ness? What is the relation between alpha, movement, and consciousness as measured by immediate responses and subsequent recall? Table 2 shows the percentage reported heard and the percentage recalled of items that occurred during movements. Since cortical potentials were partially or completely obscured by movement artifacts, it was impossible to assign these items to specific sleep levels. However, the presence or absence of alpha in the vicinity could be detected. When alpha rhythms were found during or at the end of the movement, hearing and recalling tended to be high; when no alpha was observed, subjects heard and recalled practically nothing. These results corresponded with those of alpha and nonalpha periods without movement. Thus, two conclusions can be drawn: (i) it is possible to have movement without the apparent presence of the waking alpha; (ii) the presence of alpha and not movement is the critical criterion for conscious responses.

Table 2. Items heard and recalled with and without movement and alpha frequencies.

| | Reported heard (%) | | Recalled correctly (%) | |
|---|---|---|---|---|
| | Alpha | Nonalpha | Alpha | Nonalpha |
| Move | 57 | 8 | 35 | 2 |
| No movement* | 63 | 3 | 56 | 3 |

* Where cortical patterns were not obscured by movement artifacts, the alpha category corresponds to levels O, A +, A, A − and the nonalpha category to levels B, C, D, and E, including all stimulus effects.

## Application

A systematic change has been found in the electroencephalographic patterns of alpha-dominated subjects as they go from a state of relaxed wakefulness to deep sleep.

The relation of alpha to wakefulness and delta to sleep and the probability of responding and recalling only when alpha is present negates popular contentions that learning during sleep is possible. This psychological problem has been discussed more thoroughly in other papers (*7, 9, 14*).

One important practical application of the information in this paper is in the study of factors affecting sleep and rest. In addition to the more classical measure of time (or length of sleep), electroencephalographic patterns can provide a means of continuously measuring depth of sleep without disturbing the subject. Using a two-dimensional measure—length and depth—is a more sophisticated approach to certain problems of sleep and rest and can be expected to yield more satisfactory conclusions. Such problems have important implications for both military and civilian use.

### References and Notes


1. C. W. Darrow, *Psychol. Rev.* 54, 157 (1947); D. B. Lindsley, *EEG and Clin. Neurophysiol.* 4, 443 (1952).
2. E. D. Adrian, F. Bremer, H. H. Jasper, Eds., *Brain Mechanisms and Consciousness* (Blackwell, Oxford, 1954). A general discussion of mechanisms of EEG, consciousness, and sleep can be found in this collection of papers from a UNESCO Laurentian symposium held in Quebec, Canada, August 1953.
3. Delta waves are relatively high amplitude waves, having wave periods greater than 0.25 second.
4. Alpha rhythm is the 8–13 cyclical activity recorded predominately from the occipital region.
5. H. Blake, R. W. Gerard, N. Kleitman, *J. Neurophysiol.* 2, 48 (1939).
6. A. L. Loomis, E. N. Harvey, G. Hobart, *J. Exptl. Psychol.* 21, 127 (1937).
7. A more detailed description of the materials and methods can be found in the report by C. W. Simon and W. H. Emmons, *J. Exptl. Psychol.* 51, 89 (1956).
8. L. E. Travis, *ibid.* 21, 302 (1937).
9. In a second study by W. H. Emmons and C. W. Simon, *Am. J. Psychol.* 69, 76 (1956), between 19 and 82 repetitions of ten common one-syllable nouns were played when subjects were in levels B to E. On awakening, these subjects could not pick the list of training words from a list of 50 any better than a control group could, and no better than they themselves chose another unpracticed list of ten nouns which had been selected randomly from the list of 50 nouns.
10. P. A. Davis, *J. Neurophysiol.* 2, 494 (1939).
11. R. Jung, in a chapter, "Correlation of bioelectrical and autonomic phenomena with alterations of consciousness and arousal in man" (*2*, p. 317) noted that a complex verbal command given during sleep was remembered approximately only if there was a change in the EEG to a waking state.
12. A. L. Loomis, E. N. Harvey, G. A. Hobart, *J. Neurophysiol.* 1, 413 (1933).
13. G. Moruzzi and H. W. Magoun, *EEG and Clin. Neurophysiol.* 1, 455 (1949).
14. C. W. Simon and W. H. Emmons, *Psychol. Bull.* 52, 328 (1955).


# F. Soddy, Interpreter of Atomic Structure

Frederick Soddy is best known as Ernest Rutherford's young coworker at McGill University at the beginning of this century, when the disintegration theory of radioactivity was put forward, and as the young lecturer at Glasgow who saw most clearly that the heaviest chemical elements have isotopes. Some who knew him in his later life knew him only as one who held heterodox views on economics and politics and as a "crank" on the subject of monetary policy. Those who knew him personally knew him as a fine specimen of English manhood, a good husband, a generous helper of those less well off than himself, a lover of truth (including unpleasant truth) with an original outlook on many of life's problems. He was too shy or too aloof to shine in society and much too earnest and serious minded to suffer anything approaching a fool gladly.

In appearance Soddy was a fairhaired, 6-foot Saxon type with a fine head and regular features. His voice was high-pitched and very southern English in accent. He was born on the south coast at Eastbourne in 1877, went to an English public school there and then to Oxford, where he graduated with first-class honors in chemistry in 1898, thence to McGill till 1902. After a year in London with Sir William Ramsay (during which time he showed that Rutherford's alpha particle from radium was an atom of helium) he became a lecturer at Glasgow, where he remained for 10 years till he became a professor at Aberdeen. In 1919, World War I being over, he went to Oxford as a professor and remained there till 1936, retiring at 59 to Brighton on the south coast 15 miles from where he was born. And there he died and was buried last September.

It was Soddy's misfortune that he never had a wide circle of friends among his fellow-scientists or was *persona grata* with the large staff of fellows and lecturers in chemistry at Oxford. If blame there must be for this, it may be ascribed to his upbringing. He was the youngest of seven sons of a London businessman resident in Eastbourne who was a keen nonconformist in religion. He lost his mother before he was 2 years old. A stern upbringing in a house of older brothers, housekeepers, and maids turned him into a solitary, an "original," and the doctrine that truth is the chief thing that matters in life tended to make him too serious and to look on life's problems with too painful an eye. Much of his habitual seriousness and earnestness of purpose was modified when he married Winifred, the daughter of the industrialist Sir George Beilby, F.R.S., in 1908. She made him a charming wife. She was the best type of hostess. She and her husband always got on excellently together. However blasting might be Soddy's invective against persons or things at times, there was never anything of that between the married pair. When she died in 1936 Soddy immediately made plans for resigning his chair and leaving Oxford, so heartbroken was he. They had no children.

In 1900, Rutherford at 29 in the physics department of McGill and Soddy at 23 in the chemistry department were admirably placed for bringing light into the darkness that enshrouded the subject of radioactivity then. The Curies and other workers on radium and thorium had really no idea what was taking place. Rutherford and Soddy, by their joint work and their remarkable insight, soon showed that what was occurring among the very heaviest of the elements was a spontaneous transformation of one element into another, a change, moreover, that could not be modified in any way by any physical or chemical method then available. These heavy elements lacked no properties that other elements possessed; they possessed in addition this remarkable and exciting property of radioactivity. Although Rutherford was the greater man of the two, as is shown by his subsequent work, there is no doubt that equal credit must be given to Soddy for this discovery.

Soddy's second big discovery was the existence and importance of isotopes among the radioactive elements; it came in 1913. All elements above mercury in the periodic classification are radioactive, but there are only 12 places for them in the classification. The researches of many people had shown, however, by 1913 that there were 40 or 50 different radioactive elements. Soddy showed clearly that all of these, as regards their chemical properties, could be properly placed in ten of the 12 places available. Those positioned by their chemical properties in one particular place of the classification were appropriately dubbed isotopes by him.

In later life and especially during his second Oxford period, when he was professor of inorganic and physical chemistry and fellow of Exeter College, Soddy turned his attention more and more to economic problems and made no further big discoveries in chemistry. The lessons of the great war of 1914–19 were, of course, partly responsible for this change. Its waste, its futility, and its hatreds angered him. He began to believe that the scientist ought to contribute more to the body politic than his discoveries, important though these undoubtedly are. He felt that the future is more worth working for than the present, because there is so much more of it. He felt, too, that, if science could only get going properly, the miserable poverty that assailed so many of us in Europe could be easily overcome.

Like Emerson he realized that all the good things on the bread-and-butter side of life are on the highway. The difficulty is to get them into the cottage homes at a reasonable cost. Nature and the factory —so far advanced was applied science— could get everything made at reasonable, nay at trifling, cost. The great hindrance to this, according to Soddy, was the monetary policy of England and other countries. It and the banks and the middleman were robbing all of us of quite half the benefits that science could easily give us. He believed that salvation lay in schemes like the Douglas scheme or Social Credit.

His fanatical devotion to schemes of this sort, derided by the orthodox economists, and exposed by the logician, was surprising to many who knew him first as a pioneer in chemical science and the winner of a Nobel prize, and they were shocked—many of them—when he referred to our monetary system as a private, upstart, and frustrating affair, which was a hell's brew at bottom. No doubt, he exaggerated when he described banks as morally no better than disorderly houses or gambling hells. He saw the Royal Society of London—surely one of the goodliest societies on earth—as an unofficial part of the English Civil Service, concerned more with the knowledge that preserved or strengthened the *status quo* of society than with following truth wherever it may lead us. Three of the books he wrote on these subjects were *Cartesian Economics* (1922), *Wealth, Virtual Wealth and Debt* (1926), and *The Arch-Enemy of Economic Freedom* (1943).

Although Soddy had not the wide popularity of a Ramsay or a Rutherford, those who knew him well were very fond of him. To them he showed his best side. He was on occasion generosity itself, and many of his pupils can bless him for the helping hand he gave them when finance or fortune was at a low ebb.

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