NOVEL NEUTRON-DRIVEN CYCLIC REACTION IN THE FORMATION OF POLONIUM-210

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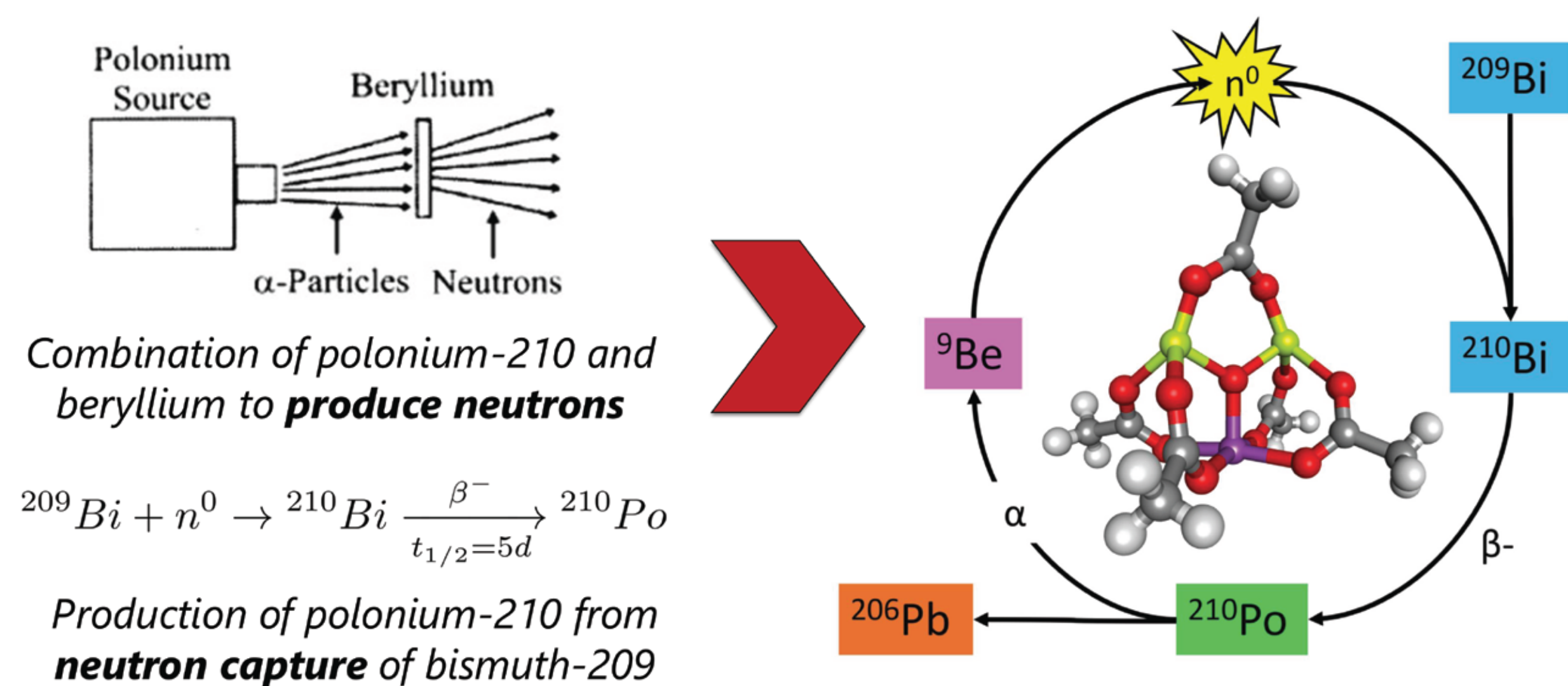
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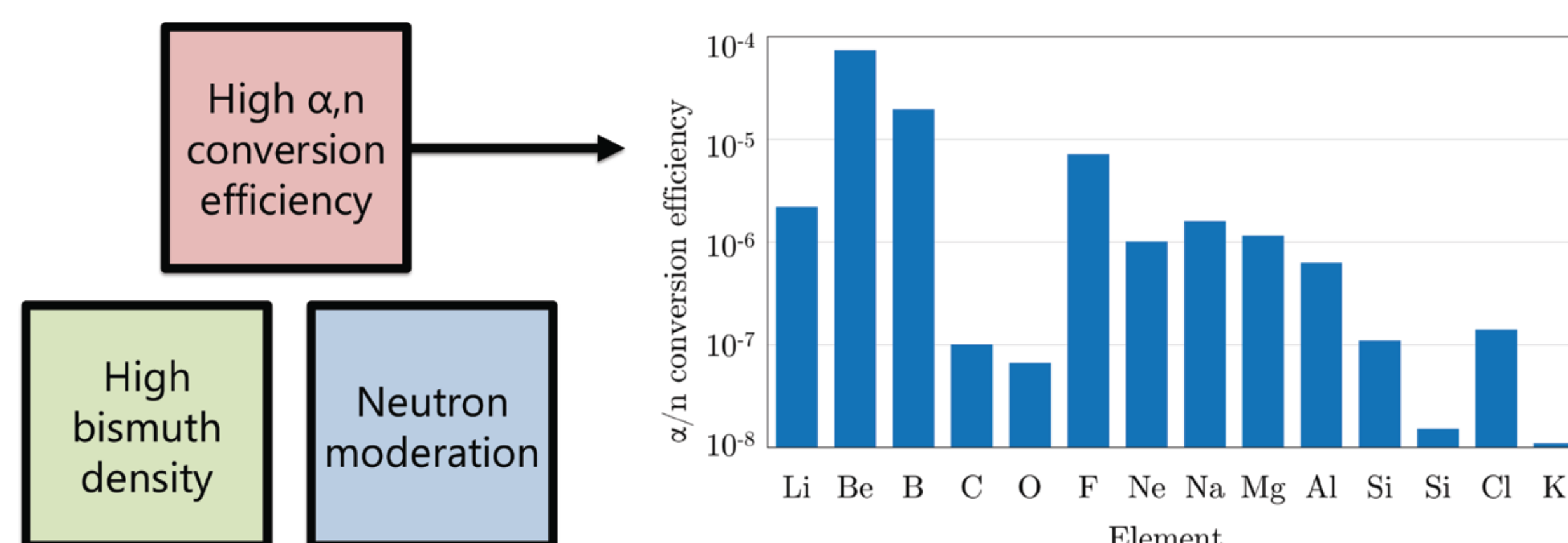
Introduction

84 Po Polonium

✓ Widely utilised in many industries

✓ Extremely valuable: $4.4M USD per gram

⚠ Highly toxic: LD50 = 10 ng/kg

⚠ Difficult to manufacture: < 8g produced per year

Project goal: Validate and characterise a novel nuclear cyclic reaction resulting in the formation of polonium-210
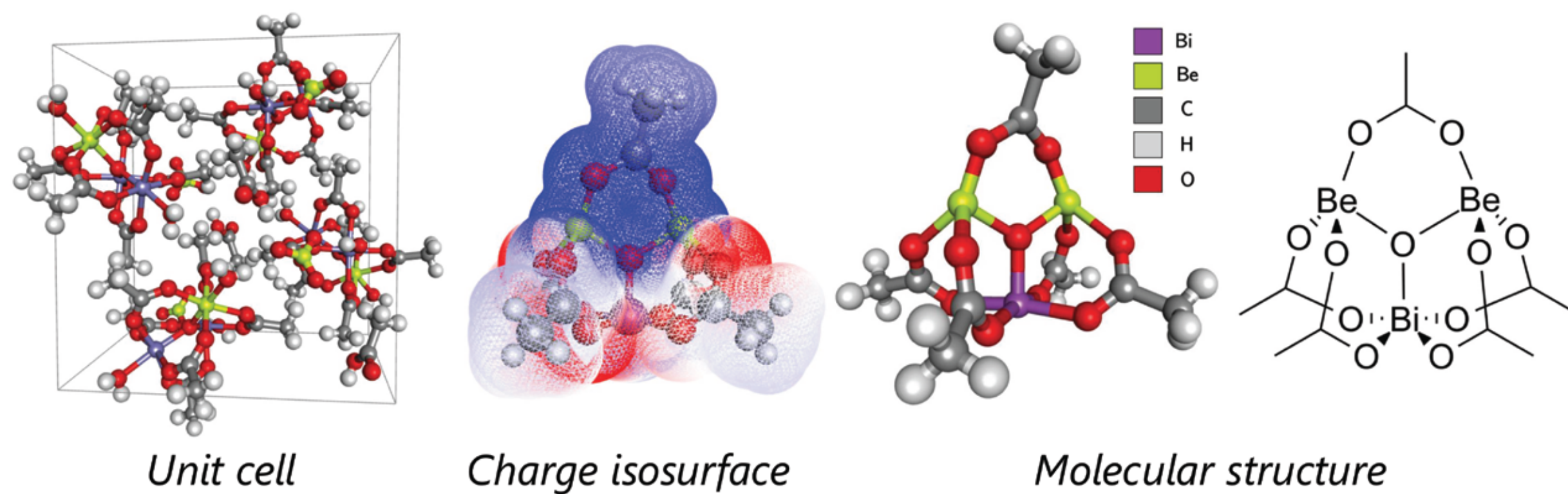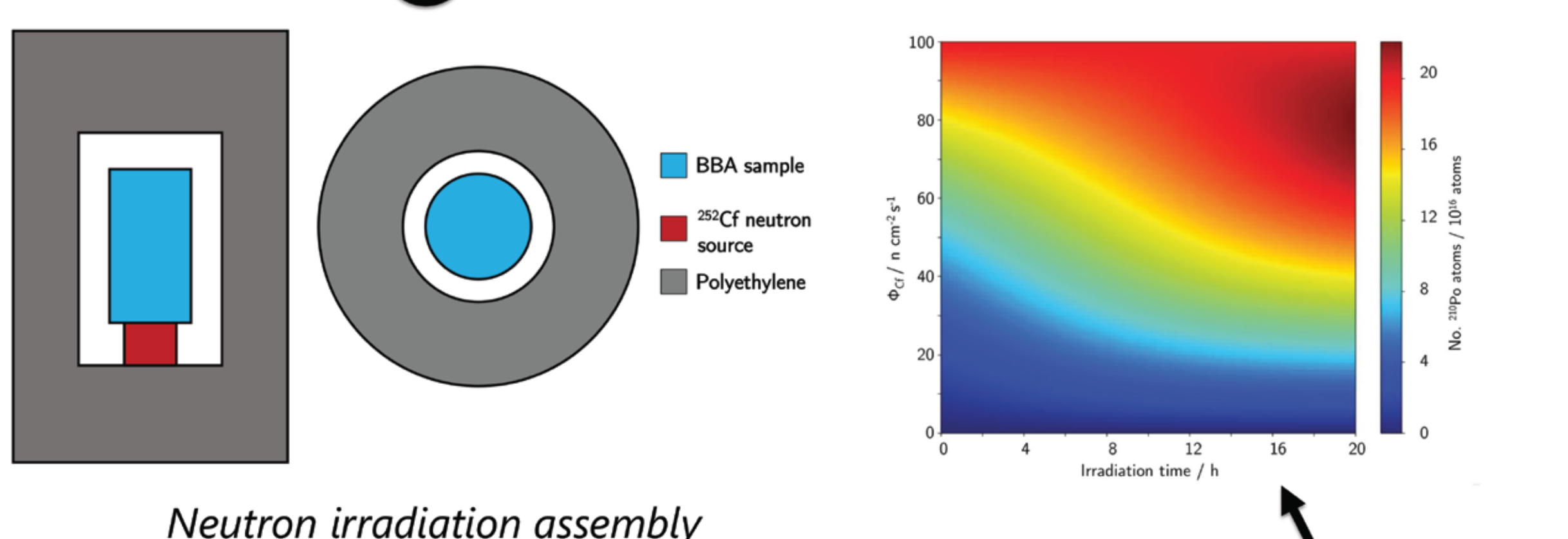

Combination of polonium-210 and beryllium to **produce neutrons**

$$^{209}Bi + n^0 \rightarrow {}^{210}Bi \xrightarrow[t_{1/2}=5d]{\beta^-} {}^{210}Po$$

*Production of polonium-210 from **neutron capture** of bismuth-209*

Methods

① Salt design and characterisation

High α,n conversion efficiency →

High bismuth density

Neutron moderation

Structure of BBA ($BiBe_2O(CH_3COO)_5$):

Unit cell   *Charge isosurface*   *Molecular structure*

② Cyclic reaction validation

BBA sample
^{252}Cf neutron source
Polyethylene

Neutron irradiation assembly

$$\begin{cases} N_{Po}(t) = \dfrac{N_{Bi}\sigma_c\Phi_T}{\lambda_{Po}+\lambda_{Bi}}(1-e^{-(\lambda_{Po}+\lambda_{Bi})T})(e^{-\lambda_{Po}(t-T)}) \\ \Phi_T = \Phi_{Cf} + \dfrac{\eta_{Be}N_{Po}(t)\phi_{Be}}{N_{Be}} \end{cases}$$

Reaction kinetics analysis of irradiated BBA to confirm cyclic dynamics

Results and Discussion

ICP-MS calibration curve of BBA   *SEM images of BBA salt*

Neutron spectrum of Cf-252 source

Polonium-210 accumulation curve   *Monte Carlo simulation of neutron irradiation*

1H(n,γ)

2.2 MeV peak indicates neutron emission from irradiated BBA

↓

Neutron emission strongly indicates occurrence of cyclic reaction

Experimental data
Simulated model

- Cross-analysed data indicates sigmoidal autocatalytic growth of polonium-210
- Iterative calculation of growth rate yields a cyclic generation of n = 2, showing that reaction has completed at least one cycle

Conclusion

- Functional design and synthesis of specialised salt (BBA) has been achieved
- Novel nuclear cyclic reaction has been successfully validated and characterised
- Reaction kinetics agree with autocatalytic dynamics

Future work:
- Purification of polonium-210 from irradiated BBA
- Optimisation of neutron moderation properties

Acknowledgements

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2. Csikai, J., & Dezsö, Z. (1976). Fission neutron spectrum of 252Cf. *Annals of Nuclear Energy, 3*(11–12), 527–530. https://doi.org/10.1016/0306-4549(76)90068-2
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