to NAD, or it may interfere with the utilization of NAD and vitamin K in cellular oxidations (*10*). If results with these microbes should apply to man, thalidomide might interfere with cellular oxidations during morphogenesis and cause abnormalities (*4, 5*). It is of interest to note that thalidomide toxicity was not reversed by riboflavin nor folic acid in the protozoan test system, although deficiencies of these two vitamins have been implicated in causing fetal malformations (*5*).

Robertson has described the development of polyneuritis and glossitis upon prolonged therapy with large doses of thalidomide in humans (*3*). These effects were controlled by the prophylactic use of vitamin B-complex. Interestingly, chick embryos injected with nicotinic acid antagonists had a high incidence of rumpleness, ectrodactylism, and ectromelia. Nicotinamide protected the embryo against these defects (*1*), and are in agreement with our results.

These investigations demonstrate the usefulness of protozoa for rapid, sensitive, and inexpensive evaluation of potential drug toxicity. Coupled with animal and clinical studies, a protozoan test system may prove useful for screening drugs (*11, 12*).

OSCAR FRANK, HERMAN BAKER,
HERMAN ZIFFER, SHELDON AARONSON,
S. H. HUTNER, C. M. LEEVY
*Seton Hall College of Medicine,
Jersey City, New Jersey,* and
Roosevelt Hospital and *Haskins
Laboratories, New York*

References and Notes

1. W. Landauer, *J. Exptl. Zool.* **136**, 509 (1957).
2. W. Lenz, *Lancet* **1**, 45 (1962).
3. W. F. Robertson, *Brit. Med. J.* **1**, 792 (1962).
4. H. B. Taussig, *J. Am. Med. Assoc.* **180**, 1106 (1962).
5. I. M. Leck and E. L. M. Millar, *Brit. Med. J.* **1**, 16 (1962).
6. H. Baker, O. Frank, S. H. Hutner, S. Aaronson, H. Ziffer, H. Sobotka, *Experientia* **18**, 224 (1962).
7. H. Baker, O. Frank, I. Pasher, H. Ziffer, S. H. Hutner, H. Sobotka, *Proc. Soc. Exptl. Biol. Med.* **107**, 965 (1961).
8. S. Aaronson, B. Bensky, M. Shifrine, H. Baker, *Proc. Soc. Exptl. Biol. Med.* **109**, 130 (1962).
9. H. Baker and H. Sobotka, in *Advances in Clinical Chem.*, H. Sobotka and C. P. Stewart, Eds. (Academic Press, New York, 1962), vol. 5, p. 273.
10. C. Martius, in *Ciba Foundation Symposium, Regulation of Cell Metabolism*, G. E. W. Wolstenholme and C. M. O'Connor, Eds. (Little, Brown, Boston, 1959), p. 194.
11. I. S. Johnson, P. J. Simpson, J. C. Cline, *Cancer Res.* **22**, 617 (1962).
12. Aided by grants from the N.I.H., the National Vitamin Foundation, and the Mental Health Association. We thank Dr. F. J. Murray of the Wm. S. Merrell Co. for thalidomide. Presented before the 35th annual meeting of the Central Society for Clinical Research, Chicago, Ill.

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Ytterbium: Transition at High Pressure from Face-Centered Cubic to Body-Centered Cubic Structure

Abstract. *Pressure of 40,000 atmospheres at 25°C induces a phase transformation in ytterbium metal; the face-centered cubic structure changes to body-centered cubic. The radius of the atom changes from 1.82 to 1.75 Å. At the same time the atom's volume decreases by 11 percent and the volume, observed macroscopically, decreases 3.2 percent.*

We present here data on a pressure-induced phase transformation from a close-packed structure to a nonclose-packed arrangement of atoms. When identical spherical atoms are stacked in honeycomb-like layers in which every atom touches six neighbors in its own layer and, in addition, touches three atoms in the layer above and also three atoms in the layer below, the total space (including voids between the spheres) occupied by a large number of atoms will be at a minimum. Such arrangements in which each atom touches 12 adjacent atoms are called closest-packed structures. Identical spherical atoms arranged in any other fashion will occupy a larger total volume.

At room temperature and pressure atoms of the metal ytterbium (Yb) are arranged in a closest-packed structure known as face-centered cubic (FCC). The FCC structure is shown in Fig. 1 by the conventional "unit cell" where only the centers of the atoms (dots) are shown. A basic dimension of the FCC unit cell is the length of the cube edge which, for Yb, is 5.481 Å at 25°C, and 1 atm. This corresponds to a radius of 1.940 Å for the metallic Yb atom. We have discovered a phase transformation occurring in Yb at 25°C, 40,000 atm, wherein the FCC phase transforms into a body-centered cubic (BCC) phase (*1*). The BCC unit cell is also shown in Fig. 1. In this structure each atom touches eight surrounding atoms.

The nature of the transition was elucidated with the aid of a high-pressure x-ray diffraction apparatus which consists of a tetrahedral anvil press (2) to which x-ray goniometers have been attached. Primary x-rays are directed into the specimen (contained in a lithium hydride-amorphous boron tetrahedron) through a tiny axial hole in one of the triangular anvil faces. Diffracted x-rays ("powder" pattern) exit through gaskets formed between the sloping anvil shoulders and then, after passing through collimating slits, pass into the counter tubes.

The fraction of total space occupied by voids (spaces between the spheres) in FCC-closest packing is 26 percent, whereas the fraction of space taken up by voids in the non-closest-packed BCC structure is 32 percent. Offhand, therefore, it would appear impossible for pressure to affect a transformation from the FCC to the BCC structure. Unit-cell data obtained from the tetrahedral x-ray press, however, make it possible to explain what has taken place. Calculation of the radii of the atoms from these data gives $r = 1.82$ Å for the FCC modification at 40,000 atmospheres and $r = 1.75$ Å for the BCC form at the same pressure. Calculation of volume changes from these values for the radii shows that an individual, spherical Yb atom shrinks in volume by 11 percent during the transition from FCC to BCC. This is even more interesting in view of the fact that the overall, macroscopic volume change at the transition is only 3.2 percent. Of course, the change to BCC structure is responsible for the greater decrease in the volume of the individual atoms.

A look at a chart of the values for the metallic radii plotted against the

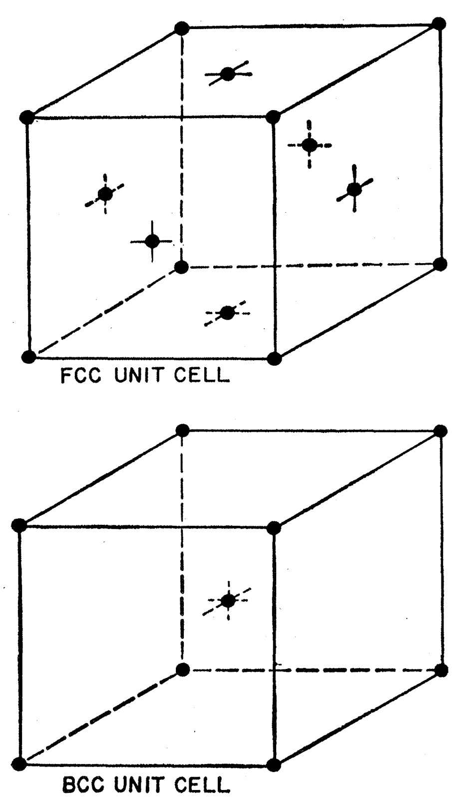

Fig. 1. Face-centered cubic (FCC) and body-centered cubic (BCC) space lattices.

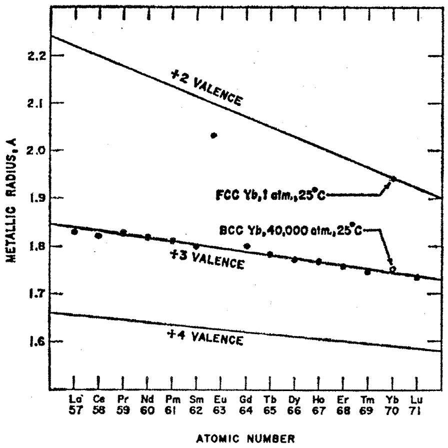

Fig. 2. Values of metallic radii of rare earths plotted against atomic numbers.

atomic numbers for the rare-earth atoms (Fig. 2) throws additional light on the nature of the transition. Note that most of the values for the radii of the rare-earth atoms fall very close to a straight line which represents a valence of +3. Europium (Eu) and Yb having anomalously large radii, deviate significantly from the line. The valence of Yb is +2. However, the value of the metallic radius of BCC Yb (1.75 Å) at 40,000 atm is very close to the line where the valence is +3. Thus under the conditions of high pressure Yb has become a "normal" rare-earth metal! The electronic structure of the rare-earth elements is unique in that, as the charge on the nucleus increases in passing from element of atomic number 58 to atomic number 71, the balancing electrons fill in the inner, incomplete $4f$ subshell. The probable electronic configuration for the "outermost" shell of Yb is $4f^{14}\ 5d^{0}\ 6s^{2}$—a situation in which the $4f$ and $6s$ levels are completely filled and the $5d$ is empty. Since this is the case, it seems logical to conclude from our data on atomic radii that the transition from FCC to BCC in Yb is "electronic" in nature and is accompanied by the promotion of a $4f$ electron to the $5d$ level. In the solid, the two $6s$ electrons and the single $5d$ electron would enter the valence band; thus a valance of +3 would be the result.

When an atom changes its valence, it becomes a "different" atom with different bonding properties. Consequently, after a valence change the crystal structure may be entirely different from that of the untransformed material. We anticipate that additional high-pressure x-ray diffraction research will show that the electronic transition from close-packed to non-close-packed structure will be found to occur in many substances if they are subjected to sufficiently high pressures.

H. TRACY HALL
J. DEAN BARNETT
LEO MERRILL
Departments of Chemistry and Physics, Brigham Young University, Provo, Utah

References and Notes

1. This is undoubtedly the same transition as the electrical-resistance transition previously reported to occur at 60,000 atm. P. W. Bridgman, *Proc. Amer. Arts. Sci.* **83**, 1 (1954).
2. H. T. Hall, *Rev. Sci. Instr.* **29**, 267 (1958).
3. Supported by U.S. Army Research Office, National Science Foundation, and Alfred P. Sloan Foundation grants.

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Discrimination of Successiveness: A Test of a Model of Attention

Abstract. *Interpreting attention as a periodic phenomenon, we show its relevance to discriminating the successiveness of signals presented to separate sense modalities. Experiments confirm the expected linear relation between the probability of discriminating pairs of successive from pairs of simultaneous signals and make it possible to infer the period of attention.*

A study was made to develop and test the hypothesis that the sensory systems consist of independent channels which can be attended only one at a time. Attention is conceived of as a periodic phenomenon. The period of attention, M, is assumed to be a fixed value. When attention is directed at one channel it may be signaled to switch to a second channel by an input arriving over the second channel. Attention can switch only at the end of a period, although it may remain on a channel for multiples of M. The periodicity of attention is internally controlled; it is independent of sensory input.

Along with these assumptions, which already imply that some inputs may have some effects when they are not attended, it can be asserted further that the temporal ordering of input signals in experience or behavior, or both, will be influenced by the switching order of attention. Let us consider vision (V) and audition (A) and assume that they, at least, cannot both be attended during a single period of attention. If attention is directed at V and inputs arrive simultaneously in the "display areas" of V and A, they will be coded in order VA—that is, in adjacent periods of attention, even when the individual asserts that the signals were perceived simultaneously. To be discriminated as successive they would have to arrive in the display areas sufficiently separated in time to be attended in nonadjacent periods. The probability that this will occur will depend upon the degree of difference in time of arrival of the inputs in relation to M. The symbol t refers to the difference in time of arrival of the V and A inputs in the display areas. If, under ideal conditions, attention switches reliably after the first input is scanned, then the probability that the inputs will be scanned in nonadjacent periods will be a linear function of t. The probability will be zero when $t = 0$ and will be unity when $t = M$, under the condition that attention is directed initially to the channel over which the first input arrives. If attention is directed to the channel of the second input when the first arrives, then for all values of t between zero and M the inputs will be scanned in adjacent periods.

The difference in times of arrival at the receptor surface (T) for auditory and visual stimuli should not be the same as the difference in times of arrival at the display areas (t), since conduction times differ for different modalities. There is some non-zero value of T, called x, for which $t = 0$. Positive values of T mean that the visual stimulus precedes the auditory, and negative values mean that the auditory precedes. Many lines of evidence suggest that conduction is more rapid in the auditory system, at least for stimuli of moderate intensity. Hence, for the inputs to arrive simultaneously in the display areas the light stimulus should precede the sound—that is, x would be expected to be positive.

Measurement of the probabilities of discriminating successiveness is accomplished by presenting two light-sound pairs on each trial and requiring the subject to indicate the pair for which the likelihood is greatest that the light preceded the sound. In one pair, the standard pair, T is the same for all trials and is set at a value less than x by an amount less than M. Since attention is directed to light, the signals should be attended always in adjacent periods for the standard pair. The other pair on each trial, the variable, may have any of several values of T greater than x. Under these conditions the