CHAPTER II

GROUND-STATE OCCUPANCIES OF f-p-g SHELL NUCLEI

In theories of nuclear structure, the concept of single particle orbits in which individual nucleons move, plays a very important role. In fact, the spherical shell model and its extension to self-consistent field theory are based on the postulates of such single particle orbits. Therefore, study of the single particle aspects of the many-body nuclear wave functions can provide a key to understanding of the nuclear structure. For a better insight, theory should always be backed by experiments. Many of the experimentally measurable properties of nuclear states are the expectation values of one-body operators in the state. The occupancy operator is a one body operator and its expectation values, that is, the orbit occupancies in the ground states of nuclei, are the simplest dynamical quantities that can be experimentally measured. Therefore, calculations of occupancies starting from effective two-body interactions, when compared with experimental data, serve as an effective tool to investigate the relevance of various effective interactions. Moreover, these calculations allow one to study the systematic changes in the nuclear structure as the number of neutrons and protons change. Several such calculations have been reported in the past. Various effective interactions in the s-d shell were studied by Potbhare and Pandya (1976)[5]. A similar analysis was done for the lower

f-p shell nuclei by Kota and Patbhare (1979)[6] and a few nuclei in the upper f-p shell were investigated by Kota et.al (1982)[7] using the fully renormalised Kuo-Brown interaction [8]; they have compared the results with the occupancies obtained from the experimental data. Here we present results for various nuclei in the upper f-p shell, the spectroscopic space used consisting of $p_{3/2}$, $f_{5/2}$ and $p_{1/2}$ orbitals. We have also included $g_{9/2}$ orbital in the calculation.

Provided that the exact shell model wave function for the ground state is available, then the occupancy calculation is trivial. This method is feasible only for the nuclei in the s-d shell, as the dimensionalities of the corresponding Hamiltonian matrices are not prohibitively large for the detailed shell model calculations. For example, the ground state wave function was obtained[9] by Soyeur and Zucker for ^{28}Si. The dimensionality of the Hamiltonian matrix for J=0 and T = 0 in this case is 839. For f-p shell ($40 < A < 60$) and the f-p-g shell nuclei ($A > 56$), this method becomes quite impractical. The number of single particle states which is 24 for s-d shell becomes 40 for the full f-p shell and 44 in the space considered, that is, upper f-p shell and $g_{9/2}$ orbital. Consequently the dimensionalities of the Hamiltonian matrices become too large for (i) construction of exact Hamiltonian matrix using a two body effective interaction and

for (ii) diagonalizing the Hamiltonian matrix so obtained. Moreover, this requires a large amount of computing time and often the output is so detailed that it becomes difficult to extract useful information from it. One can of course resort to truncation of model space, but quite often the experiments[10] show that for the heavier nuclei (A>56), it is necessary to include the $g_{9/2}$ orbital along with the f-p orbitals. In that case some other simpler method to calculate the ground state occupancies becomes necessary.

Spectral distribution methods provide the answer. The first occupancy calculation using this method was done by Chang and French[11], where they have compared the results with exact shell model results. Besides the work mentioned earlier regarding occupancy calculation, Haq and Parikh[12] have also given ground state occupancies for nuclei in the f-p shell using the MWH-2[13,14] effective interaction.

These methods make use of only the few lower moments of the eigenvalue density. This avoidance of the higher moments corresponds to the neglect of fine details about the eigenvalue distribution and the level-to-level fluctuations of the expectation values[15]. Expectation values thus calculated are averaged quantities, and hence the ground state occupancy corresponds to an average value of the occupancy in the ground state region. However one

can calculate the spread in occupancy of the j^{th} orbit; it is given by[6)]

$$\Delta_j (E) = \left[\{n_j\}^2 (E) - [\{n_j\} (E)]^2 \right]^{\frac{1}{2}}$$

where $\{n_j\}^2 (E)$ is the expectation value of the operator n_j^2 at energy E and n_j is the number operator for the j^{th} orbit. It has been shown that this spread in occupancy is very small and hence average value of occupancy is a physically meaningful quantity.

The interaction used here has been derived by Bhatt and Ahalpara (1984)[16)] from the fully renormalised Kuo-Brown interaction. Following modifications were empirically made using Hartree Fock calculations:-

1. The $\langle g_{9/2}^2 \mid V \mid g_{9/2}^2 \rangle^{JT}$ matrix elements were changed so as to reproduce ^{90}Zr and ^{92}Mo spectra.

2. The centroids of $\langle g_{9/2}\ p_{1/2} \mid V \mid g_{9/2}\ p_{1/2} \rangle^{JT}$ matrix elements were adjusted to reproduce the separation of $g_{9/2}$ and $p_{1/2}$ single particle states in ^{89}Y nucleus.

The single particle energies used are 0.0, 0.78, 1.08 and 3.0 MeV for $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ orbits respectively; the first three values come from the experimental spectrum of ^{57} Ni; while the $g_{9/2}$ single particle energy is arbitrarily fixed at 3.0 MeV. We have calculated proton-

neutron occupancies which can be directly related to the values obtained from the experimental data. Also, our calculation assumes a fixed value of T_z instead of fixed isospin. This is because as the Z value increases, the neutrons and the protons do not fill the orbits simultaneously due to increased coulomb repulsion. In that case fixed isospin T may not be a good quantum number. However, if desired, fixed T results can be readily obtained from fixed T_z results by the standard sieving procedure. In section A we discuss the theory and general formalism of the calculation. Section B gives the results, comparison with experimental data and discussion.

A GENERAL FORMALISM

Consider an m particle system, with particles distributed over N single particle states, along with a (1+2) body Hamiltonian

$$H = \sum \epsilon_i \, A_i B_i - 1/4 \sum V_{ijkl} A_i A_j B_k B_l$$

$$= H(1) + H(2)$$

where ϵ_i are the primary single particle energies, V_{ijkl} are the anti-symmetrized two body interaction matrix

elements and A_i and B_i are the creation and annihilation operators respectively. Then the occupancy of a single particle state s as a function of energy E is the expectation value of the number operator $n_s = A_s B_s$ in the state at energy E, that is,

$$n_s(E) = \langle E | n_s | E \rangle \qquad (1)$$

in the space of m particles considered.

The calculation of occupancies using Spectral Distribution methods simplifies to a great extent if the space is decomposed according to proton - neutron (p-n) configurations. A p-n configuration $(\vec{m}_p, \vec{m}_n)$ is defined by assigning a fixed number of protons and neutrons to various proton and neutron orbitals such that $\sum_{\alpha} m_{\alpha,p}$ = total number of protons, $\sum_{\alpha} m_{\alpha,n}$ = total number of neutrons where α denotes the orbitals. Such a decomposition implies a fixed value of $T_z = (N-Z)/2$, where N is the number of neutrons.

The energy eigenvalue density $\rho(E)$ with respect to energy is defined as a sum of intensities of all configurations into which the space is subdivided, that is,

$$\rho(E) = \sum_{\vec{m}_p, \vec{m}_n} \rho_{\vec{m}_p, \vec{m}_n}(E) \; \frac{d(\vec{m}_p, \vec{m}_n)}{D} \qquad (2)$$

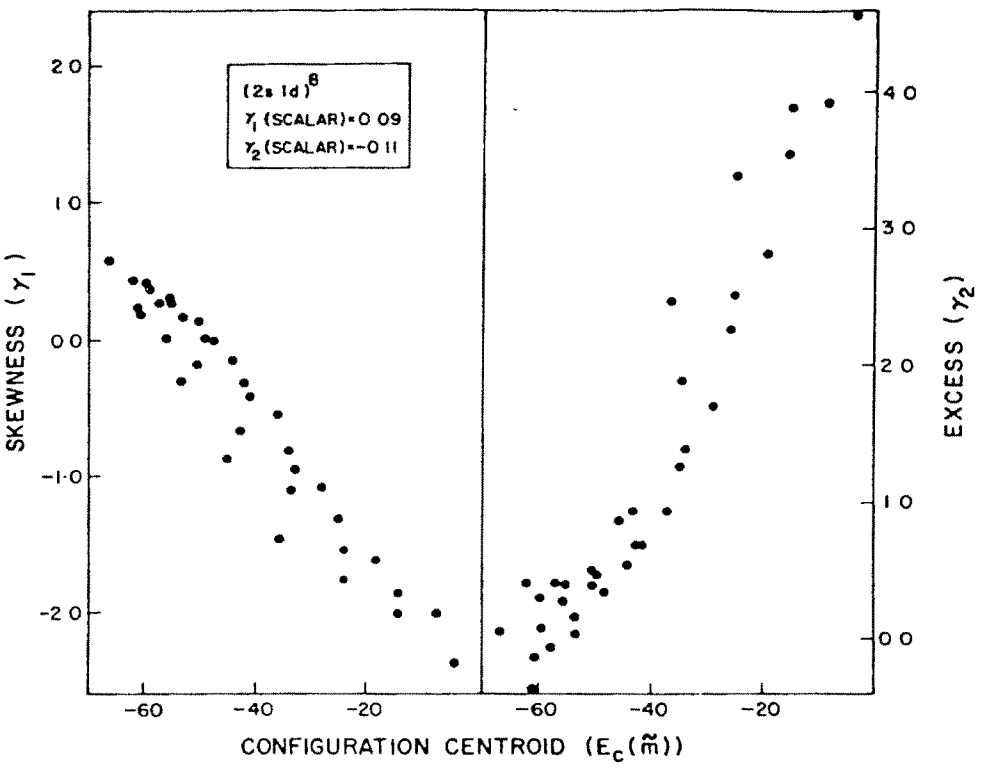
where each term in the summation corresponds to the intensity

of configuration $(\vec{m}_p, \vec{m}_n)$ in the eigenvalue distribution at energy E, d $(\vec{m}_p, \vec{m}_n)$ is the dimensionality of the configuration $(\vec{m}_p, \vec{m}_n)$ and D is the total dimensionality. The calculation can be further simplified by assuming that the intensity distribution of each configuration is described by a gaussian. This assumption is partly based on the applicability of Central Limit Theorem when the number of particles m is quite large compared to the body rank (generally = 2) of the effective interaction. In general, Central Limit Theorem cannot be applied to configuration spaces because it is found that configuration skewness and excess parameters need not always be close to null values characteristic of a gaussian. The distribution of skewness and excess parameters of intensity distributions for 35 configurations in 8-particle space in s-d shell for KLS-R interaction (Figure 1.) shows that the values of γ_1 and γ_2 are quite large for configurations which lie higher up on the energy scale. However, we see that the low lying configurations which dominate the ground state region have comparatively low values of skewness and excess. Therefore we are justified in assuming that intensity distribution of each configuration is normal since we are interested in the occupancies in the ground state region. It is given by

FIGURE 1.

Distribution of skewness (γ_1) and excess (γ_2) parameters for $(2s\text{-}1d)^8$ configurations.

FIGURE 1


(2s 1d)^8
γ1 (SCALAR)=0 09
γ2 (SCALAR)=-0 11
SKEWNESS (γ1)
EXCESS (γ2)
CONFIGURATION CENTROID (Ec(m̃))
2 0
1 0
0 0
-1·0
-2 0
4 0
3 0
2 0
1 0
0 0
-60
-40
-20

$$\rho(\vec{m}_p, \vec{m}_n) = \frac{1}{\sqrt{2\pi}\,\sigma(\vec{m}_p, \vec{m}_n)} \exp\left\{-\frac{1}{2}\left(\frac{E-\langle H\rangle^{\vec{m}_p, \vec{m}_n}}{\sigma(\vec{m}_p, \vec{m}_n)}\right)^2\right\} \qquad (3)$$

where $\langle H\rangle^{\vec{m}_p,\vec{m}_n}$ is the centroid and $\sigma(\vec{m}_p,\vec{m}_n)$ is the width of the intensity distribution for the configuration $(\vec{m}_p,\vec{m}_n)$. Thus in order to evaluate $\rho(\vec{m}_p,\vec{m}_n)$ one needs the centroid & width.

The number of states in a configuration is the dimensionality of the configuration. It can be easily calculated knowing the number of protons and neutrons in each orbit i and the corresponding permissible value N_i for the orbit. It is given by

$$d(\vec{m}_p,\vec{m}_n) = \prod_{ip}\begin{bmatrix} N_{ip} \\ m_{ip} \end{bmatrix} \prod_{in}\begin{bmatrix} N_{in} \\ m_{in} \end{bmatrix} \qquad (4)$$

where $N_{ip(n)} = (2j_{ip(n)} + 1)$

The configuration centroid and width can be calculated from the moments of the distribution, which are nothing but the traces of powers of the Hamiltonian. The average of an operator O in the space α is defined by

$$\langle O\rangle^{\alpha} = \frac{1}{d(\alpha)} \qquad \langle\langle O\rangle\rangle^{\alpha} = \frac{1}{d(\alpha)} \sum_{i\in\alpha} \langle i|O|i\rangle$$

where $\langle\langle O\rangle\rangle^{\alpha}$ is the trace of the operator in the space α. Higher order averages can be calculated by

$$\langle O^n\rangle^{\alpha} = \frac{1}{d(\alpha)} \langle\langle O^n\rangle\rangle^{\alpha} = \frac{1}{d(\alpha)} \sum_{i\in\alpha} \langle i\,|\,O^n|\,i\rangle$$

There exist polynomial propogators expressed in terms of the number of particles m and the particle rank of the operator used. These propogators convert averages in the space of a few particles to averages in the space of a large number of particles. Consider a k-body operator in m particle space ($m \gg k$). Then knowing the average of k-body operator in k particle space, the average of k-body operator in m particle space is given by

$$\langle O\ (k)\rangle^{m} = \binom{m}{k} \langle O\ (k)\rangle^{k}$$

The configuration centroid is the first moment and configuration width is given by the 2nd central moment of the state density as follows

$$E\ (\vec{m}_p,\vec{m}_n) \triangleq \frac{1}{d(\vec{m}_p,\vec{m}_n)} \sum_{i \in (\vec{m}_p,\vec{m}_n)} \langle i|H|\ i\rangle = \langle H\rangle^{\vec{m}_p,\vec{m}_n} \quad \ldots\ldots(5)$$

$$\sigma^2(\vec{m}_p,\vec{m}_n) = \frac{1}{d(\vec{m}_p,\vec{m}_n)} \sum_{i \in (\vec{m}_p,\vec{m}_n)} \langle i\ |\ (H-E\ (\vec{m}_p,\vec{m}_n))^2|i\rangle \quad \ldots\ldots(6)$$

These can be explicitly written as

$$\langle H\rangle^{\vec{m}_p,\vec{m}_n} = \Sigma\, m_i \epsilon_i + \sum_{i \gtrdot j} PR\ (i,j)\ W_{ij}$$

$$\sigma^2(\vec{m}_p,\vec{m}_n) = \sum_{\substack{i \gtrdot j \\ k \gtrdot l}} PR\ (ijkl)\ W(ijkl)$$

where the propogators PR are

$$PR\ (ij) = m_i\ (m_j - \delta_{ij})/(1 + \delta_{ij})$$

$$PR(ijkl) = \frac{m_i(m_j-\delta_{ij})(N_k-m_k)(N_l-m_l-\delta_{kl})}{N_i(N_j-\delta_{ij})(N_k-\delta_{ik}-\delta_{jk})(N_l-\delta_{il}-\delta_{jl}-\delta_{kl})}$$

and W's are given by

$$W_{ij} = \sum_J V^J_{ijij} \quad (2J+1)$$

$$W(ijkl) = \sum_J (\tilde{V}^J_{ijkl})^2 \quad (2J+1)$$

$$\tilde{V}^J_{ijkl} = V^J_{ijkl} - \delta_{ik}\delta_{jl} W_{ij} / \sum_J (2J+1)$$

where V^J_{ijkl} are two body matrix elements in the p-n formalism. It should be noted that for p-n systems, the number of orbits are doubled. Using equations (4), (5) and (6) in (3), $\rho(\vec{m}_p,\vec{m}_n)$ can be calculated.

The ground state energy $E_{g.s}$ is calculated from the eigenvalue density $\rho(E)$ using the Ratcliffe (1971) procedure,

$$\int_{-\infty}^{E_{g.s}} \rho(E)\, dE = \frac{1}{2}(2J+1)$$

$$= \frac{1}{2} * \text{ground state degeneracy.}$$

It has been shown by Draayer et.al (1977)[15] that the expectation value of an operator O at x can be expanded in terms of orthogonal polynomials P_n

$$O(x) = \langle O \rangle + \sum_{n=1}^{\infty} \langle O \hat{P}_n(H) \rangle P_n(x) \ldots \quad (7)$$

These polynomials are defined by the eigenvalue density. When the space is decomposed according to p-n configurations,

the expression can be written as

$$O(x) = \sum_{(\vec{m}_p,\vec{m}_n)} \frac{\rho_{\vec{m}_p,\vec{m}_n}(x)}{\rho(x)} \left(\langle O \rangle^{\vec{m}_p,\vec{m}_n} + \sum_{q=1}^{\infty} \langle O P_q \rangle^{\vec{m}_p,\vec{m}_n} (H) \right.$$

$$\left. P_q^{\vec{m}_p,\vec{m}_n}(x) \right) \quad .. (8)$$

For occupancy calculations $O = n_{i,p}, n_{i,n}$ where n is the number operator, $x = E_{g.s.}$ From (8) due to orthogonal properties of P_q's and the scalar character of $n_{i,p}$ in the p-n configuration space, it follows that

$$\langle n_{i,p} P_q (H) \rangle^{\vec{m}_p,\vec{m}_n} = \text{number of protons in the } i^{th} \text{ orbit} * \delta_{q,0}$$

$$= m_{ip}(\vec{m}_p,\vec{m}_n) * \delta_{q,0}$$

Hence the expression for occupancy turms out to be

$$n_{i,p}(x) = \sum_{\vec{m}_p,\vec{m}_n} m_{ip}(\vec{m}_p,\vec{m}_n) * \frac{\rho_{\vec{m}_p,\vec{m}_n}(x)}{\rho(x)} \quad .. (9)$$

This result follows directly and naturally from the polynomial expansion. However, since the ground state is far below the centroid of the eigenvalue distribution (more than four widths away from the centroid for many f-p shell nuclei), we feel that the polynomial method might not give good results near the ground state. Consider the expression

$$\rho(x) = \lim_{\Delta x \to 0} \frac{F(x) - F(x-\Delta x)}{\Delta x}$$

where $F(x) = \int_{-\infty}^{x} \rho(y)\, dy$ is the distribution function at x.

If $x = E_{g.s}$, there will be no states below x, that is at $(x-\Delta x)$. Therefore, we propose to replace the density function by the distribution function, and the expression for occupancy now reads

$$n_{i,p}(E_{g.s}) = \sum_{\vec{m}_p,\vec{m}_n} m_{ip}(\vec{m}_p,\vec{m}_n) * \frac{\int_{-\infty}^{E_{g.s}} \rho_{\vec{m}_p,\vec{m}_n}(x)\, dx}{\int_{-\infty}^{E_{g.s}} \rho(x)\, dx} \quad .. (10)$$

The results of occupancies calculated by both the methods are tabulated and analysed in the following section.

B RESULTS AND DISCUSSION

Occupancies are experimentally obtained from various pick-up and stripping single nucleon transfer reactions. Pick-up reactions measure the particle occupancies while stripping reactions give the hole occupancies.

Recently, systematic experimental studies of nuclei in the mass range A = 60 - 80 appear to show some discontinuity around N = 40, suggesting a sharp structural change between N = 40 to N = 42 ground states. For example, in particular, the experiment Ge (d, ^{3}He) Ga for Ge isotopes with masses 70, 72, 74, 76 etc. provide a direct measurement of proton

and neutron occupancies in ground state of Ge isotopes. These experiments show a sharp structural change at N=40 Apart from Ge and Se isotopes, experimental information about the upper f-p shell nuclei is scanty. We have used the available information for comparison with our numerically obtained results.

Table I gives the calculated ground state occupancies of various nuclei. The first row for each nucleus corresponds to results using equation (9) while the second row gives results using equation (10). We notice that the results obtained from both the equations are not significantly different. This, we feel can be due to two reasons (i) large dimensionalities of spaces involved and (ii) small values of spread of occupancies as mentioned earlier. We have taken proper care of the ground state parity by choosing only those configurations which have the same parity as that of the ground state. Further, in order to reduce enormous amount of computing time, we have restricted the calculations to include only those configurations which do not have more than four particles excited to $g_{9/2}$ orbit compared to the lowest configuration obtained using non-interacting particles. In principle, all the configurations should be used for such calculations, but since the configurations which lie far away from the ground state region die out by

TABLE - 1.

Calculated ground state occupancies of f-p-g shell nuclei*. The calculations are done in the (p-n) configuration space with modified fully renormalised Kuo-Brown interaction.[16)]

*The first and the second row for each nucleus corresponds to occupancies obtained by using equations (9) and (10) respectively.

TABLE I : CALCULATED GROUND STATE OCCUPANCIES*

NUCLEUS	PROTON OCCUPANCY				NEUTRON OCCUPANCY			
	p3/2	f5/2	p1/2	g9/2	p3/2	f5/2	p1/2	g9/2
^{64}Zn	1.78	0.13	0.08	0.01	2.92	1.71	1.08	0.29
	1.81	0.11	0.08	0.00	3.01	1.65	1.12	0.22
^{65}Zn	1.69	0.21	0.07	0.02	2.76	2.20	1.02	1.01
	1.73	0.18	0.07	0.02	2.84	2.19	1.07	0.90
^{66}Zn	1.76	0.18	0.05	0.01	2.93	2.58	1.13	1.36
	1.79	0.15	0.05	0.01	2.98	2.60	1.17	1.27
^{67}Zn	1.71	0.22	0.05	0.02	3.06	2.95	1.22	1.77
	1.75	0.20	0.05	0.01	3.08	2.96	1.24	1.73
^{68}Zn	1.78	0.16	0.05	0.01	3.27	3.42	1.45	1.86
	1.81	0.15	0.04	0.01	3.27	3.44	1.46	1.83
^{67}Ga	2.39	0.40	0.16	0.05	2.91	2.39	1.22	1.48
	2.45	0.35	0.16	0.04	2.94	2.40	1.25	1.41
^{69}Ga	2.43	0.34	0.20	0.03	3.30	3.28	1.53	1.88
	2.49	0.31	0.19	0.02	3.30	3.28	1.55	1.87
^{71}Ga	2.27	0.48	0.14	0.12	3.12	3.95	1.47	3.47
	2.33	0.44	0.13	0.10	3.10	3.97	1.49	3.44

Contd.

Contd... Table I.

NUCLEUS	PROTON OCCUPANCY				NEUTRON OCCUPANCY			
	P3/2	f5/2	p1/2	g9/2	p3/2	f5/2	p1/2	g9/2
^{68}Ge	3.00	0.56	0.37	0.10	3.10	2.19	1.38	1.33
	3.04	0.50	0.38	0.08	3.14	2.19	1.42	1.25
^{69}Ge	2.91	0.60	0.39	0.1	3.23	2.61	1.46	1.71
	2.98	0.55	0.39	0.08	3.25	2.59	1.48	1.67
^{70}Ge	3.01	0.49	0.45	0.06	3.43	3.10	1.64	1.84
	3.07	0.45	0.43	0.05	3.44	3.09	1.66	1.82
^{71}Ge	2.77	0.48	0.39	0.36	3.40	3.72	1.60	2.28
	2.85	0.44	0.40	0.32	3.42	3.72	1.63	2.23
^{72}Ge	2.83	0.66	0.31	0.20	3.23	3.84	1.58	3.35
	2.91	0.61	0.31	0.18	3.23	3.86	1.60	3.31
^{73}Ge	2.53	0.82	0.29	0.37	3.19	4.15	1.51	4.15
	2.61	0.77	0.29	0.33	3.18	4.17	1.52	4.12
^{74}Ge	2.61	0.76	0.28	0.35	3.16	4.52	1.58	4.75
	2.69	0.71	0.28	0.32	3.15	4.55	1.60	4.71
^{76}Ge	2.36	0.87	0.31	0.44	3.24	5.09	1.65	6.03
	2.45	0.83	0.31	0.41	3.22	5.12	1.67	6.00

Contd

Contd... Table I

NUCLEUS	PROTON OCCUPANCY				NEUTRON OCCUPANCY			
	p3/2	f5/2	p1/2	g9/2	p3/2	f5/2	p1/2	g9/2
^{73}As	3.03	0.99	0.56	0.45	3.36	3.71	1.59	3.34
	3.10	0.95	0.55	0.40	3.38	3.72	1.61	3.30
^{74}As	2.88	1.09	0.48	0.56	3.30	4.05	1.56	4.10
	2.96	1.04	0.49	0.51	3.31	4.06	1.58	4.06
^{75}As	2.79	1.16	0.46	0.60	3.27	4.37	1.57	4.79
	2.87	1.10	0.47	0.56	3.28	4.38	1.59	4.74
^{72}Se	3.54	1.05	1.07	0.34	3.63	2.92	1.73	1.72
	3.59	1.00	1.11	0.30	3.66	2.87	1.76	1.71
^{73}Se	3.37	1.13	0.84	0.67	3.52	3.39	1.66	2.44
	3.43	1.08	0.88	0.61	3.56	3.39	1.69	2.38
^{74}Se	3.32	1.26	0.78	0.65	3.48	3.63	1.64	3.26
	3.38	1.21	0.82	0.59	3.51	3.62	1.67	3.20
^{75}Se	3.08	1.45	0.65	0.83	3.37	3.96	1.57	4.11
	3.15	1.41	0.68	0.77	3.40	3.96	1.59	4.05
^{76}Se	3.09	1.48	0.66	0.77	3.38	4.27	1.62	4.73
	3.16	1.43	0.69	0.72	3.40	4.28	1.64	4.67

Contd...

Contd... Table I

NUCLEUS	PROTON OCCUPANCY				NEUTRON OCCUPANCY			
	p3/2	f5/2	p1/2	g9/2	p3/2	f5/2	p1/2	g9/2
^{77}Se	2.93	1.58	0.63	0.86	3.38	4.59	1.63	5.40
	3.00	1.54	0.65	0.81	3.40	4.60	1.65	5.35
^{78}Se	2.85	1.66	0.65	0.85	3.46	4.88	1.68	6.03
	2.92	1.61	0.67	0.80	3.43	4.89	1.70	5.99
^{79}Se	2.54	1.85	0.62	0.99	3.45	5.11	1.68	6.76
	2.61	1.81	0.64	0.94	3.46	5.12	1.70	6.72
^{80}Se	2.50	1.91	0.67	0.93	3.53	5.37	1.75	7.35
	2.57	1.87	0.68	0.88	3.54	5.38	1.77	7.31
^{77}Br	3.16	1.96	0.78	1.11	3.42	4.17	1.59	4.82
	3.21	1.92	0.81	1.06	3.44	4.17	1.62	4.77
^{79}Br	2.92	2.16	0.77	1.15	3.46	4.77	1.66	6.11
	2.98	2.12	0.79	1.10	3.47	4.78	1.68	6.07
^{81}Br	2.61	2.40	0.79	1.20	3.56	5.28	1.74	7.42
	2.66	2.37	0.81	1.16	3.57	5.29	1.75	7.38
^{80}Kr	3.15	2.59	0.95	1.31	3.53	4.70	1.70	6.08
	3.19	2.56	0.98	1.27	3.54	4.71	1.72	6.03

Contd...

Contd... Table I

NUCLEUS	PROTON OCCUPANCY				NEUTRON OCCUPANCY			
	p3/2	f5/2	p1/2	g9/2	p3/2	f5/2	p1/2	g9/2
^{81}Kr	2.92	2.76	0.92	1.40	3.52	4.95	1.70	6.82
	2.96	2.74	0.94	1.36	3.54	4.96	1.72	6.79
^{82}Kr	2.85	2.84	0.97	1.34	3.60	5.23	1.77	7.40
	2.90	2.82	0.98	1.30	3.61	5.25	1.78	7.37
^{83}Kr	2.61	2.98	0.96	1.46	3.65	5.45	1.80	8.10
	2.64	2.97	0.97	1.43	3.66	5.46	1.81	8.07
^{83}Rb	2.97	3.36	1.11	1.57	3.59	5.15	1.76	7.50
	3.00	3.34	1.12	1.54	3.61	5.16	1.77	7.47
^{84}Rb	2.84	3.44	1.13	1.59	3.67	5.41	1.81	8.10
	2.87	3.43	1.14	1.56	3.68	5.42	1.82	8.08

the time they extend their tails upto the ground state energy, we are justified in restricting to the low lying configurations.

In figures 2 (a,b,c) and 3 (a,b) we graphically present part of the information given in tables I and II. We have not been able to gather enough experimental data due to scarcity of experiments in this region. However, those available are given in table II. Comparison of the two tables shows that the 2-body interaction we have used produces proper p-orbit (l = 1) occupancy as long as the neutron number is less than 12. However, for other nuclei, calculated occupancy is much larger than the observed p-orbit occupancy. The calculated occupancy for $g_{9/2}$ orbit turns out to be fairly close to the observed values for four Selenium isotopes. The experimental $f_{5/2}$ neutron occupancy for Zn isotopes seems to be much larger than the calculated value. This may be due to the fact that the experimentally observed numbers have been obtained by considering the spectroscopic space of f-p shell only. In general the $f_{5/2}$ proton occupancy is not at all reproduced properly by the interaction used.

The calculated results do show a change of proton occupancy structure, when the number of neutrons in the spectroscopic space crosses 12. Figure 2b shows such a change for Germanium and Selenium isotopes. However, this change is not as sharp as indicated by the experimental

FIGURE 2 (a, b, c)

Proton occupancy vs neutron number for (a) $p_{3/2}$, (b) $p_{1/2}$ and (c) $g_{9/2}$ orbits of various nuclei. Notice the sharp change in structure for Ge and Se isotopes as the neutron number crosses 12.

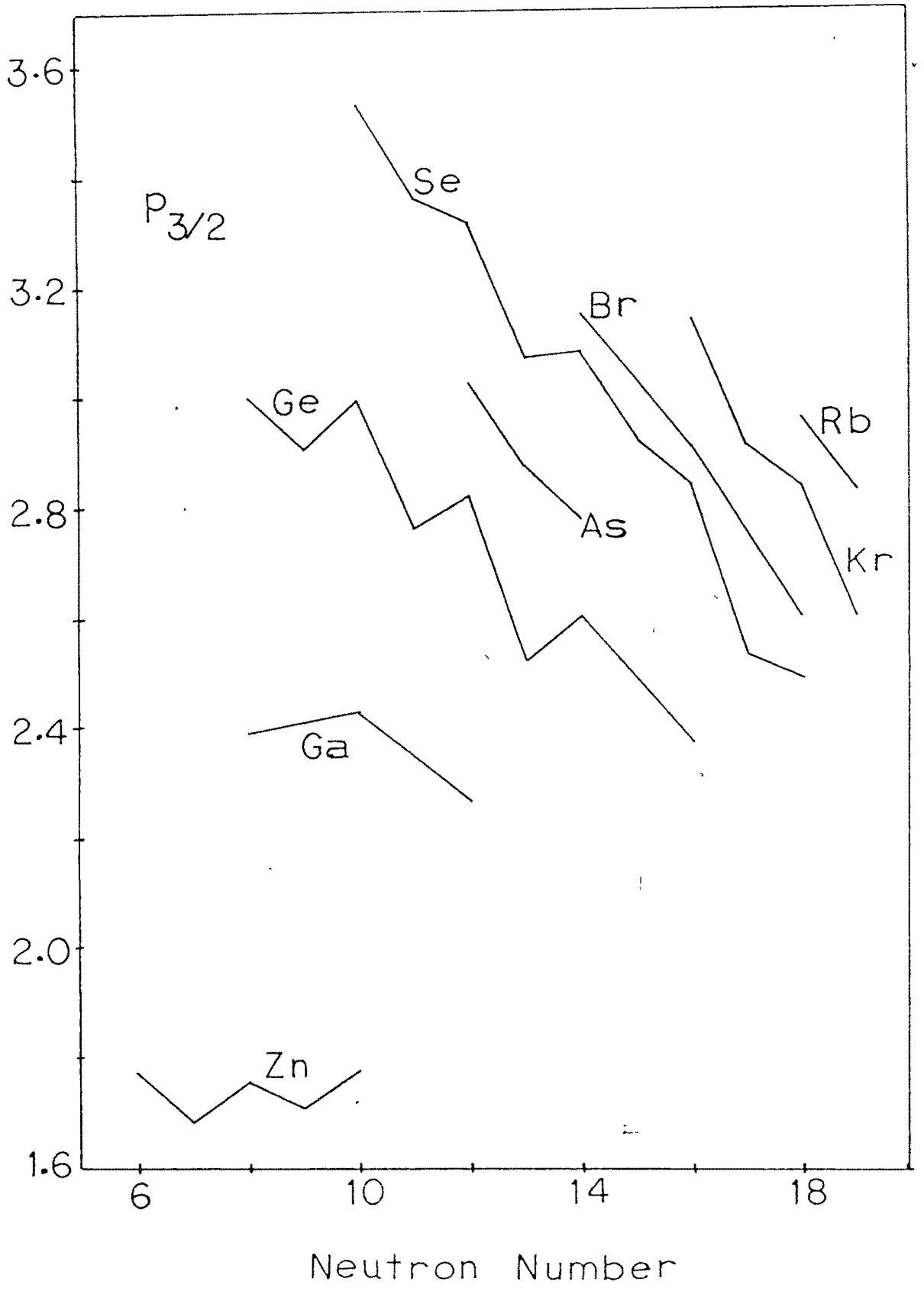

3.6
3.2
2.8
2.4
2.0
1.6
$P_{3/2}$
Se
Br
Ge
Rb
As
Kr
Ga
Zn
6
10
14
18
Neutron Number

FIGURE 2(a)

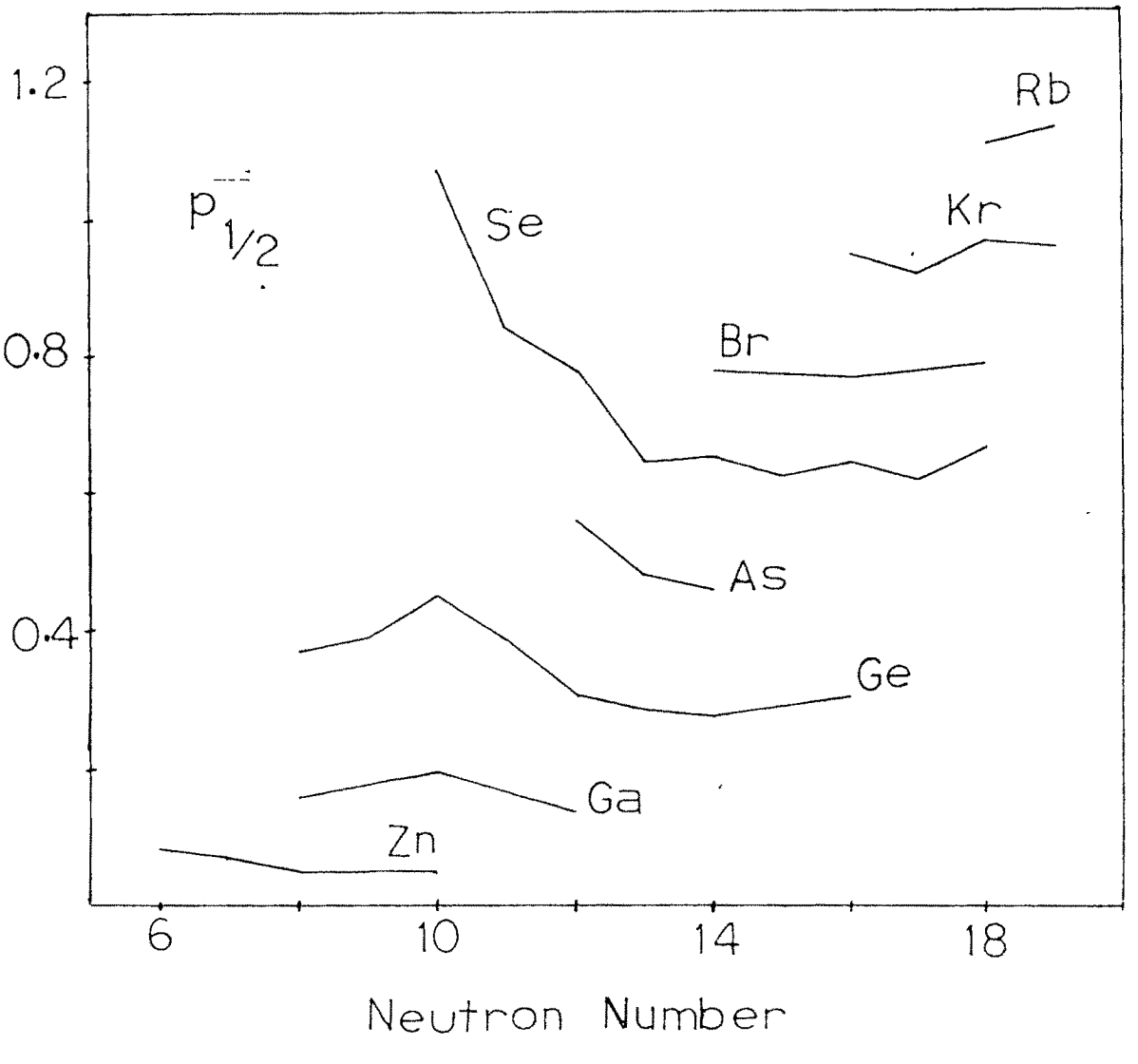


FIGURE 2(b)

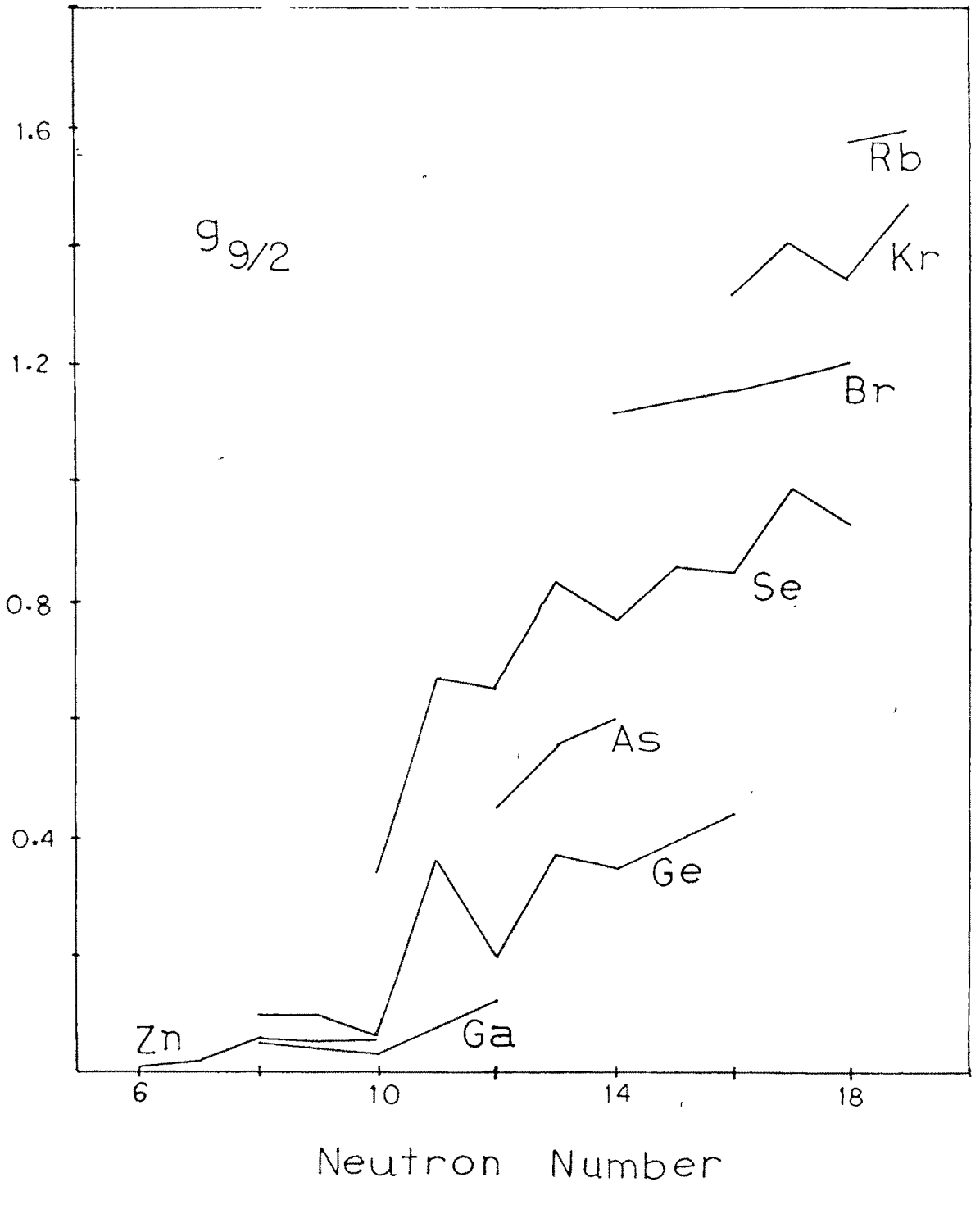


FIGURE 2(c)

FIGURE 3 (a, b)

Occupancies vs Nuclei (Neutron occupancy for Zn and Proton occupancy for other nuclei); comparison of experimental values and calculated results for (a) p and (b) $f_{5/2}$ and $g_{9/2}$ (inset) orbits. The experimental values are indicated by circles and the calculated occupancies by triangles.

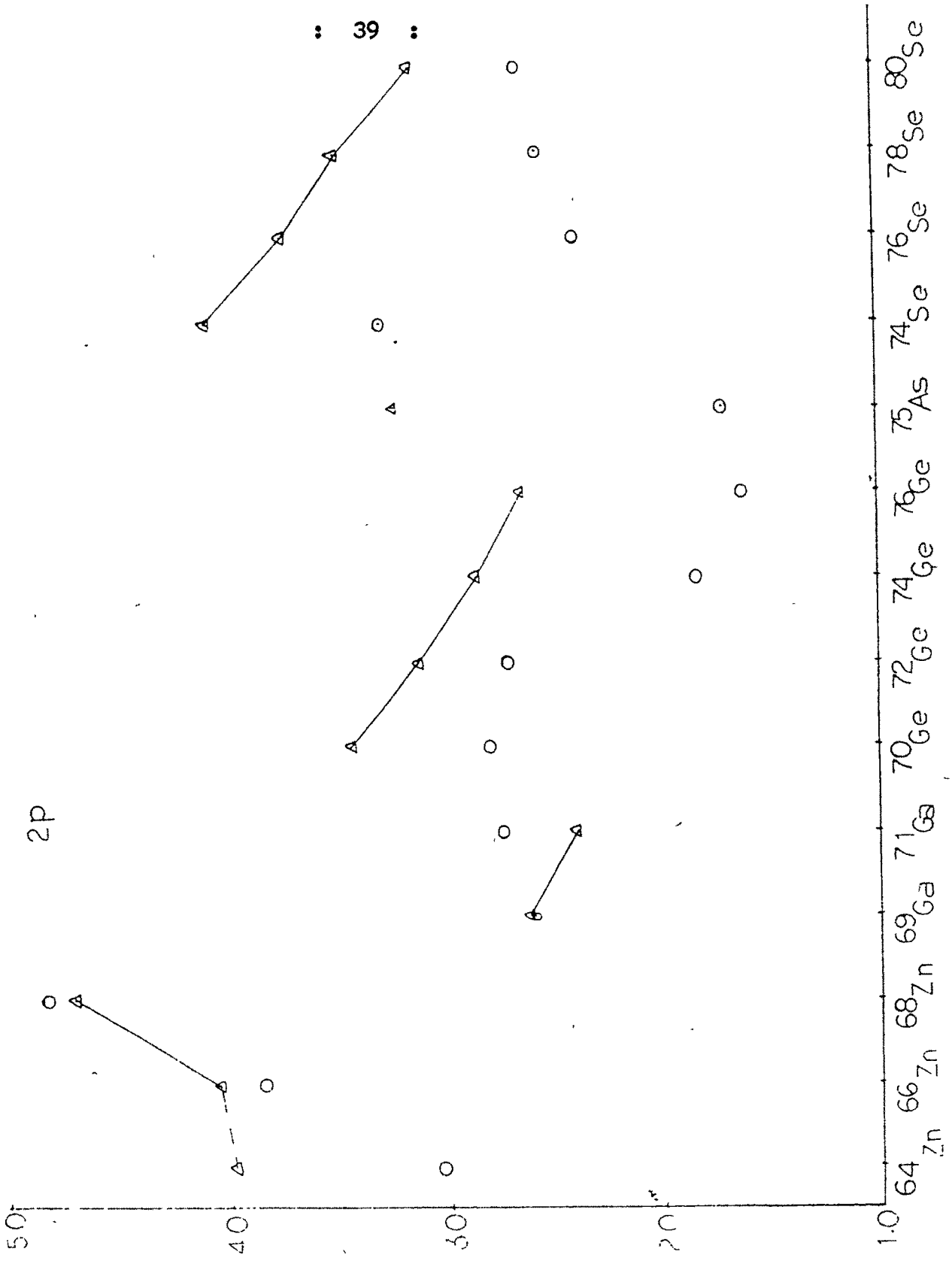

2p
50
40
30
20
1.0
64Zn
66Zn
68Zn
69Ga
71Ga
70Ge
72Ge
74Ge
76Ge
75As
74Se
76Se
78Se
80Se

FIGURE 3(a)

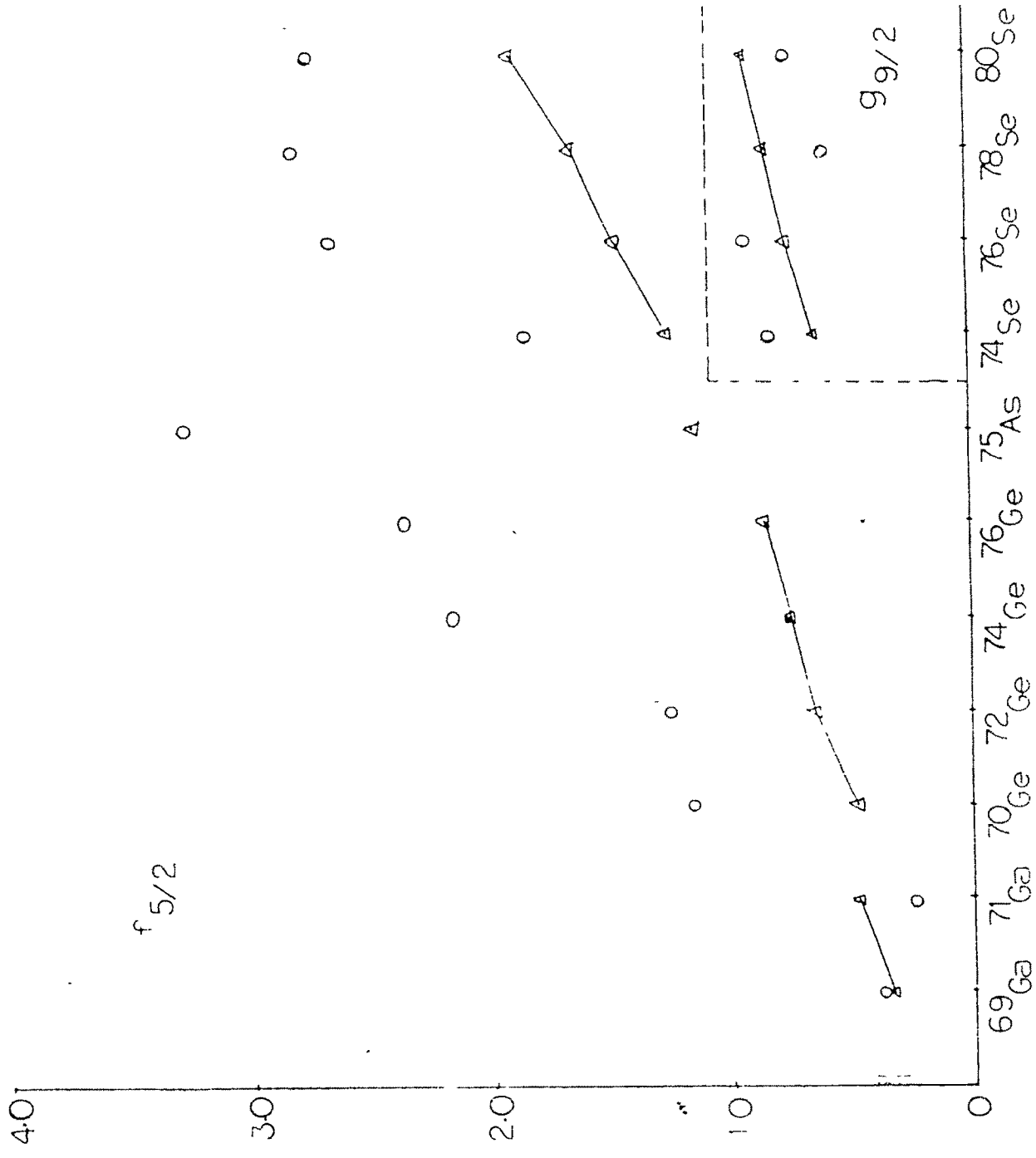

4.0
3.0
2.0
1.0
0
$f_{5/2}$
$g_{9/2}$
^{69}Ga
^{71}Ga
^{70}Ge
^{72}Ge
^{74}Ge
^{76}Ge
^{75}As
^{74}Se
^{76}Se
^{78}Se
^{80}Se

FIGURE 3(b)

TABLE - 2

Experimental ground state occupancies of f-p-g shell nuclei are given. The values for ^{64}Zn, ^{66}Zn and ^{68}Zn correspond to neutron occupancy. The rest are proton occupancies.

TABLE II : EXPERIMENTAL GROUND - STATE OCCUPANCIES

NUCLEUS	OCCUPANCIES					REFERENCE
	P3/2	p1/2	2p	f5/2	g9/2	
^{64}Zn			3.04	2.96		17
^{66}Zn			3.86	4.14		18
^{68}Zn			4.82	5.18		17
^{69}Ga			2.61	0.39		19
^{71}Ga			2.76	0.25		19
^{70}Ge			2.82	1.18		19
^{72}Ge			2.73	1.27		19
^{74}Ge			1.84	2.16		19
^{76}Ge			1.63	2.37		19
^{75}As			1.72	3.28		19
^{74}Se	2.78	0.53		1.86	0.83	20
^{76}Se	1.97	0.43		2.67	0.93	20
^{78}Se	2.25	0.32		2.82	0.61	20
^{80}Se	1.85	0.51		2.88	0.76	20

results. This failure, of the interaction used is also responsible for the poor agreement of $f_{5/2}$ orbit proton occupancies with the experimental results. Change of structure of proton occupancies is also found for $f_{5/2}$ orbits, though to a lesser extent. If the $g_{9/2}$ orbit neutron occupancy is plotted against the neutron number, it can be seen that as the number of neutrons crosses 12, there is a distinct change in the gradient of the plot for all nuclei, and the $g_{9/2}$ orbit neutron occupancy increases linearly with the number of neutrons. We also see that the $g_{9/2}$ orbit neutron occupancy is independent of the number of protons; for example the $g_{9/2}$ orbit neutron occupancies of ^{71}Ga, ^{73}Ge, ^{73}As and ^{74}Se are 3.47, 3.35, 3.34 and 3.26 respectively; and those of ^{74}Ge, ^{75}As, ^{76}Se and ^{77}Br are 4.75, 4.79, 4.73 and 4.82 respectively.

Comparing our results with those obtained by Kota et.al. (1982)[7] for fully renormalised Kuo-Brown interaction we conclude that (i) fully renormalised Kuo-Brown interaction produces a sharper change in the proton occupancy structure, and is in good agreement with the experimental results, (ii) interaction used here increases $g_{9/2}$ and $f_{5/2}$ orbit occupancies at the expense of mainly $p_{1/2}$ orbit occupancy. Increase in the $g_{9/2}$ orbit occupancy can however be attributed to the lowering of the $g_{9/2}$ orbit single particle energy by 1/2 MeV.