M.SC. Seminar

Monte-Carlo Simulation Aided Design for Preparation of Radiation Shielding Glasses

By

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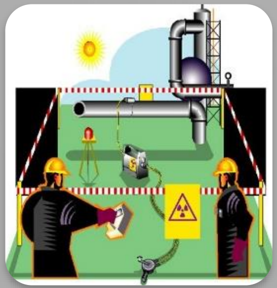
BSC. IN PHYSICS, AIN SHAMS UN., 2011

Contents

Introduction

Usage of nuclear radiation Sources



Industrial Uses (Industrial Radiography)	Medical uses (Radiotherapy, diagnosis, ….)	Energy resources	Food Irradiation for reservation

Remember that,

dealing with the radioactive sources are associated with personal radiation exposure results to several **hazards**. This implies **Radiation Safety Procedures.**

Introduction

Shielding (attenuation of radiation)

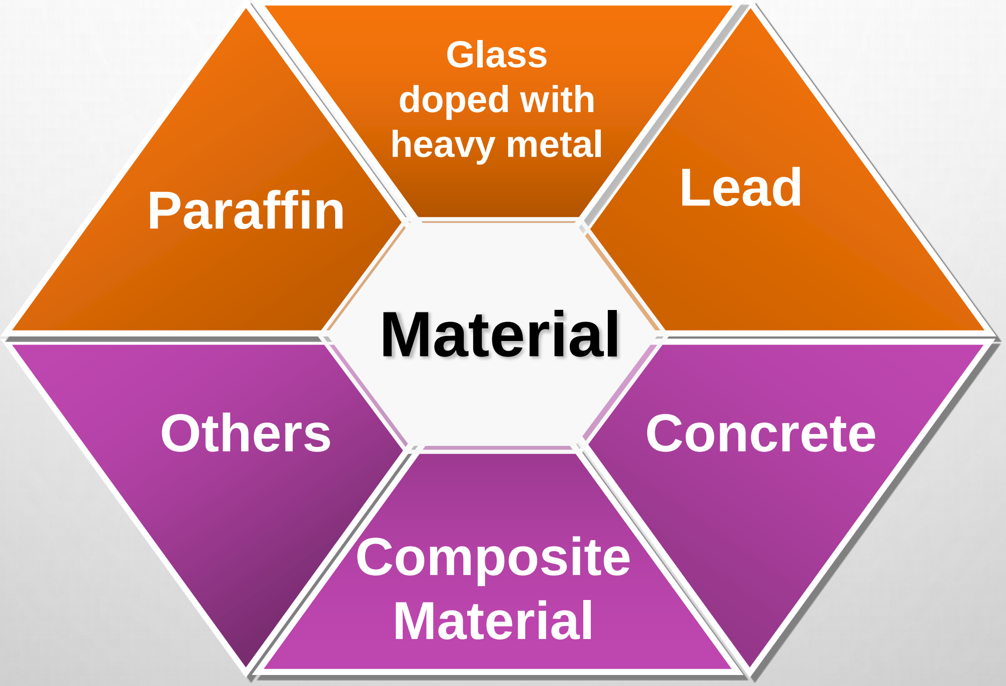
Gamma Rays
Electromagnetic waves can be attenuated due to three main interactions with matter.

Neutrons
Neutral particles can be attenuated by nuclear capture

Gamma rays and neutrons have different interactions with matter

Different shielding materials

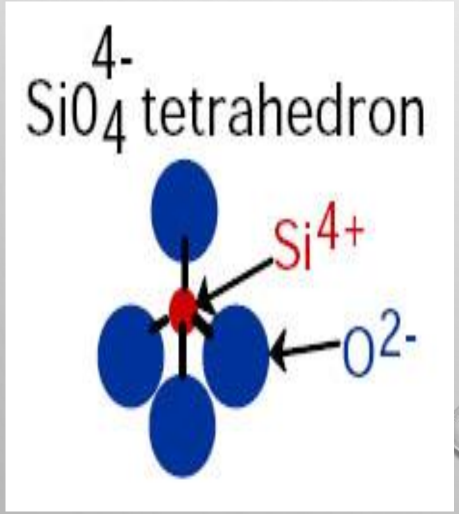
Introduction

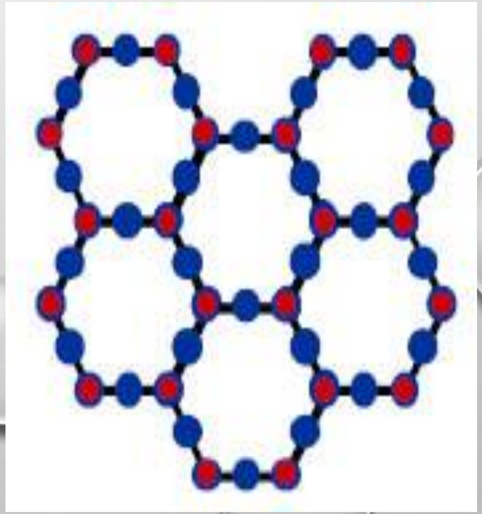


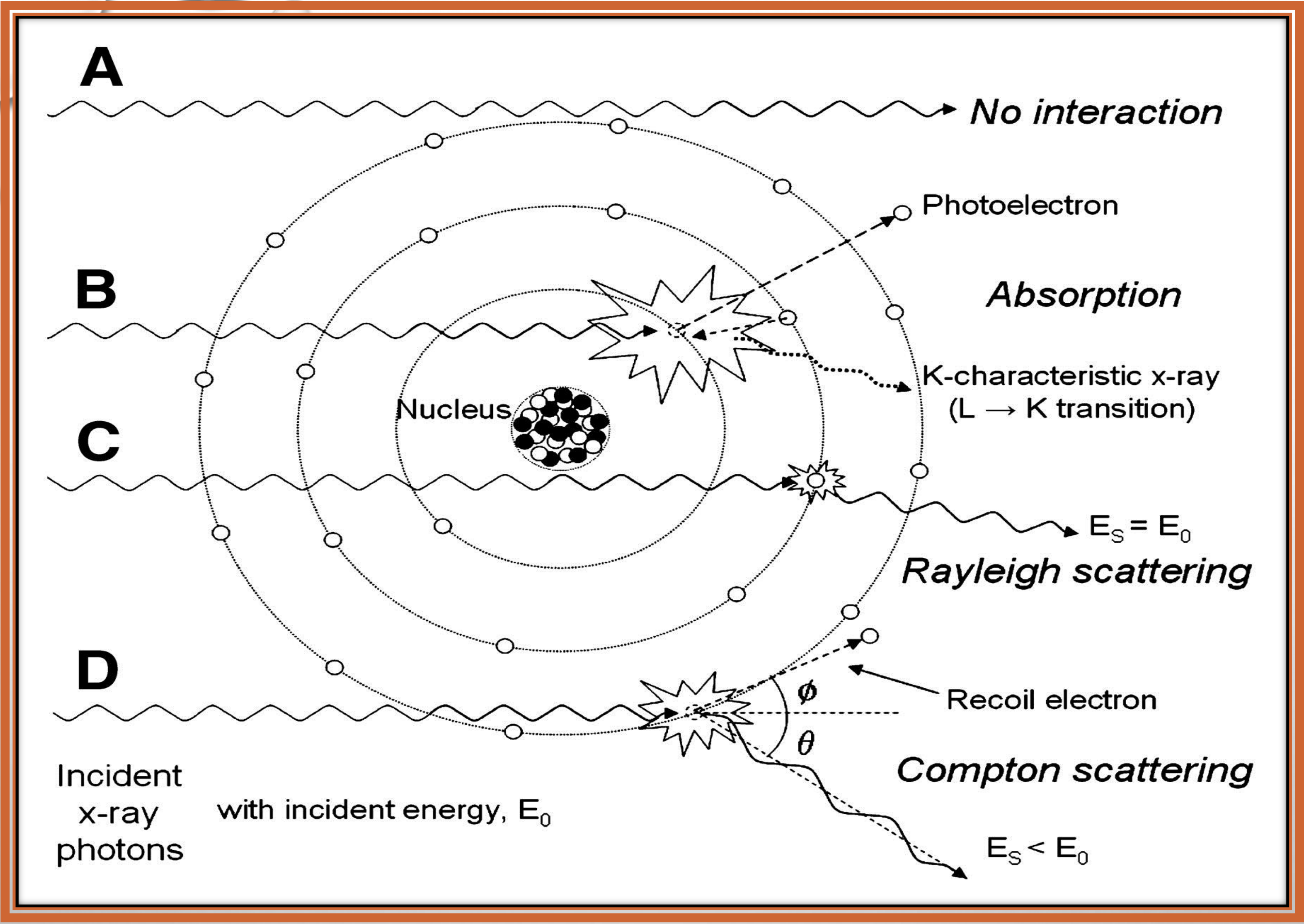
Introduction

Glass

Glass is one of three basic types of ceramics distinguished by its amorphous(noncrystalline) structure and it is considered as inorganic product of fusion which has been cooled to a rigid condition without crystallization , solid like liquid like.







Attenuation = Absorption+ Scattering

Gamma Linear Attenuation Coefficient (μ)

Attenuation = Absorption+ Scattering

- The total *gamma attenuation coefficient of any material* is equal to the sum of all three terms. Each term refer to the corresponding interaction.

$$\mu = \mu_p + \mu_c + \mu_{pp}$$

Where

μ_p : attenuation due to Photoelectric effect

μ_c : attenuation due to Compton effect

μ_{pp} : attenuation due to Pair-Production

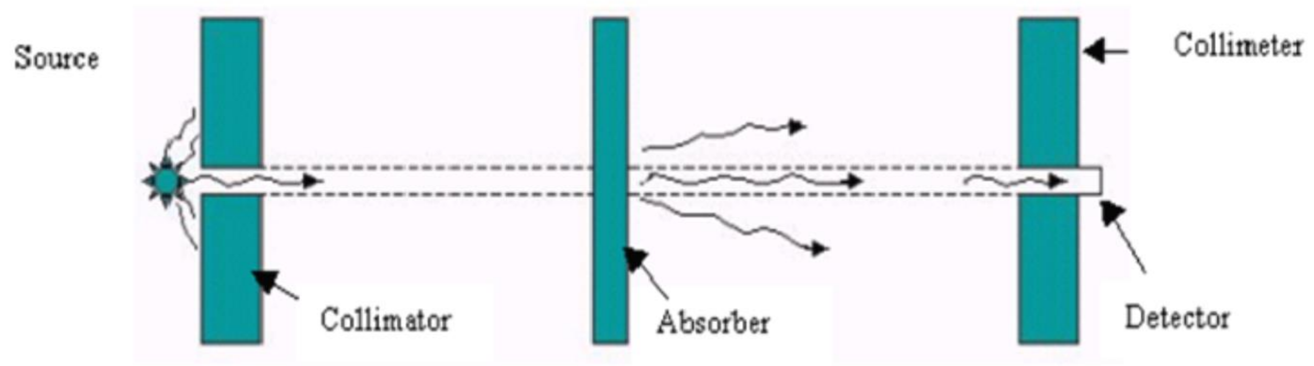
μ = the relative change in radiation intensity per unit length.

Introduction

Build up factor (B) & attenuation coefficient

In practice, we have two types of geometry:

1) Narrow beam conditions (good geometry)



Source in shielded pig.
End shield plug removed
(collimated source)

Shield

Narrow Beam Conditions

Detector with side shield collar
Detector end only exposed
(collimated detector)

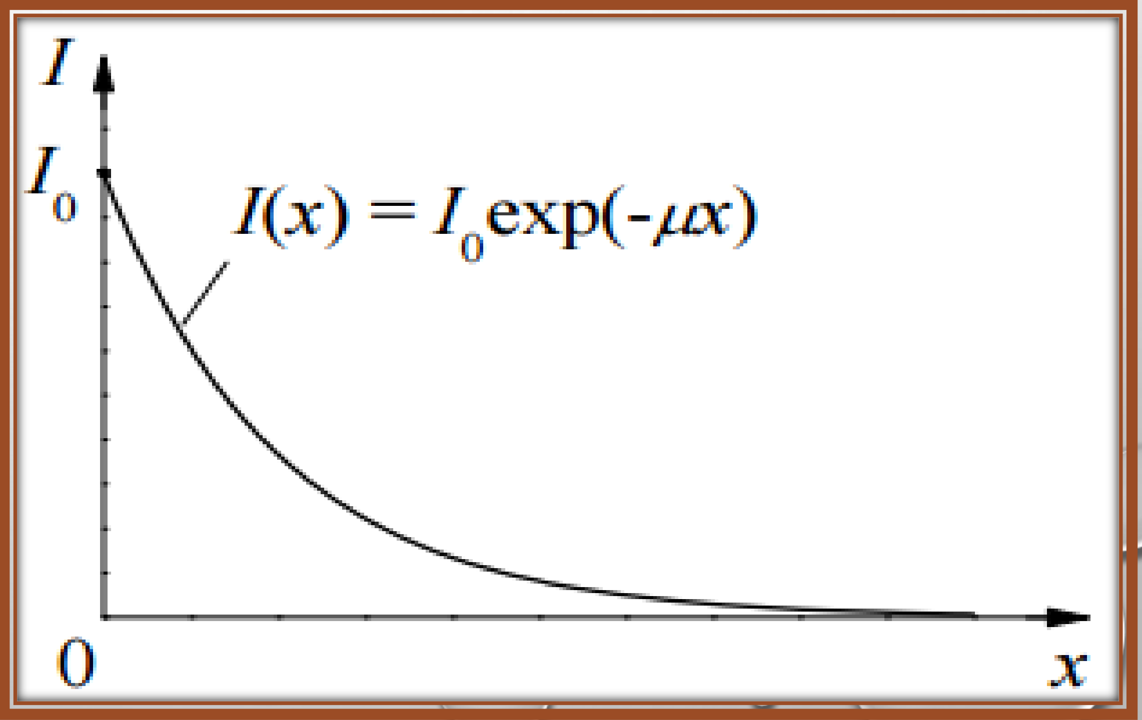
Introduction

Build up factor (B) & attenuation coefficient

During the measurements, we have two types of geometry:

1) Narrow beam conditions (good geometry)

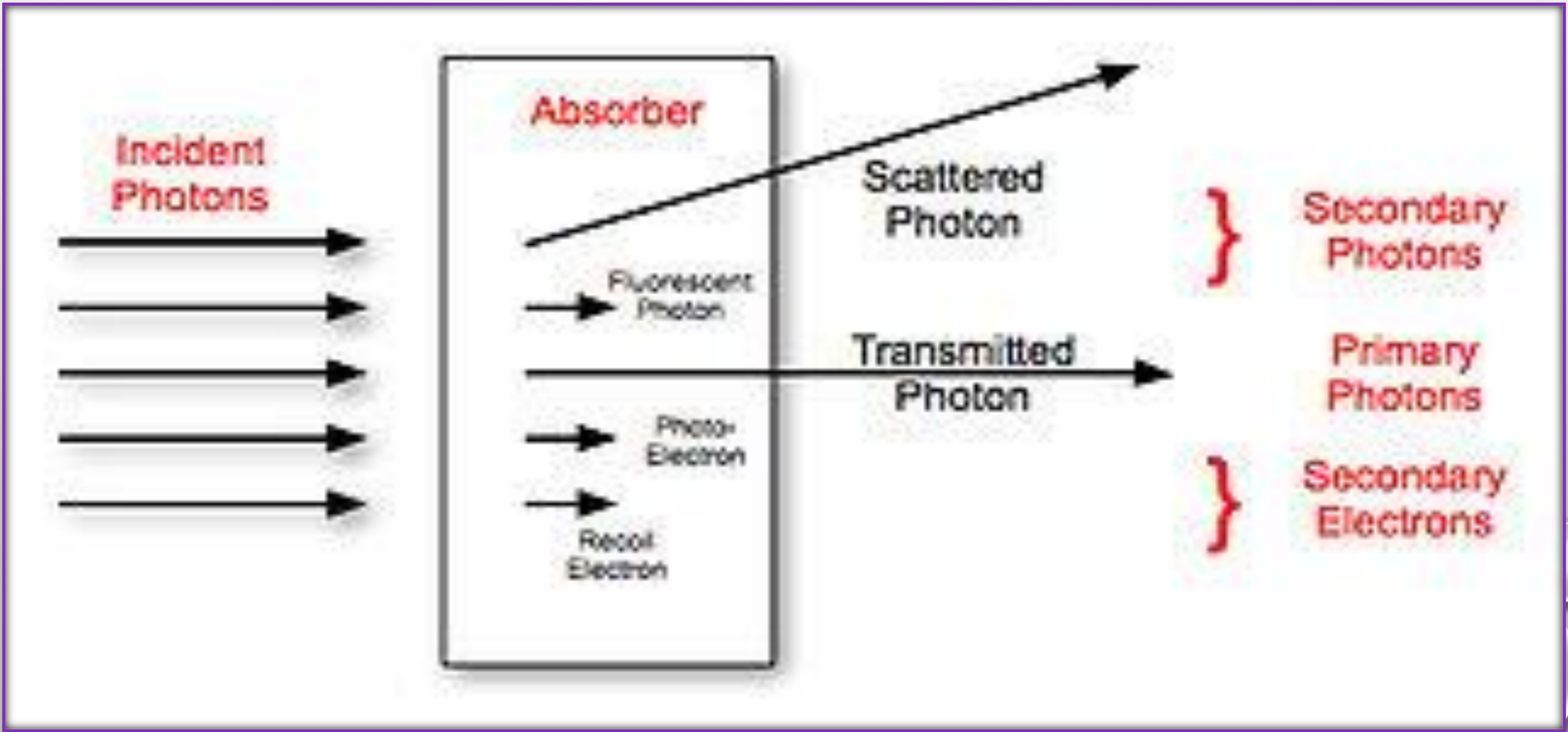
$$I = I_o\, e^{-\mu t}$$



Introduction

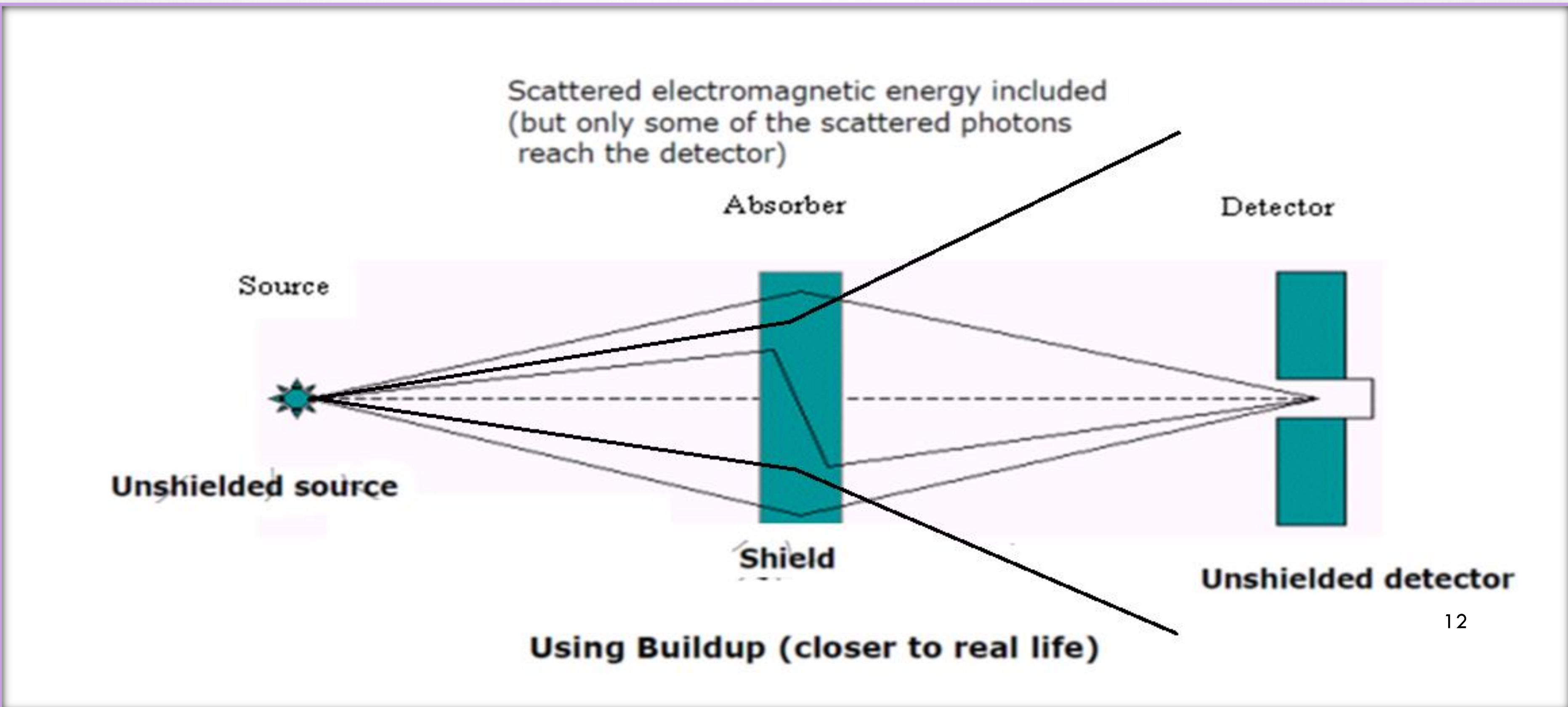
Build up factor (B) & attenuation coefficient

2) Wide beam condition (real life condition)



Build up factor (B) & attenuation coefficient

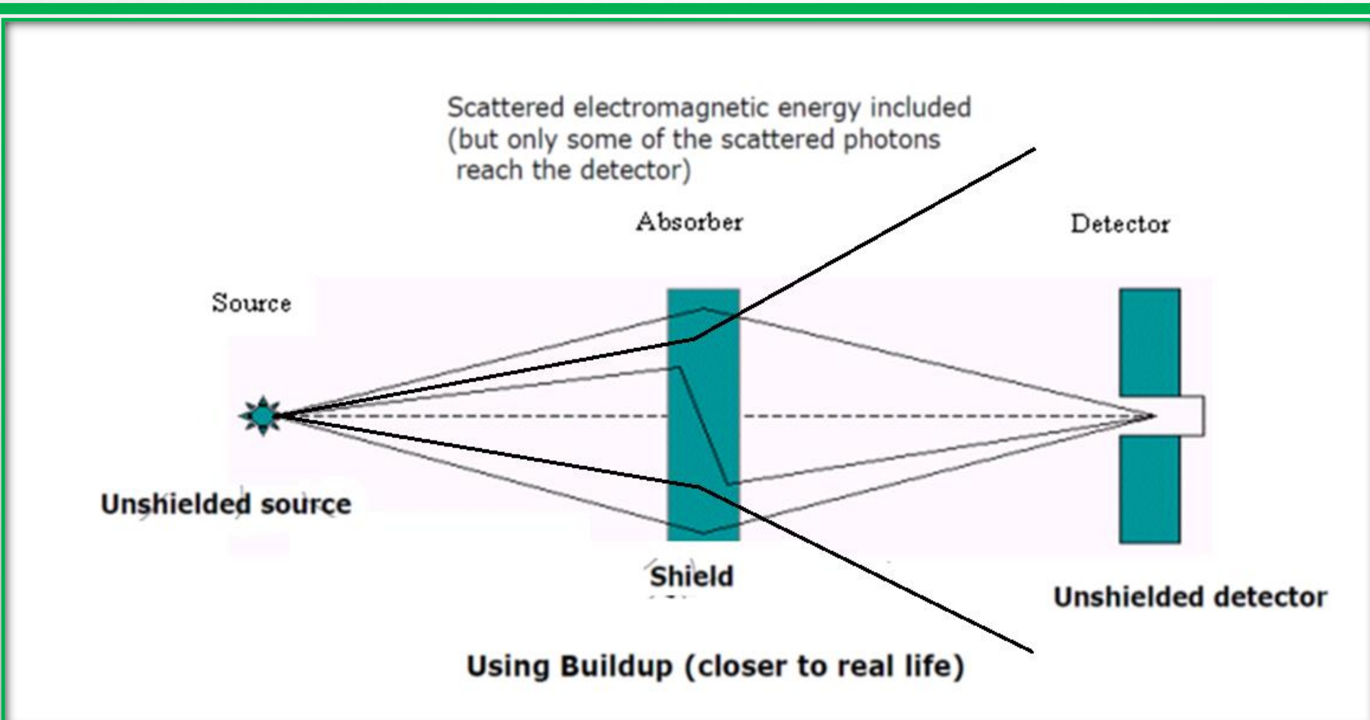
2) Wide beam condition (real life condition)



Introduction

Build up factor (B) & attenuation coefficient

2) Wide beam condition (real life condition)



$$\cancel{I = I_o\, e^{-\mu t}}$$

The build up factor (B) should be inserted to correct the above equation.

Introduction

Build up factor (B) & attenuation coefficient

The build-up factor **(B)** at any point is defined as:

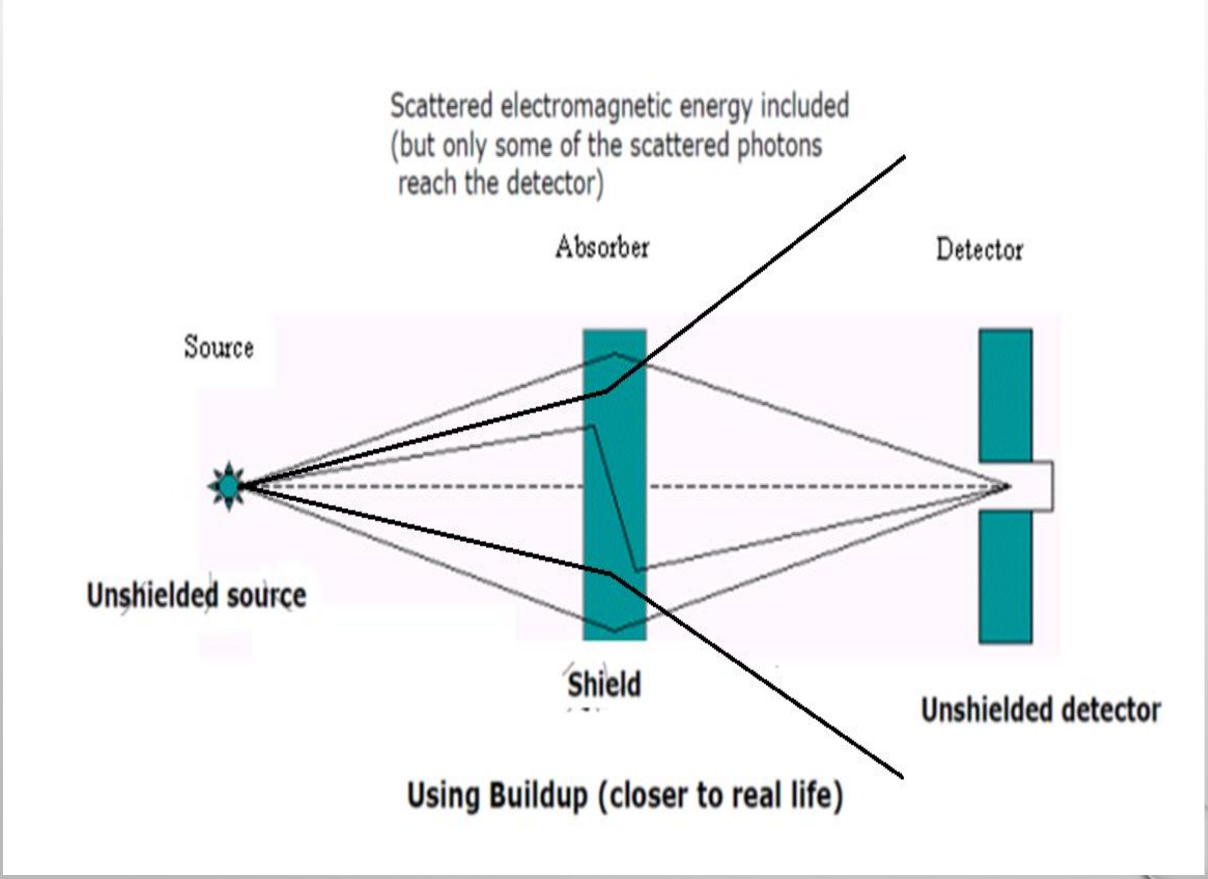
$$B = \frac{\text{The intensity of the primary and scattered radiation (Total)}}{\text{The intensity of the primary radiation only}}$$

- The build-up factor, which is always **greater than 1**.
- Build-up factors have been calculated for various gamma energies and for various absorbers.
- The build-up factor is in general a function of the total attenuation coefficient, the thickness of the shielding material d, and the energy of the gamma radiation

  i.e. $B = B(\mu, t, E)$

Build up factor (B) & attenuation coefficient

2) Wide beam condition (real life condition)



Linear Energy Absorption Shielding Formula:

$$I = BI_o\, e^{-\mu t}$$

Introduction

Build up factor (B) & attenuation coefficient

Experimentally, the build up factor B can be determined by using both setups:

$$I/I_o = e^{-\mu t} \quad . . . . \text{With collimator}$$

$$I/I_o = B\, e^{-\mu t} \quad . . . . \text{Without collimator}$$

$$B = \frac{\left(\frac{I}{I_o}\right)_{without\ collimator}}{\left(\frac{I}{I_o}\right)_{with\ collimator}}$$

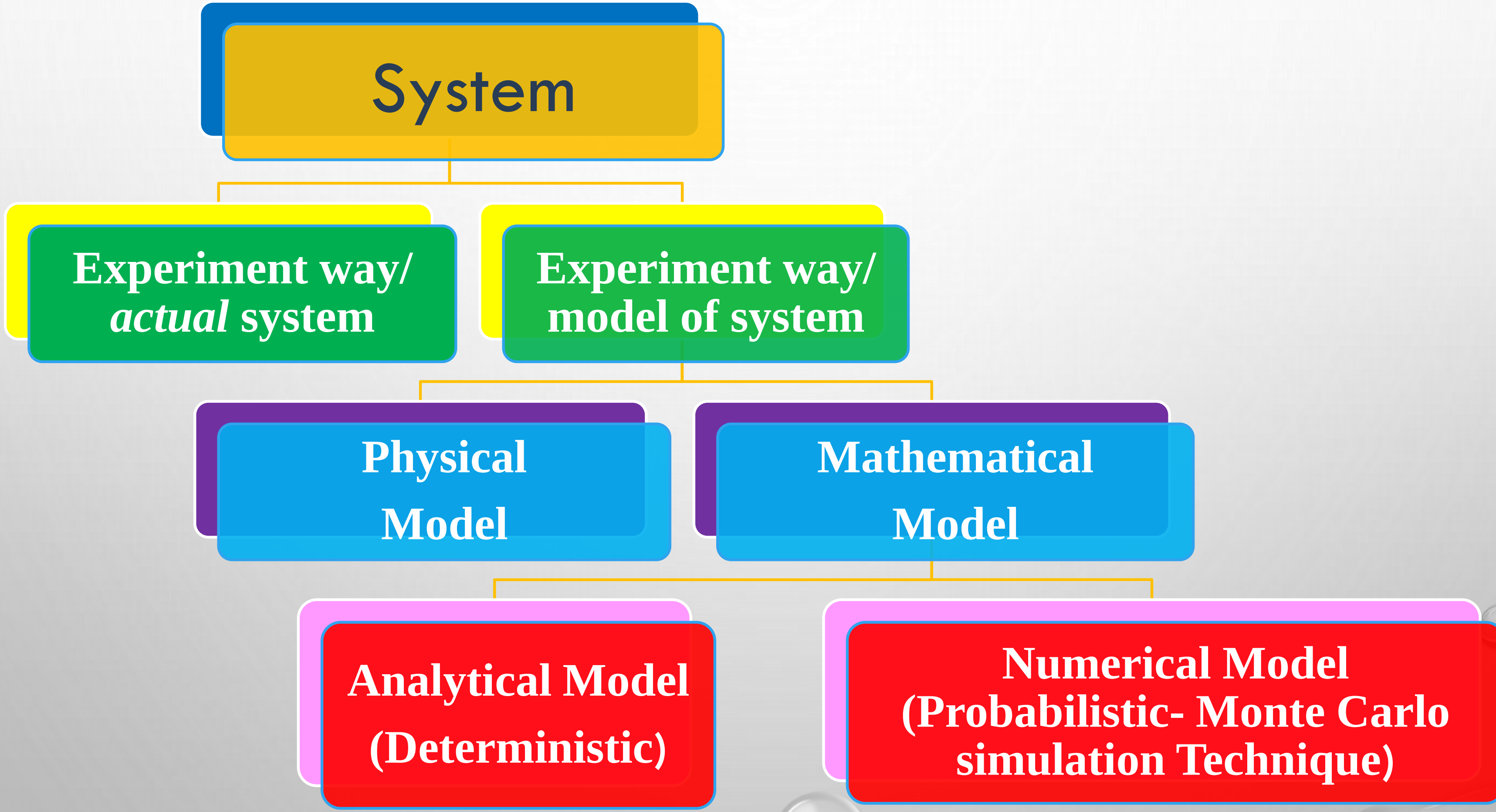
Introduction

Build up factor (B) & Dose Rate

The dose or dose rate D at a point of interest outside the shield, is related to the unshielded dose, D_0, at the point by:

$$D = B\, D_o\, e^{-\mu t}$$

WAYS TO STUDY SYSTEM



BASICS OF SIMULATION

- **SYSTEM:** THE PHYSICAL PROCESS OF INTEREST

- **MODEL:** MATHEMATICAL REPRESENTATION OF THE SYSTEM
  - MODELS ARE A FUNDAMENTAL TOOL OF SCIENCE, ENGINEERING, BUSINESS, ETC.
  - ABSTRACTION OF REALITY
  - MODELS ALWAYS HAVE LIMITS OF CREDIBILITY

- **SIMULATION:** A TYPE OF MODEL WHERE THE COMPUTER IS USED TO IMITATE THE BEHAVIOR OF THE SYSTEM.

MONTE CARLO

- The Monte Carlo method is a numerical solution to a problem that models objects interacting with other objects or their environment.
- The accuracy of the simulation is a direct function of the number of histories , consequently, of the simulation time.

Advantages of Simulation

- ✓Inexpensive to evaluate decisions before implementation
- ✓Reveals critical components of the system
- ✓Excellent tool for selling the need for change

Famous Monte Carlo codes

- MCNP (MONTE CARLO N-PARTICLE CODE)
- GEANT4 (SIMULATION OF THE PASSAGE OF PARTICLES TRANSPORT THROUGH THE MATTER.)
- FLUKA
- EG4
- OTHERS

- **GEANT4**

SIMULATION OF THE PASSAGE OF PARTICLES TRANSPORT THROUGH THE MATTER.

WHAT DOES GEANT STAND FOR?

- Generation And Tracking (End of 1970’s, at the beginning of GEANT1)
- Geometry And Tracking (Nowadays)
- Upgrade GATE for following GEANT4

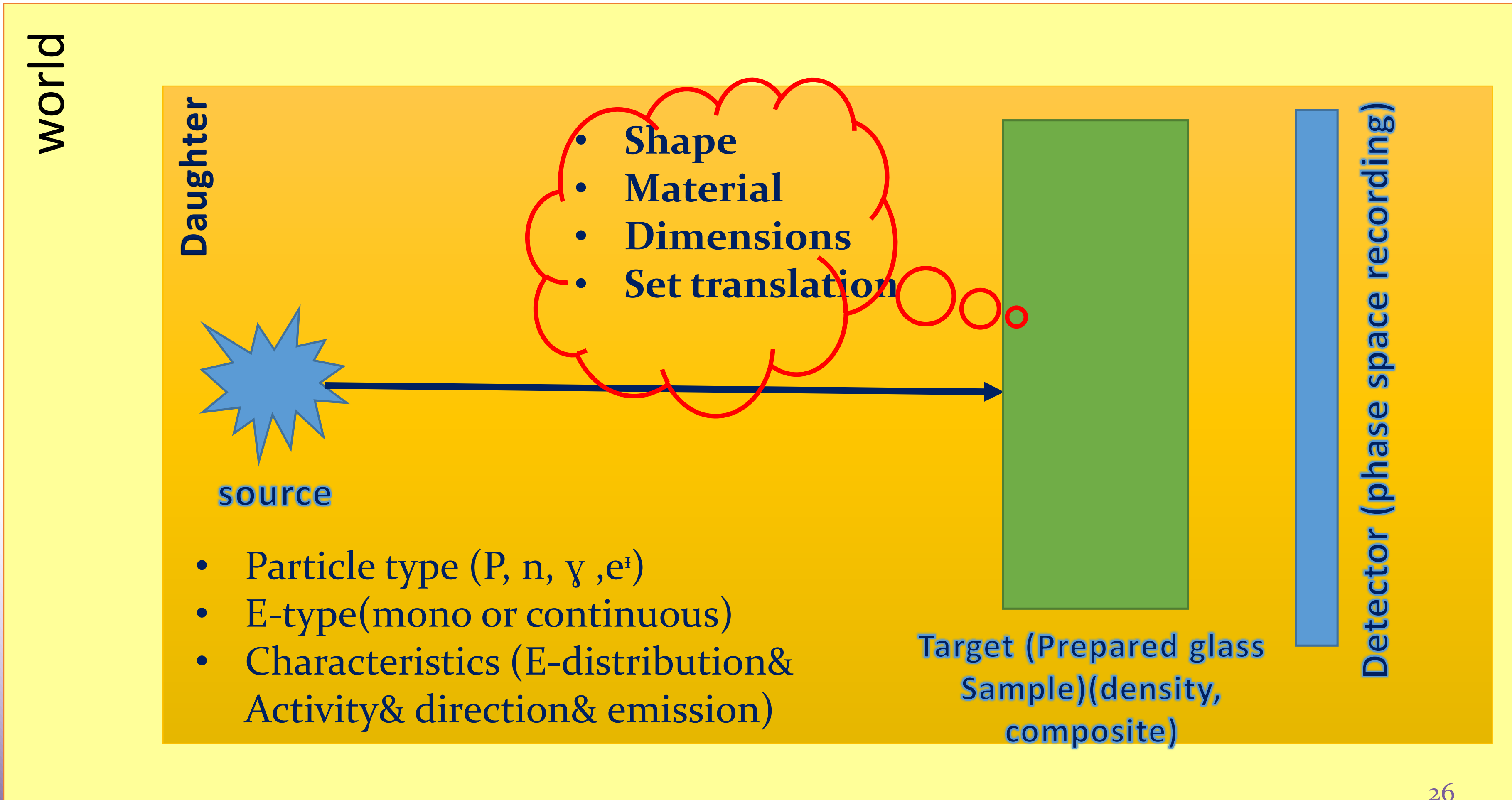
GATE- GEANT:

GATE (GEANT APPLICATION TOMOGRAPHY AND EMISSION)is an advanced open source software developed by the international Open GATE collaboration and dedicated to numerical simulations in medical imaging and radiotherapy.

WHY WE USE GATE-GEANT4?

- GEANT4 is written in C++(Object-Oriented programming);Gate using macros, without any C++ writing.
- . This way allows user to build C++ classes for describing geometry, particle interactions and physics While GATE can be configured by commands.
- The Geant4 simulation code covers a wide energy range of photon starting from 250 eV to the TeV.

Simulation Step Up:



DATA OUTPUTS

The detected spectra can be translated to ASCII and processed with custom-made programs based on ROOT (is a data analysis software developed by CERN especially to handle large sets of data (data of large scale)); it can analyze any set of data, so it can handle intensity or any thing else; it deals with them as variables.

Previous Work

Radiation Physics and Chemistry 106 (2015) 255–260

ELSEVIER

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Comparative studies on shielding properties of some steel alloys using Geant4, MCNP, WinXCOM and experimental results

CrossMark

Vishwanath P. Singh [a,b,*], M.E. Medhat [c,d], S.P. Shirmardi [e]

[a] Department of Physics, Karnatak University, Dharwad, 580003, India
[b] Health Physics Section, Kaiga Atomic Power Station-3&4, NPCIL, Karwar, 581400, India
[c] Experimental Nuclear Physics Department., Nuclear Research Centre, 13759,Cairo, Egypt
[d] Institute of High Energy Physics, CAS, Beijing, 100049, China
[e] Nuclear Science and Technology Research Institute, Tehran, 14155-1339, Iran

The simulated M/ρ and Z_{eff} values using Geant4 and MCNP code signifies that both the simulation process can be followed to determine the gamma ray interaction properties of the alloys for energies wherever analogous experimental results may not be available. This kind of studies can be used for various applications such as for radiation dosimetry, medical and radiation shielding.

Previous Work

Progress in Nuclear Energy 83 (2015) 99–104

Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: www.elsevier.com/locate/pnucene

Development of barium borosilicate glasses for radiation shielding materials using rice husk ash as a silica source

S. Ruengsri [a], S. Insiripong [b], N. Sangwaranatee [c], J. Kaewkhao [d,*]

[a] Chemistry Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand
[b] Physics Program, Faculty of Science and Technology, Muban Chombueng Rajabhat University, Ratchaburi, 70150, Thailand
[c] Applied Physics, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok, 10300, Thailand
[d] Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom, 73000, Thailand

The radiation shielding results and optical transparency of the glasses indicate that the glasses in the present study can be used as radiation shielding materials with higher transparency.

Previous Work

Radiation Physics and Chemistry 96 (2014) 153–157

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

ELSEVIER

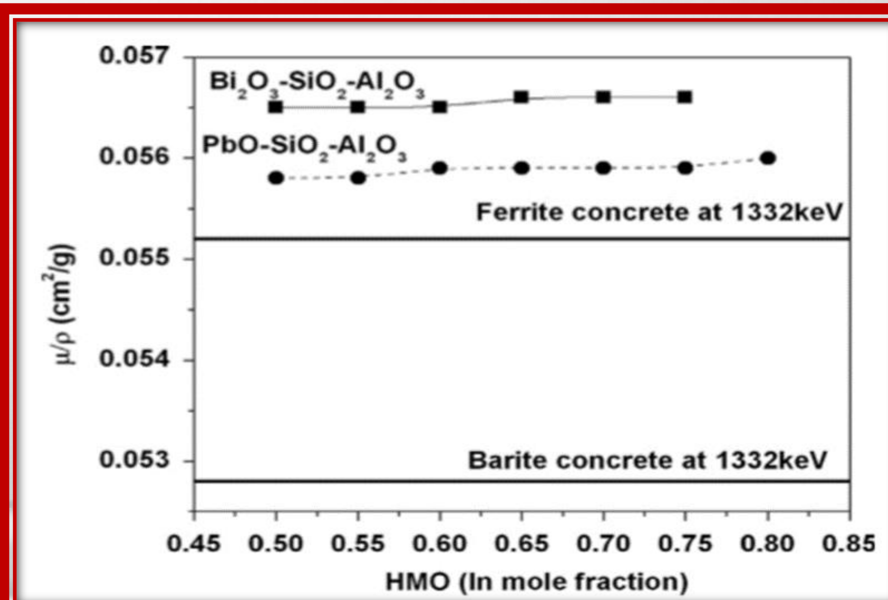
Comparative study of gamma ray shielding and some properties of $PbO–SiO_2–Al_2O_3$ and $Bi_2O_3–SiO_2–Al_2O_3$ glass systems

CrossMark

K.J. Singh *, Sandeep Kaur, R.S. Kaundal

Department of Physics, Guru Nanak Dev University, Amritsar-143005, India

Lead can be replaced by bismuth for preparation of non-conventional gamma-ray shielding materials in terms of glasses.



Aim of work

1. Preparing the base glass compound and the starting doping elements based on their optical and attenuation properties.
2. Building up validated Monte Carlo simulation code using GATE/Geant4 based on the initial proposed composition, the type and energy of radiation and material geometry.
3. Use the validated code to suggest new series of suitable shielding composition and geometry for different types of radiation.

Sample preparation

$xPbO - 40B_2O_3 - 25\ Na_2O - 5Li_2O - (30 - x)\ SiO_2$

X=0, 5, 10, 15, 20, 25 mol%

- **Borosilicate glasses have been widely used for optical lenses with high refractive index, high density, high chemical stability, high stability under radiation effect.**

- **Li : Electrical and Thermal properties ,high n**

- **Na: Melting Point**

PbO-B2O3-SiO2

- ***used as radiation hard glasses, optical and thermal properties***
- ***also the glass containning lead oxide has the highest refractive index***

characterization

Physical characterization

- XRD
- Density
- FTIR
- Optical

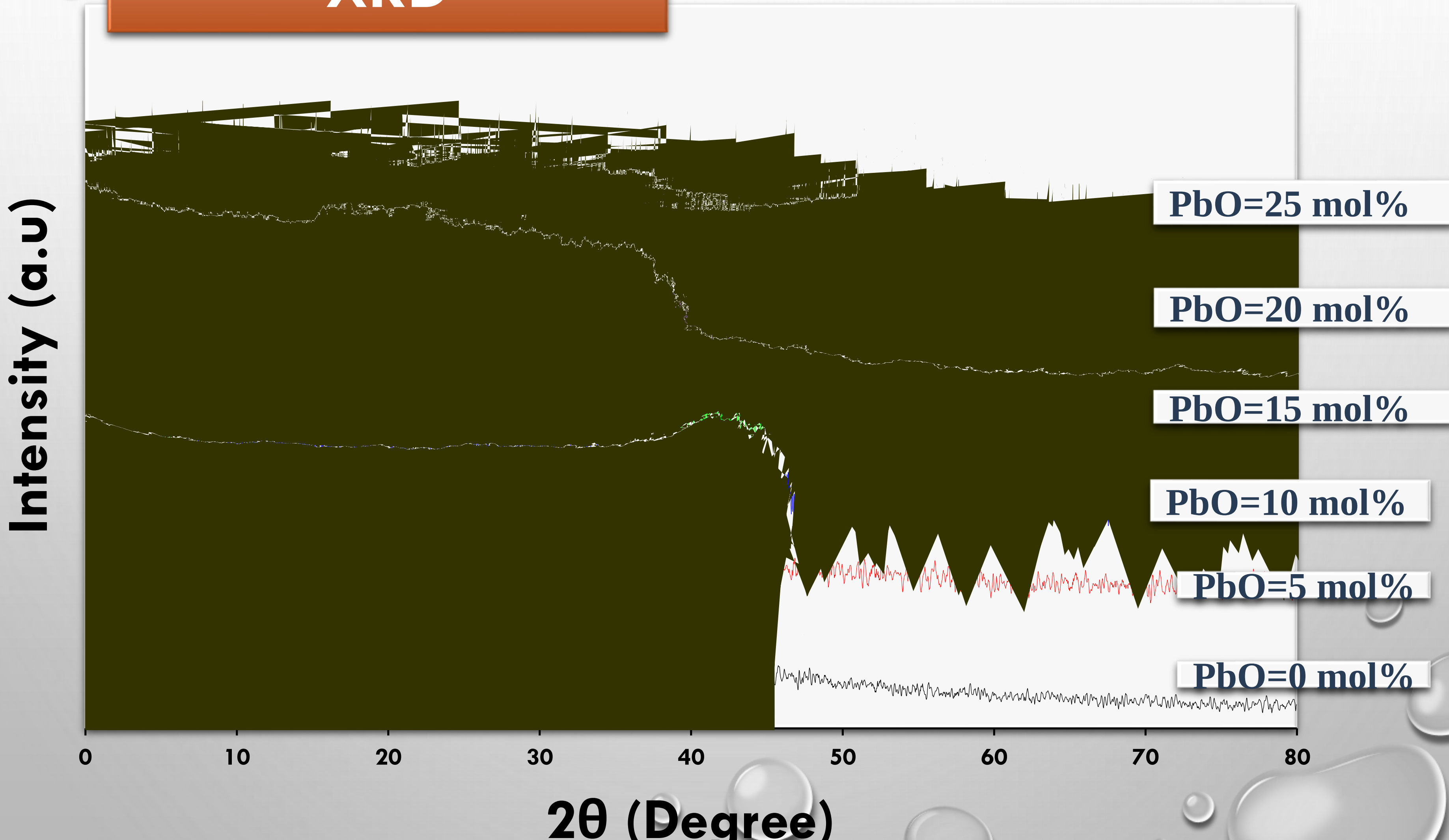
Shielding characterization

- Linear attenuation coefficient
- Buildup Factor

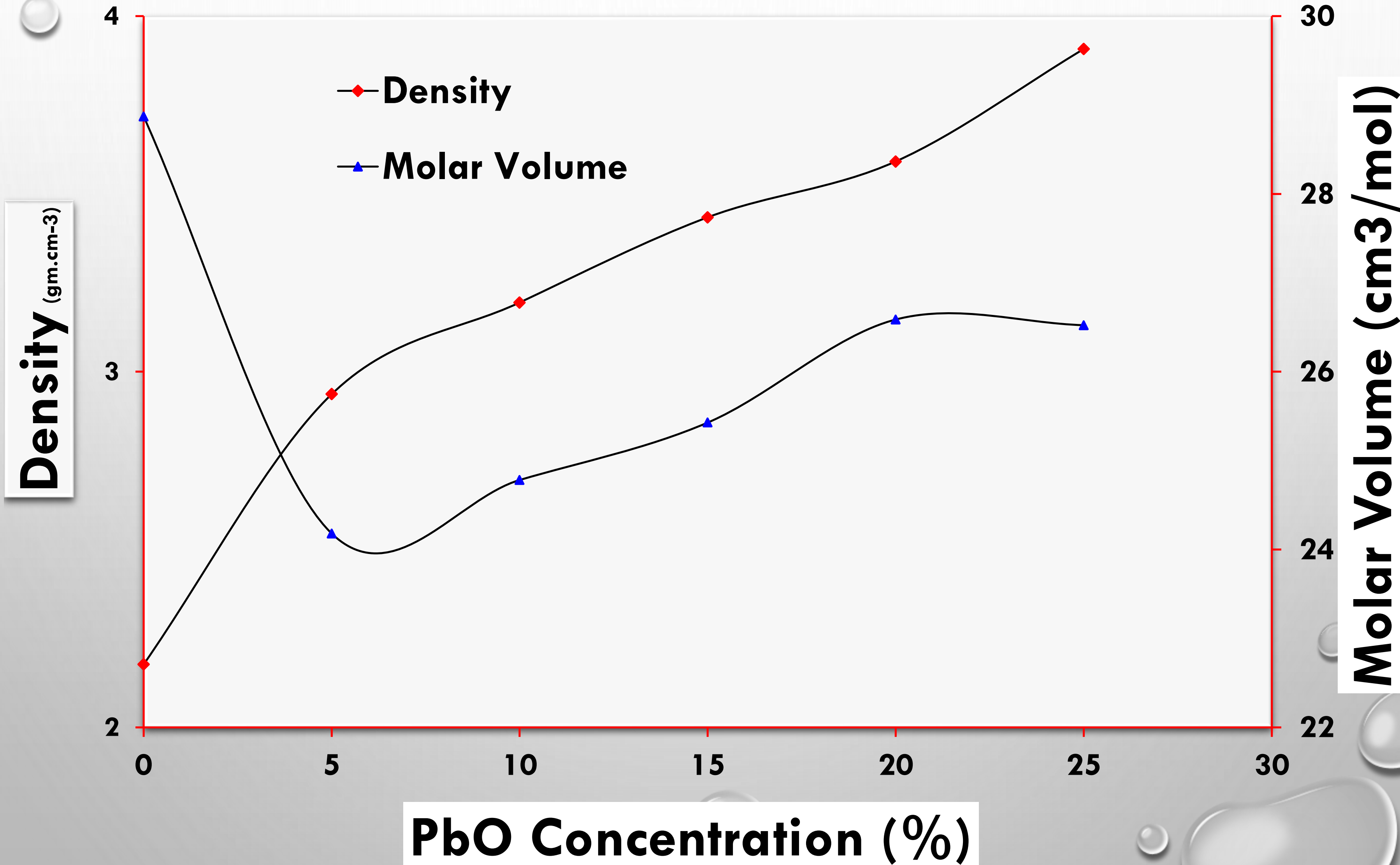
Results & Discussion

Physical characterization

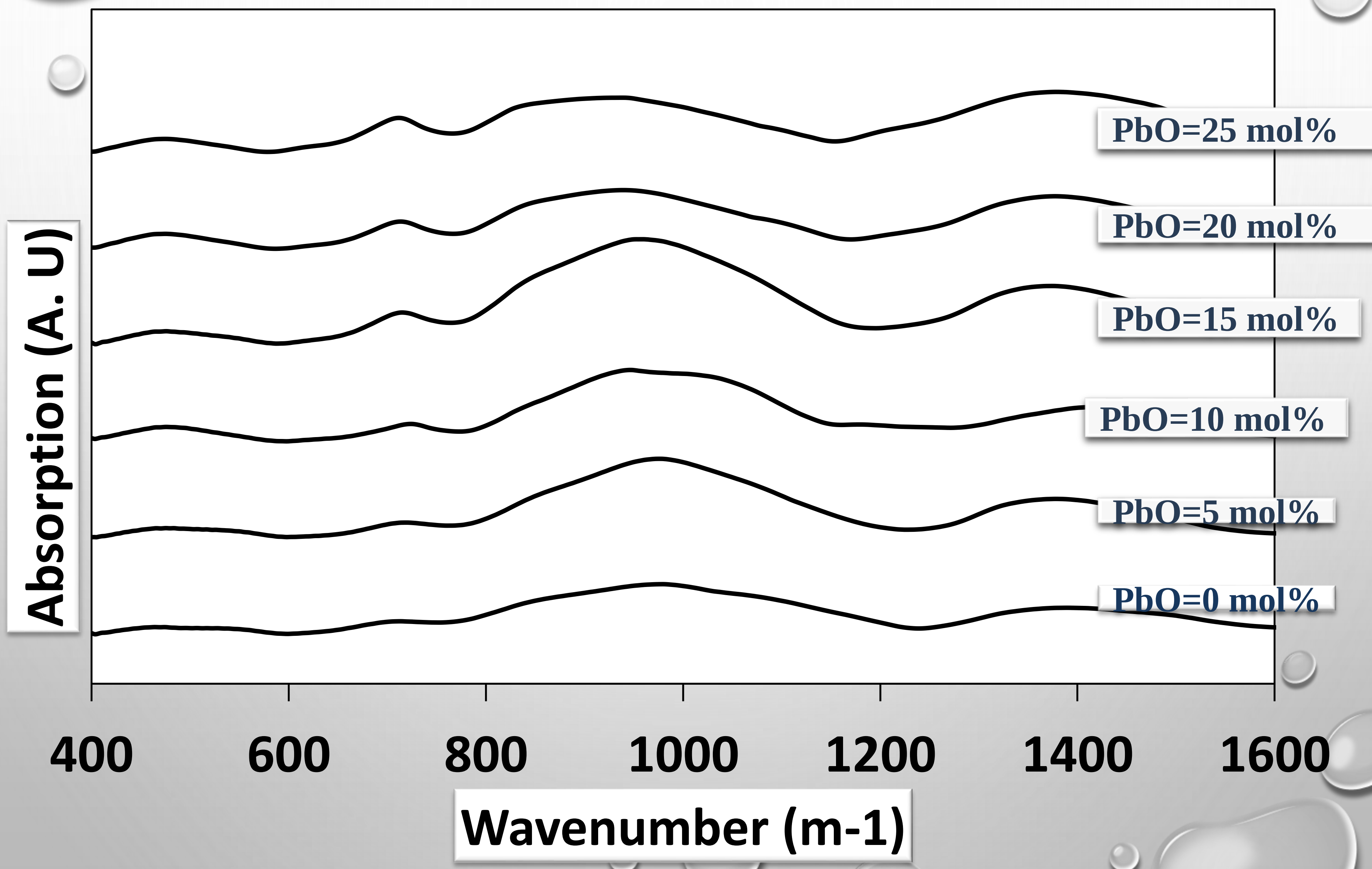
XRD



Density and Molar Volume



FTIR

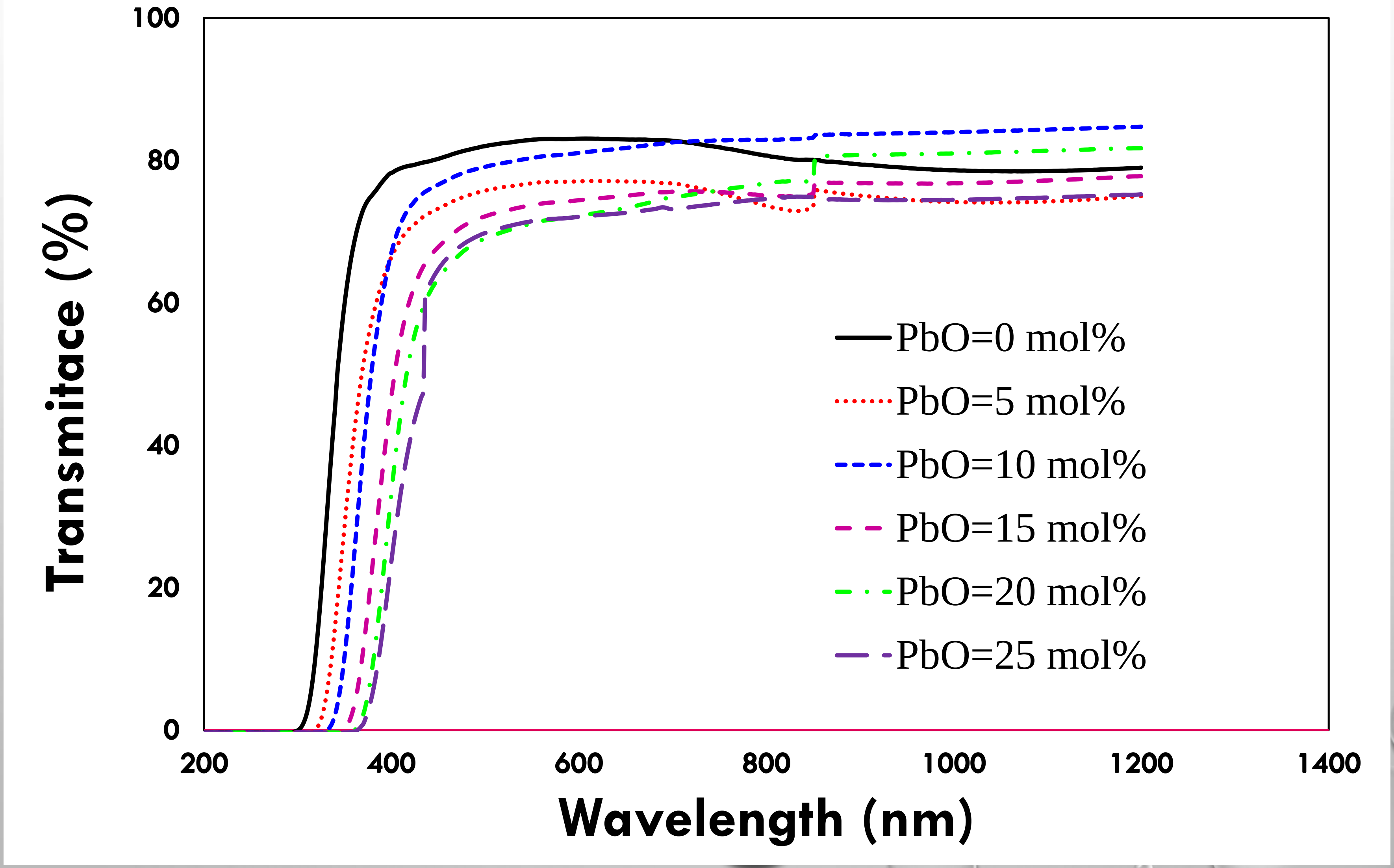


PbO=25 mol%
PbO=20 mol%
PbO=15 mol%
PbO=10 mol%
PbO=5 mol%
PbO=0 mol%
Absorption (A. U)
400
600
800
1000
1200
1400
1600
Wavenumber (m-1)

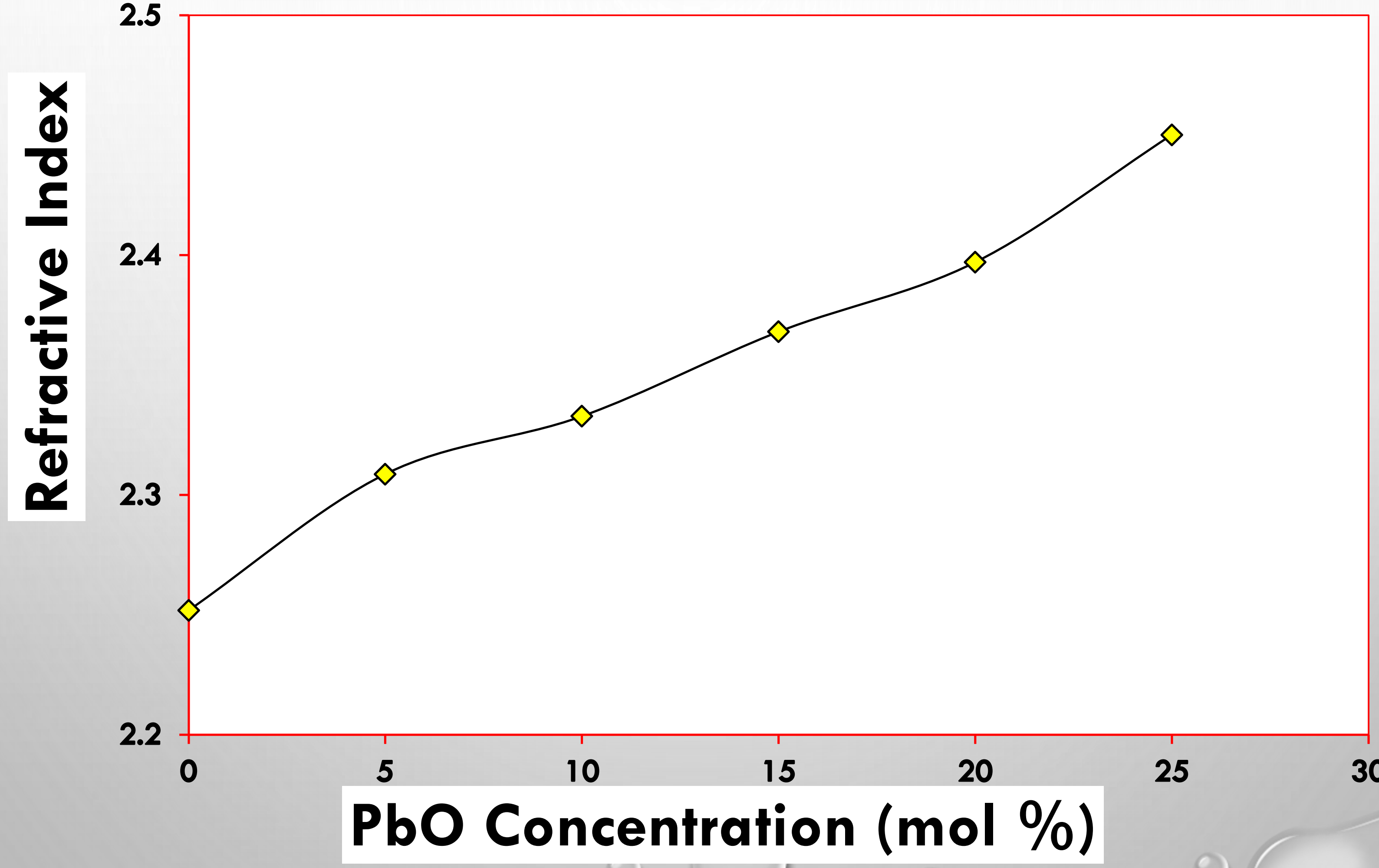
Assignment	Position (cm−1)
O–B–O bond-bending vibrations covalent Pb–O bond vibrations	433-445
B–O–B bond-bending vibrations from pentaborate groups	680-705
B–O bond-stretching vibrations in BO4 units from diborate groups	800-1200
B–O–B bending vibration and stretching in [BO3] triangles	1300-1600

Optical properties

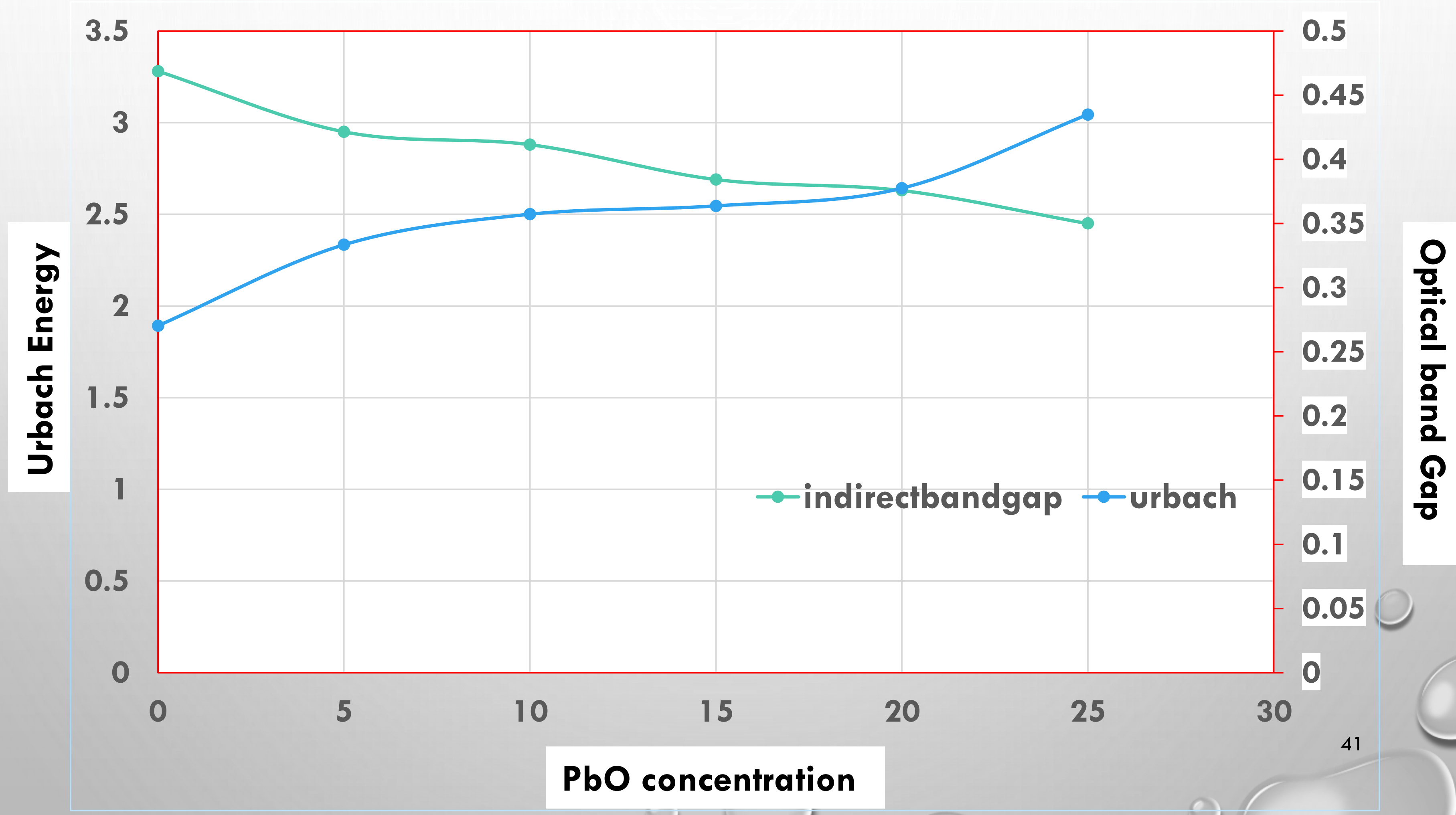
Transmission



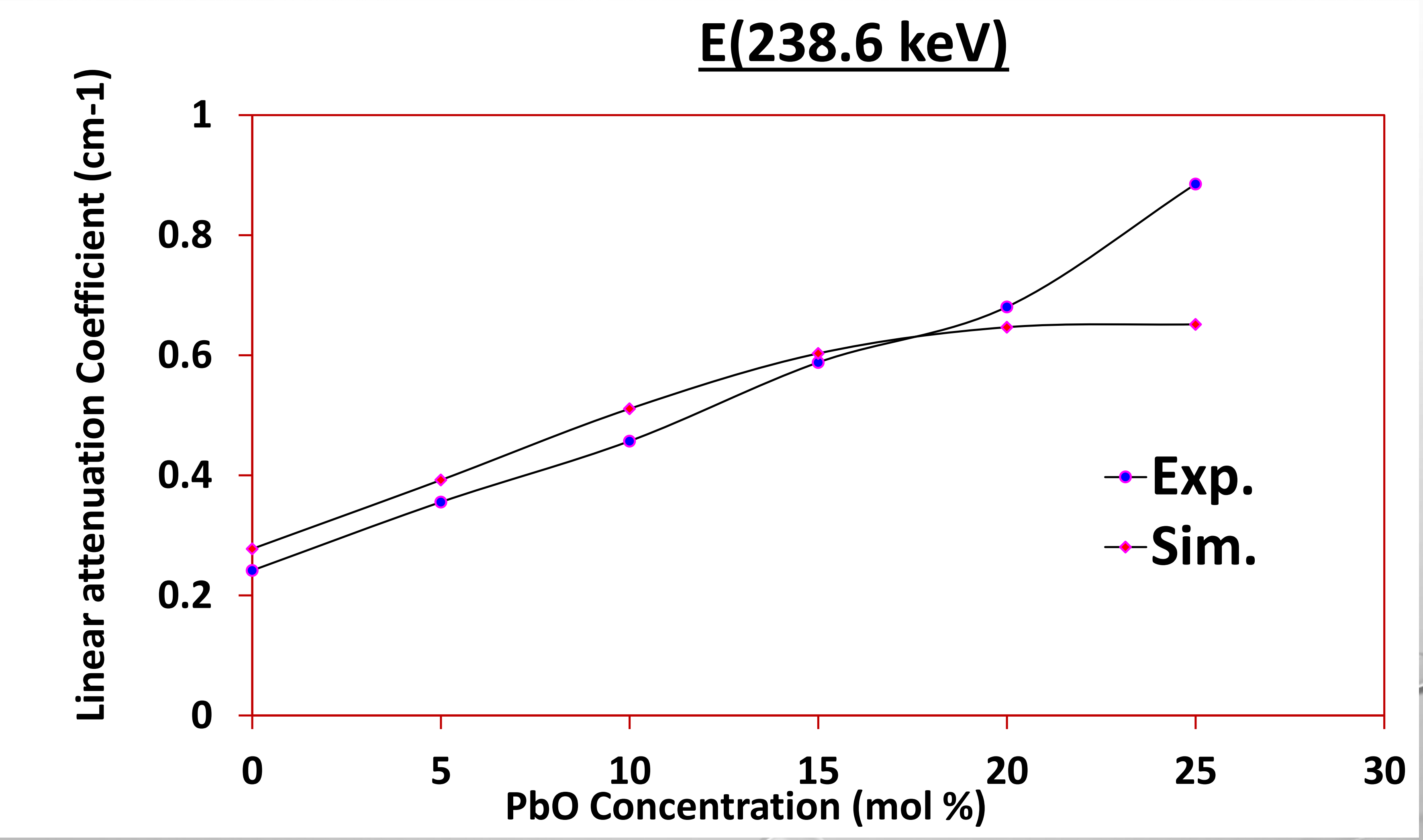
REFRACTIVE INDEX RESULTS

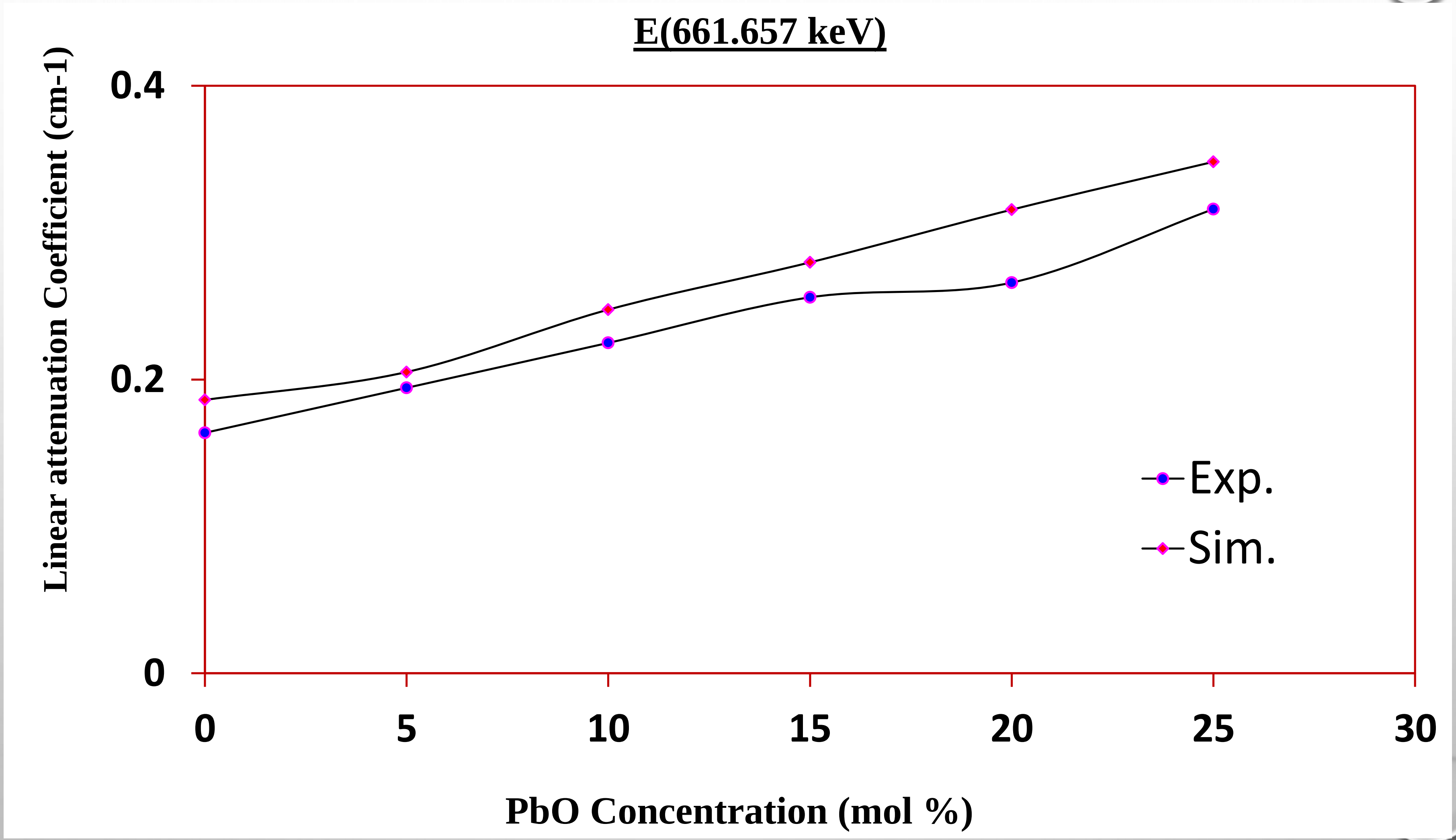


OPTICAL BAND GAB &URBACH

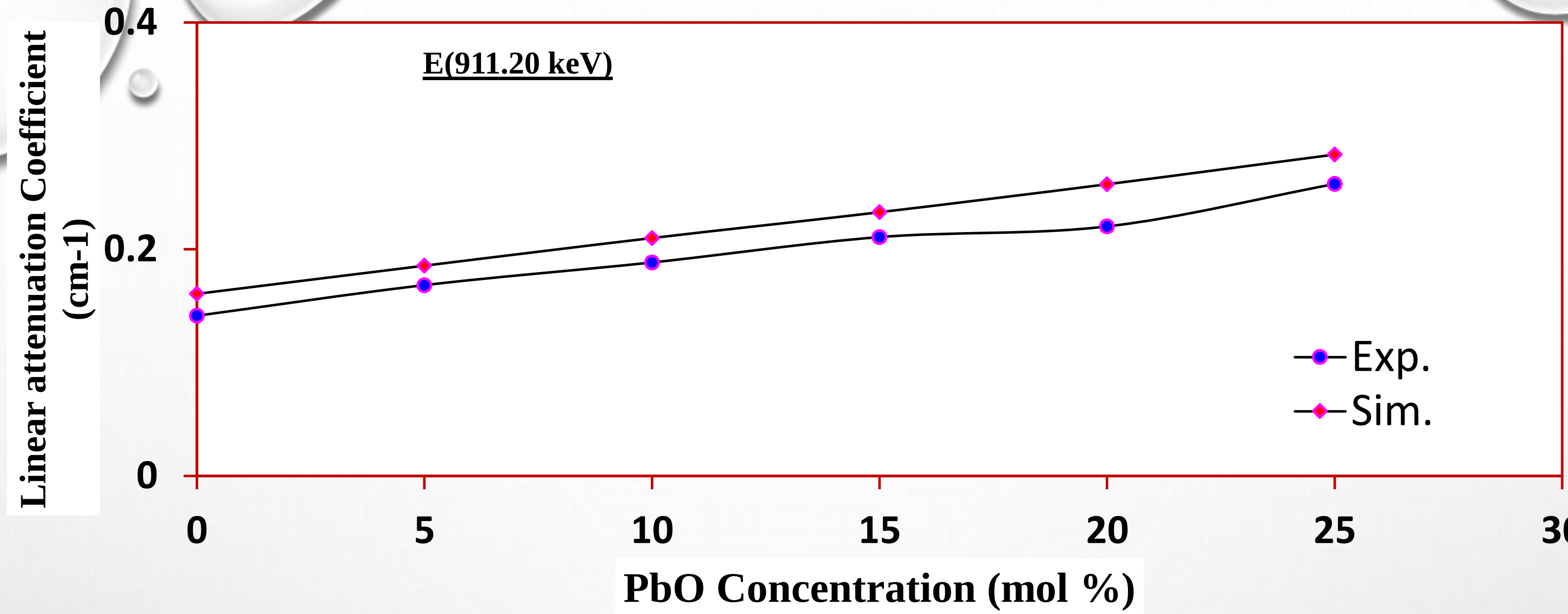


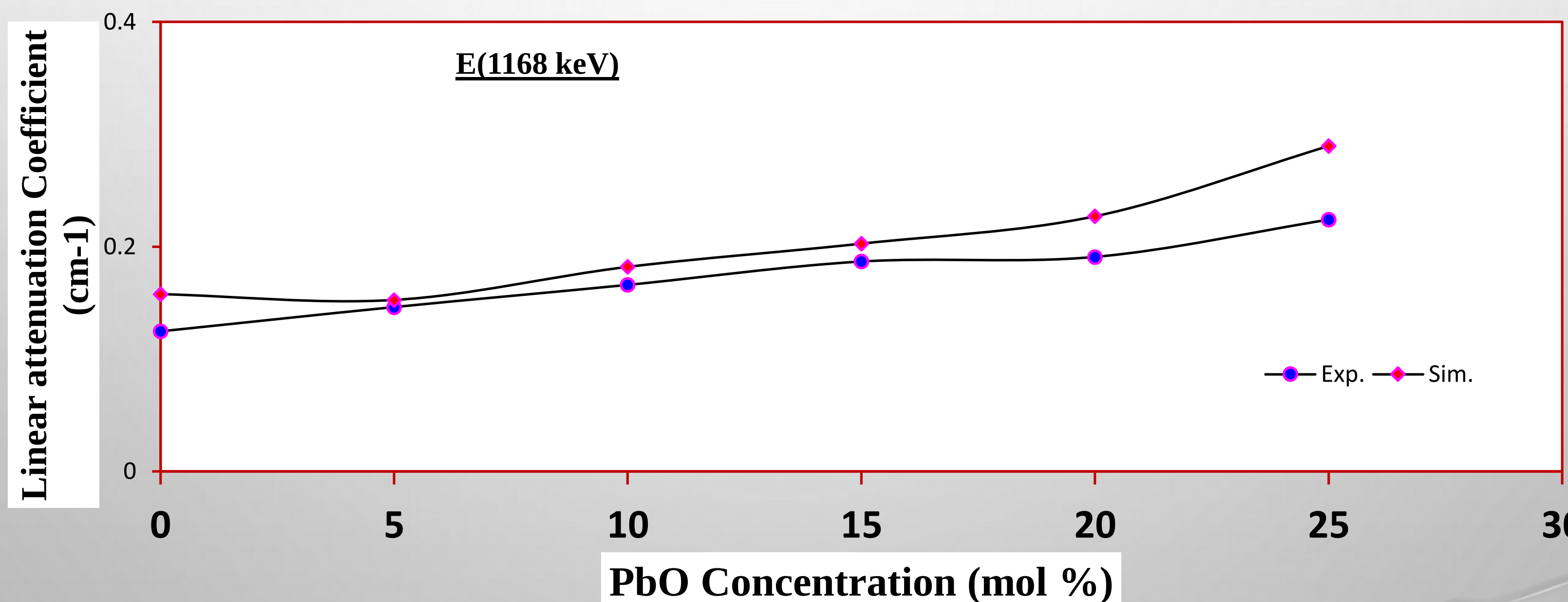
Shielding characterization

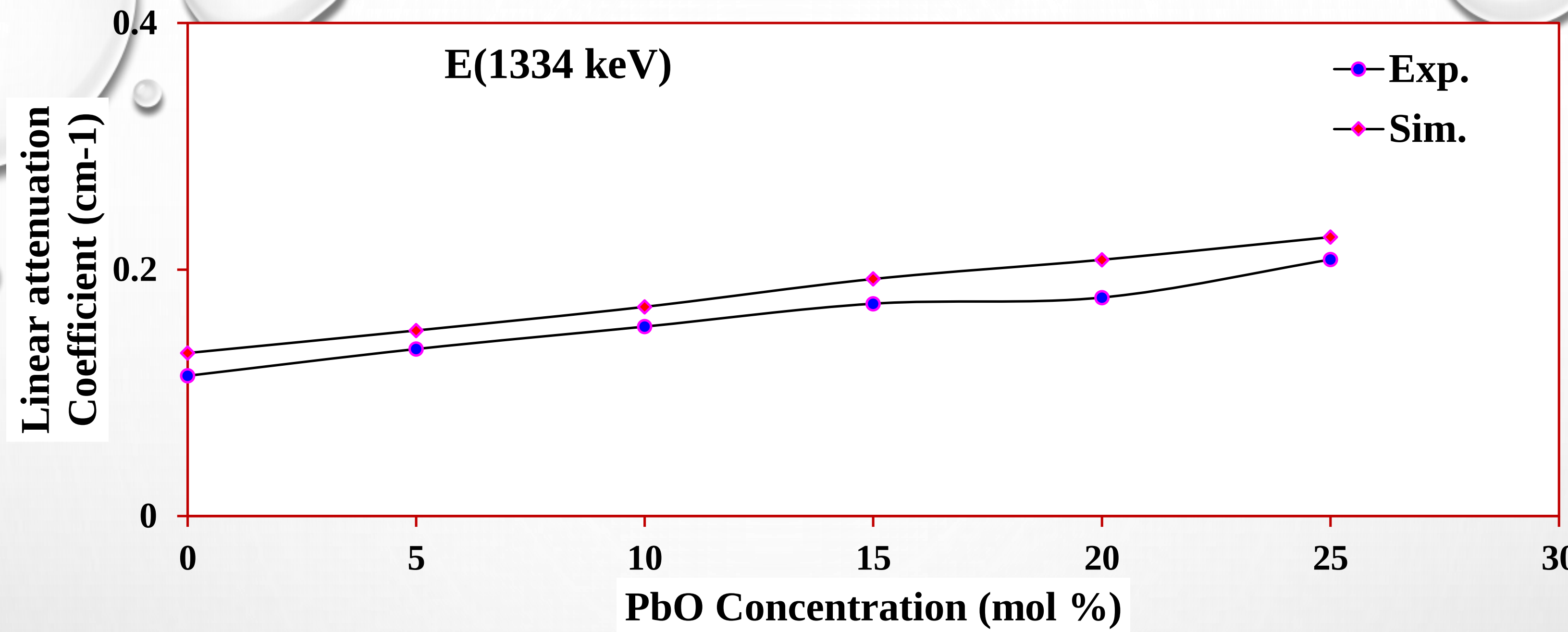




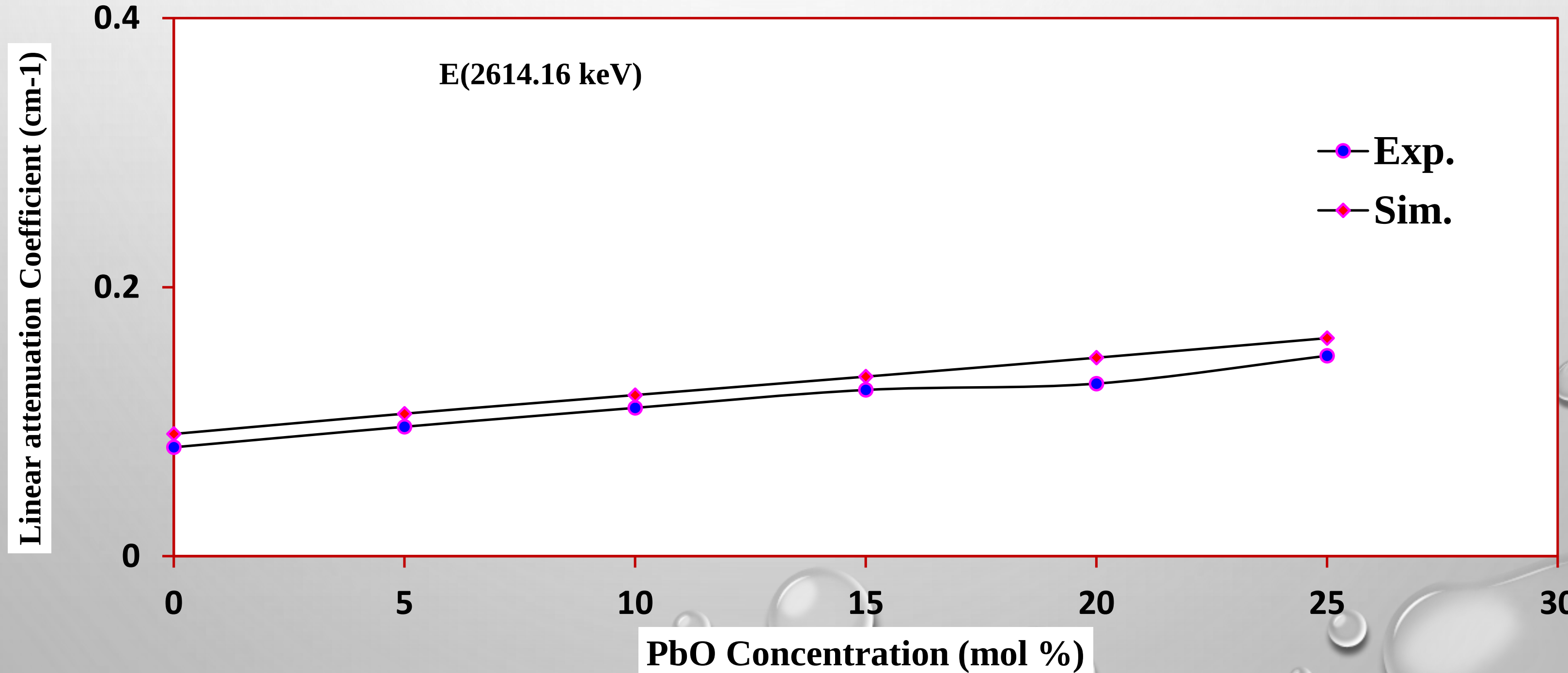
E(661.657 keV)
Linear attenuation Coefficient (cm-1)
0.4
0.2
0
0
5
10
15
20
25
30
PbO Concentration (mol %)
Exp.
Sim.


E(911.20 keV)
Linear attenuation Coefficient (cm-1)
0.4
0.2
0
0
5
10
15
20
25
30
PbO Concentration (mol %)
Exp.
Sim.

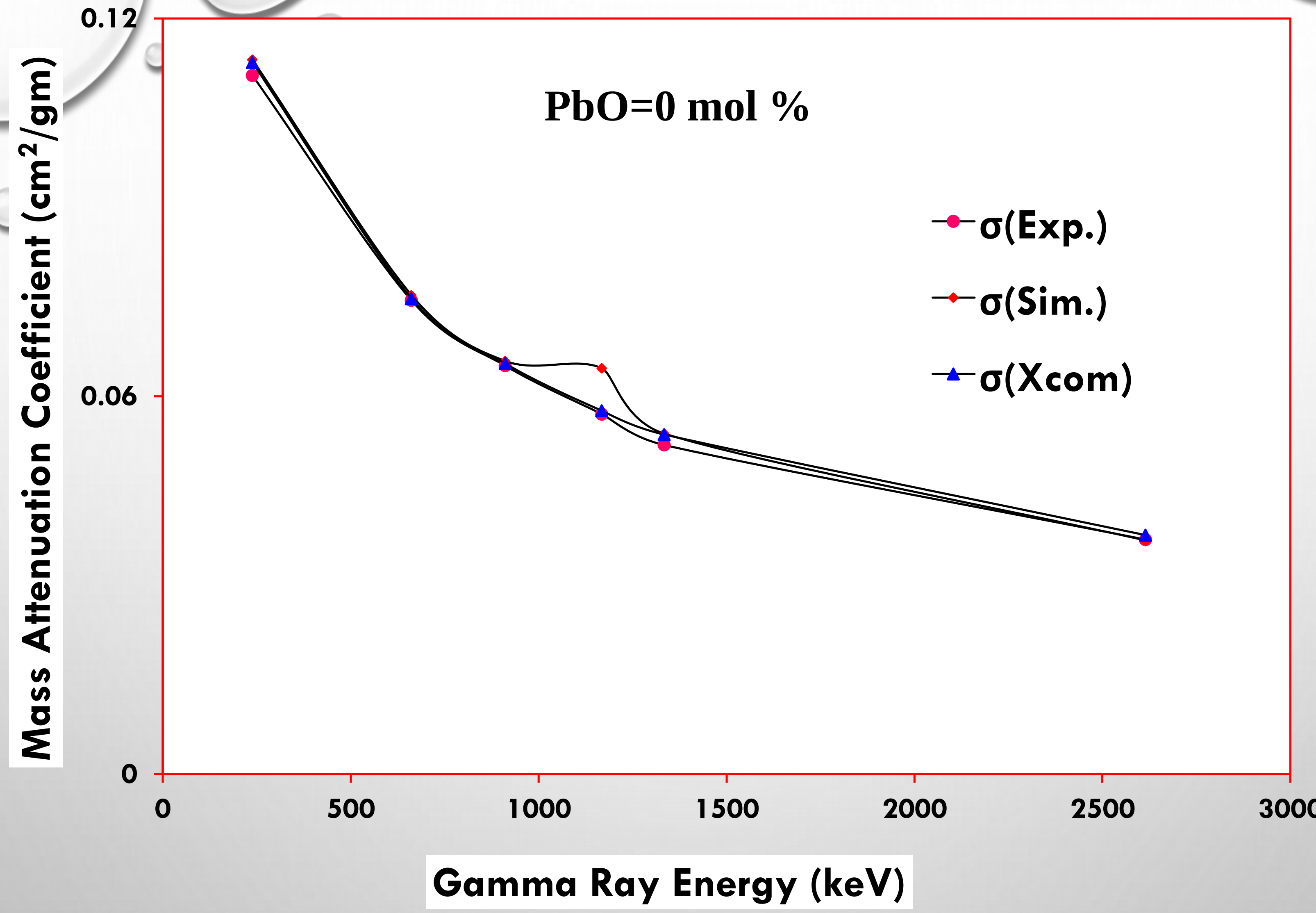

E(1168 keV)
Linear attenuation Coefficient (cm-1)
0.4
0.2
0
0
5
10
15
20
25
30
PbO Concentration (mol %)
Exp.
Sim.



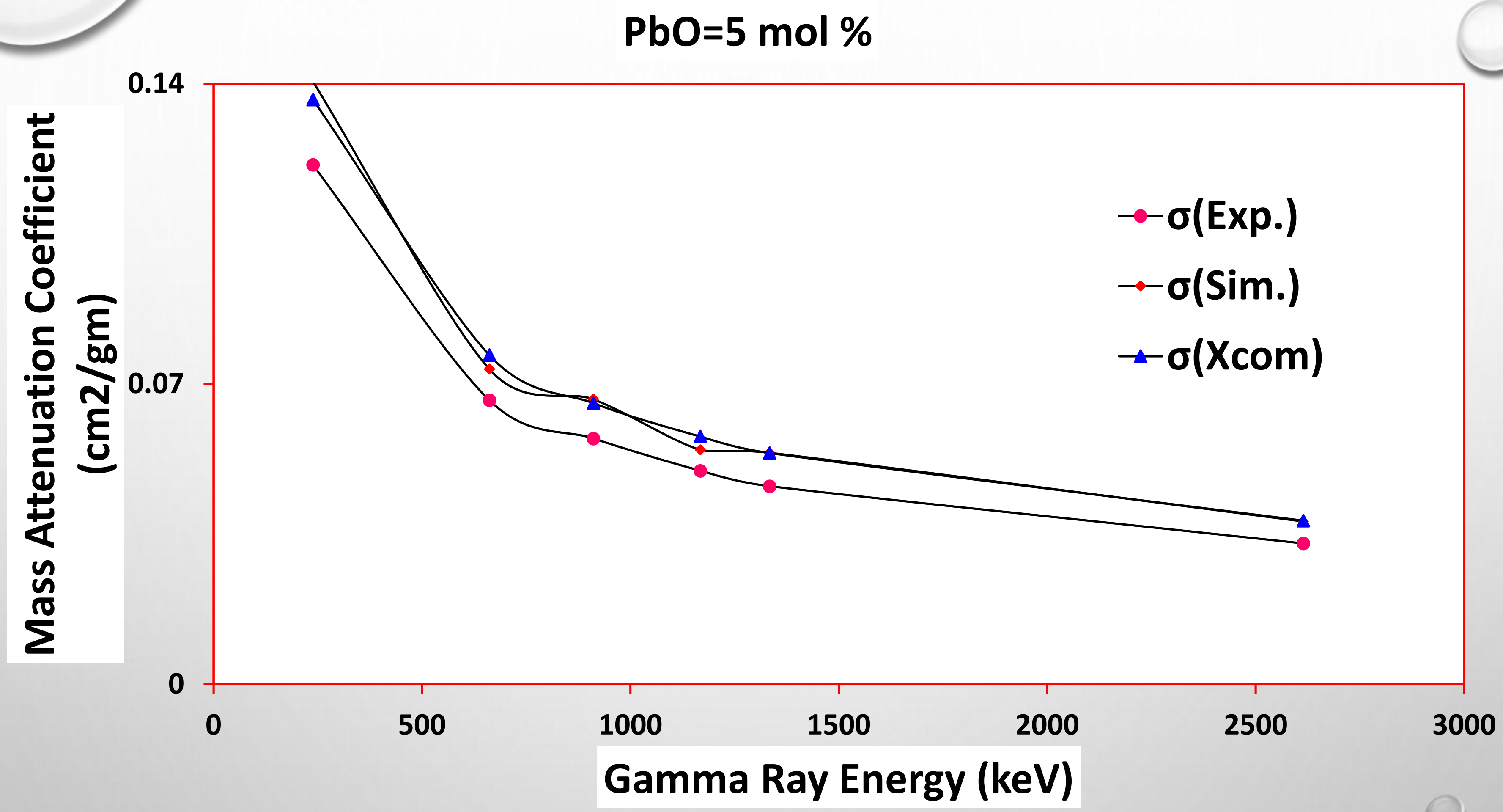
E(1334 keV)
Exp.
Sim.
Linear attenuation Coefficient (cm-1)
0.4
0.2
0
0
5
10
15
20
25
30
PbO Concentration (mol %)



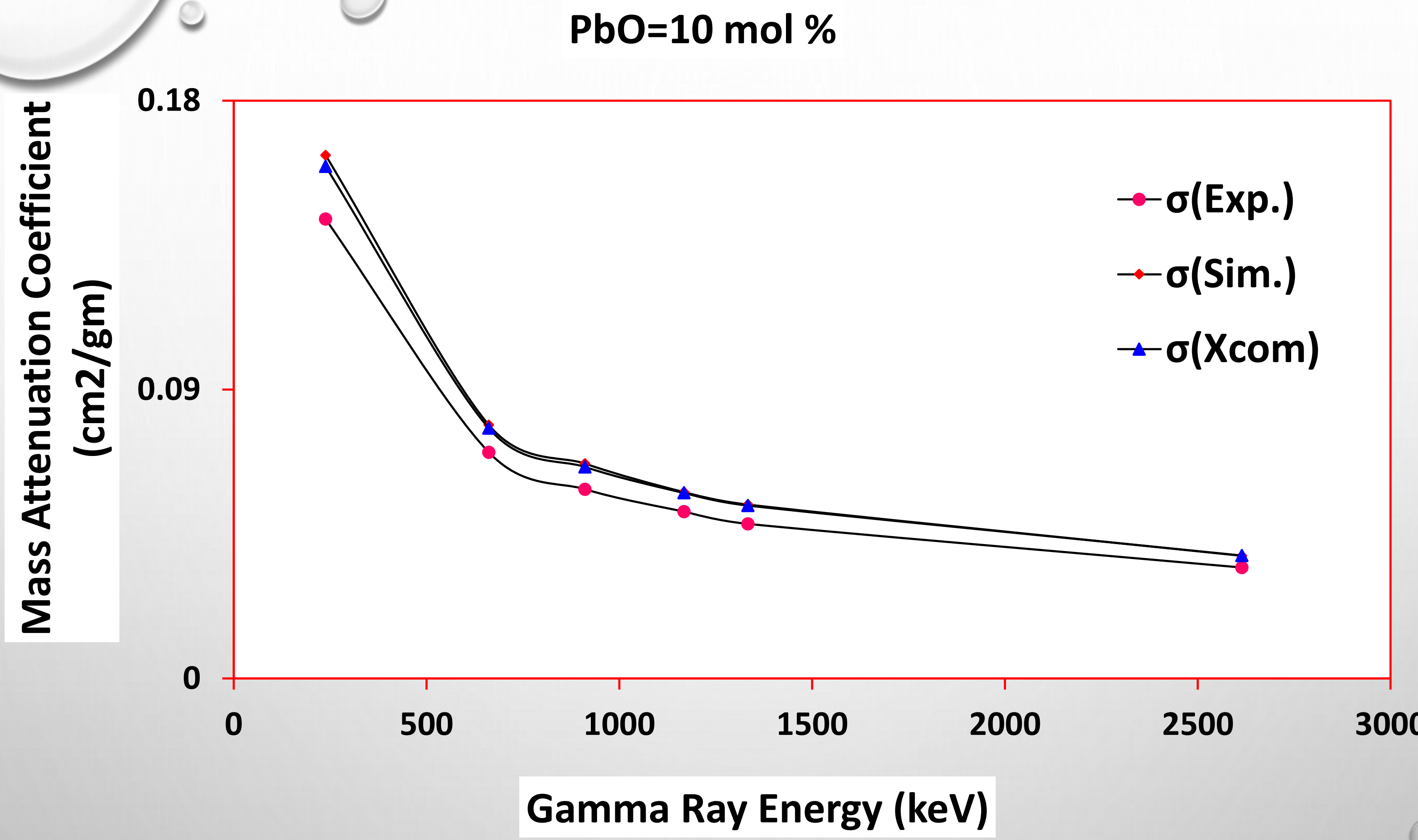
E(2614.16 keV)
Exp.
Sim.
Linear attenuation Coefficient (cm-1)
0.4
0.2
0
0
5
10
15
20
25
30
PbO Concentration (mol %)



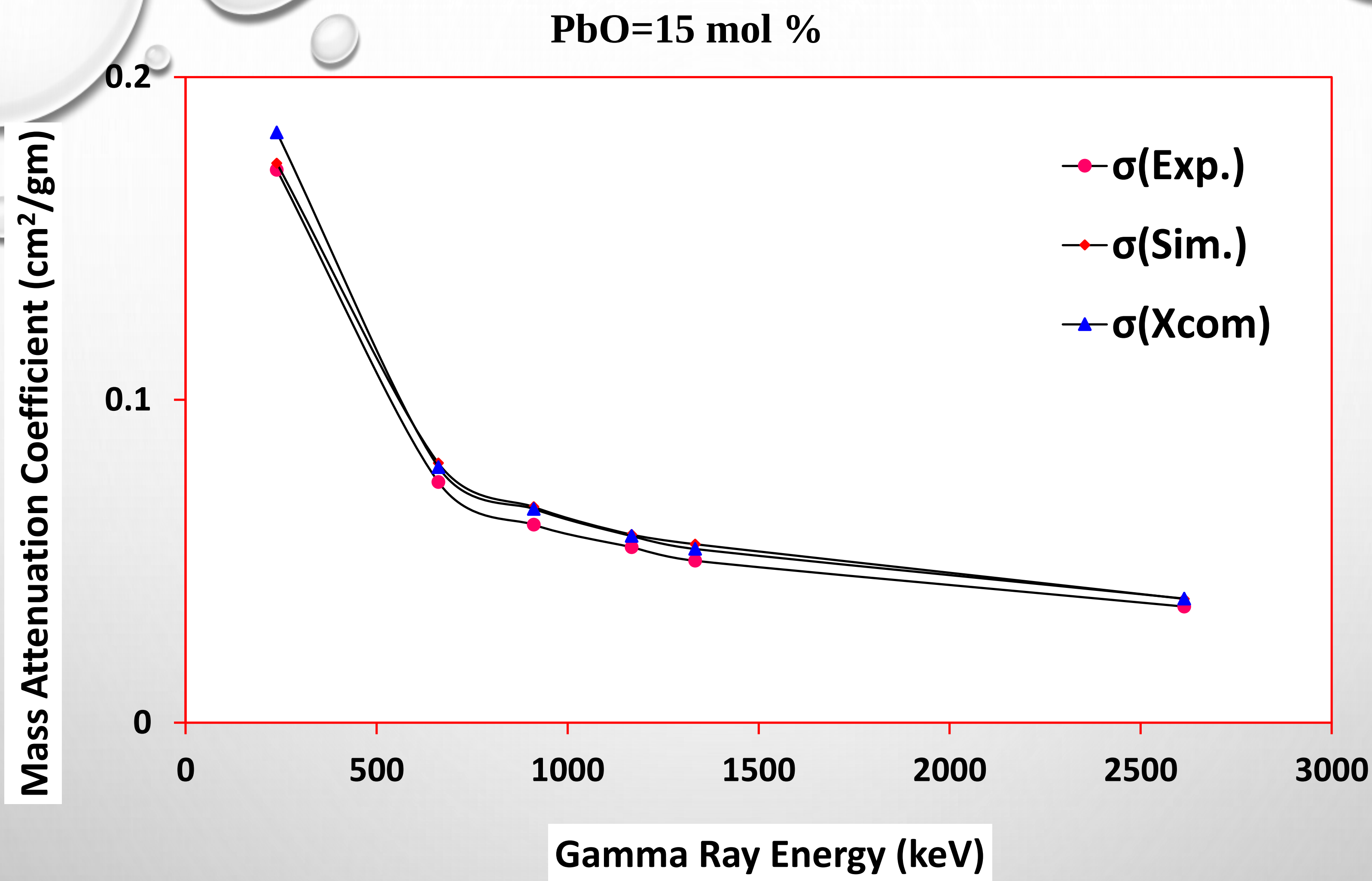
Comparison between, XCom, simulated, and measured mass attenuation coefficients as a function in gamma energy at PbO=0 mol %



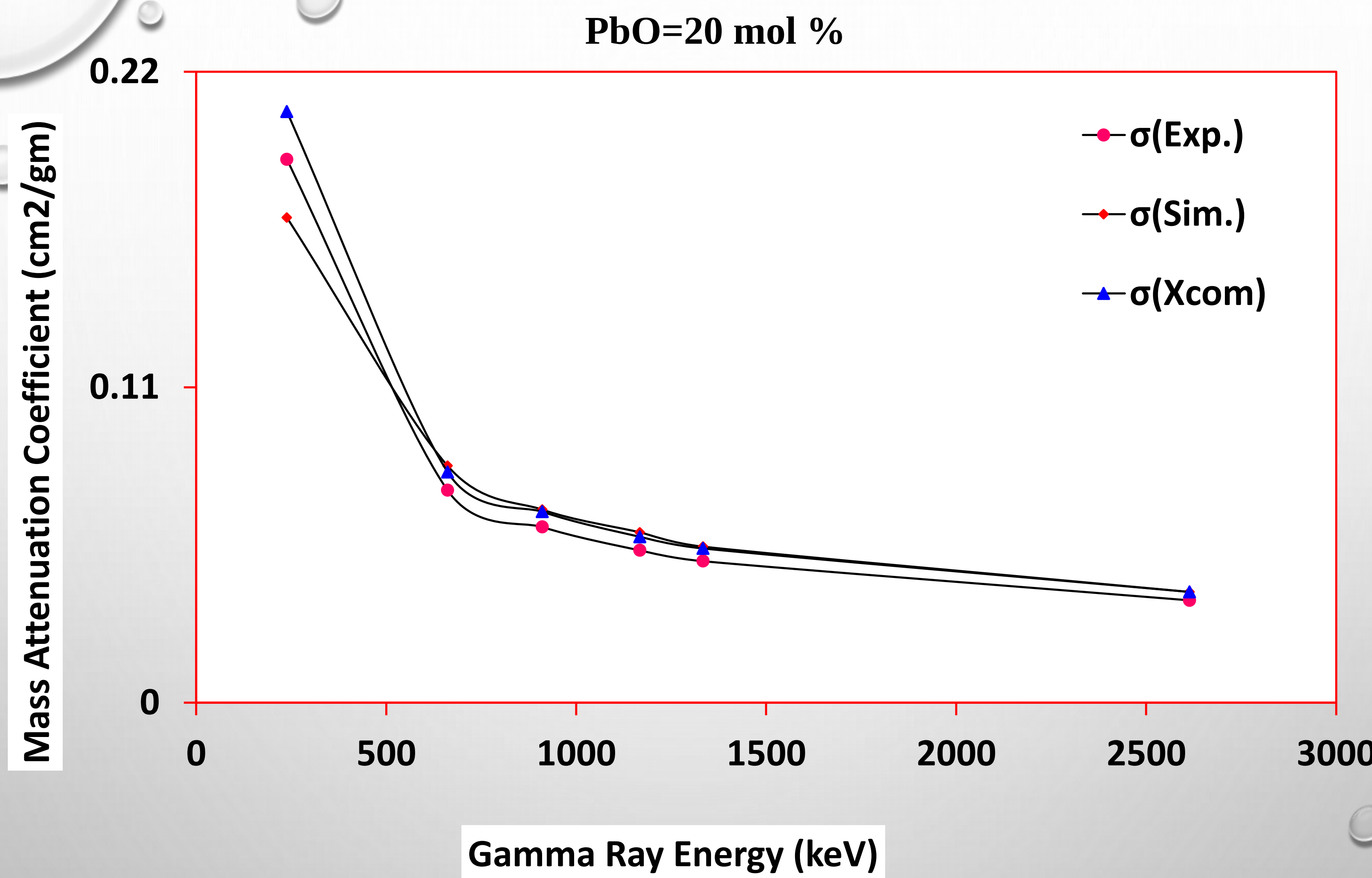
Comparison between, xCom, simulated, and measured mass attenuation coefficients as a function in gamma energy at PbO=5 mol %



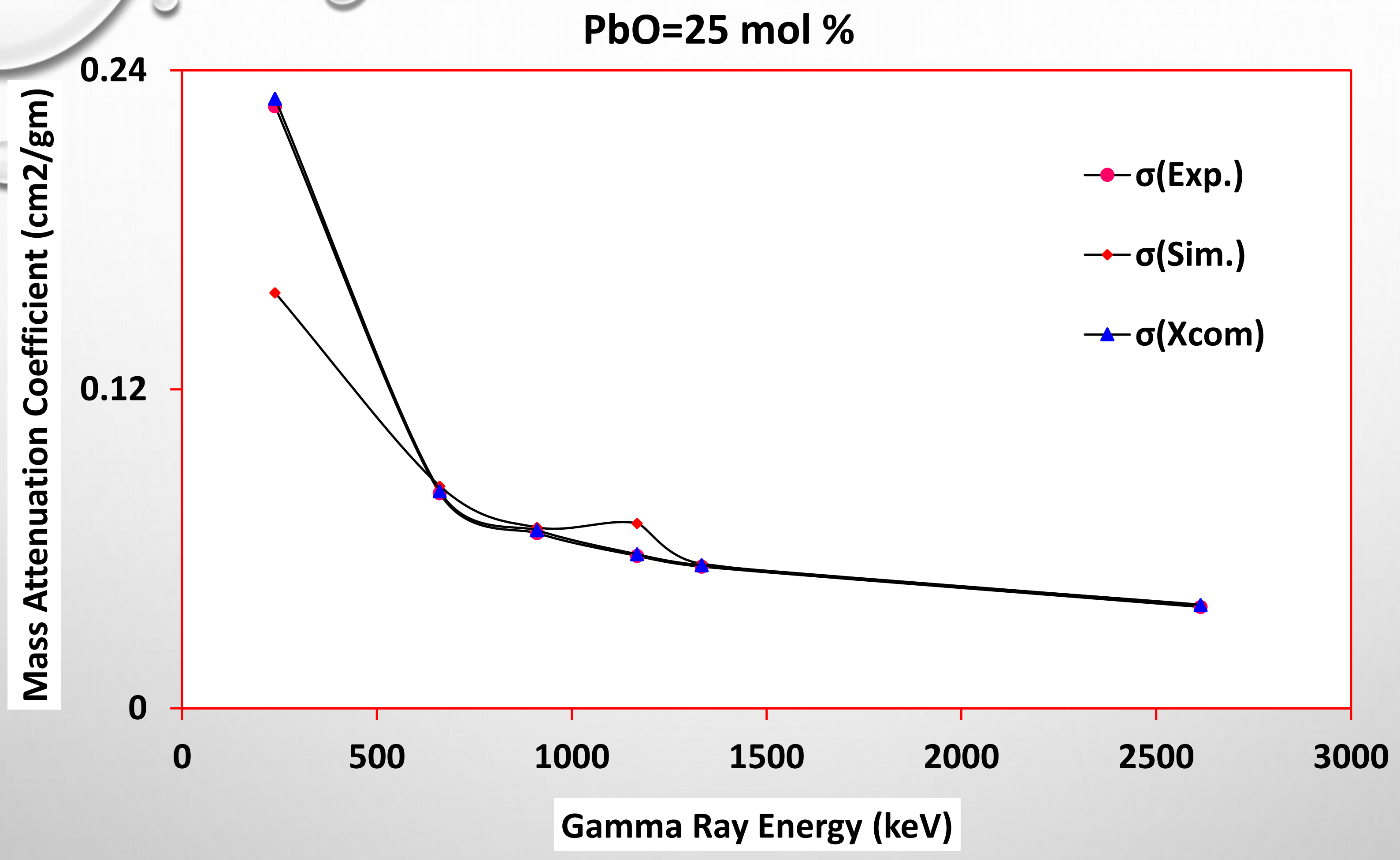
Comparison between, XCom, simulated, and measured mass attenuation coefficients as a function in gamma energy at PbO=10 mol %



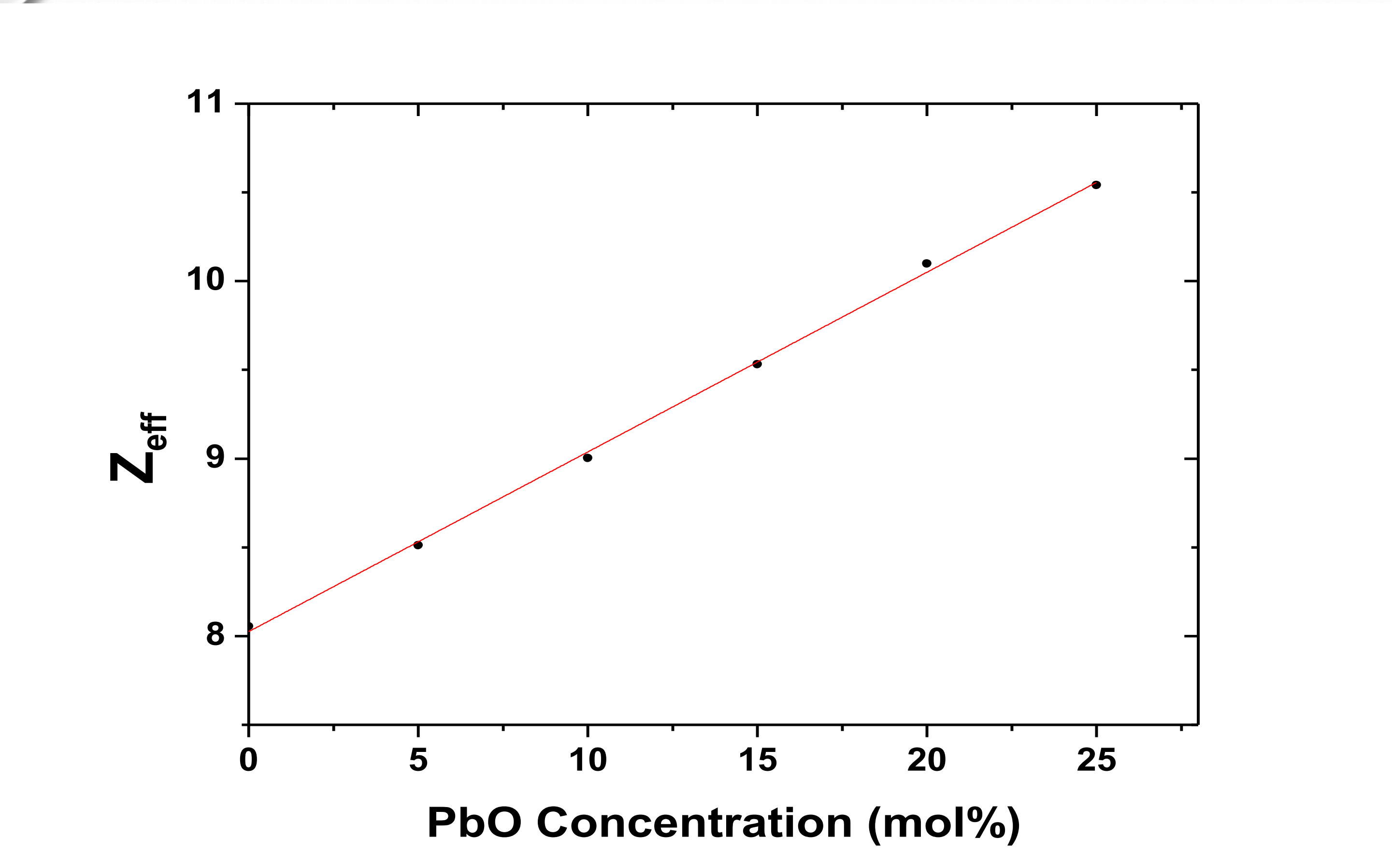
Comparison between, xCom, simulated, and measured mass attenuation coefficients as a function in gamma energy at PbO=15 mol %



Comparison between, xCom, simulated, and measured mass attenuation coefficients as a function in gamma energy at PbO=20 mol %

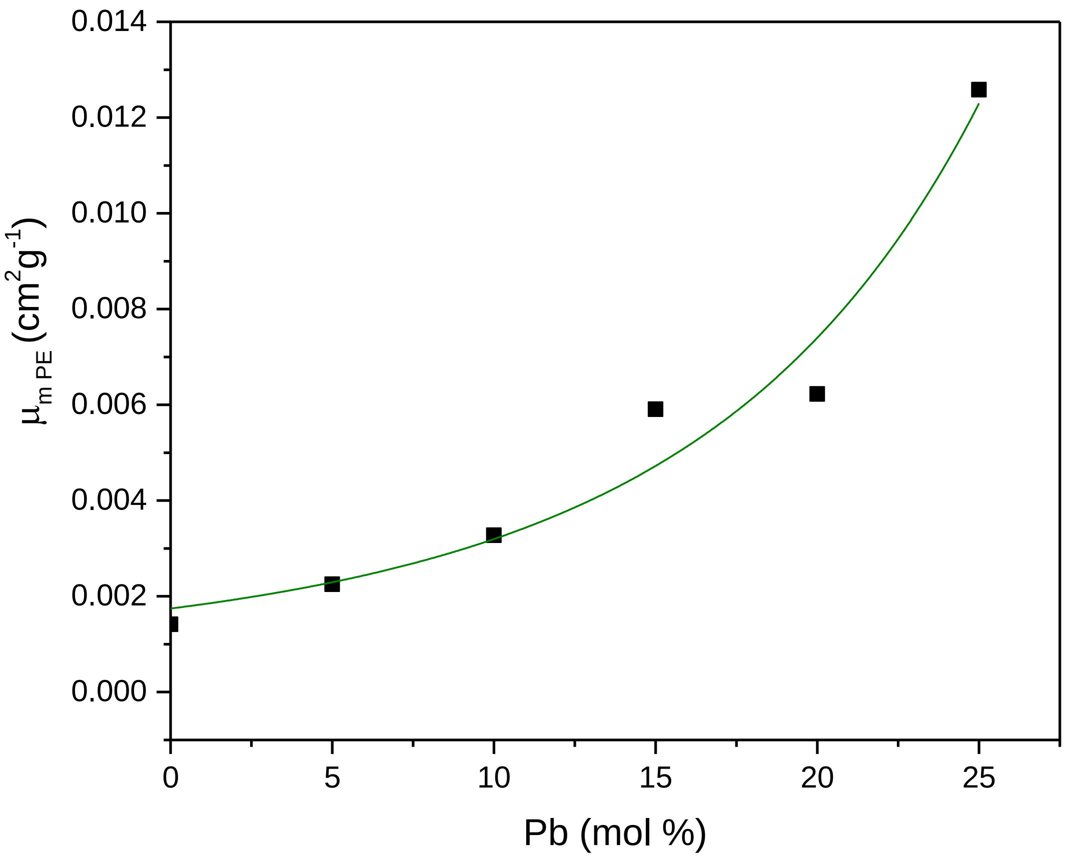


Comparison between, xCom, simulated, and measured mass attenuation coefficients as a function in gamma energy at PbO=25 mol %

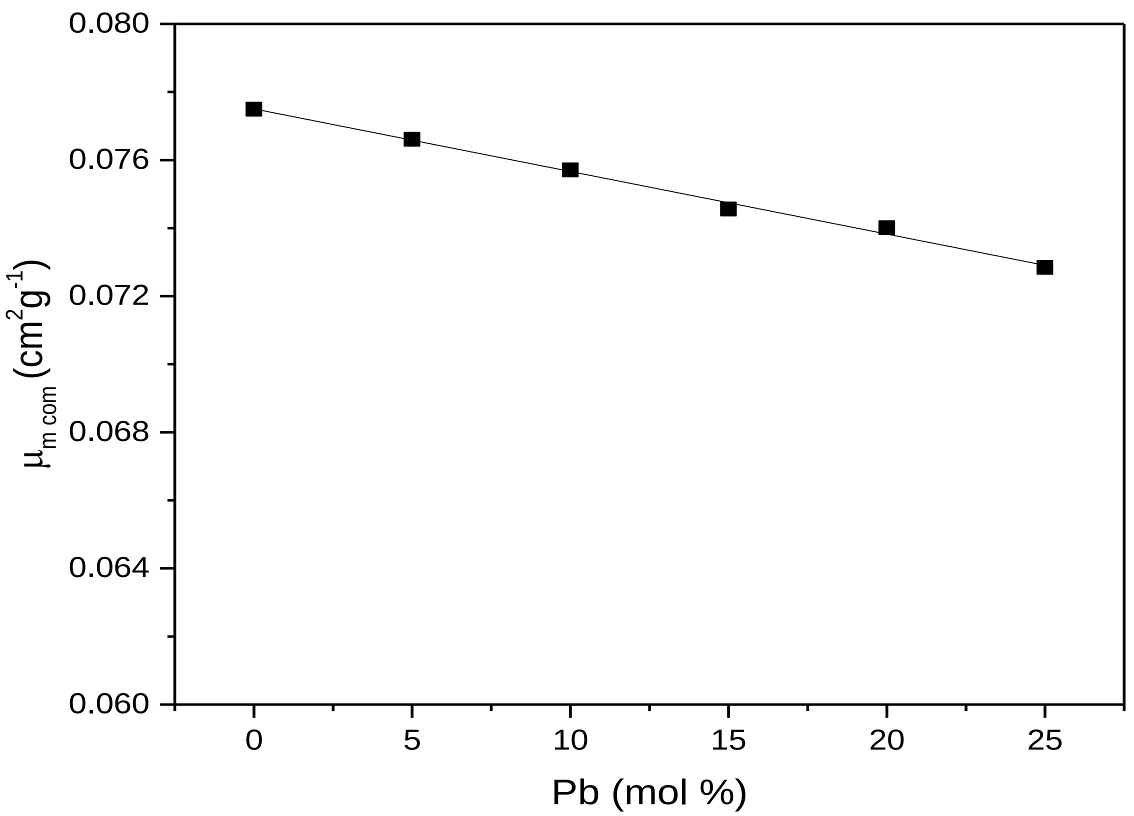


Z_{eff} **of the all prepared glasses at 0.662MeV**

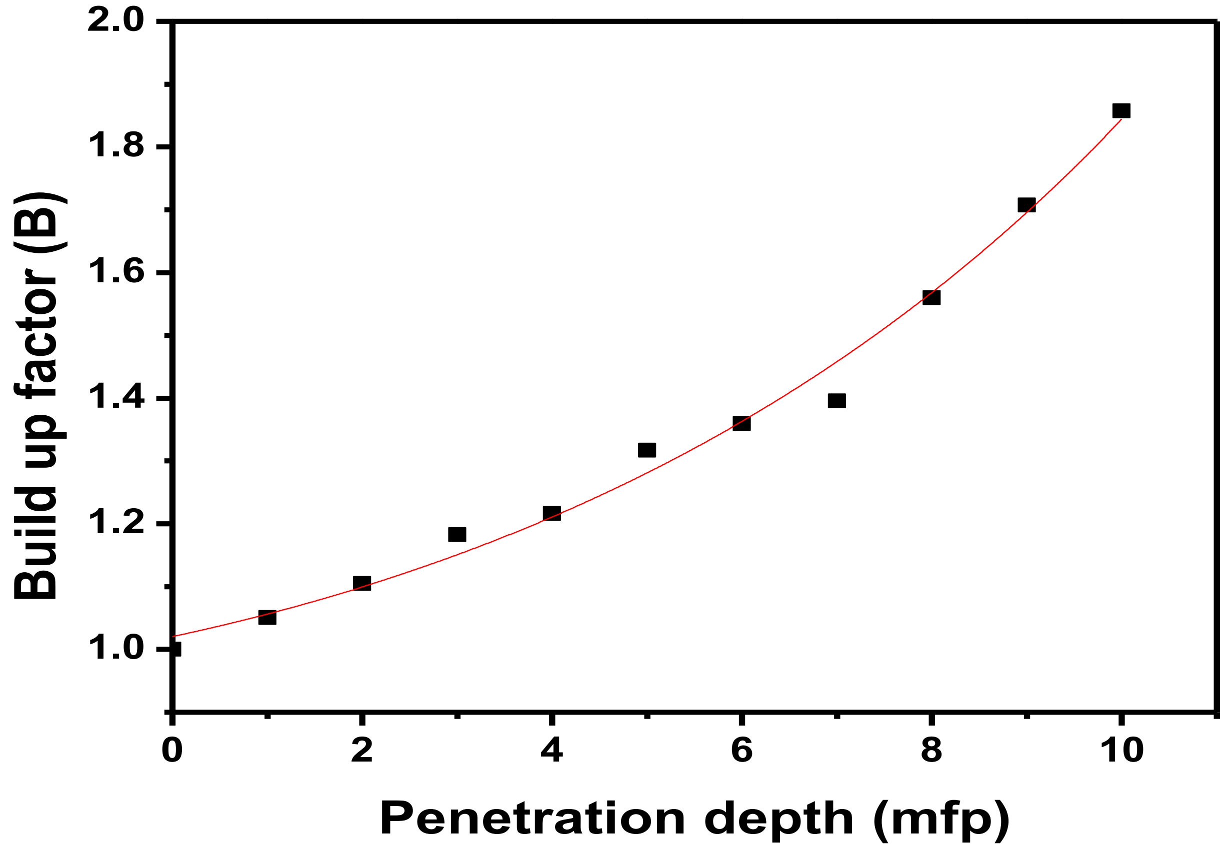
➢ Photoelectric mass attenuation coefficients for the selected glasses at 662 Kev for different compositions.



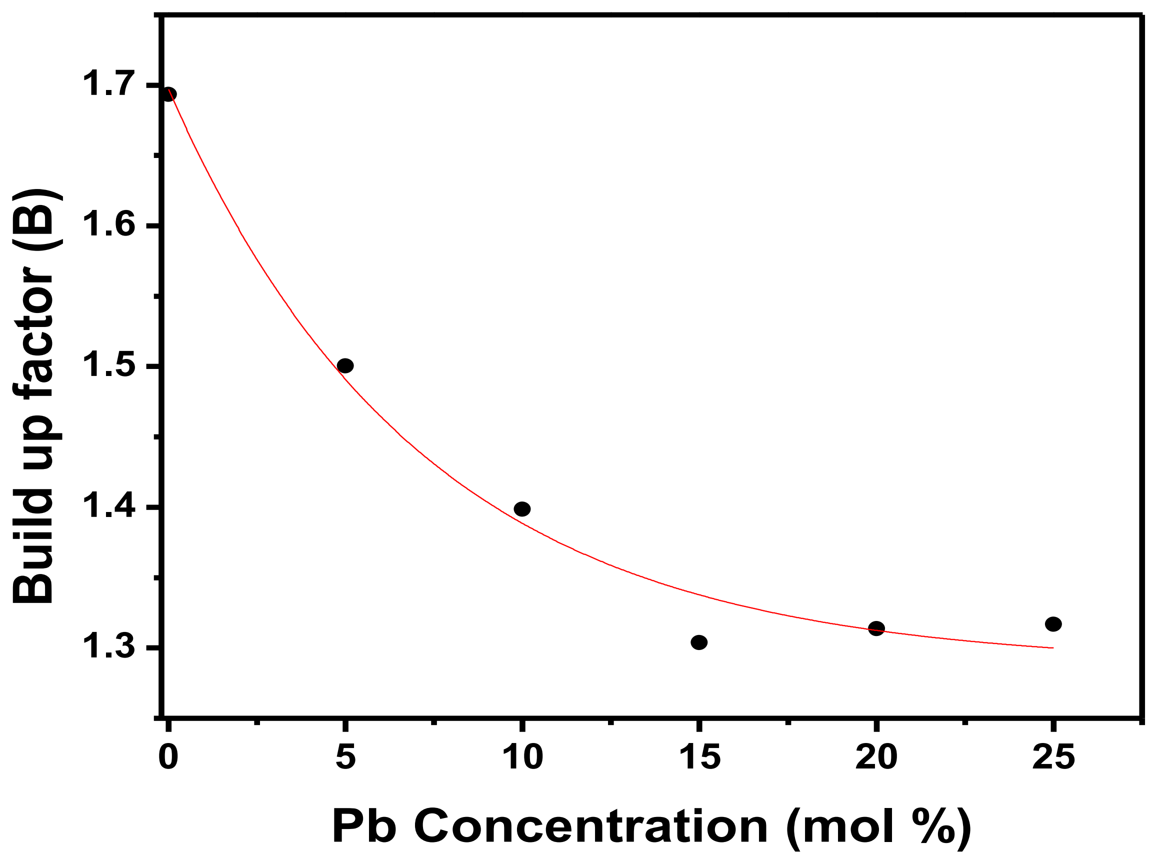
➢ Compton mass attenuation coefficients for the selected glasses at 662 Kev for different compositions.



Build up factor (B)



Build up factor (B)



THE DIFFERENCE BETWEEN WINXCOM& GATE-GEANT4

Phase space actor allows you to gain information of :

- **Number of particles**
- **The particle's direction**
- **Dose measurements**
- **Energy**
- **Probability of it's type interaction separately**
- **Special distribution of the attenuated radiation**

CONCLUSION

- Gate simulation code is successfully able to simulate attenuation of gamma ray radiation through any material composition and at different photon energies.
- The present study indicates that the gate simulation is suitable to be used as an alternative approved method for experiment in the field of radiation shielding.
- The studied glass has high optical transmission in the visible region as well as superior absorption in the UV region.

Thank You