the worth and efficiency of public servants and the vague apprehension that at fiftyfive an officer has ordinarily well-nigh exhausted his capacity for usefulness in public affairs will not stand close scrutiny. As we have pointed out that old age in the teaching profession is less due to advancing years than to circumstances and treatment, we should certainly have no hesitation in advocating the extension of the age limit to sixty years in the first instance, in the case of professors, and if the results are satisfactory, as we are confident that they will prove to be, occasion will not be wanting for a general and more comprehensive review of the rule in its bearing on other branches of educational service as well. The importance of research in our universities and of its power to create a tradition for the country is just beginning to be recognized by the public and the only tangible way of appreciating and encouraging it is to prolong the period of the usefulness of the professors in the universities upto at least sixty years.

Nuclear Structure.

By Prof. B. Venkatesachar, M.A., F.Inst.P., and T. S. Subbaraya, B.Sc.

THE isotopic constitution of a large number of elements is now known, while the study of band spectra and hyperfine-structure of line spectra has, in a considerable number of cases, led to the determination of nuclear spins with more or less certainty. There have been a number of attempts[1] to explain the isotopic constitution. The problem of explaining the observed nuclear spin has also been attacked: S. Bryden[2] and H. E. White[3] have attempted a solution on the hypothesis that nuclear spin is due to the spin and orbital motion of the protons while the electrons in the nucleus are supposed to have lost their spin. But, as Iwanenko[4] suggested and particularly as Heisenberg[5] has shown, it is unnecessary to postulate the separate existence of electrons in the nucleus; we may assume that the nucleus consists of protons and neutrons only. Now Heisenberg has deduced that the system of two protons and two neutrons, namely, an α-particle, is very stable. Hence we are led to postulate that pairs of protons and neutrons within the nucleus combine into as many α-particles as possible, an α-particle having, of course, no spin. When this is done the number of α-particles, protons and neutrons that compose a nucleus of atomic weight N and atomic number Z can be uniquely determined. The number of α-particles is the integral part of $Z/2$, and when Z is odd there is one proton. The number of neutrons is $N-2Z$ or $N-2Z+1$ according as Z is even or odd. To take an example, O_{17}, $Z=8$ contains 4 α-particles, no proton and 1 neutron, while Cl_{37}, $Z=17$ contains 8 α-particles, 1 proton and 4 neutrons. That Pauli's principle should apply to neutrons also has been pointed out by Heisenberg[6]. Considerations of the statistics of nitrogen nuclei have led him to postulate that every neutron has a spin of $\frac{1}{2}\,h/2\pi$. The occurrence of a large nuclear spin like 9/2 in the case of a few elements while in many other cases it is small, suggests that shells of neutrons which possess orbital motion must contribute to the nuclear spin. Accordingly, we have in this work assumed that the nucleus consists of $Z/2$ α-particles, and 1 proton when Z is odd, with $N-2Z$ or $N-2Z+1$ neutrons. The α-particles have no spin, and the contribution of the neutrons to the nuclear spin is the resultant of their spin and orbital moments while the resultant moment of the nucleus is equal to that of the neutrons together with that of the single proton if present. The resultant moment of the neutrons can then be calculated exactly as the resultant j-value in the case of extranuclear electrons. We may expect that the observed spin will be that corresponding to the j-value of the deepest term. Table I shows how far this procedure leads to the observed spins.

The above table shows that in the majority of cases the observed spin corresponds to the j-value of the deepest term. In the case of V, Mn, Cu, Ga, Cd, Sb, I, Cs, Ba_{137}, La, Pr and Pb the observed i-value (nuclear spin) does not correspond to the j-value of the theoretically deepest term, but to that of one of the other

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1 W. D. Harkins, *Phys. Rev.*, **38**, 1270, 1931. H. C. Urey, *J. Am. Chem. Soc.*, **53**, 2872, 1931. J. H. Bartlett, *Nature*, **130**, 165, 1932.
2 S. D. Bryden, Jr., *Phys. Rev.*, **38**, 1989, 1931.
3 H. E. White, *Phys. Rev.*, **38**, 2078, 1931.
4 D. Iwanenko, *Nature*, **129**, 798, 1932.
5 W. Heisenberg, *Zs. f. Phys.*, **77**, 1, 1932.
6 W. Heisenberg, *Zs. f. Phys.*, **78**, 159, 1932.

TABLE I.

Nucleus	(Z) Atomic Number	No. of α-particles	No. of Protons	No. of Neutrons	Neutronic Configuration	j-values of deepest and some deep terms, l-s coupling	j-values of deepest and some deep terms, J-J coupling	Observed Spin	Calculated Spin including that of proton
H	1	—	1	—	—	—	—	$\frac{1}{2}$	$\frac{1}{2}$
He	2	1	—	—	—	—	—	0	0
Li_6	3	1	1	1	$1s^1$	$\frac{1}{2}$ ($^2S_{\frac{1}{2}}$)	$\frac{1}{2}$	0	1 or 0
Li_7	3	1	1	2	$1s^2$	0 ($^1S_0$)	0	$\frac{3}{2}$	$\frac{1}{2}$
C_{12}	6	3	—	—	—	—	—	0	0
N_{14}	7	3	1	1	$1s^1$	$\frac{1}{2}$ ($^2S_{\frac{1}{2}}$)	$\frac{1}{2}$	1	1 or 0
O_{16}	8	4	—	—	—	—	—	0	0
F	9	4	1	2	$1s^2$	0 ($^1S_0$)	0	$\frac{1}{2}$	$\frac{1}{2}$
Ne	10	5	—	—	—	—	—	0	0
Na	11	5	1	2	$1s^2$	0 ($^1S_0$)	0	$\geqslant \frac{1}{2}$	$\frac{1}{2}$
P	15	7	1	2	$1s^2$	0 ($^1S_0$)	0	$\frac{1}{2}$ or 1	$\frac{1}{2}$
Cl_{35}	17	8	1	2	$1s^2$	0 ($^1S_0$)	0	$\frac{5}{2}$	$\frac{1}{2}$
K_{39}	19	9	1	2	$1s^2$	0 ($^1S_0$)	0	$\frac{1}{2}$	$\frac{1}{2}$
Ca	20	10	—	—	—	—	—	0	0
V	23	11	1	6	$2p^2$	0, 1, 2 ($^3P_{0,1,2}$)	0; 1, 2	$\geqslant \frac{5}{2}$	$\frac{1}{2}$, $\frac{3}{2}$ or $\frac{5}{2}$
Mn	25	12	1	6	$2p^2$	0, 1, 2 ($^3P_{0,1,2}$)	0; 1, 2	$\frac{5}{2}$	$\frac{1}{2}$, $\frac{3}{2}$, or $\frac{5}{2}$
Fe	26	13	—	4	$2s^2$	0 ($^1S_0$)	0	0	0
Cu	29	14	1	6	$2p^2$	0, 1, 2 ($^3P_{0,1,2}$)	0; 1, 2	$\frac{3}{2}$	$\frac{1}{2}$, $\frac{3}{2}$ or $\frac{5}{2}$
Ga	31	15	1	8	$2p^4$	2, 1, 0 ($^3P_{2,1,0}$)	0, 2: 1, 2	$\geqslant \frac{3}{2}$ ($\frac{1}{2}$?)	$\frac{5}{2}$, $\frac{3}{2}$ or $\frac{1}{2}$
As	33	16	1	10	$2p^6$	0 ($^1S_0$)	0	$\frac{3}{2}$	$\frac{1}{2}$
Br	35	17	1	10	$2p^6$	0 ($^1S_0$)	0	$\frac{3}{2}$	$\frac{1}{2}$
Rb	37	18	1	12	$3s^2$	0 ($^1S_0$)	0	$\geqslant \frac{1}{2}$	$\frac{1}{2}$
Sr	38	19	—	12	$3s^2$	0	0	0	0

Nucleus	(Z) Atomic Number	No. of α-particles	No. of protons	No. of Neutrons	Neutron Configuration	*j*-values of deepest and some deep terms, l-s coupling	*j*-values of deepest and some deep terms, J-J coupling	Observed Spin	Calculated Spin including that of proton
Cd_{111}	48	24	—	15	$3p^3$	$\frac{1}{2}, \frac{3}{2}, \frac{1}{2}$ ($^4S_{3/2}, {}^2P_{\frac{1}{2}, 3/2}$)	$\frac{3}{2}; \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$	$\frac{1}{2}$	$\frac{3}{2}, \frac{1}{2}$ or $\frac{5}{2}$
Cd_{113}	48	24	—	17	$3p^5$	$\frac{3}{2}, \frac{1}{2}$ ($^2P_{3/2, \frac{1}{2}}$)	$1\frac{1}{2}, \frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{2}$ or $\frac{1}{2}$
In	49	24	1	18	$3p^6$	0 ($^1S_0$)	0	$\frac{1}{2}$	$\frac{1}{2}$
Sb_{121}	51	25	1	20	$4s^2$	0 ($^1S_0$)	0	(?)	$\frac{1}{2}$
Sb_{123}	51	25	1	22	$3d^2 4s^2$	$^3F_{2,3,4}\,{}^3P_{0,1,2}$	0, 2; 1, 2, 3, 4	$\frac{3}{2}$	$\frac{5}{2}, \frac{1}{2}, \frac{3}{2}$ or $\frac{9}{2}$
I	53	26	1	22	$3d^2 4s^2$	2, 3, 4; 0, 1 ($^3F_{2,3,4}\,{}^3P_{0,1,2}$)	0, 2; 1, 2, 3, 4	$\frac{9}{2}$	$\frac{5}{2}, \frac{7}{2}$ or $\frac{9}{2}$ &c.
Cs	55	27	1	24	$3d^4 4s^2$	2, 3, 4; 0, 1, 2 ($^3F_{2,3,4}\,{}^3P_{0,1,2}$)	0; 1, 2, 3, 4	$\geqslant \frac{5}{2}$	$\frac{5}{2}, \frac{3}{2}, \frac{1}{2}, \frac{7}{2}$ or $\frac{9}{2}$
Ba_{135}	56	28	—	23	$3d^3 4s^2$	$\frac{3}{2}, \frac{5}{2}, \frac{7}{2}, \frac{9}{2}$ ($^4F_{3/2, 5/2, 7/2, 9/2}$)	$\frac{3}{2}; \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$	$\frac{3}{2}$	$\frac{3}{2}$ &c.
Ba_{137}	56	28	—	25	$3d^5 4s^2$	$^6S_{5/2}, {}^4D_{\frac{1}{2}, 3/2, 5/2, 7/2}$	$\frac{5}{2}; \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$	$\frac{3}{2}$	$\frac{5}{2}$ or $\frac{1}{2}$ or $\frac{3}{2}$
La	57	28	1	26	$3d^6 4s^2$	$^5D_{4,3,2,1,0}$	0, 2, 4	$\frac{5}{2}$	$\frac{1}{2}, \frac{5}{2}$ or $\frac{9}{2}$
Pr	59	29	1	24	$3d^4 4s^2$	0,1,2,3,4 ($^5D_{0,1,2,3,4}$)	0, 2, 4	$\frac{5}{2}$	$\frac{1}{2}, \frac{5}{2}$ or $\frac{9}{2}$
Hg_{199}	80	40	—	39	$4d^1 5s^2$	$^2D_{3/2, 5/2}$	$\frac{3}{2}, \frac{5}{2}$	$\frac{1}{2}$	$\frac{3}{2}$ or $\frac{5}{2}$
Hg_{201}	80	40	—	41	$4d^3 5s^2$	$\frac{3}{2}, \frac{5}{2}, \frac{7}{2}, \frac{9}{2}$	$\frac{3}{2}, \frac{1}{2}, \frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$ or $\frac{1}{2}$
Tl	81	40	1	42	$4d^4 5s^2$	2, 3, 4; 0, 1, 2	0, 2, 4	$\frac{1}{2}$	$\frac{1}{2}$ or $\frac{3}{2}$ &c.
Pb_{207}	82	41	—	43	$4d^5 5s^2$	$^6S_{5/2}, {}^4D_{\frac{1}{2}, 3/2, 5/2, 7/2}$	$\frac{5}{2}; \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$	$\frac{1}{2}$	$\frac{5}{2}$ or $\frac{1}{2}$ &c.
Bi	83	42	1	44	$4d^6 5s^2$	$^5D_{4,3,2,1,0}$	0, 2, 4	$\frac{9}{2}$	$\frac{9}{2}, \frac{1}{2}$ or $\frac{5}{2}$

deep terms. In the case of Li_7, Cl_{35}, As, Br, and Hg_{199} the spin does not follow from the configuration assumed, but if one neutron is supposed to be in a different orbit the observed spin may be accounted for. (1s 2s, 1s 2p, $2p^5 3s$, $2p^5 3s$ and $4d^2 5s^1$ would be the configurations in the case of Li_7, Cl_{35}, As, Br and Hg_{199} respectively). Such deviations from expectation are frequently met with in extranuclear configurations.

Further evidence in support of the structure assumed for the nuclei can be obtained from the known atomic weights of the lightest, heaviest and most abundant isotopes of the elements. In Table II the neutron configurations corresponding to these are given for all the elements for which data are available. This table shows that the most abundant isotope is in a majority of cases that which has a closed shell or sub-shell of neutrons. In those instances in which this is not the case, the neutron configuration of the most abundant isotope is seen to be one which may be expected to be very stable from the analogy of extra-nuclear electronic configurations.

TABLE II.

Atomic Number	Element	Lightest Isotope	Neutron Configuration of same	Heaviest Isotope	Neutron Configuration of same	Most abundant Isotope	Neutron Configuration of same	Element	Lightest Isotope	Neutron Configuration of same	Heaviest Isotope	Neutron Configuration of same	Most abundant Isotope	Neutron Configuration of same	Atomic Number
1	H	1	—	2	$1s^1$	1	—	Kr	78	$2p^2$	86	$3p^2$	84	$3s^2$	36
2	He					4	—	Rb	85	$3s^2$	87	$3p^2$	85	$3s^2$	37
3	Li	6	$1s^1$			7	$1s^2$	Sr	86	$2p^6$	88	$3s^2$	88	$3s^2$	38
4	Be					9	$1s^1$	Y					89	$3s^2$	39
5	B	10	$1s^1$			11	$1s^2$	Zr	90	$2p^6$	96	$3p^4$	90	$2p^6$	40
6	C	12	—	13	$1s^1$	12	—	Mo	92	$2p^4$	100	$3p^4$	98	$3p^2$	42
7	N	14	$1s^1$	15	$1s^2$	14	$1s^1$	Ru	96	$2p^4$	104	$3p^4$	102	$3p^2$	44
8	O	16	—	18	$1s^2$	16	—	Ag	107	$3p^2$	109	$3p^4$	107	$3p^2$	47
9	F					19	$1s^2$	Cd	110	$3p^2$	116	$4s^2$	114	$3p^6$	48
10	Ne	20	—	22	$1s^2$	20	—	In					115	$3p^6$	49
11	Na					23	$1s^2$	Sn	112	$3s^2$	124	$3d^4 4s^2$	120	$4s^2$	50
12	Mg	24	—	26	$1s^2$	24	—	Sb	121	$4s^2$	123	$3d^2 4s^2$	121	$4s^2$	51
13	Al					27	$1s^2$	Te	122	$3p^6$	130	$3d^6 4s^2$	130	$3d^6 4s^2$	52
								I					127	$3d^2 4s^2$	53
14	Si	28	—	30	$1s^2$	28	—	?X	124	$3p^4$	136	$3d^8 4s^2$	129	$3d^1 4s^2$	54
15	P					31	$1s^2$	Cs					133	$3d^4 4s^2$	55
16	S	32	—	34	$1s^2$	32	—	Ba	135	$3d^2 4s^2$	138	$3d^6 4s^2$	138	$3d^6 4s^2$	56
17	Cl	35	$1s^2$	37	$2s^2$	35	$1s^2$	La					139	$3d^6 4s^2$	57
18	A	36	—	40	$2s^2$	40	$2s^2$	Ce	140	$3d^4 4s^2$	142	$3d^6 4s^2$	140	$3d^4 4s^2$	58
19	K	39	$1s^2$	41	$2s^2$	39	$1s^2$	Pr					141	$3d^4 4s^2$	59
20	Ca	40	—	44	$2s^2$	40	—	Nd	142	$3d^2 4s^2$	146	$3d^6 4s^2$	142	$3d^2 4s^2$	60
21	Sc					45	$2s^2$	W	182	$4p^4$	186	$5s^2$	184	$4p^6$	74
22	Ti					48	$2s^2$	Re	185	$4p^6$	187	$5s^2$	187	$5s^2$	75
23	V					51	$2p^2$	Os	186	$4p^4$	192	$4d^2 5s^2$	192	$4d^2 5s^2$	76
24	Cr	50	$1s^2$	54	$2p^2$	52	$2s^2$	Hg	196	$4p^6$	204	$4d^6 5s^2$	202	$4d^4 5s^2$	80
25	Mn					55	$2p^2$	Tl	203	$4d^4 5s^2$	205	$4d^6 5s^2$	203	$4d^4 5s^2$	81
26	Fe	54	$1s^2$	56	$2s^2$	56	$2s^2$	Pb	206	$4d^4 5s^2$	208	$4d^6 5s^2$	208	$4d^6 5s^2$	82
27	Co					59	$2p^2$	Bi					209	$4d^6 5s^2$	83
28	Ni	58	$1s^2$	60	$2s^2$	58	$1s^2$	Po	210	$4d^4 5s^2$	218	$5p^2$	210	$4d^4 5s^2$	84
								Ra Em	219	$4d^9 5s^2$	222	$5p^2$	222	$5p^2$	86
29	Cu	63	$2p^2$	65	$2p^4$	63	$2p^2$	Ra	223	$4d^9 5s^2$	228	$5p^4$	226	$5p^2$	88
30	Zn	64	$2s^2$	70	$2p^6$	64	$2s^2$	Ac	227	$5p^2$	228	$5p^3$	227	$5p^2$	89
31	Ga	69	$2p^4$	71	$2p^6$	69	$2p^4$	Th	227	$4d^9 5s^2$	234	$5p^6$	232	$5p^4$	90
32	Ge	70	$2p^2$	77	$3s^1$	74	$2p^6$	Pa	231	$5p^2$	234	$5p^5$	231	$5p^2$	91
33	As					75	$2p^6$	U	234	$5p^2$	238	$5p^6$	238	$5p^6$	92
34	Se	74	$2p^2$	82	$3p^2$	80	$3s^2$								
35	Br	79	$2p^6$	81	$3s^2$	79	$2p^6$								

It will also be seen that similar neutron configurations give rise to the most abundant isotope irrespective of the total quantum number of the neutron shells. Thus $2p^2$, $3p^2$ and $5p^2$ occur equally often; so also $2p^4$ and $5p^4$ occur once. $3d^4 4s^2$ and $4d^4 5s^2$ occur the same number of times, while $3d^6 4s^2$ and $4d^6 5s^2$ also appear almost equally frequent. If we compare the relative abundance of the elements from Ca to Ni we find that the elements having the electronic configurations d^2s^2, d^4s^2 and d^6s^2 are almost equally abundant but for the extraordinary abundance of Fe. So also the neutronic configurations d^2s^2, d^4s^2 and d^6s^2 equally often represent most abundant isotopes. All these regularities show that the tentative scheme here put forward represents one aspect of reality at least and leads us to hope that we may be on the right track. We have not tried to emphasize the regularities exhibited by the lightest and heaviest isotopes because we cannot here regard the present data as final. According to the scheme here put forward X_{129} cannot be expected to be the most abundant isotope of Xenon. X_{132} is nearly as abundant as X_{129} and has a stable configuration ($3d^4 4s^2$). That there is some difficulty with regard to this element is also clear from the fact that the chemical atomic weight differs from that calculated from the relative abundance of the isotopes. In the case of light elements up to Oxygen, the configuration of 1 extra neutron and 1 proton seems to be stabler than that of 2 neutrons forming a closed s-shell. Thus although Li_7 is more abundant than Li_6, considerations of its spin show that its neutron configuration cannot be $1s^2$. In the case of Be, the one neutron cannot be very stable. Possibly this has something to do with the fact that the first discovery of the neutron was made by bombarding Be by α-rays. It is also very interesting to note that the regularity exhibited by the radioactive elements and their isotopes is similar to that shown by elements preceding them.

The Concept of Causality.

THE above is the title of the Seventeenth Guthrie Lecture delivered by Prof. Max Planck before the London Physical Society on the 17th June. Recent advances in theoretical physics have impelled physicists to examine the concept of causality and its position in modern physics. In classical physics the existence of a causal relation was looked upon as a truism. Max Planck considers in his very interesting and thought-provoking address whether the position of the law of causality has been materially altered by quantum mechanics. The Professor starts by defining a causal link. "At the outset," he says, "we agree that in speaking of a causal link between two successive events we mean a certain connection, subject to law, between the two events of which the earlier event is called the cause, the later one the effect"; and again "an event is causally conditioned if it can be predicted with certainty". Starting from this definition he makes a careful examination of the concept in the light of recent advances in Physics and comes to the conclusion that "the world picture in quantum physics is governed by the same rigorous determinism which rules classical physics". One of the most interesting contributions to the enquiry is the way he tries to solve the problem by postulating an ideal mind. The reliability of any weather forecast depends on the knowledge of the meteorologist who predicts; the more knowledge he possesses of the atmospheric and other conditions of to-day the more reliable will be his predictions of to-morrow. Extrapolating, we may say that "an ideal mind, apprehending everywhere all the physical occurrences of to-day in their minutest points, should be able to predict with absolute accuracy the weather of to-morrow in all its details." This may be extended to other physical events.

Finally, "the law of causality is neither right nor wrong, it can be neither generally proved nor generally disproved. It is rather a heuristic principle, a sign-post (and to my mind the most valuable sign-post we possess) to guide us in the motley confusion of events and to show us the direction in which scientific research must advance in order to attain fruitful results. As the law of causality immediately seizes the awakening soul of the child and causes him indefatigably to ask "Why?" so it accompanies the investigator through his whole life and incessantly sets him new problems. For science does not mean contemplative rest in possession of sure knowledge, it means untiring work and steadily advancing development."