STUDY OF NUCLEAR PARAMETERS OF SILICON 29 ENERGY LEVELS

Thesis Submitted in Partial Fulfillment of The

Requirements For M.Sc. Degree

To The

Faculty of Science,

Ain Shams University,

Cairo, U.A.R.

By

MOSTAFA MOHAMED SHALABY, B.Sc.

1968

A C K N O W L E D G E M E N T

C O N T E N T S

Contents (contd.)

CHAPTER III

--oOo--

S U M M A R Y

S U M M A R Y

A deuteron beam of 10 Mev provided by the
Aldermaston Tandem Van de Graaff has been used to
bombard a thin target of natural silicon dioxide. The
emitted protons have been analysed by a multichannel
spectrograph covering an angular range from $5°$ to $175°$
in steps of $7.5°$. By analysing the twenty four proton
spectra produced in that angular range, 82 proton groups
attributed to the $Si^{28}(d,p)Si^{29}$ reaction and correspond-
ing to excited states in Si^{29} up to an energy of 9.897 Mev
have been identified. Nuclear parameters such as spin and
parity concerning the majority of these excited states have
been also achieved through a comparison between the
theoretical curves based on Butler and Bhatia et al
stripping formula and the experimental angular distribution
of each proton group. Relative reduced widths for these
levels have been estimated using Lubitz tables (L=2).
A summary of the results presented in this work is given
as follows:

1) Angular distribution corresponding to 62 excited
states in Si^{29} up to excitation energy of 9.154 Mev

have been obtained and 48 of these distributions are considered to be new. Some of the presented angular distributions are found to exhibit a stripping structure, while the remaining ones have non strippting pattern. Good isotopic distributions are found for some of these latter states while the others are characterized by either a pronounced backward rise or sinesoidal pattern.

2) Most of the investigated proton groups are found to have angular distributions characterized by $\ell_n = 2$ particularly those of excitation energies higher than 7.1 Mev. The excited states at 1.275, 2.023, 3.06 and 8.345 Mev are found to have established spin parity assignments of $3/2^+$, $5/2^+$, $5/2^+$, and $5/2^+$ respectively. The latter state is identified as the isobaric analog for the $5/2^+$ ground state in Al^{29}.

3) Two proton groups corresponding to the ground state and to the 4.830 Mev level are found to have $\ell_n = 0$ indicating that each of them has a spin assignment $\frac{1}{2}^+$.

4) Six energy levels at 4.930, 6.374, 6.693, 5.905, 7.055 and 7.993 Mev are found to have $\ell_n = 1$. While the former two levels have established spin of $3/2^-$ and $\frac{1}{2}^-$ respectively, the remaining levels may have a spin of $\frac{1}{2}^-$ or $3/2^-$.

5) Six energy levels are found to be characterized by $\ell_n = 3$, namely those levels at 3.621, 6.189, 6.491, 6.520, 8.207 and 8.270 Mev. While the former two levels are likely to have a spin $7/2^-$ and $5/2^-$ respectively, the remaining levels may have $5/2^-$ or $7/2^-$. Moreover two levels at 5.810 and 6.779 Mev have doubted assignment of $\ell_n = 3$.

6) Three energy levels at 5.648, 6.416 and 8.331 Mev are found to have $\ell_n = 4$ indicating that each of them should have a spin $7/2^+$ or $9/2^+$. It is most likely that the latter level have a spin $9/2^+$.

7) Energy levels at 0, 1.275, 3.621, 4.930, 6.189, 6.376 and 8.331 Mev are found to exhibit strong transitions beside having relatively high reduced width. Since these levels are characterized by $\ell_n = 0, 2, 3, 1, 3, 1$ and 4 respectively it has been possible to attribute them to the single particle levels $2s_{1/2}$, $1d_{3/2}$, $1f_{7/2}$, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$ and $1g_{9/2}$, thus confirming the shell model structure.

INTRODUCTION

INTRODUCTION

The study of deuteron stripping reactions have proved to be a powerful tool in providing information about the nuclear structure of the residual nuclei. Various parameters such as energy levels, spins, parities, reduced widths, ... etc, could be easily achieved through the study of the outgoing particle spectra and analyzing the angular distribution of each particle group. In deuteron stripping reactions the angular distributions of the product particles are found to be charachterized by maximum intensity at or near the forward angles. Such a pronounced feature cannot be described on account of the compound nucleus mechanism but on a direct reaction mechanism where the deuteron when approaching close to the target nucleus is stripped off into two nucleons. The neighbouring nucleon (neutron say) is captured while the other one escapes carrying the balance of energy and momentum. Applying this mechanism, two theories have been proposed namely Butler theory (1951) and Bhatia et al theory (1952). Although both theories have been successful in interpreting the general shape of the

experimental angular distribution, yet, they neglect
some factors such as the effect of the coulomb inter-
action between the incident deuteron and the target
nucleus. Recently such effect together with factors
including the interacting potential have been taken into
consideration. A distorted wave Born approximation
theory has been developed, giving much better agree-
ment with the experimental results.

In general, the shape of the theoretical angular
distribution curve is found to depend mainly upon the
incident and outgoing particle energies, the radius
of interaction and the orbital angular momentum (ℓ_n)
with which the captured neutron entered the target
nucleus. It follows that by fitting the experimental
angular distribution with the appropriate theoretical
one, it is possible to determine such parameters.
Knowing the value of angular momentum transfer, one
can fix the parity and limit the spin of the corres-
ponding state in the residual nucleus. Such in-
formation could be also useful in checking and
establishing the shell model structure. Although the
spin-parity assignment of ground states could be easily
shown from such model yet in case of excited states the

nucleon reduced width estimated from stripping analysis could be taken as indication to the states of single particle excitation.

The experimental determination of energy levels as well as the angular distributions in (d,p) reactions have been carried out extensively applying various detecting techniques. Measurements applying conventional detecting techniques could not be made at angles less than say 15° as reported by Holt and Young (1950), Rotblat (1951), El-Bedewi (1952) and others. To extend the measurements for larger angles, trials have been made using gold absorbers of sufficient thickness to stop the scattered deuterons before being observed (Holt and Marsham (1953)). Obviously such method will affect the energy resolution due to the scattering and straggling of protons in the absorber beside the limitation for measuring protons to those of sufficiently high energy.

However, applying magnetic analysis one can observe proton groups at nearly forward angles on account of being shifted from the deuteron background. For this purpose magnetic spectrographs, such as those reported by Green and Middleton (1956) have been constructed to

achieve such separation beside their ability for
rendering high energy resolution. Moreover, to increase
the energy range of investigation, broad range magnetic
spectrographs have been later reported by Buechner
et al (1956) and Hinds & Middleton (1959).

To simplify the function of magnetic spectrographs
as well as to overcome the effect of possible deteriora-
tion of the target material and intensity monitoring
as means of normalization, a number of broad range
spectrographs have been combined together in the form
of a multichannel spectrograph in order to provide
simultaneous spectra at various angles. One of these
instruments is Aldermaston multi-channel spectrograph
reported by Hinds & Middleton (1962) in which 24 broad
range magnetic spectrographs are arranged around the
target in such a way to provide spectra corresponding to
various angles of emission ranging between 5° to 175°.
The present work has applied this spectrograph together
with the Aldermaston Tandem Van de Graaf generator
providing deuterons of energy 10 Mev in investigating the
$Si^{28}(d,p)Si^{29}$ reaction.

The choice of the even-even nucleus Si^{28} characterized
by spin 0^+ as target material minimizes the ambiguity in

the assignment of spin values to the states pro-
duced in the stripping process. Since that nucleus
contains equal number of protons and neutrons completely
filling the subshell $1d_{5/2}$ so the addition of a neutron
to form the residual nucleus Si^{29} with probably little
disturbance of the nuclear core can allow for the study
of its single particle levels $2s_{1/2}$, $1d_{3/2}$, $1f_{7/2}$, $2p_{3/2}$,
$1f_{5/2}$, $2p_{1/2}$, ... However, on account of a pure
J;J coupling for the silicon 28 core, Bromley et al (1957)
suggested that it may have a spherical shape exhibiting
features characteristic of collective vibration. Such
core deformation is considered to be of theoretical
interest in particular for nuclei around $A = 2$ where
the sign of nuclear deformation seems to change.
Dehnhard and Yntema (1967) have pointed out that although
the collective model description could be successfully
applied to nuclei in the 2s-1d shell having A = 2? yet
it is inadequate for nuclei with A = 29 which possess
oblate equilibrium shapes thus suggesting the applica-
bility of Nilson rotational model.

Earlier work on Si^{29} is summarized in the compilation
of Endt and Van-Der-Leun (1967) where energy levels of
that nucleus have been determined using $Si^{28}(d,p)Si^{29}$
reaction beside some other appropriate reactions such as