$$\times\left[\frac{\mu_2^2-\mu_1^2}{(M^2-\mu_1^2)(M^2-\mu_2^2)}+\frac{2\mu_1^2}{(M^2-\mu_1^2)^2}\ln\frac{M^2}{\mu_1^2}\right]. \tag{5}$$

Now, saturating the spectral functions $\rho_V(\mu^2)$, $\rho'_V(\mu^2)$, $\rho_A(\mu^2)$, and $\rho'_A(\mu^2)$ with the single-particle states $\rho(770)$, $K^*(890)$, $A_1(1080)$, and $K_A(1320)$, and taking as usual the common coefficient $2m_\rho^2F_\pi^2$ for the corresponding δ-functions in $\rho_i(\mu^2)$, as well as the experimentally known values $F_K = 1.28F_\pi = 220$ MeV and $\cos\theta \sin\theta = 0.22$, we arrive at the result (1).

We emphasize that in our calculation we do not encounter the problem of the so-called σ terms, since it can be readily seen that they do not appear in our case.

As is well known, the unsatisfactory result obtained when the electromagnetic mass difference of the K^+ and K^0 mesons is calculated by an analogous method, is attributed just to the unaccounted-for σ terms.

It is of interest to trace in (5) the transition to the local limit of weak interaction ($M^2 \to \infty$, $\sqrt{2}g^2/M^2 = 10^{-5}/M_p^2 = G$). In this case it can be readily seen that the matrix element $A_{K\to\bar{K}}$ diverges like ln M. It becomes finite if we use the second ("less reliable") sum rule $\int\sigma(\mu^2)d\mu^2 = 0$, which played an important role in [2] for the elimination of the divergences from the matrix element of the $K_S \to 2\pi$ decay with finite M. In our case the use in (5) of the condition $\int\sigma(\mu^2)d\mu^2 = 0$ with $M \to \infty$ and fixed G leads to the finite value $\tau_S\Delta m \approx -0.36$.

[1] T. Das, G. S. Guralnik, V. S. Mathur, F. E. Low, and J. E. Young, Phys. Rev. Lett. 18, 759 (1967).
[2] S. L. Glashow, H. Schnitzer, and S. Weinberg, ibid. 19, 205 (1967).
[3] S. N. Biswas and J. Swith, ibid. 19, 727 (1967).
[4] S. Weinberg, ibid. 18, 507 (1967).
[5] T. Das, V. S. Mathur, and S. Okubo, ibid. 18, 761 (1967).
[6] S. L. Glashow, H. Schnitzer, and S. Weinberg, ibid. 19, 139 (1967).

EXCITATION OF MOSSBAUER LEVELS WHEN HEAVY IONS ARE DECELERATED

V. I. Gol'danskii, F. I. Dalidchik, and G. K. Ivanov
Institute of Chemical Physics, USSR Academy of Sciences

Submitted 19 December 1967
ZhETF Pis'ma 7, No. 5, 180-184 (5 March 1968)

As is well known, short-period nuclei produced upon bombardment of different targets in accelerators as a result of nuclear reactions (d, p), (n, γ), etc. or Coulomb excitation, have recently come into use as sources of emission in Mossbauer transitions, in addition to the long-period parent isotopes.

We wish to call attention here to the possibility of direct or cascade excitation of nuclear levels in the accelerated nuclei themselves (beams of heavy ions) as a result of their Coulomb excitation as they are decelerated in the medium. Such a manner of exciting the Mossbauer levels would afford unique possibilities for a direct investigation of the mechanism of stopping and relaxation of the heavy ions penetrating into matter, their chemical and crystalline surroundings, the hot regions produced around these ions, and the influence of the so-called string effects.

The calculations presented by us, in conjunction with the already known data on (n, γ), (d, p), and (α, α') reactions enable us to obtain such relative estimates of the probability of excitation of the Fe^{57} nuclei for different variants of bombardment of a target of a natural mixture of iron isotopes of thickness 10 mg/cm^2 (see the table).

Table

Bombarding particles and character of interaction	Yield of excited nuclei	Energy loss in target (per incident particle)	Remarks
Thermal neutrons ($Fe^{56}(n, \gamma)Fe^{57}$)	3×10^{-4}	-	Summary yield of all levels
Deuterons ($Fe^{56}(d, p)Fe^{57}$) $E_d = 20$ MeV	10^{-5}	300 keV	
α particles $E_\alpha = 10$ MeV Coulomb excitation	4×10^{-8}	3 MeV	Yield for excitation of the Fe^{57} 136-keV $(5/2)^-$ level
Fe^{57} ions accelerated to 100 MeV (deceleration)	10^{-5}	100 MeV	

As seen from these estimates, the excitation of the Mossbauer levels not in the nuclei of the target but in the decelerating heavy ions themselves is perfectly capable of competing with other variants. A certain shortcoming of this manner of excitation is the relatively large amount of heat released in the target per particle, which can cause the need for a more effective overall cooling of the target. However, the number of local-heating regions along the nuclear track, which serve as the sources of radiation in our case and which are the most important for the Mossbauer effect probability, is not larger in our case than, for example, in the case of Coulomb excitation with α particles, since the decelerating heavy ions spend the greater part of their path in a region where their ionization losses are minimal. If the heat release is referred not to the incident particle, but to the yield of a definite interaction product, say Fe^{57} excited to the 136-keV level, then even the total heat released upon deceleration of the heavy ion turns out to be not larger than in the case of Coulomb excitation of the target nuclei in the natural mixture of the iron isotopes.

We now turn to calculations of the excitation probability of the Mossbauer levels for two examples - decelaration of the Fe^{57} and F^{19} ions. The isotope Fe^{57}, as is well known, is among the most widely used isotopes in γ-resonance spectroscopy, and F^{19} might have turned out to be the lightest Mossbauer isotope if fluorine compounds with sufficiently high frequencies (say at a Debye temperature $\theta_D \approx 1000$°K or as a result of optical branches) were available.

The probability of excitation of the f-th level of the heavy-ion nucleus decelerated in the target is obviously

$$W_f = \int_0^E \sigma_f(E) \frac{dE}{\kappa(E)}, \quad (1)$$

where $\sigma_f(E)$ is the cross section for the excitation of the f-th level of the nucleus from the ground state, $\kappa(E)$ is the decelerating ability of the target, and E is the ion energy in the laboratory system,

$$\sigma_f(E) = \sum_\lambda [\sigma_f^{E\lambda}(E) + \sigma_f^{M\lambda}(E)] + \sum_{\lambda,n} \eta_{nf} [\sigma_n^{E\lambda}(E) + \sigma_n^{M\lambda}(E)], \quad (2)$$

where $\sigma_f^{E\lambda}$ and $\sigma_f^{M\lambda}$ are the cross sections for the excitation of the direct transition of the corresponding type and multipolarity (see [1]), and $\sigma_n^{E\lambda}$ and $\sigma_n^{M\lambda}$ are the cross section for the direct excitation of the n-th higher state from which the f-th state of interest to us is produced with a probability η_{nf} after emission of a γ quantum. The deceleration of the heavy ion is determined essentially by the ionization energy loss [2]:

$$\kappa(E) = 12\pi \frac{Z_1^{*2} e^4}{mvv_0} Z_2^{1/3} \left(\frac{v}{2Z_1^* v_0}\right)^{1/3}, \quad (3)$$

where $Z_1^* = Z_1^{1/3}(v/v_0)$ is the effective (equilibrium) charge of the bombarding ion (mass number A_1), v is the velocity, $v_0 = e^2/h$, and Z_2 is the charge of the target nucleus (mass number A_2).

As a rule, $\sigma_f^{M\lambda}/\sigma_f^{E(\lambda+1)} \sim 10^{-2}$, therefore the main interest in (2) attaches to electric transition of the smallest multipolarity from among those allowed by the selection rules (usually E1 or E2). The cross sections $\sigma^{E\lambda}$ are determined by the excitation functions $f_{E\lambda}(\xi)$, which are tabulated in [1] ($\xi = Z_1 Z_2/12.65)A_1^{1/2}[1 + (A_1/A_2)](\Delta E/E^{3/2}$, ΔE is the transition energy). Approximating $f_{E\lambda}(\xi)/f_{E1}(\xi) = 75 \exp(-2\pi\xi)$ (the accuracy of the approximation is 15 - 20% at $0.3 < \xi < 2$) and $f_{E2}(\xi) = \exp(-3.5\xi^{4/3})$ (approximation accuracy 10 - 15% at $0 < \xi < 2$), we obtain for the probability W_f

$$W_f = \sum_\lambda W_f^{E\lambda} + \sum_{n\gamma} \eta_{nf} W_n^{E\lambda}, \quad (4)$$

where

$$W^{E1} = 5 \cdot 10^{-6} A_1^{3/2} Z_1^{-1/2} Z_2^{5/3} B(E1) \beta^{-1/3} [\Gamma(\frac{1}{3}) - \gamma(\frac{1}{3}, \frac{2\pi\beta}{E^{3/2}})],$$

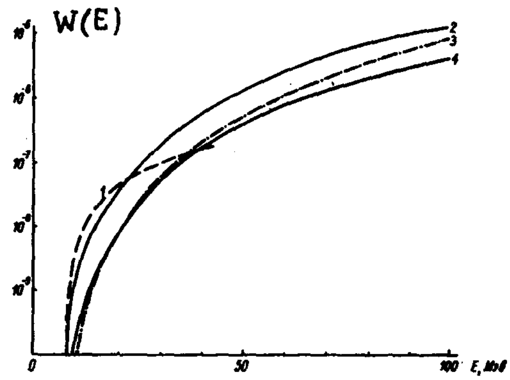
$$W^{E2} = 10^{-4} A_1^{3/2} (1 + \frac{A_1}{A_2})^{-2} Z_1^{-5/2} Z_2^{-1/3} B(E2) \beta^{1/3} [\Gamma(-\frac{3}{4}) -$$

$$-\gamma\left(-\frac{3}{4},\ \frac{3,5\ \beta^{4/3}}{E^2}\right)] \qquad (5)$$

$\gamma(q, x)$ is the incomplete γ function, and

$$\beta = \frac{Z_1 Z_2}{12,65} A_1^{1/2} \left(1 + \frac{A_1}{A_2}\right) \Delta E.$$

Probability of excitation of Mossbauer levels of the ions F^{19} and Fe^{57} decelerated in different media: 1 - F^{19} + Fe^{57}, 2 - Fe^{57} + Fe, 3 - Fe^{57} + Pb, 4 - Fe^{57} + Be.



The figure shows the excitation probability, calculated with the aid of formulas (4) and (5), of the 14.4-keV $(3/2)^-$ level of Fe^{57} and the 110-kev $(1/2)^-$ level of F^{19} when the Fe^{57} and F^{19} ions are decelerated in different media. For Fe^{57} we took into account both the direct $(1/2)^- \rightarrow (3/2)^-$ E2 transition (B(E2, $(1/2)^- \rightarrow (3/2)^-$ = 0.001 [3]) and excitation via the 136-keV $(5/2)^-$ level (B(E2, $(1/2)^- \rightarrow (5/2)^-$ = 0.05 [1]) followed by a γ(E2) transition to the $(3/2)^-$ level, $\eta_{(5/2)^-,(3/2)^-} = 0.91$ [3]. The main contribution to the excitation cross section of the 110-keV level of F^{19} is made by the direct E1 transition, for which B(E1, $(1/2)^+ \rightarrow (1/2)^-$ = 6×10^{-6} [4].

The results of the calculations show that the choice of the target introduces no appreciable changes in the character of the $W_f(E)$ dependence.

[1] K. Alder, A. Bohr, T. Huus, B. Mottelson, and A. Winther, Revs. Mod. Phys. 28, 432 (1956).
[2] N. Bohr, Penetration of Atomic Particles through Matter, E. Munksgaard, 1948.
[3] B. S. Dzhelepov and L. K. Peker, Skhemy raspada radioaktivnykh yader (A < 100) (Decay Scheme of Radioactive Nuclei (A < 100)), Nauka, 1966.
[4] P. H. Stelson and F. K. McGowan, Nucl. Phys. 16, 92 (1960).

CHARGE ASYMMETRY IN K^0_{e3} DECAYS AND PARAMETERS OF THE K^0-$\bar{K}^0$ SYSTEM

Dzh. L. Chkareuli
Physics Institute, Georgian Academy of Sciences

Submitted 20 December 1967
ZhETF Pis'ma 7, No. 5, 184-187 (5 March 1968)

1. The charge asymmetry was recently measured in K^0_{e3} (1) and $K^0_{\mu3}$ (2) decays with greatly differing values of the asymmetry parameters $\alpha_e = (\Gamma_{e^+} - \Gamma_{e^-})/(\Gamma_{e^+} + \Gamma_{e^-})$: