhao, X Yuan, Q Wang, D Li, et al. (2013) Microwave-induced plasma desorption/ionization source for ambient mass spectrometry. Analytical chemistry 85: 4512-4519.
6. K Evans Nguyen, J Gerling, H Brown, M Miranda, A Windom, et al. (2013) Towards universal ambient ionization: direct elemental analysis of solid substrates using microwave plasma ionization. Analyst 141: 3811-3820.
7. T Liang, T Schneider, SH Yoon, BL Oyler, LM Leung, et al. (2018) Optimized surface acoustic wave nebulization facilitates bacterial phenotyping. International Journal of Mass Spectrometry 427: 65-72.
8. IC Lu, EA Elia, WJ Zhang, M Pophristic, ED Inutan, et al. (2015) Development of an easily adaptable, high sensitivity source for inlet ionization. Analytical Methods 9: 4971-4978.
9. S Trimpin (2016) Magic ionization mass spectrometry. Journal of The Ameri- can Society for Mass Spectrometry 27: 4-21
10. SR Heron, R Wilson, SA Shaffer, DR Goodlett, JM Cooper, et al. (2010) Surface acoustic wave nebulization of peptides as a microfluidic interface for mass spectrometry. Analytical chemistry 82: 3985-3989.
11. N Strittmatter, A Lovrics, J Sessler, JS McKenzie, Z Bodai, et al. (2016) Shotgun lipidomic profiling of the nci60 cell line panel using rapid evaporative ionization mass spectrometry. Analytical chemistry 88: 7507-7514.
12. KC Schäfer, J Dénes, K Albrecht, T Szaniszló, J Balog, et al. (2009) *In vivo*, in situ tissue analysis using rapid evaporative ionization mass spectrometry. Angewandte Chemie International Edition 48: 8240-8242.
13. CN McEwen, VS Pagnotti, ED Inutan, S Trimpin (2010) New paradigm in ionization: multiply charged ion formation from a solid matrix without a laser or voltage. Analytical chemistry 82: 9164-9168.
14. D Xing, C Liang, X Yuan, X Zhang (2022) An 241am plasma desorptionionization (amdi) source scavenged from smoke detectors for ambient mass spectrometry sampling. Analytical chemistry 94: 8555-8560.
15. JA Plant, B Smith, X Phoon, KV Ragnarsdottir (2011) Radioactivity and radioelements. Pollutants, Human Health and the Environment: A Risk Based Approach, pp. 115-146.
16. J Campbell, L McNelles (1974) Americium-241 as a low-energy photon intensity standard. Nuclear Instruments and Methods 117: 519-532.
17. K Kostecka (2008) Americium–from discovery to the smoke detector and be- yond. Bull Hist Chem 33: 89-93.
18. E Eason (2011) Americium smoke detectors. Coursework for Physics 241.
19. F De Aquino (2007) Gravity control by means of electromagnetic field through gas or plasma at ultra-low pressure.
20. DM Taylor (1989) The biodistribution and toxicity of plutonium, americium and neptunium. Science of the total environment 83: 217-225.
21. PP Day (1955) Electromagnetic spectrum of am 241. Physical Review 97: 689.
22. F Fry (1976) Long-term retention of americium-241 following accidental inhalation. Health Physics 3: 13-20.
23. R Belanger, D Buckley, J Swenson (1979) Environmental assessment of ionization chamber smoke detectors containing am-241. Tech Rep (Science Applications, Inc, La Jolla, CA (USA)).
24. DJ Kanabar (2017) A clinical and safety review of paracetamol and ibuprofen in children. Inflammopharmacology 25: 1-9.
25. RM Zin, CF Soon, MZA Sani, ER Rizon, KS Tee, et al. (2017) Zero voltage switching driver and flyback transformer for generation of atmospheric pressure plasma jet. in AIP Conference Proceedings, (AIP Publishing,), pp. 1883.
26. V Law, S Anghel (2012) Compact atmospheric pressure plasma self-resonant drive circuits." Journal of Physics D: Applied Physics 45: 075202.
27. Z Movasaghi, S Rehman, DI ur Rehman (2008) Fourier transform in-frared (ftir) spectroscopy of biological tissues. Applied Spectroscopy Reviews 43: 134-179.
28. S Matkovic, G Valle, L Briand (2005) Quantitative analysis of ibuprofen in pharmaceutical formulations through ftir spectroscopy. Latin American applied research 35: 189-195.
29. SY Lin (2021) Current and potential applications of simultaneous dsc-ftir microspectroscopy for pharmaceutical analysis. Journal of Food and Drug Analysis 29: 182.

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