THE METHOD OF PERTURBATION OF THE γ-γ ANGULAR CORRELATIONS AND HFI USED FOR ESSENTIAL OIL RESEARCHES

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Abstract

The perturbed angular γγ-correlations method (γγ-PAC) technique is employed to study the parameters of hyperfine interactions in aqueous solutions of essential oils, using ^{154}Eu isotope as a probe nucleus. The strongly mixed and centrifuged liquid and solid solutions with and without reactivant (as 2 – ethilexil – ortho- phosphorus acid) and with or without metal were used. The measurements were carried out by means of a four-detector perturbed angular γγ-correlations spectrometer. The spectrum data suggest a high degree of local flexibility of the europium label. The attenuation is more pronounced with increasing concentration of the metal. The relaxation constant increases with increasing concentration of the solution.

Key words: γγ-PAC, four-detector PAC spectrometer, ^{154}Eu, essential oil solution, reactivant, metal

Introduction

The drugs by essential oil of the wild medicinal plants is composed mainly of fresh or dried flower heads. It contains the terpenes -α-bisabolol and -α-bisabolonoxide, the –α-bisabololoxides, the sesquiterpene-lactone matricine, various coumarins (as herniarine, imbelliferone), phenolic acids and essential and trace inorganic elements as K, Cl, Mg, P, Ca, Fe, Zn and Cr. During the steam distillation of the flower heads, mainly the sesquiterpenehydrocarbon chamazulene, an organic compound with remarkable anti-inflammatory properties, is generated from some traditional medicinal herbs.

In nuclear spectroscopy was settled down earlier that angular correlations may exist between nuclear (α, β, γ) radiation emitted from unstable nuclei. Furthermore, the angular correlations may be perturbed by interactions occurring between the decaying nuclei and their chemical environment.

The perturbed γ−γ angular correlation (PAC) is a nuclear – spectroscopic method for investigation of the hyperfine interaction (HFI) of electromagnetic moments of the nucleus with the external electromagnetic fields of the environment. The PAC method offers unique possibilities for investigation of the structure and dynamics of the local properties of the radionuclide environment and allows extracting the microconcentrations.

The ^{154}Eu time integral PAC measurements were conducted to explore the potential of essential oil of chamomile to accumulate the medicinally important substances.

Decay scheme of ^{154}Eu

Some of the recent PAC investigations in organic materials have been made using ^{154}Eu as a probe. ^{154}Eu was firstly produced by Scheichenberger (1938), using sources obtained by a neutron-capture reaction through neutron bombardment of the natural europium. It decays principally by electron capture through the cascade 1855β – 123 γ, with a half-life of 16±4

years. ^{154}Eu decays to ^{154}Gd also through the cascade $1281\gamma - 123\ \gamma$ (as 40%). This line has been obtained also from Coulomb excitation of ^{154}Gd. The second cascade with an intermediate state lifetime is suitable for perturbed angular correlation studies and was used further in the experiments. The decay scheme is shown in Figure 1.

Figure 1.The decay scheme of ^{154}Eu

Although the Auger electron emission following electron capture may significantly alter the electronic state of the daughter nucleus and cause considerable perturbation of γ-γ correlation.

Then, on the one hand, the PAC method is based on the effect of angular correlation between outgoing directions of the γ-rays cascade and on the other hand, on the perturbation of this correlation by extranuclear fields, due to the interactions of a nuclear quadrupole moment with an electric or magnetic extranuclear field. The diagram of a traditional two-detector PAC coincidence spectrometer for measuring the angular correlations of the γ–γ cascade in Figure 2 is shown.

The main characteristic of the PAC method, suitable for the measurement in vivo of essential vegetal oil, is the very small concentration of probe radionuclides (down to 10^{-15}M) to be put in the sample in a wide range of pressures, temperatures and external electromagnetic fields.
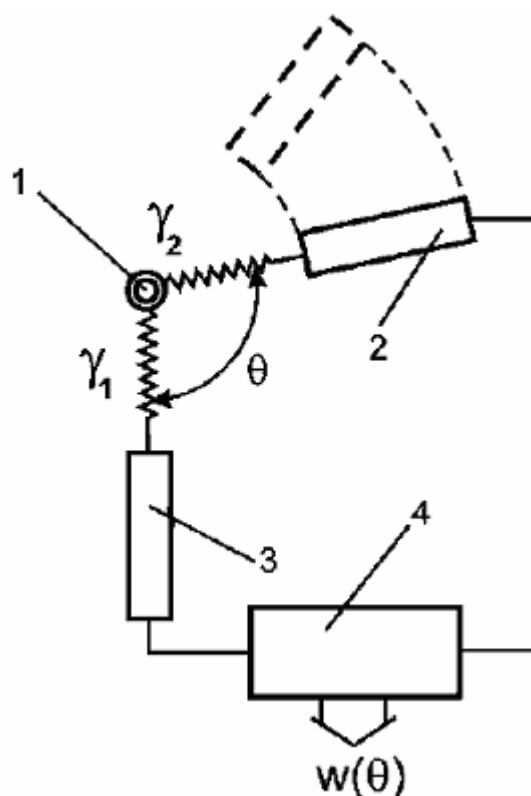
Figure 2. Schematic view of the two-detector typical PAC experimental block diagram
1 - source; 2,3 - detectors; 4 - coincidence unit.

Experimental

The measurements were performed by a four-detector perturbed angular $\gamma\gamma$-correlations spectrometer. The experimental layout has been described in detail in (V.B. Brudanin, NIMA 547, 2005). This PAC spectrometer works on the principle corresponding to total detector charge collection and operates a time selection to reducing the equipment noise. The four detectors (DET1-DET4) are 40 x40 mm in size, cylinder-shaped BaF_2 or NaI(Tl) crystals mounted on XP2020Q photomultipliers, connected to the amplifier. A CANBERRA discriminator (CFD 2126) is used for time referencing at the anode of the detector. So twelve time spectra and four energy spectra were simultaneously registered in the basic mode.

The Master PAC unit provides the selection of two time coincidence events for any pair of detectors. The energy selection of events is done automatically by a PC computer. The four-detector PAC spectrometer can operates also by a set-up mode, in which energy windows may be set-up, assuring the control of the detector sections operation. The own characteristics of the system are: - time range $1 - 800$ ns; time resolution (^{60}Co $1173 - 1332$ keV) 200 ps with BaF_2, 2 ns with NaI(Tl); energy resolution at the line 662 keV of ^{137}Cs is 10% with BaF_2 and 8% with NaI(Tl). A cryostat and a high temperature furnace facilitate measurements in the temperature range from 120 to 1300K. An encased electromagnet can generate a magnetic field up to 2T on a target. The PAC system includes a press device provided with a high-pressure chamber allowing sample measurements up to 60 GPa.

The four-detector PAC installation of perturbed angular $\gamma\gamma$ correlations was aimed for investigations of hyperfine interactions in condense matter. It allows studies in a wide range of applications in solid state physics and physical chemistry.

Application to essential oil

Biological measurements were carried out on essential oil with the PAC assembly using the specific activity of [154]Eu. The goal of the present study was to reveal the factors of the dynamic character of the perturbation of the angular correlation in the aqueous oil solutions at the room temperature. Some of the measured anisotropy spectra are shown in Figure 3.
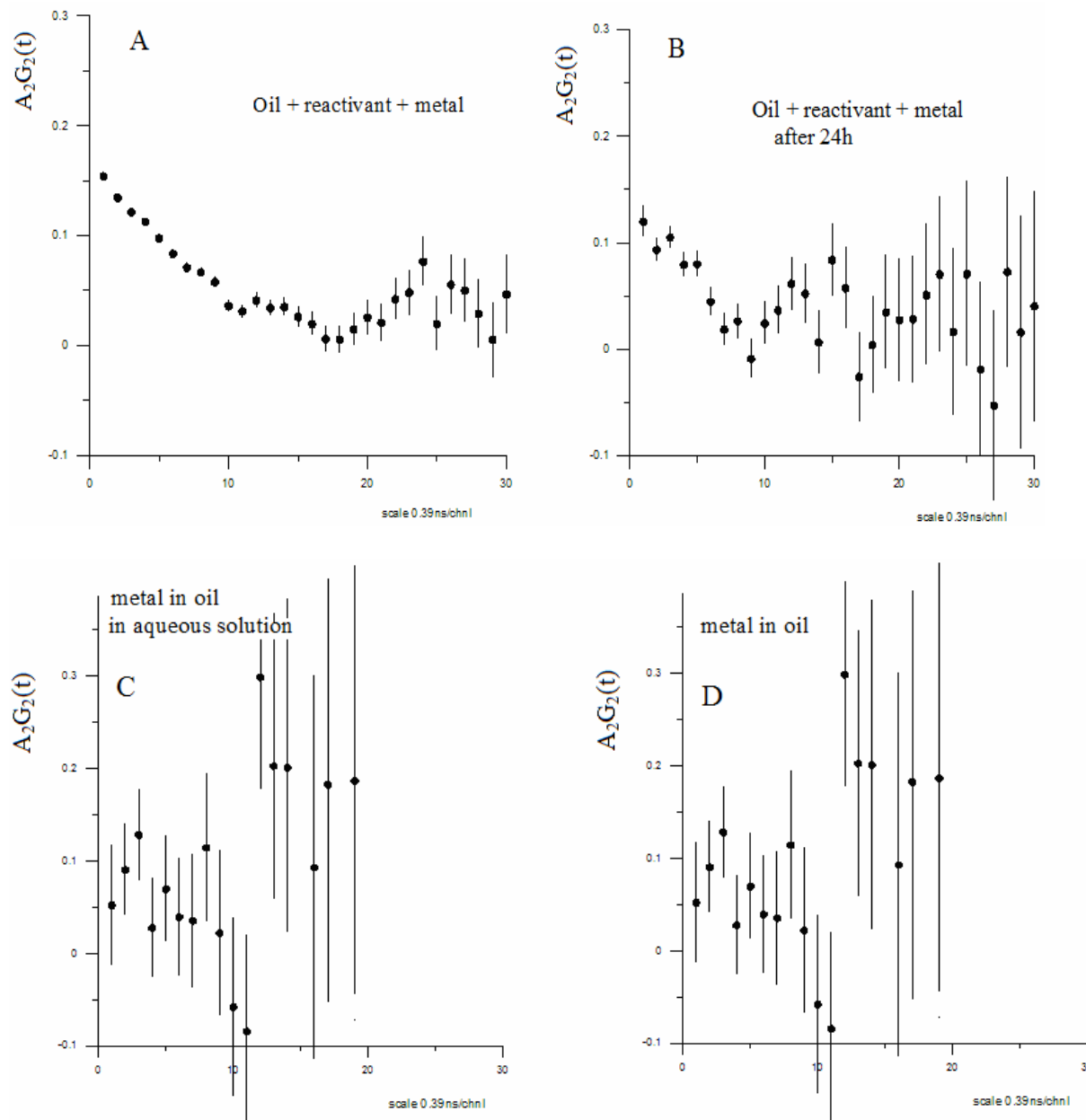

Figure 3. Time spectra of angular anisotropy for the essential oil in different solutions:
A – oil+reactivant+metal; B – the same solution measured after 24h;
C – usual aqueous solution +metal; D – simply metal in essential oil.

The spectrum data suggest a high degree of local flexibility of the europium label. The "activity" of the metal (i.e. degree of the perturbed angular correlation) in the measured essential oil solution varied by time and solution concentration. The complex essential oil +

reactivant + metal is active due to the reactivant (2 – ethilexil – ortho- phosphorus acid). We mention that solution was strongly mixed and centrifuged. In the spectra 3B compared with 3A it could be observed that the metal increases with some percents his "activity". In spectra 3C it can be seen that the "activity" of the metal is very low. In the spectra recorded on oil solution from figure 3D, if metal "activity" exists, it has a local character.

Conclusions

Without reagent the metal from the solution "feel" only the local environment. The reactivant increases by two orders of magnitude (considerably) the so called "activity" of the metal in liquid solution in oil. Only metal in oil with reactivant increase a little his "activity" in comparison with case of absence of the reactivant. It is possible to use $\gamma\gamma$ - PAC method by four-detector spectrometer for concentration determination in essential oil probes.

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