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RESEARCH ARTICLE OPEN ACCESS

STRATEGIC REUSE OF RADIOACTIVE SOURCES: NUCLEAR REACTION ANALYSIS AND IMPLICATIONS FOR WASTE MANAGEMENT

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ABSTRACT

This research aimed to analyze selected types of nuclear reactions applicable to the main radioisotopes used in Brazil. The study focused on identifying feasible reaction pathways and evaluating their nuclear characteristics, including reaction products and the energy requirements associated with them. Such analysis is relevant for understanding the production and optimization of radioisotopes used in important sectors of Brazilian society, particularly in medicine, industry, research, and education, thereby contributing to a more efficient and controlled use of nuclear technologies in the country.

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INTRODUCTION

A nuclear reaction refers to a process that involves a change in one or more atomic nuclei. In this context, the interaction can release energy, absorb energy, or produce new atoms (isotopes). These nuclear reactions are important because they allow the production of radionuclides with specific properties that are useful in different fields. To map the physical and chemical characteristics of the radioisotopes most commonly used in Brazil, an analysis was conducted based on the document titled *"Identification of Radioactive Sources and Devices"*, published by the IAEA. This reference provides the main applications of each radioisotope and their major global manufacturers—essential information for identifying the physical and chemical attributes of each radioactive source, given that these aspects are defined during their production stage. The collection and analysis of these data can enable new approaches to handling radioactive sources before they are discarded and sent to radioactive waste repositories. When their physical and chemical characteristics are properly managed, it becomes possible for the material to acquire new parameters that may allow it to be repurposed for different applications. After identifying the most common radioisotopes in Brazil, it was possible to analyze several nuclear reactions using virtual tools that provide the stability curve table for radioisotopes, along with other relevant information for this study. Five types of reactions were selected for the proposed analysis: (p,n), (p,2n), (n,γ), (n,α), and (n,p).

For each reaction, criteria such as the target, the resulting product, the minimum energy required for the nuclear reaction to occur (Q-value), and the appropriate handling equipment were evaluated. A literature review was also conducted for each proposed nuclear reaction to identify previous studies, applications, and other relevant data. In this way, it becomes possible to outline a detailed action plan for the main nuclear reactions involving the most widely used radioisotopes, enabling the advancement of nuclear physics in Brazil safely and effectively.

MATERIALS AND METHODS

This study employed a descriptive research method to analyze radioisotopes used in Brazil. The research was based on documents published by CNEN to identify the types, practices, and purposes of radioactive sources in licensed facilities across the country. Data were analyzed alongside IAEA guidelines. A questionnaire was also sent to professionals working at these facilities to gather information about the infrastructure, operation, capacity, and safety of intermediate radioactive waste repositories, following current regulations. This step aimed to fill informational gaps not covered by bibliographic or database sources.

RESULTS

The following graph illustrates the most frequent radionuclides sent to Brazilian intermediate facilities, according to the survey conducted.

The x-axis represents the most commonly used radionuclides, and the y-axis represents their occurrence in the analysis of the areas in which they are used across all radiative facilities in Brazil:

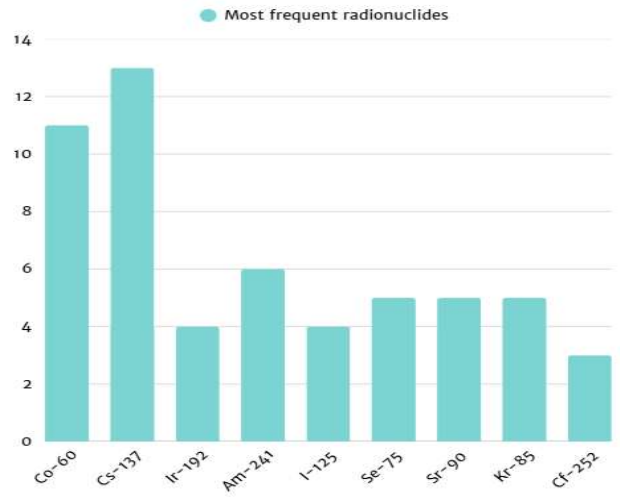

Figure X. Most frequent radionuclides in Brazil

The study of nuclear reactions of the types (p,n), (p,2n), (n,γ), (n,α), and (n,p), focusing on the radioisotopes most frequently used in Brazil, provided the products of these nuclear reactions, which are tabulated below:

Table X. Products obtained from the nuclear reactions of the main studied radioisotopes

Radioisotopes	(p,n)	(p,2n)	(n,y)	(n,a)	(n,p)
Cs-137	Ba-137	Ba-136	Cs-138	I-134	Xe-137
Co-60	Ni-60	Ni-59	Co-61	Mn-57	Fe-60
Am-241	Cm-241	Cm-240	Am-242	Np-238	Pu-241
Kr-85	Rb-85	Rb-84	Kr-86	Se-82	Br-85
Se-75	Br-75	Br-74	Se-76	Ge-72	As-75
Sr-90	Y-90	Y-89	Sr-91	Kr-87	Rb-90
Cf-252	Es-252	Es-251	Cf-253	Cm-249	Bk-252
I-125	Xe-125	Xe-124	I-126	Sb-122	Te-125
I-192	Pt-192	Pt-191	Ir-193	Re-189	Os-192
Ra-226	Ac-226	Ac-225	Ra-227	Rn-223	Fr-226
Ba-133	La-133	La-132	Ba-134	Xe-130	Cs-133
Ge-68	As-68	As-67	Ge-69	Zn-65	Ga-68
Na-22	Mg-22	Mg-21	Na-23	F-19	Ne-22

The Q-values of each of the studied reactions were also evaluated, that is, the minimum energy required for the reaction to occur efficiently. It is possible to see an example of the Q-value for the radionuclide Cs-137 in the following line graph:

Figure X. Q-value of the nuclear reactions studied for the target formed by the radioisotope Cs-137

DISCUSSIONS

The results obtained demonstrate that it is possible to develop a plan for carrying out nuclear reactions using radioactive waste from the radionuclides most commonly used in Brazil. This study enabled the identification of isotopes used in medical treatments as the primary source of the country's radioactive waste, and that the decay of these isotopes can generate new radionuclides of interest to both medicine and industry. All this information is essential for analyzing the type of isotope, its chemical and geometrical form, the energy required for the reaction to occur, the necessary equipment, and other key parameters needed to make the reaction feasible.

CONCLUSION

The study highlights the importance of planning in the use of radioactive materials to ensure their proper control. Additionally, the proposal to reuse radionuclides as targets in potential nuclear reactions opens new possibilities for research and applications involving materials that previously had no defined use. Following this path would not only reduce the need for disposal but also alleviate the strain on the country's currently limited radioactive waste repositories, since these materials would gain new purposes instead of becoming waste.

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