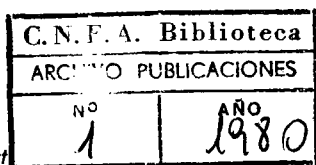


Total cross section and diffusion parameters of benzene

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Abstract

The transmission technique and the pulsed-neutron method were used in conjunction with a Linac, to obtain the absolute total cross-section (0.001 eV to 225 eV) and the diffusion parameters ($0.01 \text{ cm}^{-2} < B^2 < 0.8 \text{ cm}^{-2}$) of benzene with improved precision.

Zusammenfassung

Totaler Neutronenwirkungsquerschnitt und Neutronendiffusionsparameter des Benzols

Es wurde der totale Neutronenwirkungsquerschnitt (von 0,001 eV bis 225 eV) und der Neutronendiffusionsparameter ($0,01 \text{ cm}^{-2} < B^2 < 0,8 \text{ cm}^{-2}$) des Benzols mit Hilfe der Transmissions- und Flugzeitmethode mit gepulster Neutronenquelle gemessen.

INIS DESCRIPTORS

TOTAL CROSS SECTIONS	TRANSMISSION
NEUTRON BEAMS	DIFFUSION
MILLI EV RANGE	BENZENE
EV RANGE	

Introduction

The pulsed-neutron-technique has been used extensively in determining neutron cross-section and diffusion parameters of moderators. Nevertheless, organic compounds have not received as much attention as others and noticeable discrepancies still exist among the published experimental data. Theoretical values are also found in the literature in a wide range, as a result of the use of different thermalization models, or from modifications introduced into the same model by different authors.

As organic compounds are considered as possible coolant for future versions of heavy-water natural-uranium reactors, it is important to have experimental data sufficiently accurate for checking theoretical models.

For these reasons, we have initiated a careful study of the neutron thermalization for the simplest of the polyphenyls, namely benzene. The first part of this study, which includes total cross-section and diffusion parameters measurements is presented in this paper. In future papers, the comparison of these results against those obtained with different theoretical models will be present.

Experiment

The Linac facility of the Centro Atómico Bariloche, in conjunction with an adequate heavy material target was used as pulsed-neutron-source in both determinations.

Total cross-section measurement

The time-of-flight transmission method was used for this experiment. A lead target and a paraffin moderator acted as the neutron source. The Linac was run at 12.5 pps, 3 μA average current.

A bank of seven He-3 detectors (10 atm filling gas pressure), each of 2.5 cm diameter and 15 cm active length was placed at the end of a 17.68 metres flight path. A collimator of 5 cm

diameter was used in the sample position. Conventional electronics and a time-of-flight unit connected on-line to a computer were used to collect the signal from the detector bank. The data were recorded in 2048 channels, each 32 μsec wide. The experimental lay-out is shown in Fig. 1.

Two samples were used, one $0.442 \pm 0.001 \text{ cm}$ thick for the absolute measurement and another of 0.146 cm for the lower energy range. They were placed at 8.22 metres from the neutron source. The sample containers were cylinders with aluminium walls, 0.44 cm thick.

For each sample two hundred runs were made, each consisting in a succession of one hundred sample-in/sample-out cycle (free tube-sample-background). An air-filled container identical with that of the sample was placed in the neutron path in the free tube case. A 7 cm thick paraffin block acted as black filter in the background case.

Raw data were corrected for dead-time, mean emission-time of the pulsed-neutron-source and background. Other corrections (in-scattering, multiple-scattering) have shown to be negligible. Corrections due to sample impurities (less than 0.001 %) were not made. The final σ_T was taken as an average of the two hundred curves. The measurements were performed with the sample at 23 °C.

Time channels were grouped in order to obtain an energy resolution of 10 % from 225 eV to 3.5 eV, 5 % to 0.4 eV and 2 % in the rest. The total error (70 % confidence), is less than 2 % from 225 eV to 0.16 eV; less than 1 % to 0.008 eV; less than 5 % to 0.0015 eV; and greater than 10 % at lower energies.

Diffusion parameters determination

The classical approach based on the pulsed source-method was used to determine the diffusion parameters of benzene. The time constant of the thermalized neutron field of the moderator was obtained experimentally and correlated with the geometrical buckling B^2 of the assembly.

Under certain limitations, the thermalized neutron field decays exponentially with time with a decay constant α given by

$$\alpha = \Sigma a \bar{v} + DB^2 - CB^4 + O(B^6)$$

where $\Sigma a \bar{v}$ is the absorption probability, D the diffusion coefficient, C the diffusion cooling coefficient and $O(B^6)$ indicates higher order buckling terms.

For a rectangular sample of sides a , b , c , the buckling B^2 is given by

$$B^2 = \left(\frac{\pi}{a+2\epsilon}\right)^2 + \left(\frac{\pi}{b+2\epsilon}\right)^2 + \left(\frac{\pi}{c+2\epsilon}\right)^2$$

where ϵ is the extrapolation distance, calculated by

$$\epsilon = 0.71 \lambda_{tr} = 0.71 \frac{3D}{v}$$

Measurements of α for a variety of sample sizes, yield data that can be fitted to obtain the parameters $\Sigma a \bar{v}$, D , C . We have also used an iteration procedure to obtain ϵ from the data. Temperature corrections (maximum 2 °C) were introduced through another loop in the calculation procedure, changing the value of $\Sigma a \bar{v}$ and D , according to the relations given by K \ddot{u} chle [1].

In the work described in this paper, we have attempted to eliminate all the possible sources of error, such as contamination from higher harmonics in the thermal decay, interference from the container materials, existence of a time-dependent background due to neutron scattering in the laboratory walls and the shape effect that could exist in the buckling using flat and square geometries.

For the measurements, our Linac was used with a water-cooled fansteel target as pulsed-neutron-source. Electron pulses 1 μsec wide, at a repetition rate of 50, 100, and 200 pps were used.

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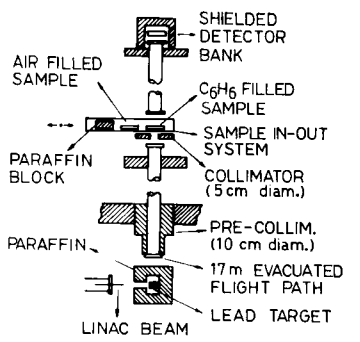


Fig. 1: Experimental set-up for cross-section measurements

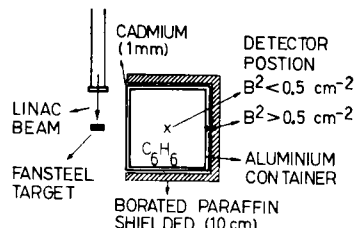


Fig. 2: Experimental set-up for life-time measurements

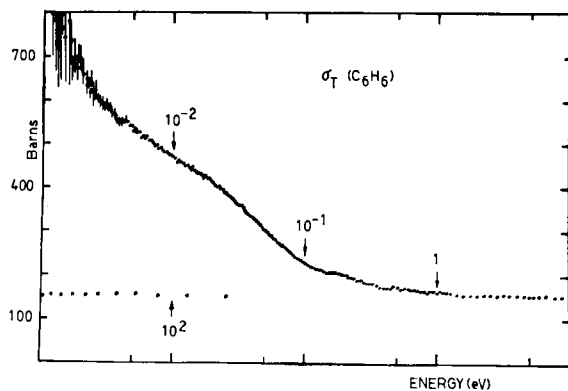


Fig. 3: Total cross section of benzene, experimental points

The experimental geometries comprised rectangular aluminium tanks with walls 1 mm thick for the large tanks and 0.5 mm for the others, lined with cadmium sheet and shielded with a boron mixture. The experimental lay-out is shown in Fig. 2. To prevent container effects, in each run the top of the tank used was lowered to match perfectly the liquid level. This was kept constant by a simple siphon device.

The detector used for the life-time-measurements, was a 3.2 cm³ U-235 miniature fission chamber. For large and intermediate geometries ($B^2 < 0.5 \text{ cm}^{-2}$), it was located in the container geometrical centre; for small geometries it was located in the centre of the tank wall opposite the neutron source. In either case the detector was at a node of all even harmonics. The perturbation effect of the detector was investigated by comparing the measured decay with the detector immersed in the centre of the tank, to that measured with the detector externally located on a surface; no perturbation effects could be detected. A thin lucite tube was used to protect the detector from water. A thermocouple was inserted into the tank for temperature control, the mean temperature for all the measurements was 20.4 °C. Forty four different samples with values of the geometrical buckling from 0.01 cm⁻² to 0.8 cm⁻² were studied. In order to prevent shape effects, the same ratio between width and depth was maintained for all the samples, so that we could attribute the same extrapolation distance to all sides.

The time decay data for each sample were registered through our time-of-flight electronics. The Linac current was adjusted to give no more than 5% counting loss per channel at the beginning of the measured decay; 512 channels, 4 μsec wide were used.

Since higher harmonics die out faster than the fundamental one, the decay constant determined as a function of delay, will asymptotically reach a steady value which is the decay constant of the fundamental. To eliminate higher harmonics, the decay constants were determined in the following manner: The complete set of channel counts is first corrected for dead time and background. These data are then fitted to a single exponential by a weighted least squares computer programme [2]. The procedure is repeated, the early time channels being dropped to any channel number specified in the programme. From the plot of decay constant versus initial channel, the presence of higher order harmonics could readily be ascertained.

A correction was applied for neutron backscattering from the container walls. This correction was based on the thin shell reflector model used in calculating reflector savings, i.e. the walls of the container were considered equivalent to an added amount of moderator weighted on the basis of the diffusion coefficients of the two media, this correction was always smaller than the error attributed to the sample dimensions.

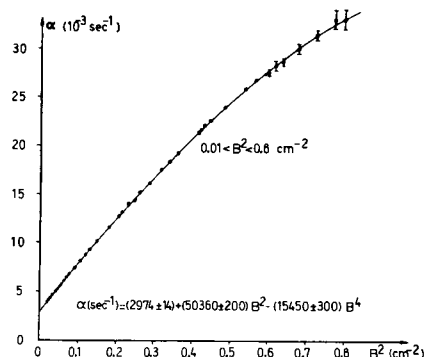


Fig. 4: The decay constant vs. geometrical buckling for benzene, experimental points and least squares fit to data

Experimental results

Fig. 3, shows in a semi-logarithmic plot, the total cross-section dependence on energy for benzene in the energy range from 0.001 eV to 225 eV. A complete set of data will be sent to EXFOR Library (NDS, IAEA, Vienna).

Fig. 4, shows the experimental α versus B^2 points and the least squares fit to data. The obtained results from it corrected to 20.4 °C, were

$$\begin{aligned} \Sigma a \bar{v} &= (2974 \pm 14) \text{ sec}^{-1} \\ D &= (50360 \pm 200) \text{ sec}^{-1} \text{ cm}^2 \\ C &= (15450 \pm 340) \text{ sec}^{-1} \text{ cm}^4 \end{aligned}$$

As a by-product, it was found for hydrogen

$$\sigma_a (2200 \text{ m sec}^{-1}) = 329 \pm 2 \text{ mb}$$

In Figs. 3 and 4, the standard deviation of the measured values is smaller than the radius of the dot at the points where the error bars are drawn.

From the small quoted errors of our determinations, it is clear that the present results can properly be used to check the different theoretical models describing neutron scattering by benzene molecules; they also support the view that the neutron-pulsed-source method is adequate to obtain total cross section and diffusion parameters of moderator materials.

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