

Citation of Articles from Volume 58 of the *Journal of Physical Chemistry*

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The self-citation intensity in references per 100 pages was found to decrease with a half life of three and one half years, only partially counterbalanced by a doubling of journal size every six years. *SCI* data, on the other hand, suggest that the chance for citation of a given paper may be fairly constant. About 80% of the articles written in Volume 58 of the *Journal of Physical Chemistry* were cited in the sources surveyed. A superficial study of these uncited papers showed no noticeable difference from other papers in the journal except for a few, such as an introduction to a symposium, that might not be expected to be cited.

Most of the publications concerned with the evaluation of scientific journals have been oriented toward evaluation of whole journals rather than specific articles. These studies have been primarily concerned with helping libraries to get the most for their journal subscription dollar. Frequency of journal citation, abstract counts, and frequency of journal loan requests at libraries are examples of the type of data used. A comprehensive study of journals from these standpoints has been published by C. H. Brown (1).

In this paper an attempt is made to see what influence specific articles have on later publications.

In order to evaluate the usefulness of specific articles, some indicator must be chosen. In this survey, the frequency of citation of individual articles has been selected as the measure of usefulness [impact (2)]. It should be made clear that usefulness or impact is not synonymous with importance. The citation rate for a given paper is influenced by the popularity of its author, the popularity of the field, errors perpetrated, innovations, and discoveries, none of which are necessarily equated with importance. Garfield has illustrated this very nicely: "It is preposterous to conclude blindly that the most cited author deserves a Nobel Prize. On this basis, Lysenko... might have been judged the greatest scientist of the last decade" (2). Despite these weaknesses and "... the evident malpractice of some authors in preferentially citing their own papers, those of their special friends, or those of powerful or important scientists that confer status on their work" (3), references do serve to indicate what is being read and utilized.

A complete survey of all publications that may cite a given article is, of course, an endless task. *Science Citation Index* (4), however, has started a reasonable approximation to just that. Information from *SCI* will be utilized in this study.

JOURNAL SELF-CITATION

The high rate of journal self-citation (the tendency for articles in a given journal to cite other articles from that same journal) suggests that such citations may amount to an easily obtainable sample of the citations of a given paper. Barrett and Barrett (5) reported that nearly 40% of the citations in the *Journal of the American Chemical Society* were taken from that journal. Similarly, Brown (1) gives a table (pp. 102-03) listing the 29 most cited journals in the *Journal of the American Chemical Society*. Journal self-citations make up 44% of these. Comparison of this table with other, more complete tables in Brown (1) suggests that the top 29 journals should contain about 90% of the total citations in the journal. If this prediction is correct, then Brown also suggests about 40% journal self-citation for the *Journal of the American Chemical Society*. This, of course, does not mean that 40% of all citations of articles from the *Journal of the American Chemical Society* will be found in that journal. More general information on journal self-citation rates has been published by Garfield and Sher (4). They report that 20% of all citations are journal self-citations. The value obviously varies from journal to journal.

Journal of Physical Chemistry. It was decided to check journal self-citation rates in the *Journal of Physical Chemistry* and to compare these with more general citations published in *SCI*. This particular journal was selected for the following reasons:

1. It is an important journal.
2. It is of moderate size.
3. The author's interests lean toward physical chemistry.

The importance of the *Journal of Physical Chemistry* is demonstrated in Table I. It is apparent that any library used by chemists should have this journal. The two entries for 1954 allow some qualitative interpretation. The journal

Table I. Ranking of the *Journal of Physical Chemistry*

Date	Rank	Type of information	Reference
1899	11	Citations in chemical journals	6
1919	16	Citations in chemical journals	6
1916-25	6	Citations in <i>J. Am. Chem. Soc.</i>	7
1926	7	Citations in <i>J. Am. Chem. Soc.</i>	7
1939	5	Citations in chemical journals	6
1944	13	Citations in chemical journals	1
1946	below 20	Citations in chemical journals	6
1954	13	Citations in chemical journals	6
1954	31	Abstract count (<i>Chem. Abstr.</i>)	1
1960-61	32	Library journal usage (Sci. and Tech.)	8

ranks 31st in an abstract count (essentially an article count) and 13th in a citation check. This indicates that usage per article is somewhat above average. Volume 58 (1954) was chosen for the citation check. The 10 volumes of the *Journal of Physical Chemistry* immediately following (1955-1964) were surveyed for references, as were the 1964 and 1965 volumes of *Science Citation Index*.

The percentage of journal self-citation in the *Journal of Physical Chemistry* was not so high as the 40% internal citation rate mentioned above for the *Journal of the American Chemical Society*. A spot check of two issues of the *Journal of Physical Chemistry* indicated that journal self-citations ran about 20%. Of more interest than the self-citation rate is the percentage of all citations to *Journal of Physical Chemistry* that are self-citations. The 1964 *SCI* lists 232 citations of Volume 58 of *Journal of Physical Chemistry*. During that same year there were 44 citations of the same volume in the journal, about 20%. If all the scientific publications in the world were surveyed, other citations would likely be found so this is an upper limit for the percentage of all citations of *Journal of Physical Chemistry* articles that one would expect to find in the *Journal of Physical Chemistry*.

The rapid expansion of the chemical literature is evident in the *Journal of Physical Chemistry*. This journal more than tripled in size in 11 years (1954-64), which is somewhat more rapid than the doubling every 15 years as an average suggested by Price (9) for scientific journals.

The numbers of citations of articles from Volume 58 in each of the journals surveyed are summarized in Table II, along with similar data from 1964 and 1965 *Science Citation Index*.

As might be expected, the number of citations decreases with increasing time lapse between publication and citation. The decrease in citation rate is even more striking when adjustments are made for the growth of the *Journal of Physical Chemistry*. The "citation intensity" in citations per 100 journal pages was about seven times larger in 1955 than in 1964. The decrease in citation intensity with time can be approximated by a first-order rate law with a half life of three and one half years (Figure 1).

Price (3) gives an average doubling time of about 15 years for science generally, and he also presents evidence for a citation intensity half life of about the same length. The chance of citations somewhere in the scientific literature should then be about constant from year to year for any paper. These generalities, however, should not be expected to apply to individual journals. The size of the *Journal of Physical Chemistry* has been doubling

in size every six years (Figure 2), while the citation intensity decays with a half life of three and one half years. The net result is that the total number of citations from Volume 58 of the *Journal of Physical Chemistry* in later issues of that journal should be decreasing with a half life of a little over 8 years. The citations appearing in two years of *Science Citation Index* do not reflect a decrease in the citation rate from Volume 58 in the general science literature. In fact there is an increase between 1964 and 1965. This increase is probably due to the increasing coverage of *SCI*. In 1964 *SCI* surveyed 700 journals while in 1965 the coverage had been increased to 1148 journals. It does appear, though, that the suggestions of a fairly constant probability of citation from year to year may hold for individual *Journal of Physical Chemistry* articles over the whole of the scientific literature.

Citation of Individual Articles. The information in Table II applies principally to the journal as a whole, but a similar evaluation of individual articles could be made. Table III lists the number of times that specific articles were cited in the volumes surveyed. While it is interesting to note that nearly one-third of the papers in Volume 58 of the *Journal of Physical Chemistry* were not cited in the next 10 years of that journal, this certainly does not present the whole picture. The 1964 *SCI* cites 20 papers that were not cited in the 10-year survey. In 1965 *SCI* adds 13 more to the list of papers cited. These citations drop the uncited total to 51, or 19%.

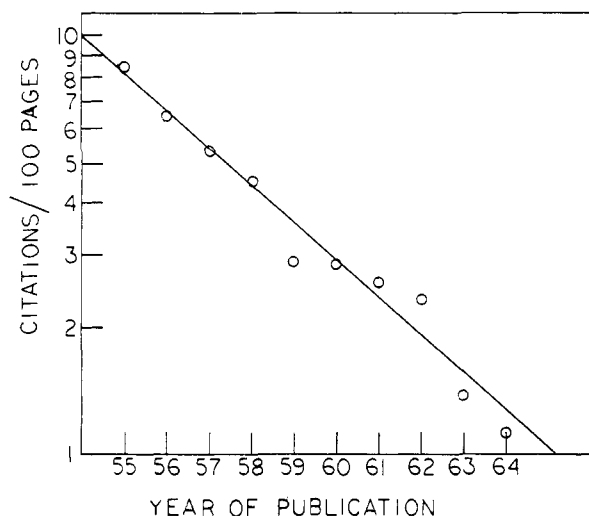
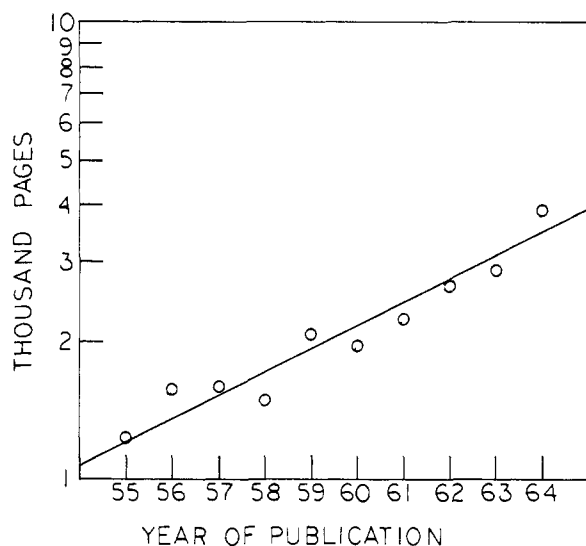
Looking at some specific cases may be instructive. The February issue of *Journal of Physical Chemistry*, Volume 58, has a symposium on protein denaturation. The five articles in this symposium would seem to be of more interest to biochemists than to physical chemists. As expected, only one of these papers was cited (twice) in the surveyed volumes. On the other hand, *SCI* notes 18 citations to three of these papers. Another indication of papers not cited in the *Journal of Physical Chemistry* but cited elsewhere concerns five papers that were cited three or more times in 1964 and 1965 *SCI* but not cited at all in the 10 years of *Journal of Physical Chemistry*. Inspection of their titles will indicate that all are of interest to areas other than physical chemistry. These papers are:

(1a) (10 citations) B. R. Ray, E. O. Davisson, H. L. Crespi, "Experiments on the Degradation of Lipoproteins from Serum," *J. Phys. Chem.* **58**, 841 (1954).

(2a) (7 citations) D. H. Templeton, G. F. Carter, "The Crystal Structures of Yttrium Trichloride and Similar Compounds," *J. Phys. Chem.* **58**, 940 (1954).

Table II. Frequency of Citation of Articles from Volume 58 of the *Journal of Physical Chemistry* in Subsequent Volumes of that Journal and in Science Citation Index

<i>J. Phys. Chem.</i> Volume	Year	No. of Pages in Journal	No of Articles Cited at Least Once	Number of Vol. 58 Citations	References Per 100 Pages
59	1955	1233	74	106	8.60
60	1956	1673	75	106	6.34
61	1957	1687	67	91	5.37
62	1958	1608	48	74	4.60
63	1959	2090	45	61	2.92
64	1960	1960	41	56	2.86
65	1961	2277	46	61	2.68
66	1962	2718	43	66	2.43
67	1963	2889	40	45	1.56
68	1964	3912	37	44	1.13
SCI	1964	...	113	232	...
SCI	1965	...	121	322	...

Figure 1. Intensity of citation of articles from Volume 58 (1954) of the *Journal of Physical Chemistry* in later issues of that journal.Figure 2. Rate of growth of the *Journal of Physical Chemistry*.

(3a) (5 citations) F. Haurowitz, R. L. Harden, M. Dicks, "Denaturation of Hemoglobins by Alkali," *J. Phys. Chem.* **58**, 103 (1954).

(4a) (5 citations) K. E. Russell, "The Abstraction of Hydrogen Atoms from Mercaptans by 2,2-Diphenyl-1-picrylhydrazyl," *J. Phys. Chem.* **58**, 437 (1954).

(5a) H. Morawetz, Paula E. Zimmerling, "Reaction Rates of Polyelectrolyte Derivatives. I. The Solvolysis of Acrylic Acid-*p*-Nitrophenyl Methacrylate Copolymers," *J. Phys. Chem.* **58**, 753 (1954).

Papers 1a and 3a are biochemical, papers 4a and 5a deal with polymer chemistry, while 2a tends to be inorganic in nature.

Going back to those papers cited in the *Journal of Physical Chemistry*, the five most cited papers in Table III are:

(1b) (18 citations) R. A. Beebe, D. M. Young, "Heats of Adsorption of Argon," *J. Phys. Chem.* **58**, 93 (1954).

(2b) (16 citations) F. E. Bartell, R. M. Suggitt, "Heat of Wetting of Copper, Graphite and Silica Gel," *J. Phys. Chem.* **58**, 36 (1954).

(3b) (16 citations) W. N. Hubbard, C. Katz, G. Waddington, "A Rotating Combustion Bomb for Precision Calorimetry. Heat of Combustion of Some Sulfur-Containing Compounds," *J. Phys. Chem.* **58**, 142 (1954).

(4b) (16 citations) E. F. Hare, E. G. Shafrin, W. A. Zisman, "Properties of Films of Adsorbed Fluorinated Acids," *J. Phys. Chem.* **58**, 236 (1954).

(5b) (15 citations) J. H. Singleton, G. D. Halsey, Jr., "The Adsorption of Argon on Xenon Layers," *J. Phys. Chem.* **58**, 330 (1954).

CITATIONS OTHER THAN AUTHOR SELF-CITATIONS

In surveying citations, one striking thing is noted—the number of times authors cite themselves. One-third of all the citations taken from the *Journal of Physical Chemistry* in this study have at least one author in common with the article in which the citation appears. This is, of course, to be expected since the papers of a given author are generally related; but self-citation by an author is probably not a good measure of the influence a given paper has on science. For this reason, Table IV was prepared. In this table only publications by authors other

Table III. Number of times that individual articles from Volume 58 of the *Journal of Physical Chemistry* were cited in Volumes 59–68 with averages from 1964 and 1965 of *Science Citation Index*

No. of Citations in <i>J. Phys. Chem.</i>	No. of Articles	% of Total	Av. No. of Times Cited in <i>SCI</i>
0	84	31.2	0.82
1	54	20.1	1.31
2	36	13.4	2.2
3	24	8.9	2.2
4	18	6.7	2.2
5	15	5.6	3.0
6	8	3.0	2.3
7	7	2.6	2.9
8	5	1.9	5.6
9	5	1.9	8.8
10	2	0.7	5.5
11	2	0.7	5.5
12	3	1.1	6
13	1	0.4	6
14	0
15	1	0.4	5
16	3	1.1	4
17	0
18	1	0.4	2

Table IV. The Same Information as Table III with All Author Self-Citations Omitted in the *Journal of Physical Chemistry* Citations

No. of Citations in <i>J. Phys. Chem.</i>	No. of Articles	% of Total	Av. No. of Times Cited in <i>SCI</i>
0	120	44.6	0.83
1	56	20.8	1.98
2	24	8.9	2.9
3	24	8.9	2.1
4	11	4.1	3.0
5	13	4.8	3.0
6	4	1.5	5.3
7	6	2.2	8.0
8	4	1.5	12.5
9	1	0.4	4.0
10	1	0.4	7.0
11	3	1.1	10
12	0
13	1	0.4	4
14	1	0.4	2

than those who wrote the original paper are included. Note that only 55% are cited. The interrelationship between the 1964 and 1965 *SCI* citations and citations within the *Journal of Physical Chemistry* is better when the author self-citations are not included in the *Journal of Physical Chemistry* data (cf. Table III and IV).

The five papers cited most frequently by authors other than those who wrote the cited paper differ somewhat from the list where author self-citation is included:

- (1c) (14 citations) see 1b.
- (2c) (13 citations) see 2b.
- (3c) (11 citations) see 5b.

- (4c) (11 citations) H. L. Frisch, R. Simha, "The Adsorption of Flexible Macromolecules. II," *J. Phys. Chem.* **58**, 507 (1954).
- (5c) (11 citations) H. Boedtker, P. Doty, "A Study of Gelatin Molecules, Aggregates and Gels," *J. Phys. Chem.* **58**, 968 (1954).

CITATIONS IN GENERAL SCIENTIFIC LITERATURE

All of the papers in Volume 58 of the *Journal of Physical Chemistry* were checked in *SCI* for 1964 and 1965. Citations rates went from 0 to 32, with 40% of the papers not cited. The five papers most frequently cited are:

- (1d) (32 citations) N. S. Bayless, E. G. McRae, "Solvent Effects in Organic Spectra: Dipole Forces and the Franck Condon Principle," *J. Phys. Chem.* **58**, 1002 (1954).
- (2d) (14 citations) N. S. Bayless, E. G. McRae, "Solvent Effects in the Spectra of Acetone, Crotonaldehyde, Nitromethane and Nitrobenzene," *J. Phys. Chem.* **58**, 110 (1954).
- (3d) (12 citations) R. Lumry, H. Eyring, "Conformation Changes of Proteins," *J. Phys. Chem.* **58**, 110 (1954).
- (4d) (12 citations) see 5c.
- (5d) (11 citations) A. I. Vogel, W. T. Cresswell, J. Leicester, "Bond Refractions for Tin, Silicon, Lead, Germanium and Mercury Compounds," *J. Phys. Chem.* **58**, 174 (1954).

DISCUSSION AND SUMMARY

Journal self-citation appears to give only a moderate indication of the citations to be found in other journals. Even though some 20% of the references to a paper can be found (on the average) in the same journal in which the paper was published, the sample is not truly representative. The relationship between journal self-citation and over-all citations is better if one excludes author self-citation (cf. Tables III and IV). Journal self-citation was surprisingly unsuccessful in predicting the papers that would be most cited after 10 years. Only one paper (4d) in the top five of the 1964–1965 *SCI* citation was in the top five of those journal self-citations, and then it was in the list omitting author self-citations.

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- (5) Barrett, R. L., and Barrett, M. A., *J. Chem. Educ.* **34**, 35–38 (1957).
- (6) Fussler, H. H., *Library Quart.* **19**, 119 (1949).
- (7) Gross, P. L. K., and Gross, E. M., *Science* **64**, 385 (1927).
- (8) *Chem. Eng. News* **41**, (19), 68 (1963).
- (9) Price, D. J. deS., "Science Since Babylon," Ch. 5, Yale University Press, New Haven, Conn., 1961.