

Extraction of bismuth from nitric acid media using 1-octanol and hydrophobic liquid binary mixtures

Introduction

²¹¹At is a promising cancer treatment nuclide with 5.9 MeV α -emission. It is produced in a cyclotron by irradiation of metallic bismuth.



Efficient ²¹¹At separation from ²⁰⁹Bi after target dissolution in HNO₃ is crucial.

Fig. 1 Periodic Table of the Elements. This project investigates bismuth ($Z = 83$) used in ²¹¹At production. Bi is also of interest to study the superheavy element moscovium ($Z = 115$).

Liquid-Liquid Extraction (LLE)

LLE involves two immiscible liquid phases, aqueous and organic. Fig. 2 outlines the steps of LLE:

- (A) – Species of interest (black dots) begins in the aqueous phase (HNO₃).
- (B) – Phases are mixed vigorously. Liquid contact surface area increases and analyte partitions.
- (C) – Phases separate again. Analyte remains extracted into the organic phase.

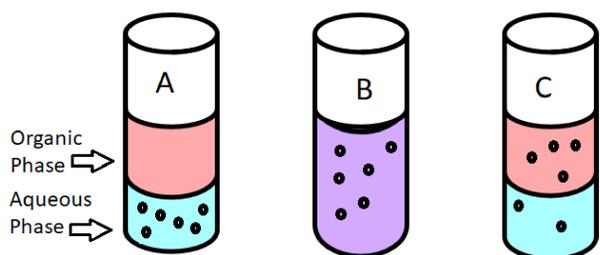


Fig. 2 Simplified liquid-liquid extraction schematic showing species movement to organic phase. [1]

Experimental Methods

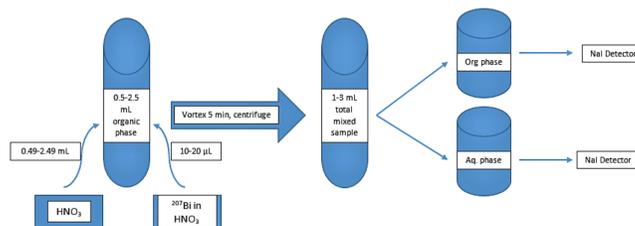


Fig. 3 A simplified schematic of the method of extraction of ²⁰⁷Bi ($T_{1/2}=32.2 \text{ y}$).

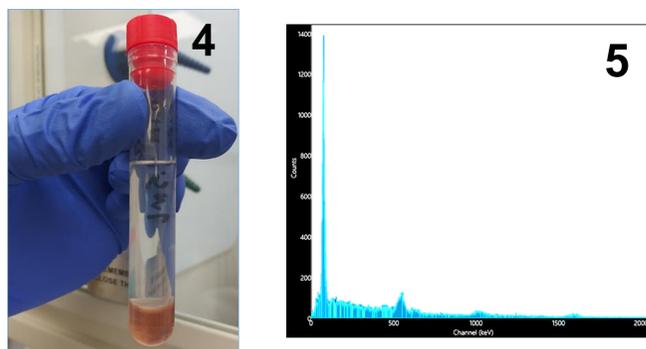


Fig. 4 A sample tube demonstrating aqueous (top phase) and organic (bottom phase) separation.

Fig. 5 An example NaI spectrum of the ²⁰⁷Bi source material.

Hydrophobic Liquid Binary Mixtures

In some cases, a mixture of two or more compounds may result in a depression in the mixture melting or glass transition temperature relative to those of the individual compounds. For the compounds used in this work, the result of this combination is a hydrophobic liquid at room temperature that can be used in LLE.



Fig. 6 DL-menthol ($T_m = 37^\circ \text{C}$) and Ibuprofen, ($T_m = 77^\circ \text{C}$) are mixed at a 7:3 respective mass ratio to form a liquid at room temperature ($T_g = -64.47^\circ \text{C}$). [2]

Liquid Binary Mixture Results

The ratio of the specific activity in each liquid phase, the distribution ratio D , was calculated for binary mixtures. The results of three systems are presented in Fig. 7.

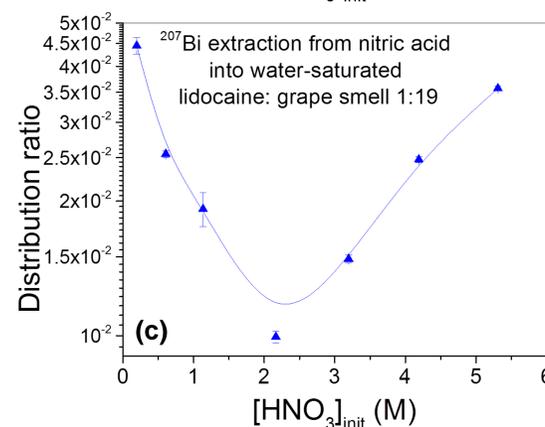
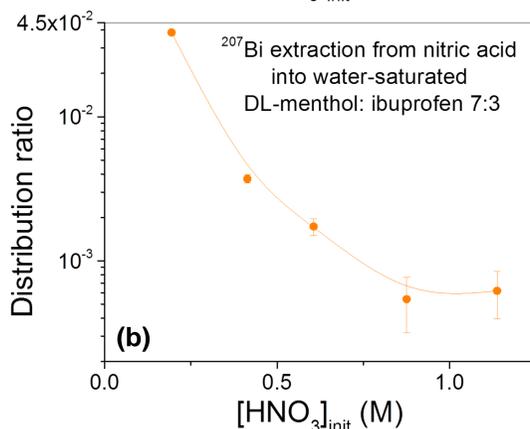
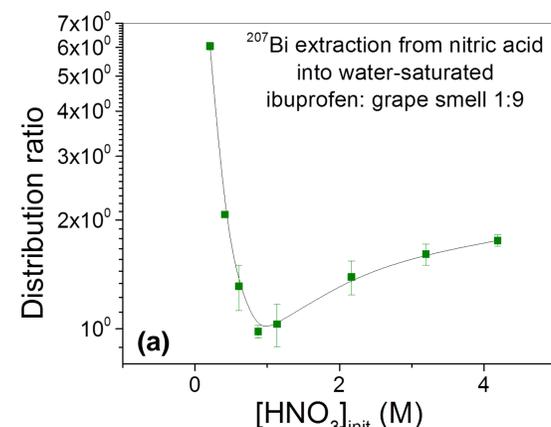


Fig. 7 The distribution ratio plotted as a function of the change in the initial HNO₃ concentration: (a) ibuprofen: grape smell 1:9, (b) DL-menthol: ibuprofen 7:3, and (c) lidocaine: grape smell 1:19. Lines are drawn to guide the eye.

1-Octanol

1-octanol has been shown to extract ²¹¹At. [3] Therefore, Bi behavior in 1-octanol is of interest.

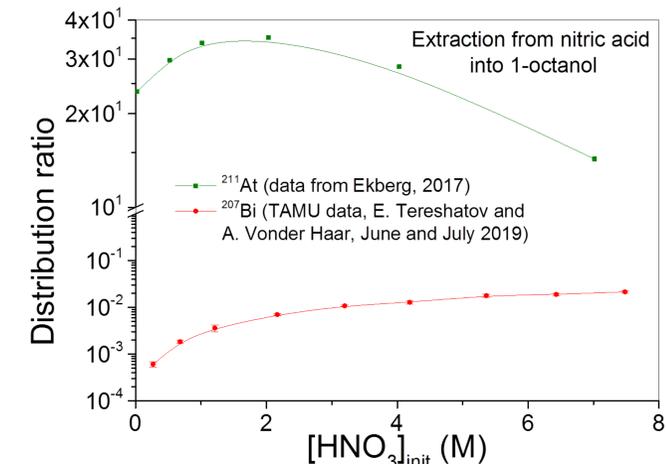


Fig. 8 ²¹¹At extraction compared to ²⁰⁷Bi extraction. Lines are drawn to guide the eye.

Conclusion and Future Work

The isotope ²¹¹At, interesting for radiotherapy, can be synthesized via irradiation of a bismuth target which is then dissolved in nitric acid. 1-octanol is a promising solvent for separating ²¹¹At from the target. Liquid binary mixtures may also be suitable for the same separation while providing more insight into bismuth, and perhaps astatine, partitioning mechanisms. Future work includes the determination of a mechanism of extraction for each system and wet chemistry experiments with At.

References

- [1] E. E. Tereshatov *et al.*, The Journal of Physical Chemistry B, 120 (9) (2016).
- [2] J. M. Edgecomb, E. E. Tereshatov, M. Boltoeva, C. M. Folden III (in preparation).
- [3] C. Ekberg, H. Jensen, S. P. Mezyk, B. J. Mincher, and G. Skarnemark, *J. Radioanal. Nucl. Chem.*, **314**, 235 (2017).

Acknowledgements

The authors thank NSF grant PHY-1659847, DOE grant DE-FG02-93ER40773 and Dr. Sherry Yennello and the TAMU Nuclear Solutions Institute for support.