

## Highly Cited Articles. 38. Physics and Chemistry Papers Published in the 1950s.

Earlier this year we presented and discussed three lists of the classic papers of the 1940s: one for biochemistry,<sup>1</sup> one for biomedicine,<sup>2</sup> and one for physics, chemistry, and mathematics.<sup>3</sup> Now we are moving on to the next decade. The list of highly cited physics and chemistry papers which follows is the first of three groups of classic papers published from 1950 to 1959. Later on we will list the biochemical classics and the biological, medical, and behavioral classics of the 1950s.

Overall, the 41 articles listed in Figure 1 are a remarkable group. During the period from 1961 to 1975, each was cited more than 500 times. The significance of over 500 citations in the 15-year period can be better appreciated when one considers that only 550 papers--out of a universe estimated at over 10 million items--were so highly cited during the same period.

Six items listed in Figure 1 have been cited more than 1,000 times-a level reached by only 200 papers-and three of these were cited more than 1,600 times: Bardeen et al. (3), Jaffe (14), and Karplus (18). Jaffe's review article, like the article by McDaniel and Brown (24), deals with the Hammett equation, widely used to determine how changes in the structure of a molecule affects its reactivity.

The other three articles in Figure 1 which were cited more than 1,000 times include an article on molecular orbital theory by Roothan (32), and a two-part article by Pariser and Parr. They developed the so-called P-P method for studying the electronic spectra of various kinds of conjugated molecules. Pariser also authored another paper (29) on this list.

The data in columns D (citations in 1974) and E (citations in 1975) of Figure 1 are general indicators of the degree of current interest in these 1950s papers. Despite the 20year time lapse since these articles were published, six of them (3, 7, 11, 12, 15 and 24) are still attracting an increasing amount of interest. The 1974 citation count of these articles (column D) exceeded their average yearly citation rate for the years 1961-1975 (column C)--and their 1975 citation count (column E) exceeds that for 1974.

Seven of these 41 papers were authored by 11 Nobel laureates. In one article (2) three of the five Figure 1. Highly cited articles in physics and chemistry published in the 1950s. A = item number. B = total citations 1961-1975. C = average yearly citations 1961-1975. D = citations in 1974. E = citations in 1975. Articles are listed alphabetically by first author.

A	В	С	D	E	Bibliographic Data
Ι.	873	58	11	7	Ajzenberg-Selove F & Lauritsen T. Energy levels of light nuclei. VI. Nuclear Physics 11:1-340, 1959.
2.	740	49	34	20	Alder K, Bohr A, Huus T, Mottelson B & Winther A. Study of nuclear structure by electromagnetic excitation with accelerated ions. <i>Revs. Mod. Physics</i> 28:432-542, 1956.
<b>3</b> .	1662	111	95	68	Bardeen J, Cooper L N & Schrieffer J R. Theory of super- conductivity. Physical Rev. 108:1175-1204, 1957.
4.	758	51	12	12	Berghuis J, Bertha J J, Haanappel M, Potters M, Loopstra B O, MacGillavry C H & Veenendall A L. New calculations of atomic scattering factors. Acta Cryst. 8:478-83, 1955.
5.	544	36	38	41	Brown H C & Okamoto Y. Electrophilic substituent constants. J. Amer. Chem. Soc. 80:4979, 1958.
6.	641	43	62	52	Carr H Y & Purcell E M. Effects of diffusion on free pre- cession in nuclear magnetic resonance experiments. <i>Physical Rev.</i> 94:630-39, 1954.
<b>7</b> .	531	35	42	56	Dexter D L. A theory of sensitized luminescence in solids. J. Chem. Physics 21:836-50, 1953.
8.	770	51	31	25	Feynman R P & Gell-Mann M. Theory of the Fermi interaction. Physical Rev. 109:193-98, 1958.
9.	652	43	43	49	Gutowski H S & Holm C H. Rate processes and nuclear magnetic resonance spectra. II. Hindered internal rotation of amides. J. Chem. Physics 25:1228, 1956.
10.	525	35	41	40	Hahn E L. Spin echos. Physical Rev. 80:580-94, 1950.
11.	707	47	64	65	Hammond G S. A correlation of reaction rates.
					J. Amer. Chem. Soc. 77:334, 1955.
12.	748	50	64	85	Hatchard C G & Parker C A, A new sensitive chemical acti- nometer. II. Potassium ferrioxalate as a standard chemical acti- nometer. Proc. Roy. Soc. A. 235:518, 1956.
13.	818	55	87	33	Jacob M & Wick G C. On the general theory of collisions for particles with spin. Ann. Physics 7:404-28, 1959.
14.	1667	111	106	76	Jaffe H H. A reexamination of the Hammett equation. Chem. Revs. 53:191-261, 1953.
15.	684	46	58	3 57	Johnson C E Jr. & Bovey F A. Calculation of nuclear magnetic resonance spectra of aromatic hydrocarbons. J. Chem. Physics 29:1012, 1958.
16.	523	35	24	23	Johnston W G & Gilman J J. Dislocation velocities, dislocation densities, and plastic flow in lithium fluoride crystals. J. Appl. Physics 30:129-44, 1959.
17.	619	41	55	44	Kane E O. Band structure of indium antimonide. J. Phys. Chem. Solids 1:249-61, 1957.

## Figure 1 continued

18.	1629	109	101	68	Karplus M. Contact electron spin coupling of nuclear magnetic moments. J. Chem. Physics 30:11-15, 1959.
19.	610	41	53	41	Kubo R & Tomita K. A general theory of magnetic resonance absorption. J. Phys. Soc. Japan 9:888-919, 1954.
20.	947	63	88	78	Kubo R. Statistical-mechanical theory of irreversible process. I. General theory of simple applications to magnetic and conduc- tion problems. J. Phys. Soc. Japan 12:570-86, 1957.
21.	688	46	55	42	Lane A M & Thomas R G. R-matrix theory of nuclear reactions. Rev. Mod. Physics 30:257-353, 1958.
22.	605	40	23	24	<ul> <li>Lemieux R U, Kullnig R K, Bernstein H J &amp; Schneider W G.</li> <li>Configurational effects on the proton magnetic resonance spectra of six-membered ring compounds.</li> <li>J. Amer. Chem. Soc. 80:6098-6105, 1958.</li> </ul>
23.	518	34	20	34	<ul> <li>Gennell H M &amp; Chesnut D B. Theory of isotropic hyperfine interactions in <i>π</i> -electron radicals.</li> <li>J. Chem. Physics 28:107-17, 1958.</li> </ul>
24.	632	42	46	47	McDaniel D H & Brown H C. An extended table of Hammett sub- stituent constants based on the ionization of substituted benzoic acids. J. Org. Chem. 23:420, 1958.
25.	762	51	38	42	Mulliken R S. Molecular compounds and their spectra. II. J. Amer. Chem. Soc. 74:811-27, 1952.
26.	960	64	38	42	Mulliken R S. Electronic population analysis on LCAO MO molecular wave functions. I. J. Chem. Physics 23:1833-40, 1955.
27.	1090	72	77	51	<b>Pariser R &amp; Parr R G.</b> A semi-empirical theory of the electronic spectra and electronic structure of complex unsaturated molecules. 1. J. Chem. Physics 21:466-71, 1953.
<b>28</b> .	1134	76	66	54	Pariser R & Parr R G. A semi-empirical theory of the elec- tronic spectra and electronic structure of complex unsaturated molecules. J. Chem. Physics 21:767-76, 1953.
29.	510	34	31	10	<ul> <li>Pariser R. Theory of electronic spectra and structure of the polyacenes and of alternant hydrocarbons.</li> <li>J. Chem. Physics 24:250-68, 1956.</li> </ul>
<b>30</b> .	666	44	35	26	Paul M A & Long F A. H <sub>0</sub> and related indicator acidity functions. Chemical Rev. 57:1-45, 1957.
31.	976	65	66	49	Pople J A. Electron interaction in unsaturated hydrocarbons. Trans. Faraday Soc. 49:1375-85, 1953.
32.	1229	82	129	94	Roothaan C C J. New developments in molecular orbital theory. Rev. Mod. Physics 23:69, 1951.
33.	652	43	49	44	Rouse P E. A theory of the linear viscoelastic properties of dilute solutions of coiling polymers. J. Chem. Physics 21:1272-80, 1953.
34.	648	43	26	34	Ruderman M A & Kittel C. Indirect exchange coupling of nuclear magnetic moments by conduction electrons. <i>Physical Rev.</i> 96:99-102, 1954.

## Figure 1 continued

<b>35</b> .	521	35	36 28	Shockley W & Read W T Jr. Statistics of the recombinations of holes and electrons. <i>Physical Rev.</i> 87:835-42, 1952.
36.	572	38	73 47	Slater J C. A simplification of the Hartree Fock method Physical Rev. 81:385-90, 1951.
87.	558	37	49 27	Tanabe Y & Sugano S. On the absorption spectra of complex ions. I. J. Phys. Soc. Japan 9:753-66, 1954.
38.	582	39	<b>3</b> 5 45	VanHove L. Correlations in space and time and born approximation scattering in systems of interacting particles. <i>Physical Rev.</i> 95:249-62, 1954.
<b>39</b> .	533	36	47 38	Williams M L, Landel R F & Ferry J D. The temperature dependence of relaxation mechanisms in amorphous polymers and other glass-forming liquids. J. Amer. Chem. Soc. 77:3701-07, 1955.
40.	710	47	75 54	Wolfsberg M & Helmholz L. Spectra and electronic structure of the tetrahedral ions M <sub>n</sub> O <sub>4</sub> ., CrO <sub>4</sub> . J. Chem. Physics 20:837, 1952.
41.	511	34	47 40	Zimm B H. Dynamics of polymer molecules in dilute solution; viscoelasticity, flow birefringence and dialectic loss. J. Chem. Physics 24:269-78, 1956.

authors won Nobel Prizes. Alder of Germany won the 1950 Prize in chemistry, and Bohr and Mottelson, both of Denmark, shared the 1975 Prize in physics. A. Bohr is the son of Neils Bohr, the Danish physicist who contributed to the development of quantum theory.

The remaining eight Nobel iaureates on the list are Americans. The three authors of the second most highly cited article on the list (3), Bardeen, Cooper, and Schreiffer, shared the 1972 Nobel Prize for physics. In addition, Bardeen won the 1956 Prize for physics.

Two well-known physicists, Feynman and Gell-Mann, are the authors of a paper on the Fermi interaction (8). Gell-Mann, who predicted and named the "quark" in particle physics, won the Nobel Prize for physics in 1965. Feynman, who recently helped develop the parton model of the proton--and whose fundamental paper on quantum mechanics appeared on our 1940s list--won the Nobel Prize for physics in 1969. Purcell, the author of an article concerning nuclear magnetic resonance (6), won the Nobel Prize for physics in 1952. Mulliken, the author of two articles on the list (25, 26), won the 1966 Prize for chemistry, and Shockley won the Nobel Prize for physics in 1956.

The names of several authors of these highly cited 1950s papers also appeared on our 1940s list.<sup>3</sup> Mulliken (25, 26) was the sole author of two highly cited 1940s articles, and the primary author of a third 1940s article. Zimm (41) was also the sole author of two 1940s articles and primary author of a third. Four more of the authors listed in Figure 1 appeared on our 1940s list: Purcell (6), Feynman (8), Kittel (34), and Shockley (35).

Of these 41 articles of the 1950s,

one was published in 1950, two in 1951, three in 1952, six in 1953, five in 1954, four in 1955, five in 1956, four in 1957, seven in 1958, and four in 1959.

In our discussion of the 1940s classics we noted that 95% of the articles were published in English.<sup>3</sup>

Figure 2. Journals that published the highly cited 1950s articles listed in Figure 1, according to number of articles. A = number of articles. (Present title of journal given in parentheses).

## A Journal

- 12 J. Chem. Physics
- 8 Physical Review
- 5 J. Amer. Chem. Soc.
- 3 J. Phys. Soc. Japan
- 3 Rev. Mod. Physics
- 2 Chemical Rev.
- 1 Acta Crystallographica
- 1 Annals Physics
- 1 J. Appl. Physics
- 1 J. Organic Chem.
- 1 J. Phys. Chem. Solids
- 1 Nuclear Physics
- 1 Proc. Roy. Soc. London A.
- 1 Trans. Faraday Soc.
  - (J. Chem. Soc. Faraday)

The original language of publication of all of the 41 articles published in the 1950s was English.

In Figure 2, the journals that published the 41 articles are listed according to the number of such articles published in each. Only two journals account for almost half of the articles. Twelve of the articles were published in Journal of Chemical Physics, and 8 in Physical Review. A decade earlier, in the 1940s, the same two journals were the leading publishers of highly cited physical science articles.

Other journals which published more than one article listed in Figure 1 are Journal of the American Chemical Society (5 articles), Journal of the Physical Society of Japan (3 articles), Reviews of Modern Physics (3 articles), and Chemical Reviews (2 articles). It is significant that two of the top six producers of these articles--Reviews of Modern Physics and Chemical Reviews--are review journals. The importance of review journals is well-documented.4

A revolution in physics began in the 1950s and continues to the present. It began by overthrowing the simple concept of the atom as a nucleus composed of protons and neutrons and surrounded bv orbiting electrons. This model was replaced with an examination of the internal constituents of protons and neutrons themselves, an examinaion which has given rise to some weird, almost mystical concepts, including quarks, charm, strangeness, and color. Many of these classic physics and chemistry papers of the 1950s helped to lay the groundwork for studying the complex subatomic world.

- 1. Garfield E. Highly cited articles. 35. Biochemistry papers published in the 1940s. Current Contents No. 8, 21 February 1977, p. 5-11.
- -----Highly cited articles. 37. Biomedical articles published in the 1940s. Current Contents No. 13, 28 March 1977, p. 5-12.
- ------Highly cited articles. 36. Physics, chemistry, and mathematics papers published in the 1940s. Current Contents No. 10, 7 March 1977. p. 5-11.
- 4. -----Significant journals of science. Nature 264: 609-15, 16 December 1976.