Fabrication of Colorless Phosphate Glass Doped with Bi_2O_3 for Lead-Free Radiation Shielding in X-ray and Gamma Ray Applications: A Study Using PHITS Monte Carlo Simulation and Experimental Analysis

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Outline

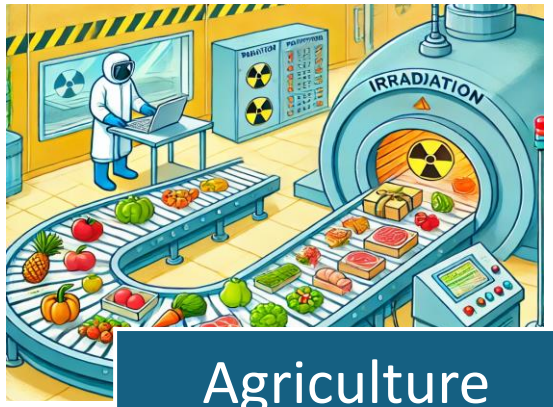
- Introduction
- Objective
- Materials and methods
- Results and discussion
- Conclusions

1. Introduction

- Radiation is used in many applications

Medicine

Industry



Agriculture

Nuclear facilities

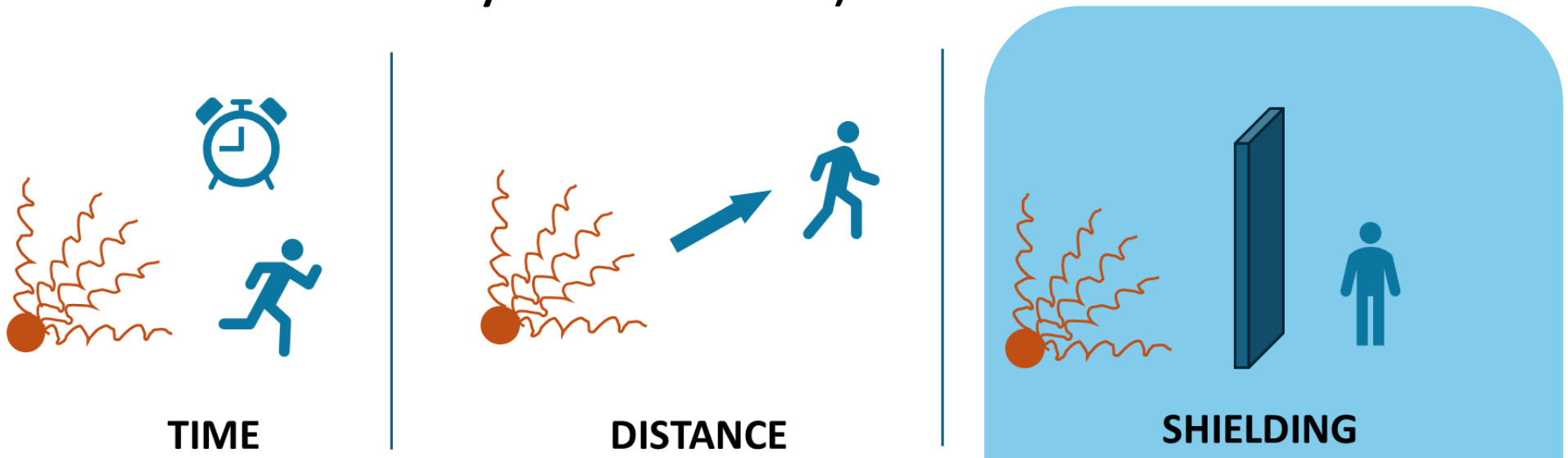
1. Introduction

Medicine

In medicine, gamma ray and X-ray are mostly used for the diagnosis in nuclear medicine.

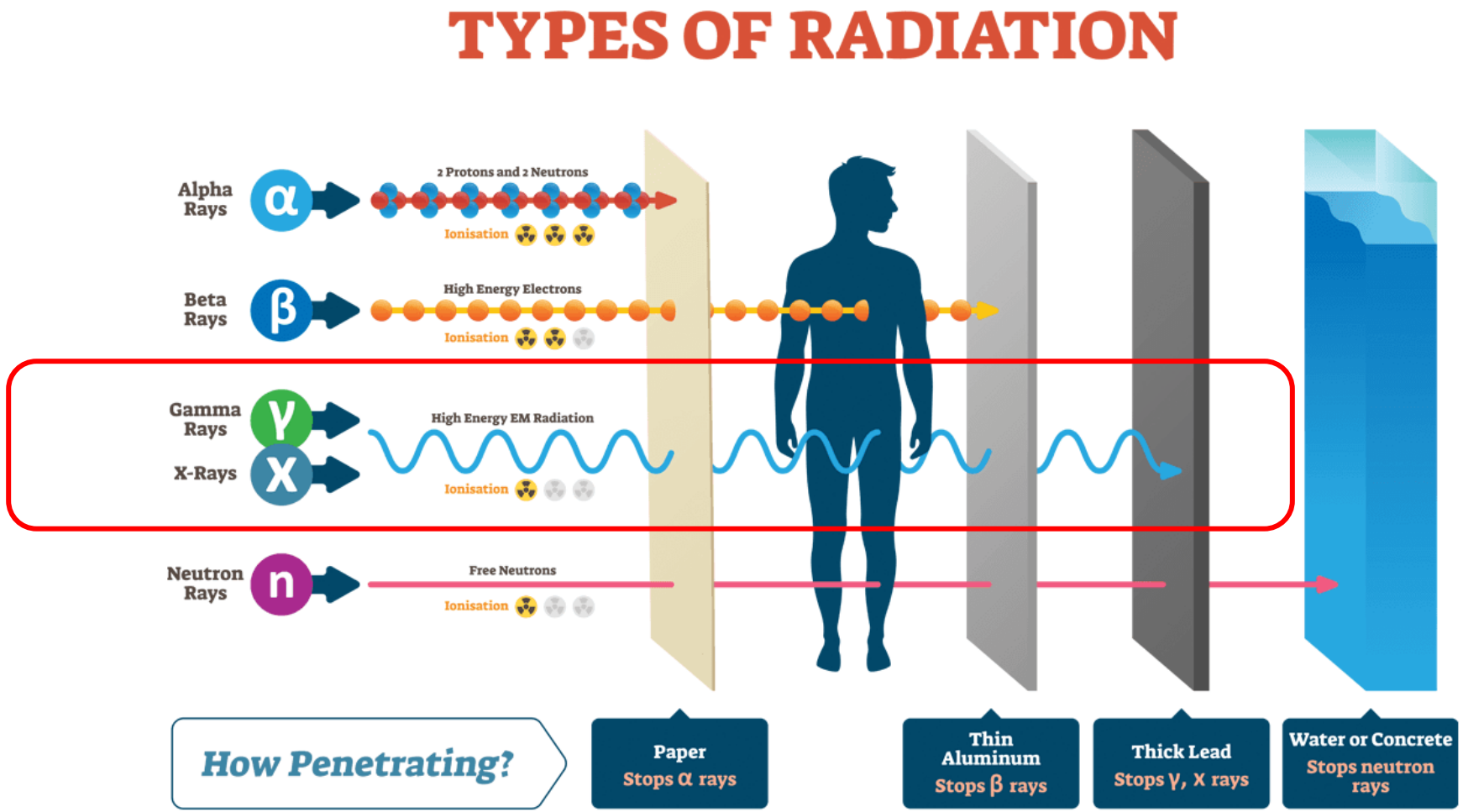
1. Introduction

- Fundamental strategies in radiation protection is ALARA (As Low As Reasonably Achievable)



Radiation Shielding: Crucial for protecting against harmful X-ray and gamma radiation.

1. Introduction



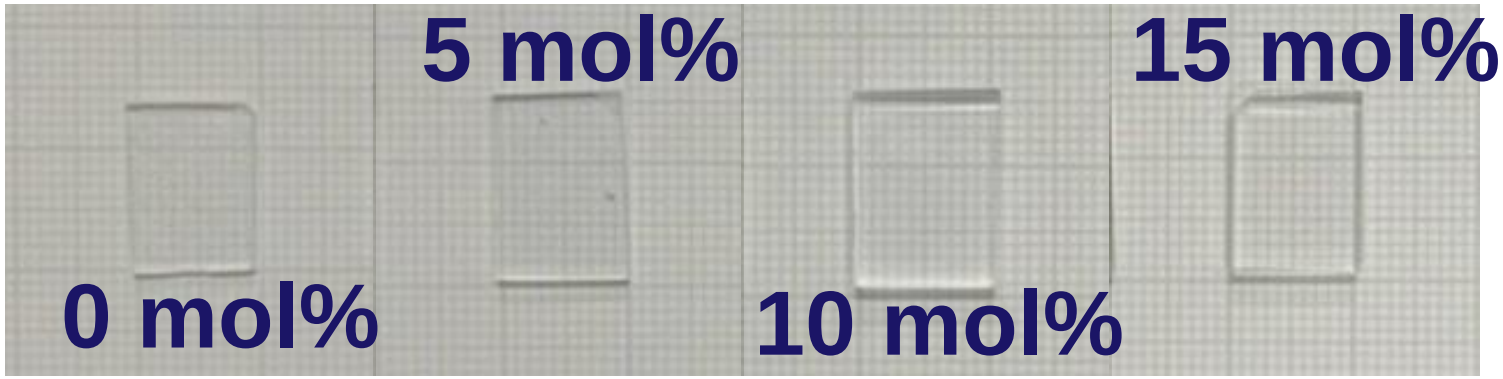
https://octopart.com/pulse/p/where-to-find-rad-hard-components-for-military-and-aerospace-systems

1. Introduction

Due to

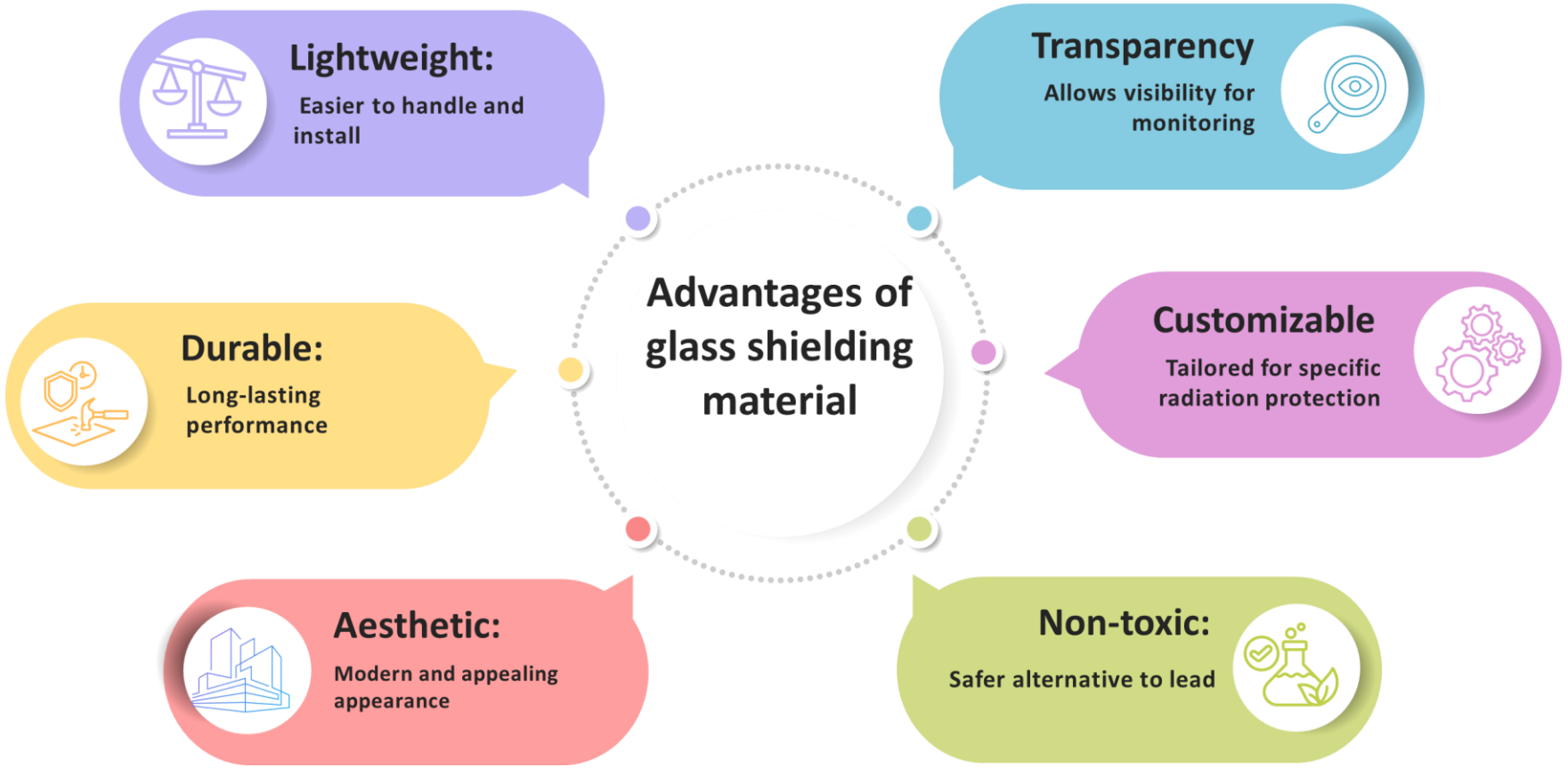
- **Lead has toxicity and environmental concerns.**

High-density glass has been developed to reduce toxicity while enhancing opacity for improved radiation shielding efficiency.



$(65\text{-}x)P_2O_5 + 5CaF_2 + 10NaF + 10KF + 10AlF_3 + xBi_2O_3$ x = 0, 5, 10, 15 mol%

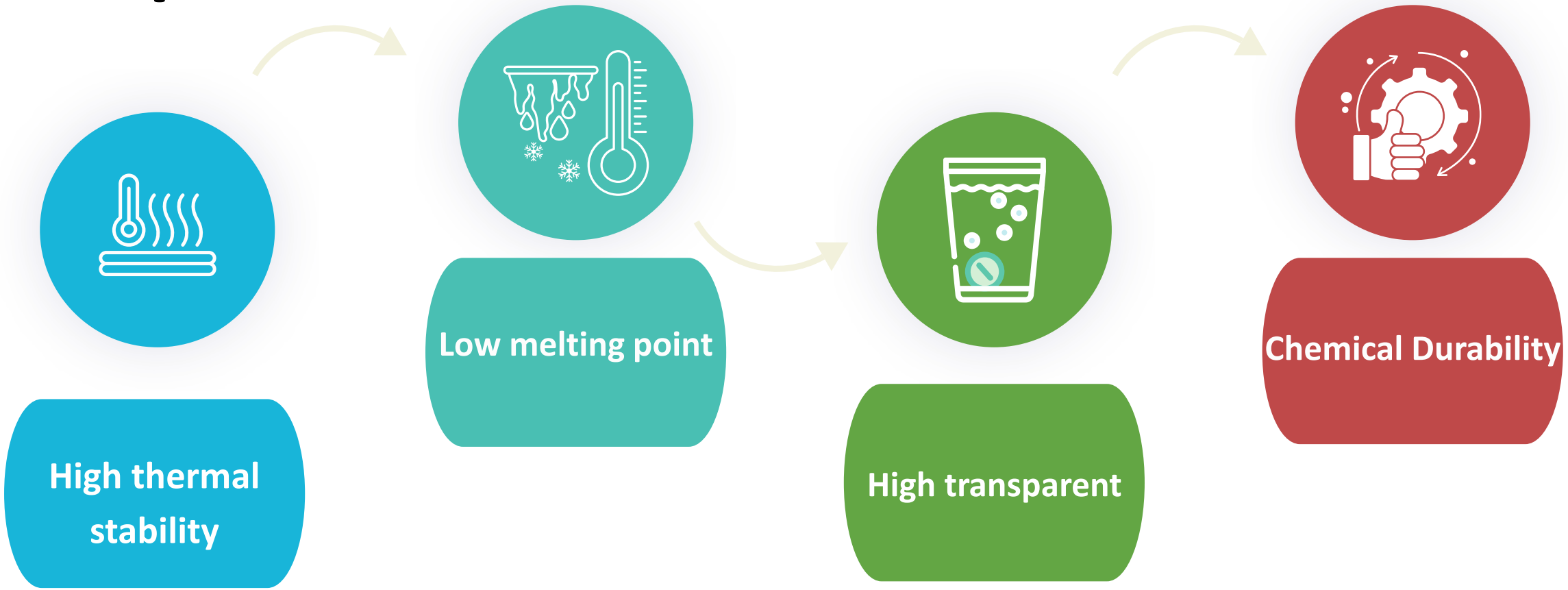
1. Introduction



Making it an attractive alternative to lead-based shields.

1. Introduction

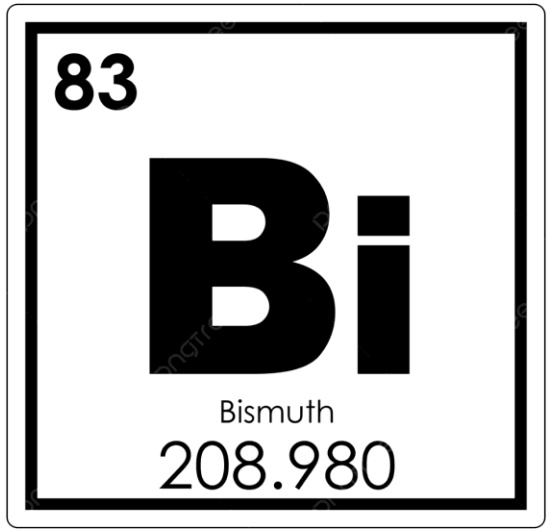
Phosphate



1. Introduction

Toxic of Lead

Change to



High atomic number

1. Introduction

Monte Carlo simulation is a simulation method created to guide decision making in problems which depends on the principle of chance called law of chance by take a random of sampling.

PHITS

1. Introduction

What is PHITS?

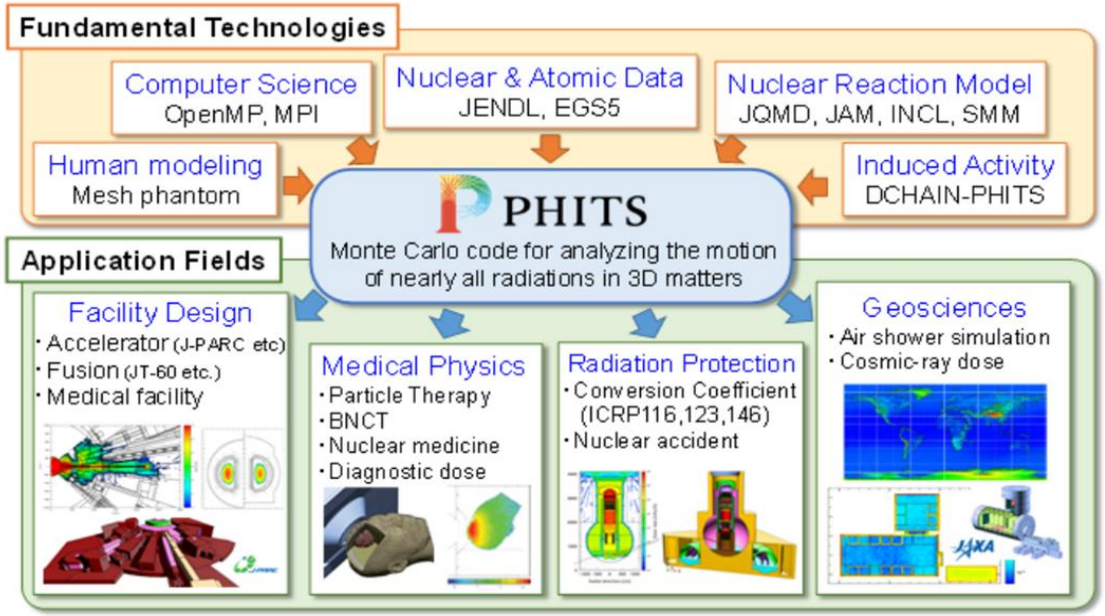
Particle and Heavy Ion Transport code System

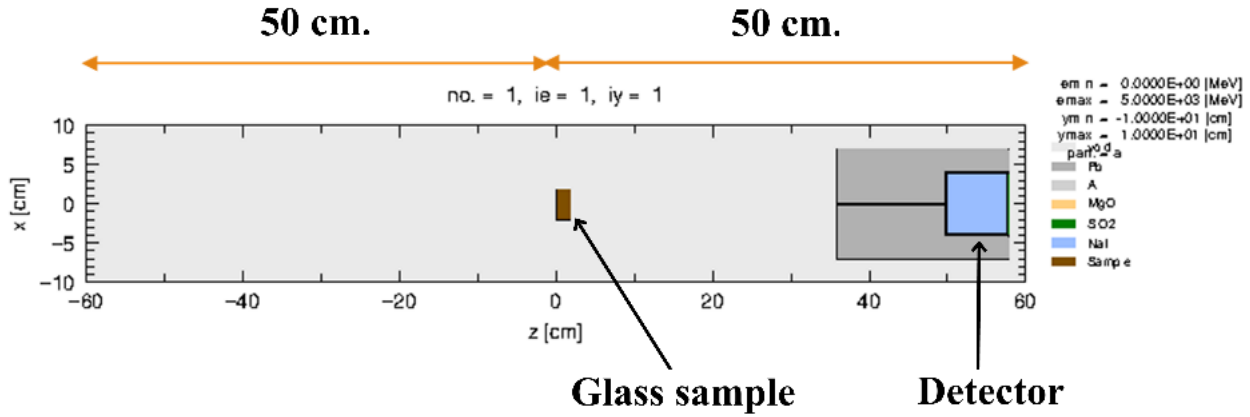
Capability

Transport and collision of nearly all particles over wide energy range using Monte Carlo method

neutron, proton, ions, electron, photon etc

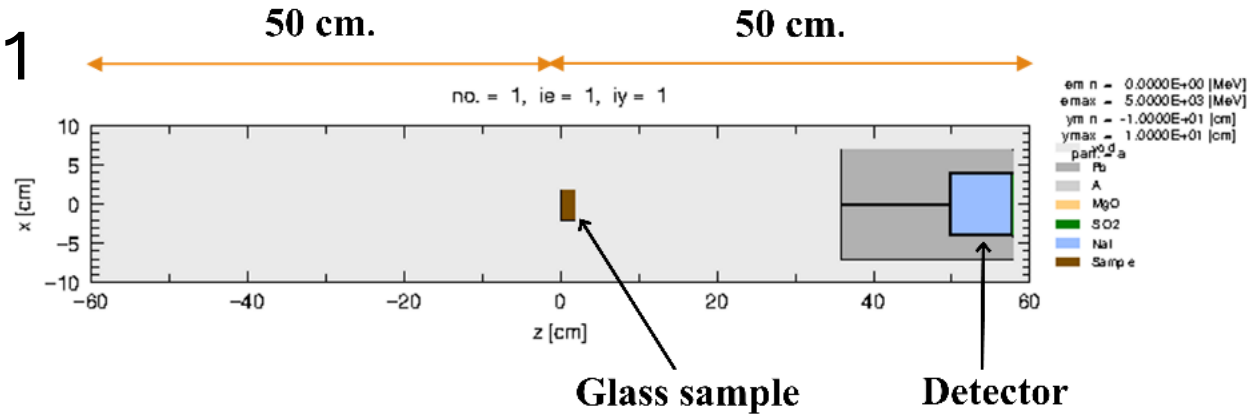
10^{-4} eV to 1 TeV/u





1. Introduction

1



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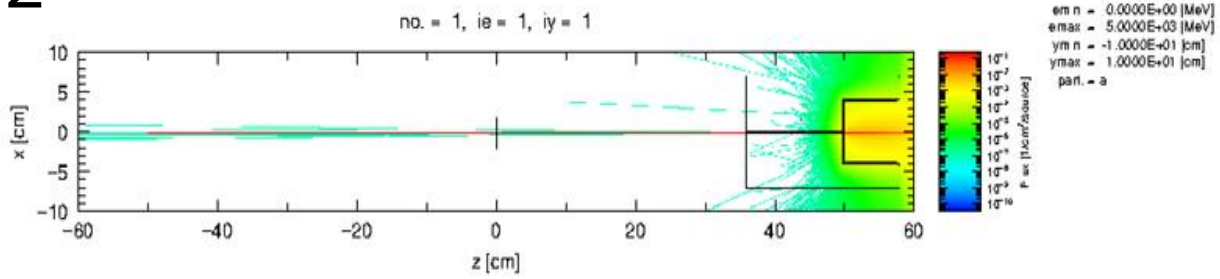

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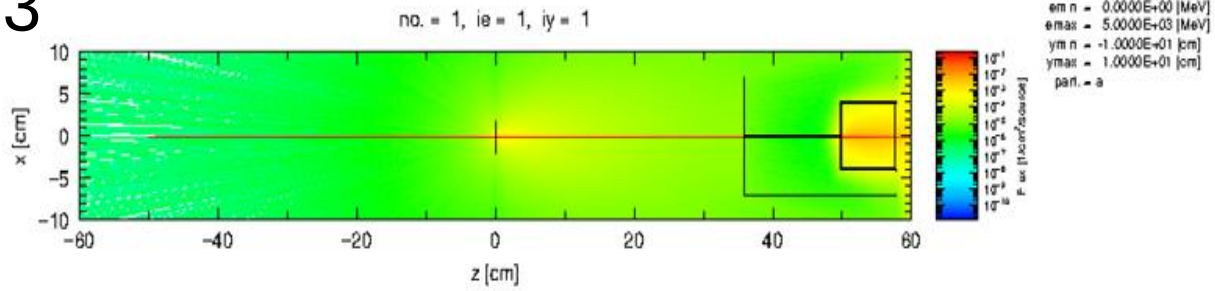


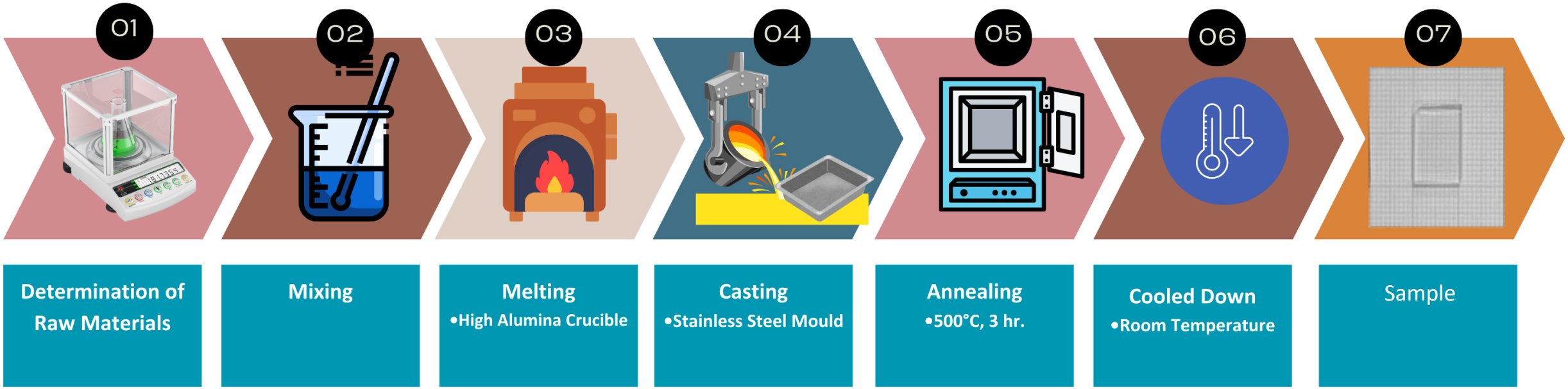
2. Objective

- To create a high-performance, environmentally safe, and versatile radiation shielding materials that combines effective protection with optical transparency of glass

3. Materials and methods

Glass Preparation:

Composition: $(65\text{-}x)P_2O_5 + 5CaF_2 + 10NaF + 10KF + 10AlF_3 + xBi_2O_3$ x = 0, 5, 10, 15 mol%



3. Materials and methods: Analysis

Physical Measurements

- Density
- Molar volume

01

Optical Analysis

- Transmittance

02

Radiation shielding (Gamma ray: Ba133, Cs137, Co60)

- Mass Attenuation Coefficient
- Half-Value Layer (HVL)

Compare between experimental vs PHITS

03

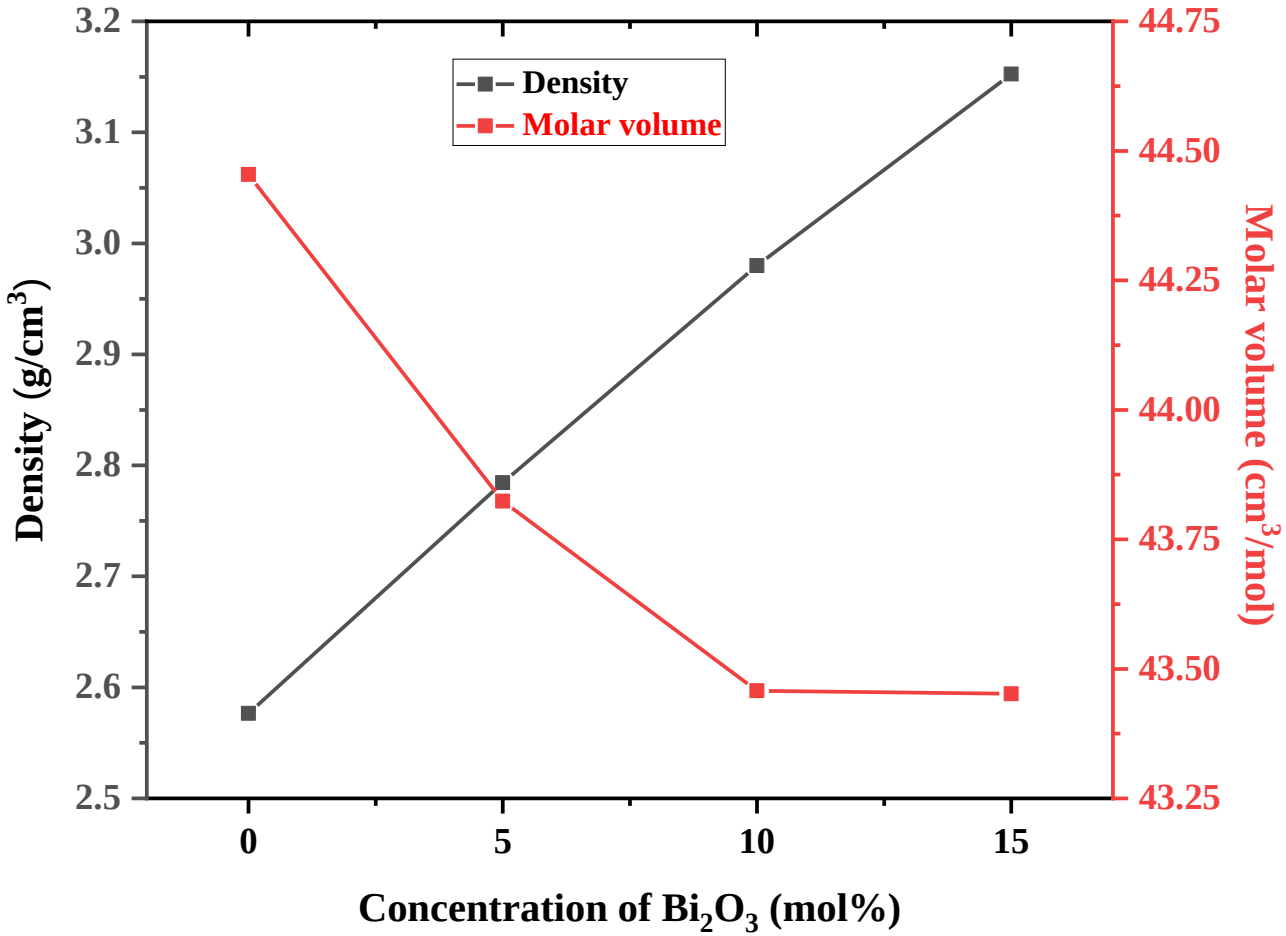
Radiation shielding (X-ray 50-120 kVp)

- Mass Attenuation Coefficient
- Half-Value Layer (HVL)
- Half-Value Layer compare with standard materials

04

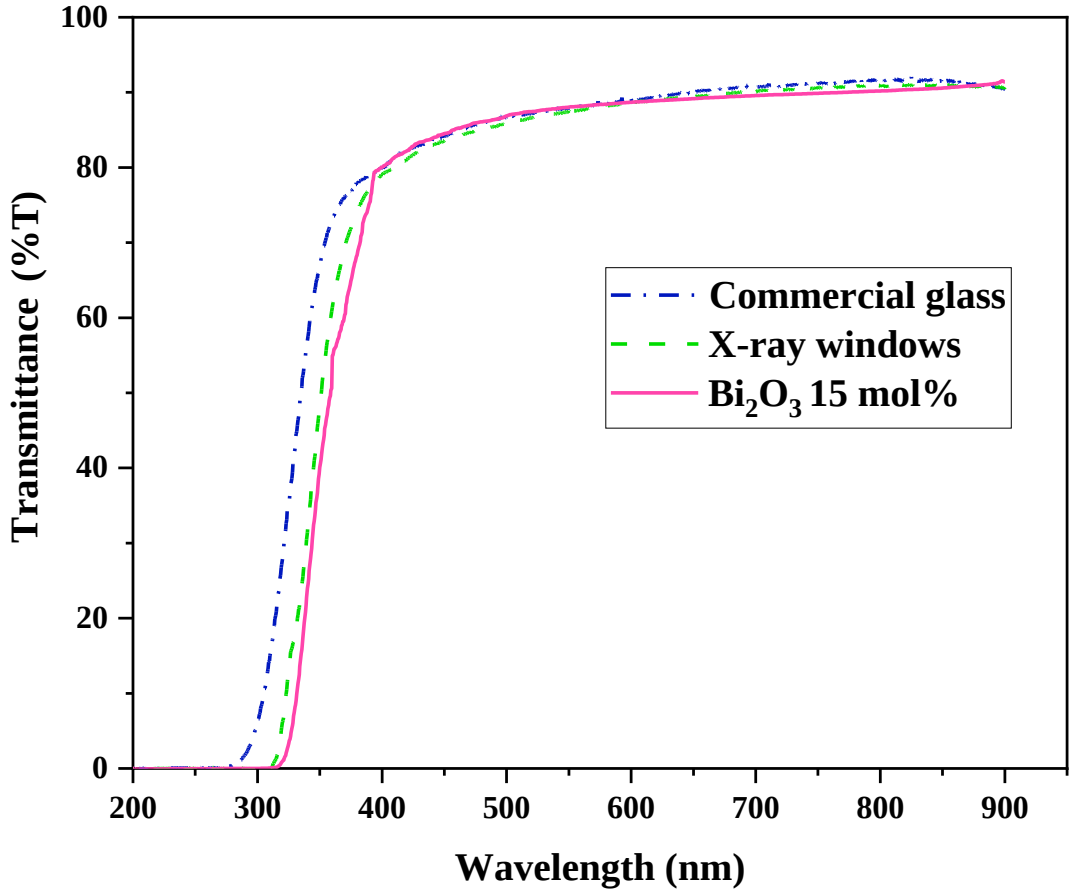
4. Results and discussions:

Density & molar volume



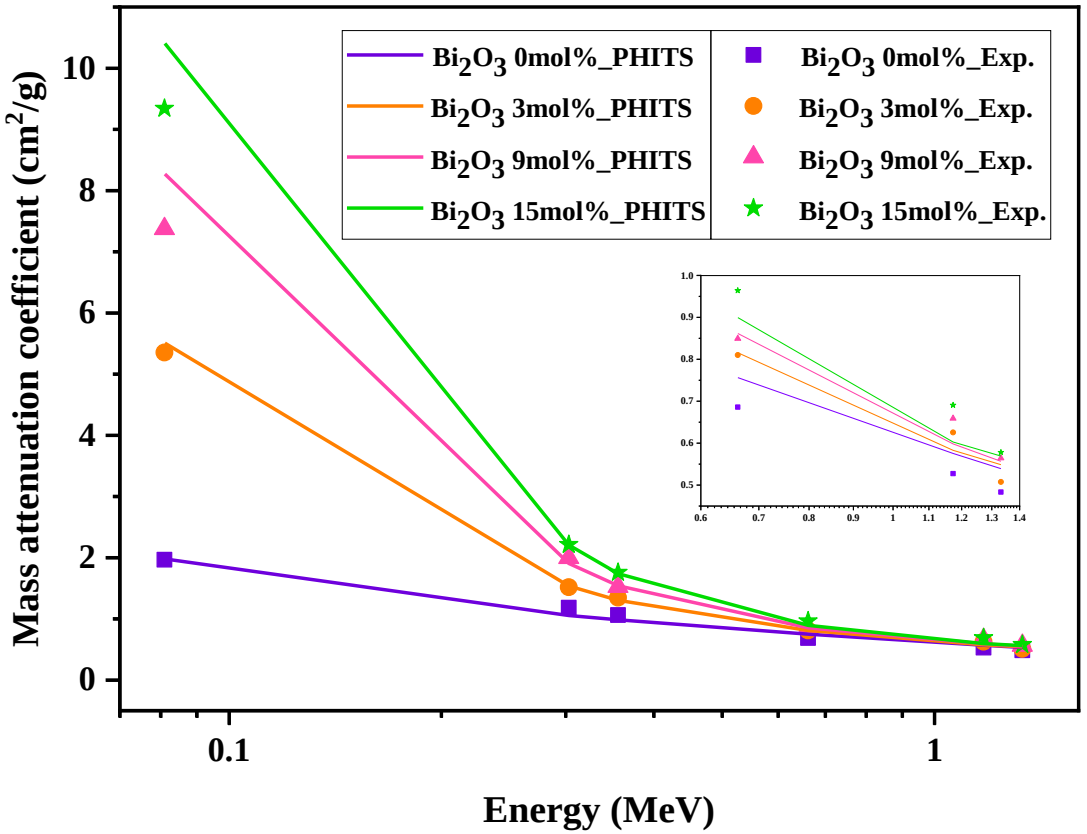
Increasing Bi_2O_3 concentration leads to higher density but molar volume decrease.

4. Results and discussions:



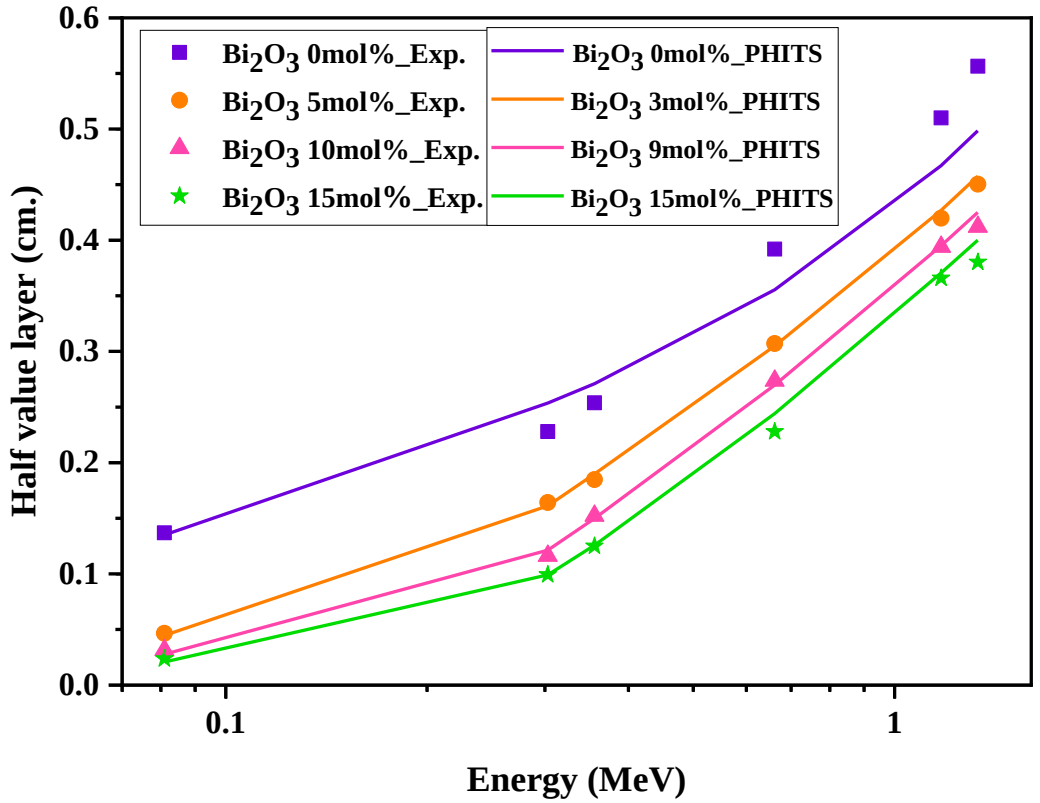
- The transmittance of glass samples Bi_2O_3 15 mol% compared with standard materials

4. Results and discussions: Radiation shielding (Gamma)



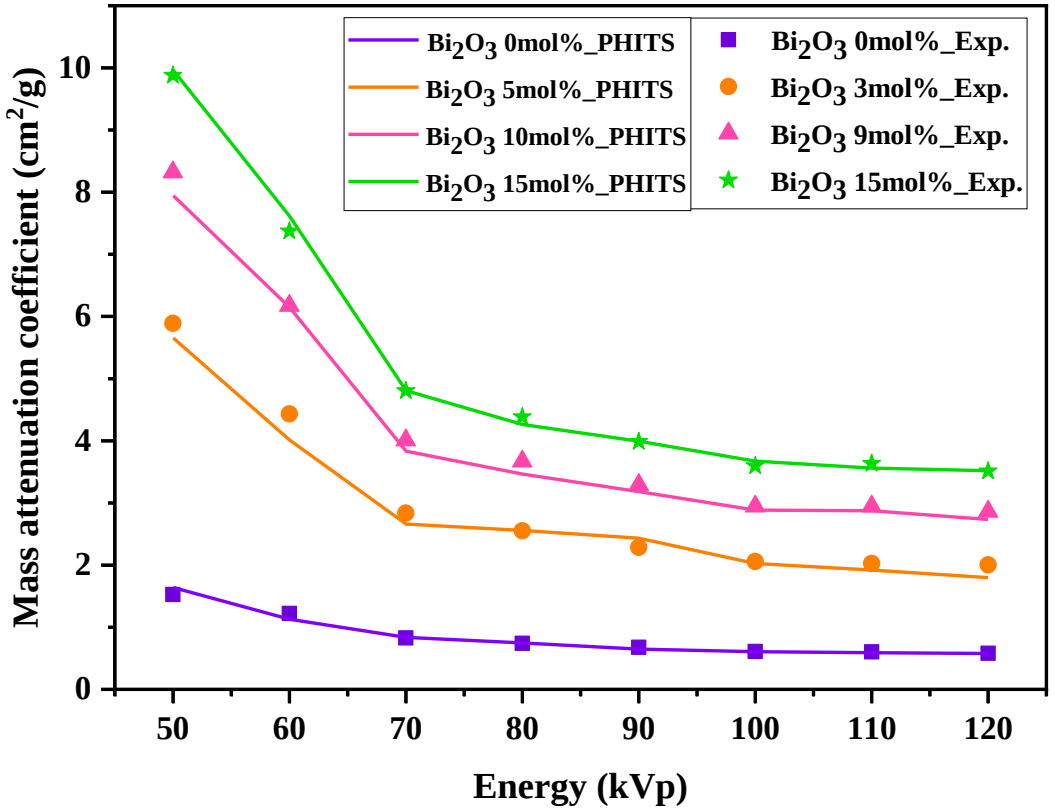
- MAC decreases as energy increases.
- Higher Bi_2O_3 concentrations result in better photon attenuation, especially at lower energies.
- Close match between experimental data and PHITS Monte Carlo simulation.

4. Results and discussions: Radiation shielding (Gamma)



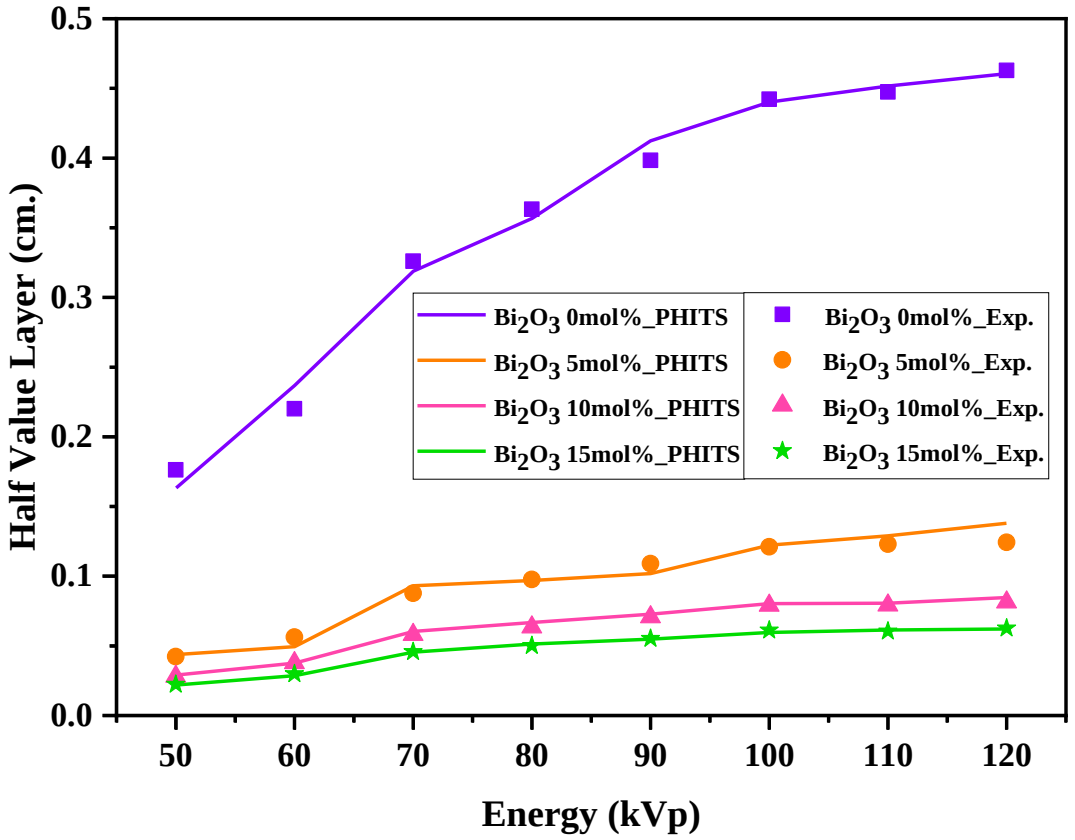
- Increasing Bi_2O_3 concentration enhances the HVL.
  - This trend indicates that higher energy gamma rays require a thicker material to be attenuated to half of their original intensity.

4. Results and discussions: Radiation shielding (X-ray)



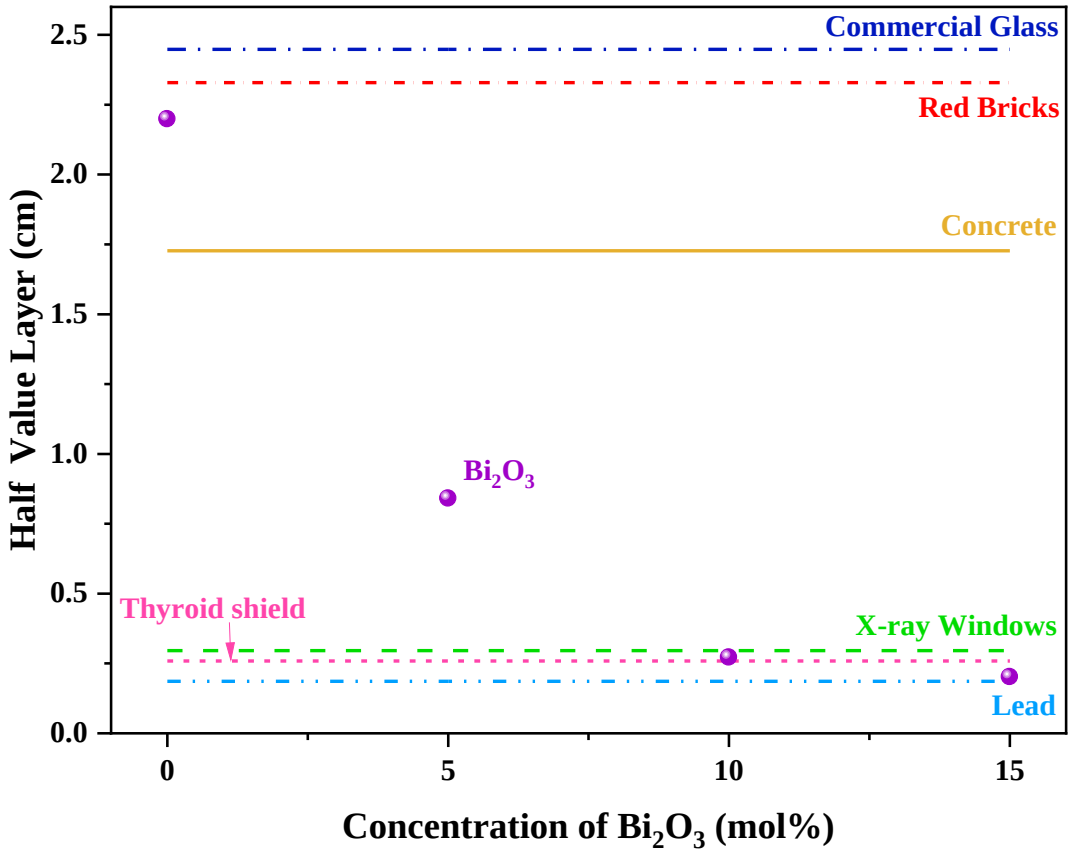
- When the concentration of Bi increases, the mass attenuation coefficient also increases.

4. Results and discussions: Radiation shielding (X-ray)



- When the concentration of Bi increases, the half-value layer decreases.

4. Results and discussions: Radiation shielding (X-ray)



The glass samples Bi_2O_3 15 mol% compared with standard materials

5. Conclusion

Increasing Bi_2O_3 concentration

- enhances density.
- Enhances radiation attenuation.

Higher mass attenuation coefficients and lower HVL , and shielding radiation material better than commercial glass, red brick, concrete and x-ray window

- **indicate enhanced of shielding efficiency**.

Thank you for your attention