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STUDY OF THE GEOMETRICAL CONFIGURATION OF A SET-UP FOR THE PURPOSE OF ANALYSING ORGANIC MATTER USING NEUTRON BACKSCATTERING WITH AN AM-BE SOURCE AND A HE^3 DETECTOR

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Abstract

Neutron backscattering is a powerful technique to analyse organic matter and recently a set-up has been developed by our laboratory to determine bitumen content in asphalt concrete [1].This set-up is mainly composed of an Am-Be neutron source and a He-3 detector, the source being placed under the He-3 detector. In this work, we study two geometrical configurations, the first where the source is placed under the detector and the other one is when the source and the detector are side by side. The calibration curves for the determination of bitumen content in asphalt concrete, hydrogen and the ratio C/H are built for the two geometries and then compared in terms of sensitivity. Finally, some Algerian oil samples are analysed with these setups.

Keywords: *Neutron, Backscattering, Hydrogen, Bitumen, Oil*

INTRODUCTION

The neutron backscattering method is well known for the determination of moisture and hydrogen content in different materials (soils, oils…). In industry, gauges working with this principle are used for the characterization of hydrogen containing liquids and the localization of the different interfaces between these liquids in a tank : as example, in petroleum industry, it is important to localize in a crude oil tank , the interface between oil and water. In asphalt production units, the determination of bitumen concentration during process production is very important for quality control: for this purpose, a set-up has been developed in our previous work using a 1Ci am-Be neutron source and a ^{3}He neutron detector and the results are very satisfactory when compared to those obtained by classical chemical methods.The neutron backscattering technique is even faster as it takes only a few minutes to obtain results when it needs hours to get results from solvent extraction method which is generally used in this case.

The principle of the neutron backscattering method consists of irradiating a hydrogen containing sample with neutrons emitted generally by isotopic neutron sources(Am-Be,Pu-Be,…) and these fast neutrons will interact mainly with hydrogen through elastic collisions and after successive collisions the neutrons will be slowed down to thermal energies. A fraction of these thermal neutrons is backscattered and detected by a ^{3}He neutron detector. The number of detected thermal neutrons is proportional to the hydrogen concentration in the sample. As the fraction of backscattered neutrons will depends strongly on the geometrical configuration of the irradiation and detection set-up, we propose here to study in terms of sensitivity two geometrical configurations of the set-up : the one is when the neutron source and the detector are side by side and in the other one, the source is placed under the detector. Analysis of organic materials for their hydrogen content and their (C+O)/H ratio , assay of nuclear materials in solution are reported in literature [2-6] In this work , some Algerian crude oils will be analysed with two setups for their hydrogen content and their (C+O/H) ratios. The results will be discussed and compared to published data.

EXPERIMENTAL

The two setups studied in this work are shown in figure 1. The two setups use an Am-Be neutron source with a cylindrical shape emitting 2.2 10^6n/s and a ^{3}He detector(2.5 cm diameter and 24 cm active length).In the vertical geometry, the neutron source an the detector are embedded and centered in a cylindrically shaped polyethylene which acts as a reflector for neutrons, the detector being situated below the source. In the side by side geometry, the source and the detector are put side by side in a parallelipedic steel box which was originally the head of a neutron gauge as used for level measurements as applied in the field of radio-isotope and radiotracer technology. In the two cases, the active length of the detector is comparable to the diameter of the aluminum sample holder. In order to count only the thermal neutrons coming from the sample ,the detector is partly covered with a 1 mm thick Cd sheet.

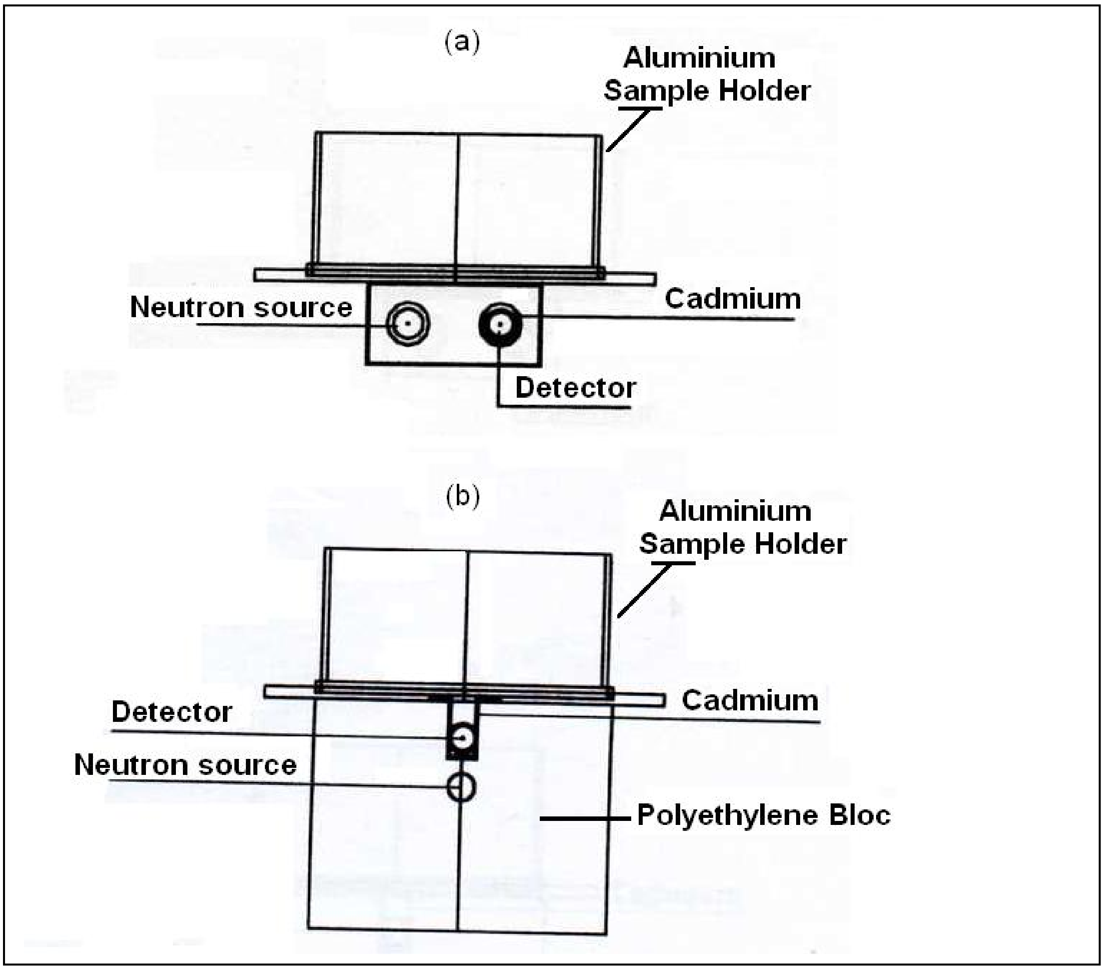

Figure 1. (a) Side by side geometry set-up (b) Vertical geometry set-up

The relative excess neutron count rate $(I-I_0)/I_0$ normalized to the physical density ρ of the sample is related to the neutron reflection parameter η , i.e.:

$$I = \frac{1}{\rho}\frac{I - I_0}{I_0} \qquad (1)$$

where I and I_0 are respectively the thermal neutron count rates with and without the sample. For a given geometry, there exists a linear relationship between the excess count rate η and the bitumen or hydrogen content in the sample. The different counting rates were measured with a rate-meter Ludlum Model 16.The polarization voltage of the ^{3}He detector was chosen on the response plateau and is actually 1580 V.

RESULTS AND DISCUSSION

The calibration of the setups for bitumen determination in asphalt concrete was done with five samples containing (0%,2.14%,3.14%,4.14% and 5.14%) and prepared with aggregate proportions given by the asphalt concrete producing plant. The entire sample preparation procedure was according to the American standard method [7] The volume of the samples is 4500 cm3 corresponding to a thickness >10 cm which is the critical value above which the backscattered counting rate is constant. .The counting conditions are set so that the statistical errors on the relative excess count rates was less than 0.5%.The linear calibration curves for the two geometries are shown in figure 2.For the two geometries, the linear correlation coefficient is >0.99.

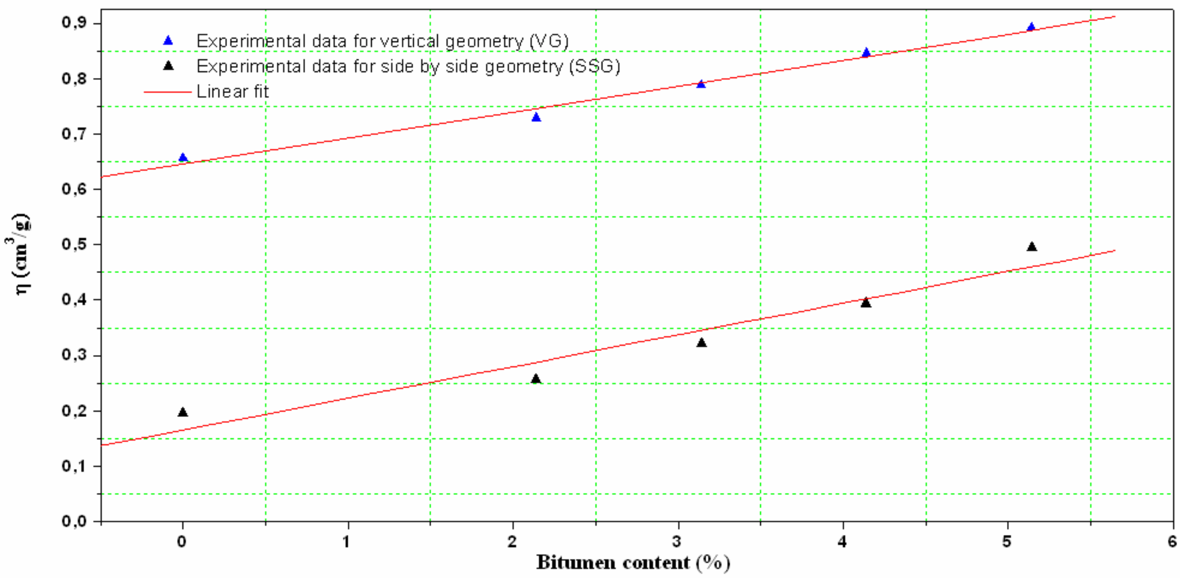

Figure 2. Linear calibration curves for bitumen determination in asphalt concrete

For the hydrogen content and (C+O)/H ratio in organic samples, calibration curves were determined using well known organic compounds and which data are given in table 1.Pure analytical compounds were used and the volume was limited to 900 cm^3.For each compound , its relative excess count rate was measured and this parameter was plotted against hydrogen content (see figure 3) and against (C+O)/H (see figure 4) .

The measured η values were linearly fitted for hydrogen or bitumen content and with fist order exponential decay for (C+O)/H ratio. The slope of the linear curve for bitumen or hydrogen content determination represents the sensitivity .For bitumen, It is respectively 0.057±0.009 and 0.047 ±0.003 for side by side geometry and vertical geometry. For the hydrogen content determination, the sensitivity is respectively 0.323±0.007 and 0.193±0.004 for SSD and VG geometries.

Table 1. Hydrogen content and (C+O)/h ratio for some organic compounds

Compound	Formula	Density(g/cm^3)	Hydrogen(%)	(C+O)/H
Acethylether	$C_4H_{10}O$	0.713	13.49	6.41
Hexane	C_6H_{14}	0.659	16.24	5.14
Heptane	C_7H_{16}	0.683	15.96	5.25
Benzene	C_6H_6	0.873	7.68	12
Toluene	C_7H_8	0.866	8.68	10.5
Paraxylene	C_8H_{10}	0.861	9.41	9.6
Ethylic alcohol	C_2H_6O	0.789	13.08	6.66

As observed , for hydrogen or bitumen determinations, the sensitivity is higher when side by side geometry despite the high values registered for relative excess count rates in the case of vertical geometry. The sensitivity is enhanced in the side by side geometry by the neutron source-sample solid angle which is higher than that of the vertical geometry.

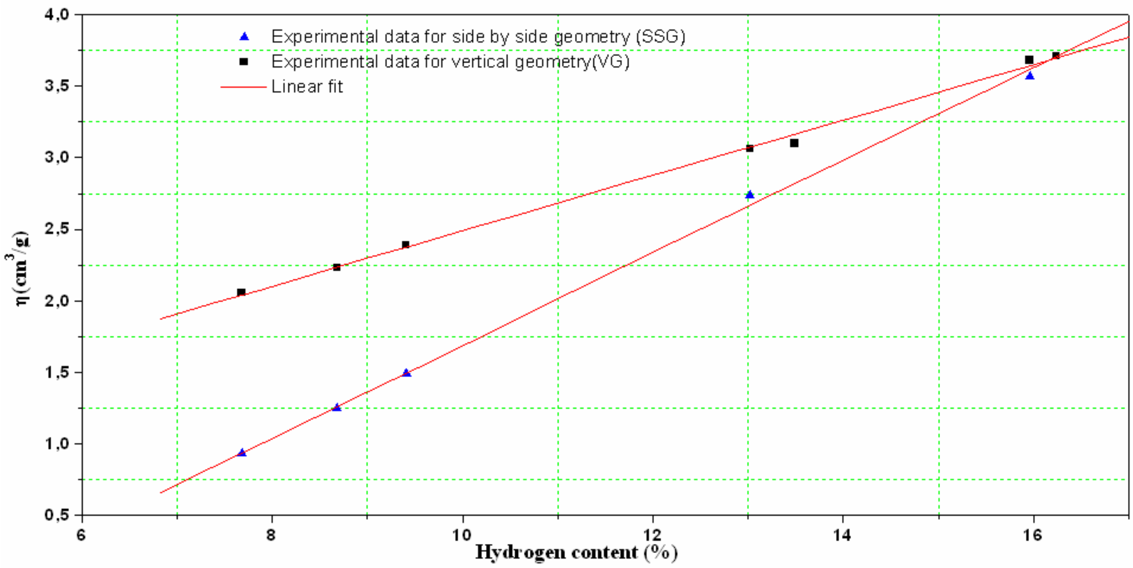

Figure 3. Calibration curves for hydrogen determination

We observe the same trend in the case of (C+O)/H calibration curves as if we compare the slopes of the curves , the sensitivity of SSG geometry is higher than that of VG geometry .Globally, we observe also in the curves that sensitivity is higher for low (C+O)/H ratios.

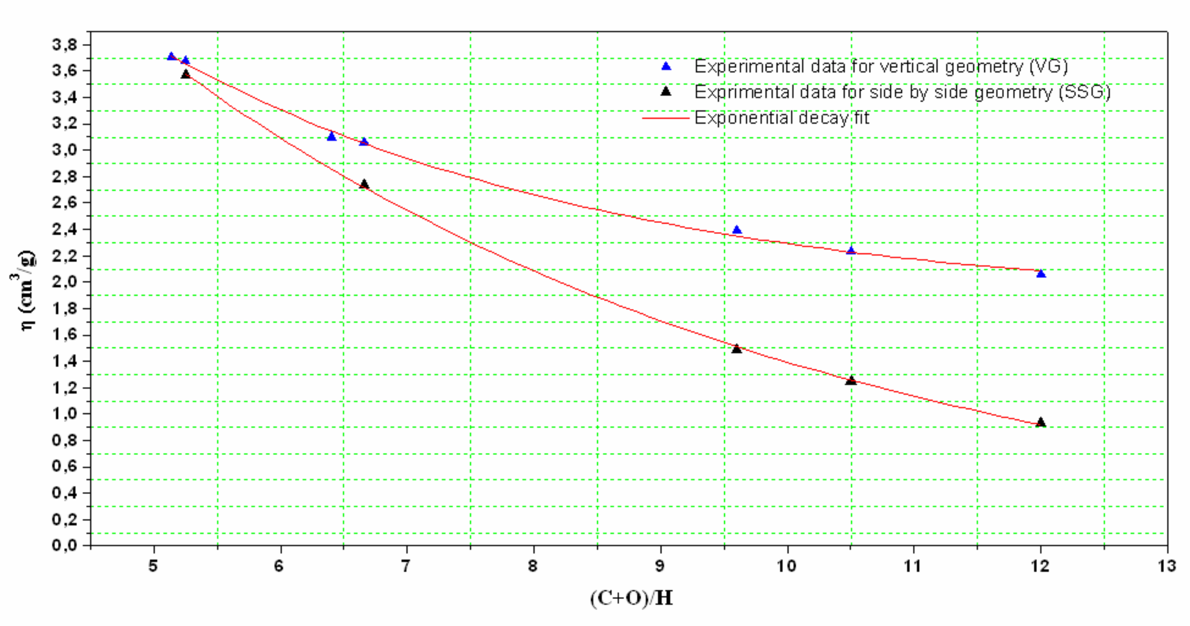

Figure 4. Calibration curves for (C+O)/H

Finally, some Algerian crude oils were analysed for hydrogen content and (C+O)/H ratio using the previous curves. The results are presented in table 2 given below.

Table 2. Hydrogen contents and (C+O)/H ratios for some Algerian crude oils.

Sample	H(%) *VG*	H(%) *SSG*	(C+O)/H *VG*	(C+O)/H *SSG*
A	13.97	14.36	6.13	5.98
B	14.11	14.85	6.04	5.72
D	14.28	14.29-	5.95	6.03

The samples were analysed with the two setups and we can observe a good agreement between the values obtained using the two geometries. The results are also comparable with those published for Nigerian crude oils with slightly higher values for hydrogen content and slightly lowest values for(C+O=/H) in the case of Algerian crude oils which are known to be light.

CONCLUSION

We have studied in this work two setups for neutron backscattering analysis with different geometries in terms of sensitivity and we have observed that sensitivity for side by side geometry is higher than that of vertical geometry. In the next work , , we shall use a Monte Carlo Code like MCNP to simulate and optimize the set-up adding more parameters(source emission rate, sample dimensions,…).

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