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Prompt Gamma Neutron Activation Analysis of Carbon Bulk Samples with an Am-Be Neutron Source

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ABSTRACT
Analysis of carbon was carried out using an Am-Be PGNAA set-up. The gamma rays were produced via the capture of thermal neutron and inelastic scattering of fast neutron. In the present paper a prompt gamma neutron activation analysis (PGNAA) set-up for carbon bulk analysis was describe and optimized using Mont Carlo neutron transport calculations with MCNP4C code[1].

Keywords
Neutrons and gamma-rays, Elemental neutron/gamma analyzer, Am-Be Neutron source, Carbon Bulk Samples.

1. INTRODUCTION
Only fast neutrons and gamma-rays (or high energy X-rays) have the required penetration for bulk determination of carbon in bulk solids such as graphite. Parameters of particular interest include accuracy, analysis and geometry[2].

Elemental neutron/gamma analyzers rely on neutrons interacting with atoms present in the sample and producing gamma- rays with energies characteristic of the emitting nuclei. The two most important nuclear interactions are thermal neutron capture (TNC) in which a low energy neutron is absorbed by a nucleus and neutron inelastic scattering (NIS) in which a fast neutron collides with a nucleus to produce gamma-rays.

2. NEUTRON INELASTIC SCATTER USING FAST NEUTRONS
Fast neutrons emitted from the Am- Be source interact with C and produce 4.43MeV gamma rays via $C+n \rightarrow C+\gamma$ reaction.

The threshold for the production of 4.43MeV neutron inelastic scatter gamma-rays from carbon is 4.8MeV and the cross-section rises to about 0.46 b at about 8MeV (Fig. 1). Because of the threshold neutron energy of 4.8MeV, Am–Be neutron sources is suitable for excitation of 4.43MeV gamma-rays.

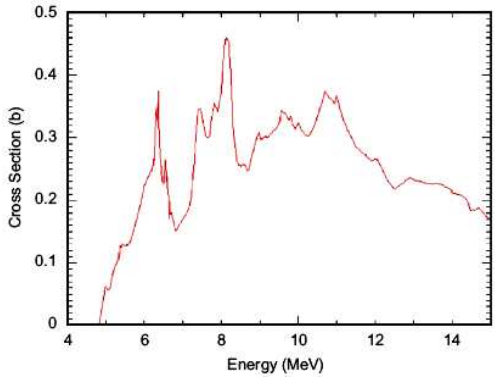

Fig. 1. Cross-section for the excitation of the 4.43MeV first excited state of by neutron inelastic scattering.

3. THE THERMAL NEUTRON CAPTURE GAMMA-RAYS
In this section, When low energy (or thermal) neutrons are captured by carbon, 4.945MeV gamma-rays are produced. Thermal neutron capture (TNC) cross-sections vary widely from element to element (IAEA, 2006). The TNC cross-section for carbon is only 0.0035 b compared to 0.332 b for hydrogen, 0.172 b for silicon and 33.1 b for chlorine. Because of its low neutron absorption cross-section TNC is not favoured for carbon determination (Fig. 2) [3].

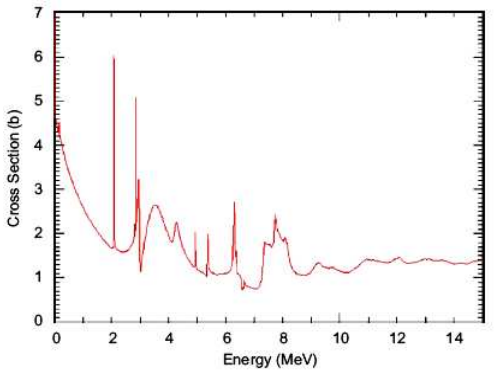

Fig. 2. Neutron total cross-section for carbon.

4. GEOMETRY

In the work Reported measurements of carbon in bulk samples using an Am–Be source and NaI (Tl) detector in annular geometries. Am–Be source neutrons are produced via there action Be(α,n)C and neutron emission is accompanied by the emission of a4.43MeV gamma ray ,the same energy as the carbon in elastic scatter gamma-ray from the sample.

In this set up, the source is confined in an cubic Cistern which is immersed in the Beside of the Cistern. Note that an analyzer using an Am-Be neutron source requires a shadow shield to prevent direct source gamma-rays from reaching the detector, thus reducing the geometrical efficiency of the analyzer.

5. MONTE CARLO SIMULATION AND EXPERIMENTAL CALCULATIONS

Monte carlo calculations using monte carlo N-Particle (MCNP4-C) code were used to investigate the effect of increasing the distance of americium-beryllium neutron source to carbon sample on reducing the flux of received Thermal neutrons.[4] the effect of existence pb shield and absence pb shield on decreasing the neutron dose equivalent received by carbon sample is shown in Figures 3, 4.

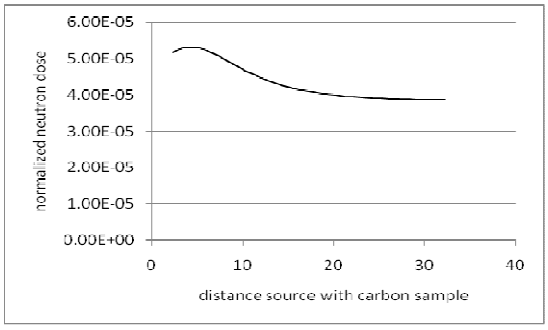

Fig. 3. The flux of thermal neutron received by carbon in absence pb shield.

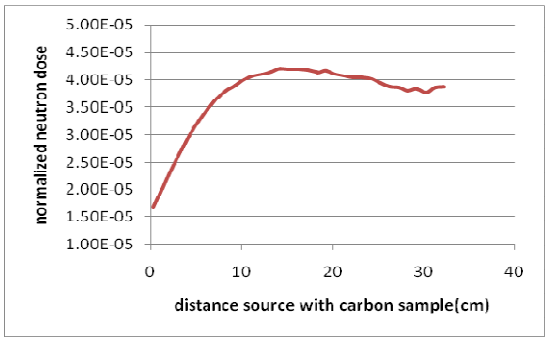

Fig. 4. The flux of thermal neutron received by carbon in existence pb shield.

An experimental setup of a carbon detection system using PGNAA method is shown in figure 5. In this system, a 5 Ci Am-Be neutron source (producing about 107 n/sec and 6×106 γ/sec) have been embedded in the Besides of a Cistern (here 1m×1m×2m). The Cistern made of steel and contains aquapura. Neutron source is fixed and carbon sample is mobile.

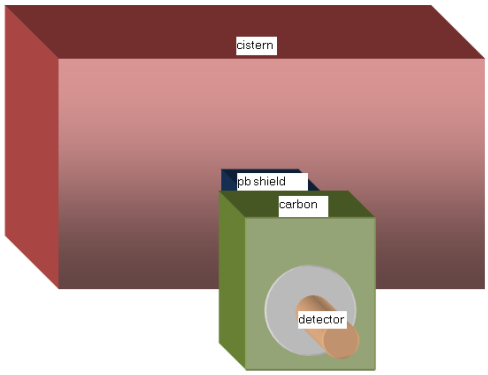

Fig. 5. The flux of thermal neutron received by carbon in existence pb shield.

Monte carlo simulation and experimental results of increasing the thickness carbon sample on decreasing the gamma rays by detector shown in fig. 6, 7, 8.

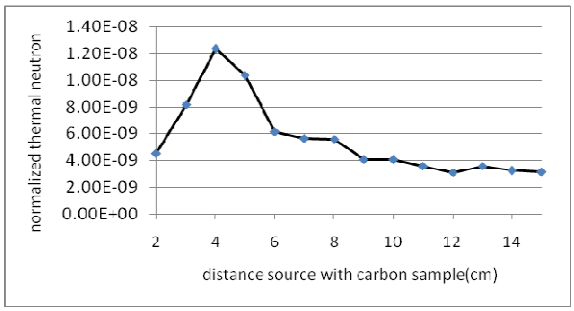

Fig. 6. The effects of thickness carbon sample on outgoing 4.945 gamma rays, using by monte carlo simulation.

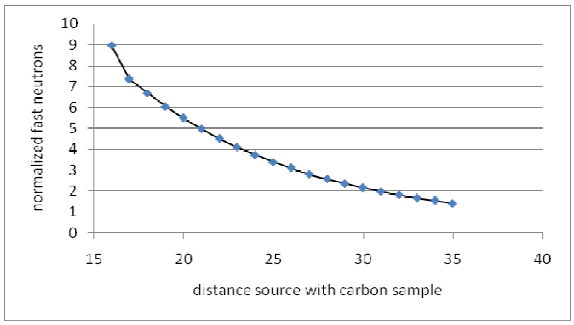

Fig. 7. The effects of thickness carbon sample on outgoing 4.43 gamma rays, using by monte carlo simulation.

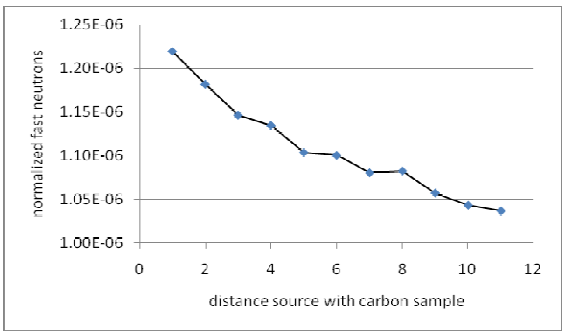

Fig. 8. The experimental results of thickness carbon sample on outgoing 4.43 gamma rays.

6. CONCLUSIONS

The use of 4.43MeV neutron inelastic scatter gamma-rays is the most widely reported method for the bulk determination of carbon in coal and other minerals.

Neutron inelastic scattering (NIS) would be the clear choice for such an analyzer. If the analyzer is optimized specifically for accurate carbon determination it should be capable of determining carbon to within about 0.5 wt% with an analysis time of about 5 min.

7. REFERENCES

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