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CURRENT COMMENTS

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

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Earlier this year we presented and discussed three lists of the classic papers of the 1940s: one for biochemistry,[1] one for biomedicine,[2] and one for physics, chemistry, and mathematics.[3] 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 20-year 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	B	C	D	E	Bibliographic Data
1.	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. *Revs. Mod. Physics* **28**:432-542, 1956.
3.	1662	111	95	68	**Bardeen J, Cooper L N & Schrieffer J R.** Theory of superconductivity. *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 precession in nuclear magnetic resonance experiments. *Physical Rev.* **94**:630-39, 1954.
7.	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 actinometer. II. Potassium ferrioxalate as a standard chemical actinometer. *Proc. Roy. Soc. A.* **235**:518, 1956.
13.	818	55	37	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	53	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 conduction 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	**Lemieux R U, Kullnig R K, Bernstein H J & Schneider W G.** Configurational effects on the proton magnetic resonance spectra of six-membered ring compounds. *J. Amer. Chem. Soc.* **80**:6098-6105, 1958.
23.	518	34	20	34	McConnell H M & Chesnut D B. Theory of isotropic hyperfine interactions in π-electron radicals. *J. Chem. Physics* **28**:107-17, 1958.
24.	632	42	46	47	**McDaniel D H & Brown H C.** An extended table of Hammett substituent 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	**Pariser R & Parr R G.** A semi-empirical theory of the electronic spectra and electronic structure of complex unsaturated molecules. I. *J. Chem. Physics* **21**:466-71, 1953.
28.	1134	76	66	54	**Pariser R & Parr R G.** A semi-empirical theory of the electronic spectra and electronic structure of complex unsaturated molecules. *J. Chem. Physics* **21**:767-76, 1953.
29.	510	34	31	10	**Pariser R.** Theory of electronic spectra and structure of the polyacenes and of alternant hydrocarbons. *J. Chem. Physics* **24**:250-68, 1956.
30.	666	44	35	26	**Paul M A & Long F A.** H_0 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. *Physical Rev.* **96**:99-102, 1954.

Figure 1 continued

35.	521	35	36	28	**Shockley W & Read W T Jr.** Statistics of the recombinations of holes and electrons. *Physical Rev.* **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.
37.	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	35	45	**VanHove L.** Correlations in space and time and born approximation scattering in systems of interacting particles. *Physical Rev.* **95**:249-62, 1954.
39.	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 MnO_4^-, CrO_4. *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 laureates 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.[3] 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.[3]

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 by orbiting electrons. This model was replaced with an examination of the internal constituents of protons and neutrons themselves, an examination 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.
2. ----------Highly cited articles. 37. Biomedical articles published in the 1940s. *Current Contents* No. 13, 28 March 1977, p. 5-12.
3. ----------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.