On the observed variation of nuclear temperature with bombarding energy in the $^{55}Mn(\alpha,n)^{58}Co$ reaction

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On the observed variation of nuclear temperature with bombarding energy in the ^{55}Mn(α, n) ^{58}Co reaction

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Abstract. The available data on the ^{55}Mn(α, n) ^{58}Co reaction are analysed, the variation of the inverse reaction cross section with neutron energy and the newly proposed theory of the pre-compound particles being taken into account. The estimated revised temperatures are found to be 1·39 ± 0·08, 1·44 ± 0·08 and 1·46 ± 0·08 MeV corresponding to bombarding energies 14, 17 and 20 MeV. Thus it has been found that the nuclear temperature is independent of bombarding energy in the reaction under consideration, unlike the previous investigations.

In recent years studies on the evaporation of outgoing nucleons in some charged-particle induced reactions (Lassen *et al.* 1960, Lassen and Larsen 1963, Sidorov 1962, Holbrow and Barschall 1963, Alevra *et al.* 1964) have indicated an apparent variation of nuclear temperature with bombarding energy, for the same range of excitation of the residual nucleus. Since temperature is essentially a parameter describing the nuclear level density, such an explanation of the observed results is highly artificial in so far as no tangible origin can be found for such temperature dependence on bombarding energy, at least within the framework of the compound nucleus theory. Sidorov (1962) suggested that such behaviour could be explained in the emission of nucleons before the equilibrium in the compound nucleus could be established. Holbrow and Barschall (1963) found in their study of (p, n) reactions that most of the apparent temperature variation disappears if the energy dependence of the inverse cross section is taken into account. However, Alevra *et al.* (1964) studied the evaporation spectra of the outgoing neutrons in the ^{55}Mn(α, n) ^{58}Co reaction at bombarding energies of 14, 17 and 20 MeV and confirmed the existence of temperature variation with bombarding energy for the same range of excitation of the residual nucleus. It is the aim of the present paper to demonstrate the independence of nuclear temperature on bombarding energy by a proper analysis of their experimental data.

Alevra *et al.* (1964) made two important assumptions in extracting the nuclear temperature from their evaporation spectra:

(i) They have chosen a common region, 4–7 MeV excitation of the residual nucleus, for temperature calculations at all bombarding energies. The lower limit 4 MeV is set to eliminate direct interaction particles, based on angular distribution studies conducted at 14 MeV bombarding energy; however, the same limit was also used for other energies.

(ii) They have completely ignored the variation of inverse reaction cross section with neutron energy.

Griffin (1966) evolved a theoretical criterion to assess the importance of non-evaporative particles emitted in nuclear reactions. He developed an expression by which the region of domination of these 'pre-compound' particles can be identified from the energy spectra. Secondly, the optical model calculations of Campbell *et al.* (1960) show that the variation of the inverse reaction cross section with neutron energy is considerable in the energy region of interest. We have, therefore, based our re-analysis of the experimental spectra of Alevra *et al.* (1964) on the above two refinements.

Figure 1 shows the application of Griffin's (1966) criterion to the energy spectra corresponding to the three bombarding energies. The straight line portions parallel to the energy axis indicate the regions of excitation energy up to which the pre-compound particles dominate over compound nuclear particles in the reaction. It may be observed that these regions extend up to 4, 5·5 and 6 Mev excitation, respectively, for bombarding energies of 14, 17 and 20 Mev. It is obvious that the common lower limit of 4 Mev set by Alevra *et al.* is inadequate to eliminate all non-compound neutrons. In fact, the region chosen by them, 4–7 Mev, contains pre-compound neutrons to varying extents at different bombarding energies, partly explaining the

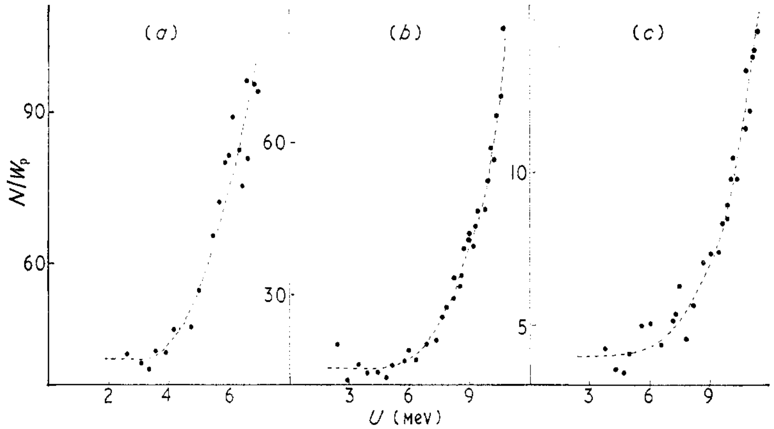

Figure 1. Plot between N/W_p and U at bombarding energies: (*a*) 14 Mev, (*b*) 17 Mev and (*c*) 20 Mev. N, intensity of the emitted particles; W_p, pre-compound probability; U, residual excitation energy.

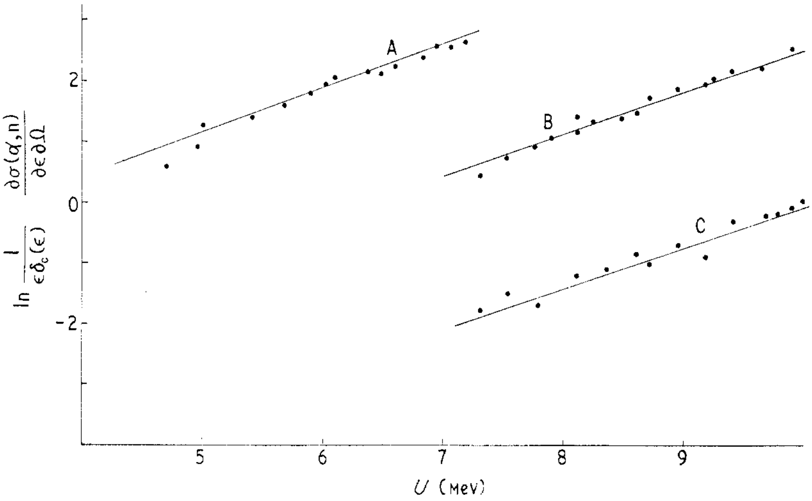

Figure 2. Least-squares-fit plots at the following bombarding energies: curve A, 14 Mev; curve B, 17 Mev; curve C, 20 Mev.

observed increase of nuclear temperature. In our analysis we have chosen the regions for calculation of nuclear temperature as 7–10 MeV in the cases of 17 and 20 MeV bombarding energies, and 4·5 to 7 MeV for the case of 14 MeV where the experimental data are sparce. It may be noted that the upper limit 10 MeV corresponds to the threshold of the ^{55}Mn(α, pn) reaction, which has the lowest Q value among all possible secondary-particle reactions.

Figure 2 shows the replotted spectra, after account has been taken of the variation of inverse cross section with neutron energy as given by Campbell *et al.* (1960). The straight lines are drawn by a least-squares fit of the experimental points in the respective regions described above. The nuclear temperature obtained from the slopes of these plots are 1·39 ± 0·08, 1·44 ± 0·08 and 1·46 ± 0·08 MeV for bombarding energies 14, 17 and 20 MeV respectively. It can be seen that the equality of temperature is quite convincing within the range of errors.

The present analysis thus indicates that the temperature variation with bombarding energy is fictitious, and disappears when proper account is taken of all the factors influencing the energy spectra of the emitted particles. Further, the observation that the temperatures in the range 4–7 MeV and 7–10 MeV are nearly the same lends support to the viewpoint of a phase transition model from a paired to an uncorrelated state.

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