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Citations in Chemistry at the Dawn of Open Science

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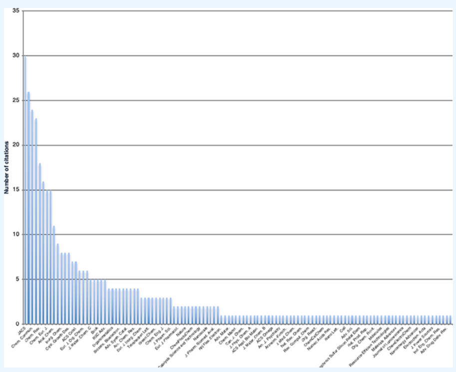
ABSTRACT: Citation-based metrics such as the *h*-index and the journal impact factor continue to play a key role in the evaluation of scholarships for employment, promotion, and tenure in academia, as well as in funding decisions. As happens with most scientometric aspects concerning their discipline, knowledge of citation patterns in chemistry in the chemistry community is rather limited. Critically reviewing the outcomes of studies devoted to citations in chemistry and adding new insight from the analysis of contemporary chemistry research, this study aims to fill at least in part knowledge gaps concerning publishing, citations, and citation habits in the chemical sciences.



1. INTRODUCTION

Citations, "the acknowledgment that one document receives from another",[1] are used worldwide to measure the scientific impact of the research carried out by a scholar,[1] as well as by a university department, entire universities and research centers, and even nations.[2] Regardless of pleas to replace conventional scholarship evaluation based on citation counts (and citation-based metrics) with expanded evaluation criteria,[3−5] citations continue to play a key role in the evaluation of scholarship in academic retention, promotion, and tenure processes.[6]

Research in chemistry comprises a significant fraction of the overall science and engineering (S&E) global output. Said output in 2020 reached 2.94 million articles.[7] In the same year, chemistry was present amid the eight largest fields of research in S&E with a significant share of 8.30% in China, 8.19% in India, and 7.80% in Japan, when only in the USA (3.43%) and Great Britain (3.80%), the chemistry research output was below 4% of their overall S&E output.[7] Even with the restriction of the analysis to journals indexed in two widely employed scientific databases (Scopus and Web of Science), growth in scientific output has further accelerated. Driven by the emergence of "special issues" and in contrast with the limited growth in the overall number of practising scientists, the overall number of scientific articles published in 2022 was nearly 50% (∼47%) higher than in 2016 (∼2.82m articles in 2022 compared to ∼1.92m articles in 2016).[8]

In general, as happens with many other scientometric aspects of their discipline, including the journal impact factor[9] and the Hirsch (*h*-) index,[10] knowledge of the said aspects in the research chemistry community is rather limited. It would be enough to ask even senior research chemists simple questions such as "how many chemistry papers are published yearly?" or "how many citations do chemistry papers receive every year?" or even "how many chemistry journals exist?" to get widely different answers, often away from the true numbers.

Alongside a general lack of updated education on scholarly publishing in the open science and digital age,[11] one of the main reasons explaining these outcomes is the fact that studies on the scientometric aspects of chemistry are generally published in journals that chemists do not read. Citation analysis was a developed field of scholarly research already in the early 1980s.[12] As underlined by Ortega citing work dating back to 1927,[13] "chemistry and biochemistry literature has been researched for decades".[14] However, a search with the query "citations in chemistry" carried out in Google Scholar as of early September 2023 returned only 127 studies.[15] Limiting the search to the time interval 2019−2023, furthermore, returned only 19 studies.

Therefore, a study on citations in chemistry seems timely, especially in light of rapid changes affecting the market of chemistry academic publishing. For example, for nearly 2 decades, chemistry has been the basic science with the lowest uptake of open science in academic publishing.[16] In the early 2020s, however, chemists too started to publish a significant number of open access (OA) research papers.[17] In 2021, 57% of all research indexed in "multidisciplinary chemistry" journals was published without a paywall, with 46% of papers published

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Table 1. Type of Sources Cited by 600 Articles Sampled from 10 ACS Journals, 2011-2015[a]

journal title	total references analyzed	% articles	% reviews	% conference papers	% book or book chapter	% other
ACS Chemical Biology	2,594	75.9%	19.1%	1.0%	1.4%	2.6%
ACS Nano	2,948	86.1%	10.5%	1.2%	1.1%	1.1%
Analytical Chemistry	2,343	81.6%	12.5%	2.1%	1.8%	4.3%
Chemical Reviews	25,195	84.5%	10.4%	1.8%	1.6%	0.2%
Inorganic Chemistry	3,751	83.7%	9.4%	1.4%	2.5%	3.4%
Journal of Medicinal Chemistry	2,730	75.4%	17.3%	1.4%	1.5%	4.3%
Journal of Organic Chemistry	3,440	83.6%	8.3%	9.0%	4.1%	3.1%
Journal of Physical Chemistry C	2,928	88.6%	5.1%	1.6%	3.4%	1.4%
The Journal of the American Chemical Society	3,881	82.6%	10.5%	1.2%	3.0%	2.7%
Macromolecules	3,318	85.1%	8.0%	1.9%	3.2%	1.9%
Average	5,313	82.7%	11.1%	2.3%	2.4%	2.5%

[a]Reproduced from ref 29, with kind permission.

as "gold" OA articles upon payment of an article processing charge (APC), and the remainder being "green" self-archived by authors.[18]

Critically reviewing the outcomes of studies devoted to citations in chemistry and adding new results from the analysis of contemporary chemistry research, this study aims to fill at least in part knowledge gaps in the chemistry community concerning scientific publishing, citations, and citation patterns in the chemical sciences.

2. RESULTS AND DISCUSSION

In the following, we first provide an outlook on today's publishing in chemistry. Hence, we review the main outcomes of selected studies devoted to citations in chemistry. Thus, we add new results from the analysis of citations in a recent issue of the leading communication journal in chemistry research.

2.1. Academic Publishing in Chemistry. Academic publishing in chemistry is growing at a substantial rate. The annual growth rate of chemistry papers was 3.7% for the period 1907−1960 and 4.3% in the period 1997−2006 (doubling time of 16 years).[19] Amid the natural and medical sciences, in 2014, chemistry was the most concentrated sector of the scientific publishing oligopoly, with over 70% of papers chemistry papers between 1973 and 2013 published by five major publishers only (Elsevier, Springer, Wiley-Blackwell, American Chemical Society, and Taylor & Francis).[20]

Since 2013, however, a major change has taken place in the chemistry publishing landscape with the emergence of MDPI, an online-only OA publisher. In just one decade (2013−2022), MDPI became the world's third largest scientific publisher with over 301,000 articles published in 2022, preceded only by Springer (nearly 450,000 published in 2022) and Elsevier (with over 702,000 articles).[21]

Another new successful online-only OA publisher was Frontiers Media, also based in Switzerland, that in 2022 ranked sixth amid the world's largest publishers with 126,116 articles published.[21] Both publishers own several chemistry journals. MDPI by August 2023 published 107 journals in "Chemistry & Materials Science".[22] For comparison, the entire list of journals under the subject "chemistry" ranked by Scimago on the same month included 907 journals.[23]

As expected, all major publishers active in the chemistry field reacted to the increase in the global number of research chemists (in China between 2000 and 2017, the number of Chemistry departments rose by 182%, from 243 to 686, and correspondingly, the number of researchers tripled)[24] and manuscript submissions by launching several new journals. The Royal Society of Chemistry (RSC), a scientific society based in Great Britain, currently publishes 54 journals. In 2002, it published 26 journals. Similarly, the American Chemical Society (ACS) publishes both well-established and new chemistry journals associated with high scientific reputation. The society in 2002 published "30 electronic journals and 3 magazines".[25] Currently, they publish over 75 journals.

In the same two decades (2002−2022), all other large chemistry publishers including Elsevier, Wiley, and SpringerNature launched numerous new chemistry journals as well as cross-disciplinary OA journals such as *Heliyon, Advanced Science*, and *Scientific Reports* that regularly publish chemistry articles too. In brief, never in the past have chemists had so many journal venues wherein to publish their research work. Furthermore, though at slow pace, chemists in the late 2010s started to preprint their papers.[26] Even if being a tiny fraction of the number of preprints in physics, mathematics, and in the life sciences published yearly, chemistry preprints are highly read and increasingly cited. For example, the nearly 20,000 (19.598) preprints available at ChemRxiv on early September 2023 had been cited nearly 5,083 times[27] (even though, for comparison, the 6,600 articles published in 10 years in the OA journal *Frontiers in Chemistry* have received over 89,000 citations).

All this suggests that, inevitably, the number of both research articles and citation counts in chemistry has substantially increased in recent years. Indeed, between the five-year periods of 2008−2012 and 2013−2017 in the research field of "Chemistry", the number of citations grew of ∼50%, going from slight more than 4.45 million to nearly 7 (6.89) million.[28] In the same interval, the number of papers published in 5 years recorded a growth of about 20% going from about 725,000 to nearly 880,000.[28]

2.2. What Do Chemists Cite? In 2018, Rose-Wiles and Marzabadi published a seminal study aimed at identifying citation patterns of chemists publishing in ACS journals.[29] In detail, the scholars analyzed over 53,000 references from 600 articles randomly sampled published in 10 ACS journals (60 articles per journal sampled) between 2011 and 2015. Excluding *Chemical Reviews* with an average of 418 references, the average number of references per article was 52 while the age of references was 6 years, with 44% of the references being five years old or younger and only 11% more than 20 years old. The number of references cited, ranging from 39 to 64, was significantly higher than that observed by Ortega for articles published in nine years studied between 1975 and 2005 by

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research chemists affiliated with an American university (16.5 in 1975 and 32.4 in 2005).[14]

The fact that only about 10% of references cited in chemistry articles are more than 20 years old is common to virtually all highly dynamic research fields in natural sciences. For example, as shown by Marton in 1985, in seven fields of life sciences, in each of the seven life science main disciplines, the decrease in the frequency of references is faster in the first 5−10 years than later.[30] This fact, however, should not be interpreted that published research rapidly becomes obsolete but rather that the younger articles receive extra citations (Price's immediacy hypothesis).

Table 1 shows that, for the 600 articles published in ACS journals between 2011 and 2015, chemists chiefly cited journal articles and original research articles in particular (82.7%), followed by reviews (11.1%). References followed the 80/20 "Pareto Rule" with 20.2% of the journals cited accounting for 80% of the references. The three most cited journals cited were *The Journal of the American Chemical Society*, *Angewandte Chemie International Edition,* and *Chemical Communications*. The full list (over 100 journals) includes well-known chemistry journals such as *Tetrahedron* and *Tetrahedron Letters*, but also physics journals such as *Physical Review Letters* and cross-disciplinary journals such as *Science* and *Proceedings of the National Academy of Sciences of the United States of America*. These journals, the scholars concluded, "should be considered valuable or "core" across the various fields of chemistry".[29]

In agreement with findings reported 10 years before by Kousha and Thelwall for which in chemistry, 88.5% of the citations retrieved by Google Scholar were from journal papers,[31] books and book chapters were cited only in 2.4% of the sampled articles, similar to conference proceedings (2.3%), and Web sites and other sources such as brief communications, dissertations, letters to the editor, notes, patents, personal communications, short surveys, and software or software manuals (2.5%). For comparison, in 2008 in physics, e-prints/preprints accounted for 47.7% of unique citations, and in computer science, conference/workshop papers, 43.2%, were the major sources of citations.[31]

As expected, Rose-Wiles and Marzabadi found a lack of correlation between the impact factor and the number of references to a journal. The journal impact factor (JIF) is a misleading statistical indicator resulting from a highly skewed distribution (of citation vs the number of published research articles)[32] for which the vast majority (typically 85%) of a journal's articles actually get fewer citations than indicated by the JIF.[33] In a seminal work published in 1997, which took into consideration citation rates in 1986 or in 1987 for papers published in 1983 or in 1984 in three biochemistry journals (*Journal of Biological Chemistry*, *Biochimica Biophysica Acta*, and *Biochemical Journal*), Seglen found that citations did not correlate with the JIF.[32]

2.3. Factors Driving Citations. Studying 1899 short communication manuscripts reviewed in year 2000 by researchers accepting the invitation to review of the editors of *Angewandte Chemie International Edition* (a prestigious chemistry journal published by Wiley-VCH on behalf of Germany's Chemical Society), in 2012 Bornmann and co-workers identified the main factors driving citation counts in the subsequent decade.[34] In detail, citation counts were found to positively correlate with four factors: (a) the publication *h*-index for the cited references in a publication, (b) the language of the publication with a clear advantage for journals published in English, (c) the research subfield with publications in physical, inorganic, and analytical chemistry more frequently cited than publications in biochemistry, and (d) the number of highly cited authors of a paper.

The aforementioned analysis included citations to the studied papers up to March 2010. Papers published in paywalled journals and subsequently made OA via green self-archiving receive a substantially higher number of citations also in chemistry,[16] even though the scope and nature of the said advantage need to be carefully analyzed from today's digital age perspective in which things change at fast rate.

In 2022, indeed, Maddi and Sapinho reported surprising empirical findings concerning the open access citation advantage (OACA).[35] In detail, comparing the citation impact of 2,458,378 publications in fully OA journals to that of a control group of non-OA publications over the period 2010−2020, the team found that there is no OACA for publications in fully OA journals and that there is rather a disadvantage.

The OACA was found to be negative in Physical Sciences and Engineering, particularly in Materials Engineering, Physical And Analytical Chemical Sciences, and Synthetic Chemistry And Materials with OACA rates, respectively, of −12, −13, and −14%. On the other hand, the significant level of OACA found in "hybrid" journals (journals which host both OA and paywalled articles) comparing 1,024,430 OA publications to a control group consisting of 11,533,001 publications dramatically decreased from 70% in 2016 to 9% in 2020 (Figure 1).

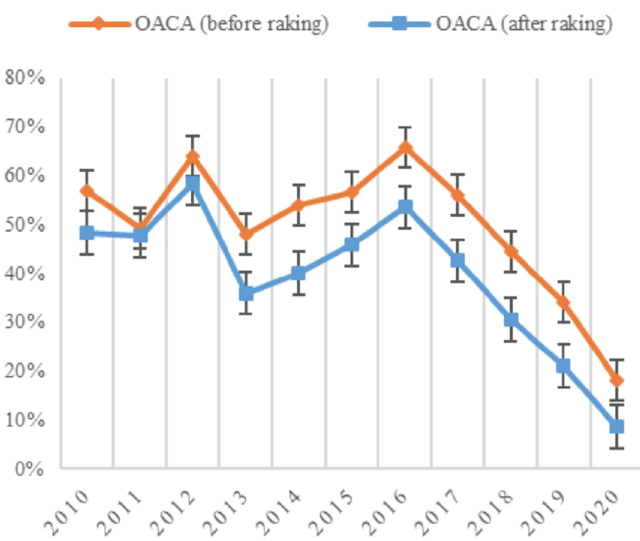

Figure 1. Open access citation advantage (OACA), all disciplines combined, for hybrid journals. [Reproduced from ref 35a, arXiv.org perpetual nonexclusive license].

The team ascribed the lack of (and the negative) OACA for publications in fully OA journals to the large number of newly established OA journals that are less attractive to highly cited researchers, whereas the positive OACA of publications in hybrid journals would be due to the fact that these journals usually are well-reputed publications for the respective scientific communities. As expected, any OA article in said journals would have higher citations than paywalled articles in the same journal. Yet, the fact that the OACA nearly vanished in 2020 would be due to the fact that Sci-Hub is now widely used by scholars in all countries to freely access paywalled articles. A Web site illegally granting free access to scholarly

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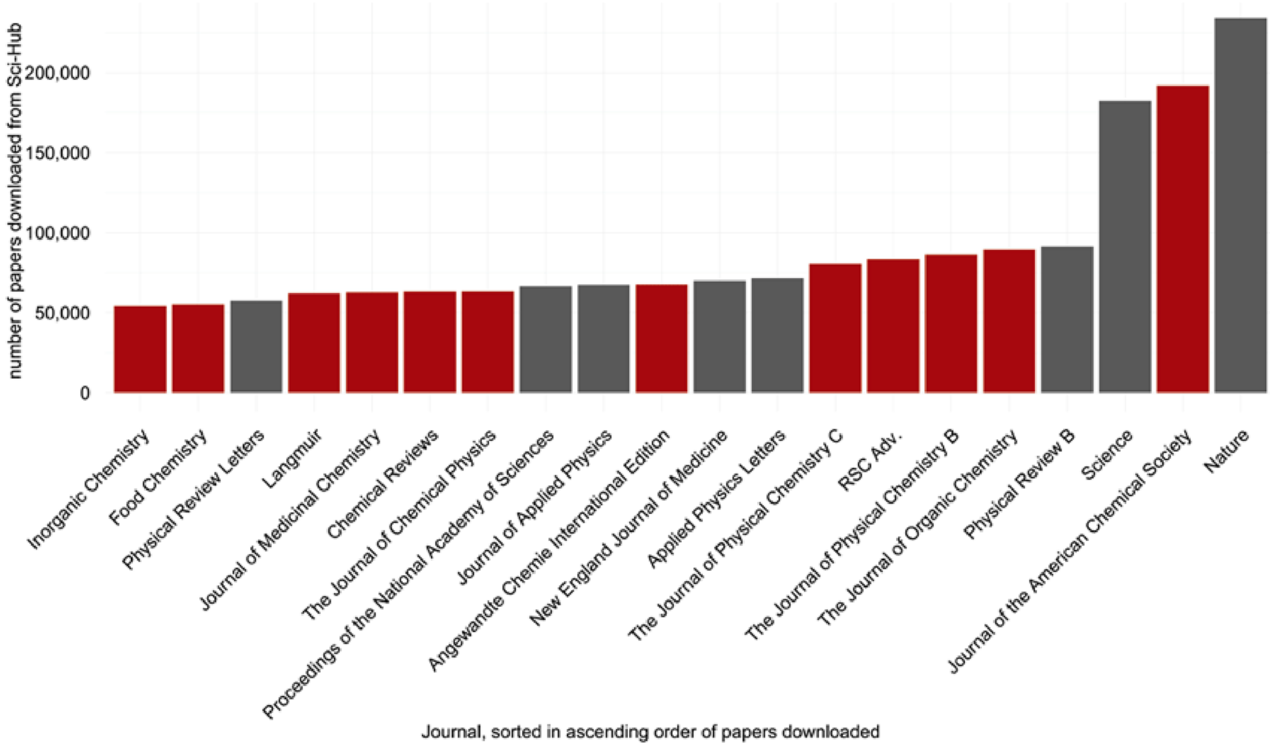

Figure 2. 20 journals with the most downloads from Sci-Hub between September 2015 and February 2016. Chemistry journals are highlighted in red. [Reproduced from ref 38, Creative Commons Attribution License, and Creative Commons Zero "No rights reserved"" data waiver].

articles, indeed, Sci-Hub by early 2017 already contained 85.1% of articles published in paywalled journals.[36] This fact, the researchers concluded, "instantly cancels the positive effect of OA publication insofar as question of access to scientific content no longer arises".[35a]

In other words, Sci-Hub has made nearly all scholarly articles OA *de facto* available to anyone having an Internet connection. Accordingly, articles downloaded from Sci-Hub are cited 1.72 times more than papers not downloaded from the platform.[37]

As it may be expected for a field with a large number of researchers globally having the largest share of the paywalled literature amid all basic sciences,[20] the use of Sci-Hub was found particularly frequent and significant amid research chemists, with 12 of the top 20 requested journals, based on the 28 million downloads from Sci-Hub between September 2015 and February 2016, specializing in chemistry (Figure 2).[38]

In today's science publishing age enabled by the Internet the citation drivers in chemistry are no longer only those identified by analyzing manuscript submitted in year 2000 to an élite general chemistry journal (the publication *h*-index for the cited references in a publication, the research subfield, and the number of highly cited authors of a paper).[34]

New citation drivers for example include: (i) the purposeful use of social media to communicate research achievements,[39] (ii) the use of the preprint for more effective (anticipated, disintermediated, and freely accessible) scholarly publishing, and (iii) the utilization of academic social networks to reach out a largely higher number of scientists than it happens when academic publications featured only in print journal issues or in the corresponding Web site of the publisher. ResearchGate, for example, by March 2022 had 23 million users,[40] and recent research indicates a clear positive correlation between mentions on ResearchGate and citation counts.[41]

Many other factors drive citations of chemistry studies including even non-scientific features such as the author experience, the number of authors, the level of collaboration, the article length, and the number of references that all positively correlate with citation counts, particularly in chemistry and in biology.[42] Furthermore, studying 16,378 articles published between 2000 and 2009, Thelwall and Didegah found that in chemistry, the number of pages together with the number of cited references is an important driver of increased citations, suggesting that in chemistry long articles do not necessarily need to have a long list of cited references to receive higher number of citations.[42] Finally, in chemistry international collaboration associates with increased citations.[43]

In addition, any article in a "hot" research topic, namely, a field in which numerous research groups work in the same years, will tend to attract more citations than an article in the same journal dealing with a research field with only a few researchers. Today such topics include solar energy, batteries, sustainability, the bioeconomy, biorefineries, data science, flow chemistry, capacitors, and CO_2 reduction, while in the early 2000s, they included carbon nanotubes, supramolecular chemistry, mesoporous silicas, nanocellulose, microencapsulation, and asymmetric catalysis. For example, in 2020, the first chemistry article in the top 100 scientific articles of the year according to the Altmetric score was a study on a two-enzyme system for plastic depolymerization,[44] and thus to treat the plastic waste problem. In the subsequent three years, the study has accrued 251 citations.

2.4. Today's Citation Habits. Since the seminal study[29] of Rose-Wiles and Marzabadi identifying citation patterns of chemists publishing in ACS journals between 2011 and 2015,

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Table 2. Selected Citation Aspects for 10 Communication Articles in Issue 50/2023 of *Chemical Communications*

entry	communication title	accessibility	number of citations	citations of journal articles	citations of books	citations of reports/preprints	citations of Web sites/software/patent/note
1	Dimethylnonacethrene - en route to a magnetic switch	OA	44	44			
2	Spontaneous preparation of a fluorescent ratiometric chemosensor for metal ions using off-the-shelf materials	OA	44	42	1		1
3	Synthesis of indene-fused spiro-dibenz(ox)azepines via Rh(III)-catalyzed cascade regioselective C−H activation/annulation	paywalled	37	37			
4	Metal-coordinated distibene and dibismuthene dications−isoelectronic analogues of butadiene dications	OA	68		2		1
5	Synthesis of complex aryl MIDA boronates by Rh-catalyzed [2 + 2+2] cycloaddition	OA	44	42	2		
6	CRISPR-Cas12a coupled with cyclic reverse transcription for amplified detection of miRNA	paywalled	31	31			
7	Iodine-mediated photoinduced tunable disulfonylation and sulfinylsulfonylation of alkynes with sodium arylsulfinates	OA	47	47			
8	Aqueous mediated iodine catalyzed C−N coupling followed by C−C coupling toward 5H-pyrazino[2,3-b]indoles	paywalled	48	47			1
9	Modulation of bulk and surface electronic structures for oxygen evolution by Cr, P codoped Co3S4	paywalled	20	20			
10	Reversible interconversion of pharmaceutical salt polymorphs facilitated by mechanical methods	paywalled	38	38			

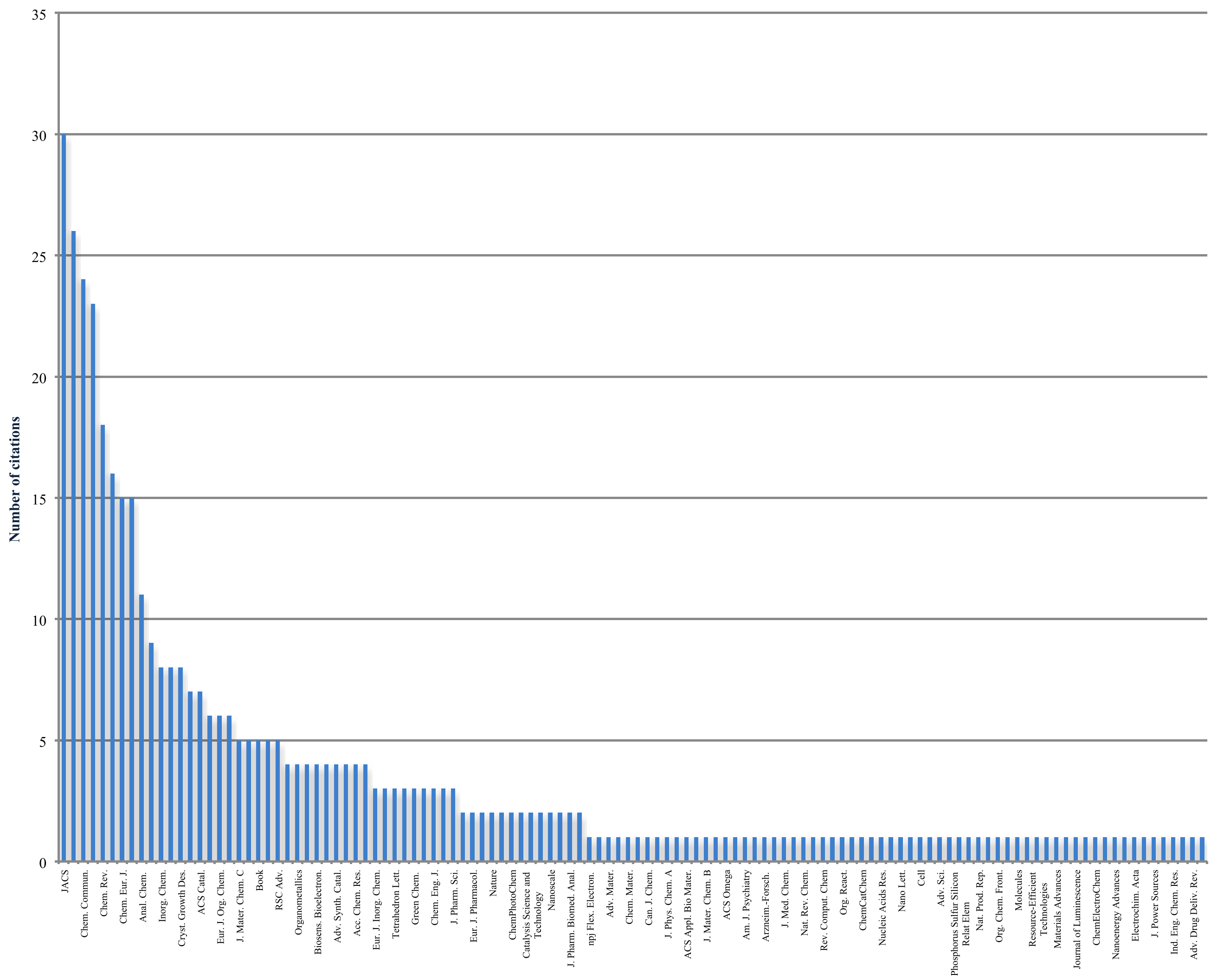

Figure 3. Journals cited and number of citations in 10 selected communication articles in issue 50/2023 of *Chemical Communications* (from pages 7743 to 7782).

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researchers in the chemical sciences significantly increased the share of OA papers published.[17,18] Still, the citation habits of research chemists have barely changed. It is instructive, in this respect, to review the references cited in 10 communication articles from a recent issue (50/2023) of *Chemical Communications*, the leading communications journal in chemistry.

Results in Table 2 show that élite research chemists continue to cite nearly exclusively journal articles. In agreement with findings pointing to increasing uptake of OA publishing also in chemistry,[18] five out of ten communications were found to be openly accessible. Once again, the highly skewed distribution following a power law (ubiquitous in scholarly publishing)[45,46] for which a few journals account for most citations is observed (Figure 3). Out of 421 overall citations, the first ten journals cited (Table 3) account for nearly 50% (44.4%) of all citations. The first 23 journals (20% of the 115 journals cited) accounted for 62.5% of all citations.

Table 3. Top 10 Journals Cited and Number of Citations in 10 Selected Communication Articles in Issue 50/2023 of *Chemical Communications*[a]

entry	journal	citation counts
1	*The Journal of American Chemical Society*	30
2	*Organic Letters*	26
3	*Chemical Communications*	24
4	*Angewandte Chemie International Edition*	23
5	*Chemical Reviews*	18
6	*Chemical Society Reviews*	16
7	*Chemistry A European Journal*	15
8	*Journal of Organic Chemistry*	15
9	*Analytical Chemistry*	11
10	*Chemical Science*	9

[a]From pages 7743 to 7782.

Inspection of Figure 3 displaying the journals cited and number of citations and of Table 3 showing the top ten journals cited and number of citations clearly shows that the élite chemists publishing in *Chemical Communications* nearly exclusively cite research articles from élite chemistry journals such as *The Journal of American Chemical Society* (JACS), *Angewandte Chemie International Edition* (ANIE), *Organic Letters,* and the very same *Chemical Communications*.

The only two review journals cited were *Chemical Reviews*, *Chemical Society Reviews* alongside *Coordination Chemistry Reviews*. *Chemical Science*, namely, the "main free to publish and free to read" journal published by the RSC, ends the ranking.

The analysis limited to a small sample comprised of 10 articles in a communications journal obviously does not represent what today's research chemists actually cite. It is enough to review the research articles published in a recent issue of a specialized journal, such as *ChemCatChem*, *Nature Catalysis*, or *Catalysts*, to identify a different citation pattern for which many more references are cited, with many of them citing specialized journals in the field (catalysis, in this case).

Alone, researchers in the broad field of catalysis science and technology contribute more than 51,000 research articles yearly, with papers getting published in 160 different research journals, most of which multidisciplinary venues.[47] Similarly, citations in full research articles published by general chemistry or multidisciplinary journals such as *Molecules* and *Scientific Reports* follow a different pattern, although a clear preference of research chemists for citing journal articles persists.

For example, one selected article in *Molecules* published around the same time of the *Chemical Communications* 50/2023 issue mentioned above, includes (see the Supporting Information) 40 citations, 37 of which refer to journal articles. Yet, citations are significantly more scattered, with 23 journal articles receiving a single citation and only the main natural product chemistry journal (*Journal of Natural Products*, Table 4) receiving more than one citation.

Table 4. Top Five Journals Cited and Number of Citations in a Selected Article in Issue 12/2023 of *Molecules*[a]

entry	journal	citations
1	*Journal of Natural Products*	7
2	*Phytochemistry*	5
3	*Fitoterapia*	3
4	*Molecules*	2
5	*Chinese Traditional and Herbal Drugs*	1

[a]S. Yan, C. Ke, Z. Feng, C. Tang, Y. Ye, The first phytochemical investigation of *Artemisia divaricate*: sesquiterpenes and their anti-inflammatory activity, *Molecules* 28 (2023) 4254.

Another article published around the same time in the multidisciplinary journal *Scientific Reports* had its 44 references scattered across 36 different journals and one software. The journals cited spanned a wide field, from élite physics journals such as *Physical Review B* to neurology journals. Again, only six journals received more than a single citation (Table 5).

Table 5. Top Five Journals Cited and Number of Citations in a Chemistry Article Published in May 2023 by *Scientific Reports*[a]

entry	journal	citations
1	*Food Chemistry*	3
2	*Journal of Natural Products*	2
3	*Journal of Agricultural and Food Chemistry*	2
4	*Journal of the American Chemical Society*	2
5	*Phytomedicine*	2

[a]Y. Shimamoto, T. Fujitani, E. Uchiage, H. Isoda, K.-i. Tominaga, Solid acid-catalyzed one-step synthesis of oleacein from oleuropein, *Sci. Rep.* 13 (2023) 8275.

3. CONCLUSIONS

Experiencing rapid growth in knowledge production since the early 1990s,[48] today's chemistry research is highly cross-disciplinary field of the natural sciences in which knowledge from biochemistry, bioengineering, biology, and microbiology has been steadily growing into chemistry territory since over 30 years.[49]

The analysis presented in this study suggests three main findings that will hopefully assist chemistry researchers in gaining a closer knowledge of citation patterns and citation habits of fellow chemists. First, research chemists continue to chiefly cite journal articles over any other form of citeable items (software, book, patent, preprint, data set, Web site, book chapter, etc.). Second, élite research chemists chiefly cite articles in reputed general chemistry journals, including relatively new OA journals established by the leading chemistry publishers in the early 2010s. Third, chemistry researchers

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publishing research articles in general chemistry or multidisciplinary journals tend to cite many more journals including specialized publications.

Further studies using large data sets will reach conclusive outcomes of general value. For example, the 2013 study of Thelwall and Didegah based on 16,378 articles published between 2000 and 2009 found that in chemistry, a unit increase in the JIF increases the mean citation count by 31.9%.[43] The fact that no correlation was found between the JIF and citations in the 2018 study identifying citation patterns of chemists publishing 600 articles published in 10 ACS journals between 2011 and 2015[29] may result from the smaller sample size studied in the latter case.

Today's research chemists are no exception to the reality of today's hypercompetitive research landscape in which the amount of information produced vastly exceeds the amount of attention available.[50] Chemists too compete for the attention of their peers and increasingly use digital media to attract such attention. Accordingly, after about a decade in which no correlation was found between research impact metrics alternative to citation-based metrics ("altmetrics") and citations,[51] the increasingly widespread use of social media by chemistry scholars[39] has lately translated into a strong positive correlation between the altmetric score and number of citations.[52]

A similar outcome in chemistry is likely to occur for preprints that are already cited and widely read by research chemists.[53] For instance, the aforementioned 19.598 preprints online at ChemRxiv by September 5, 2023 had been downloaded 10,706,202 times.[27] This means that by preprinting their research chemists not only accelerate the pace of innovation,[54] but they increase the visibility of their research and thus the likelihood to have their work cited.[55]

Chemistry researchers should not naively assume that publishing in OA journals will automatically translate into increased citations, because Web sites such as Sci-Hub already make their research output published in the international literature openly accessible.[35] It is more beneficial, in this respect, to "green" self-archive all published research articles in a personal academic Web site, thereby offering to colleagues interested in a research chemist's work a complete and logically ordered outlook of one's researcher activity. Yet, in late 2023, most research chemists in their institutional or personal academic Web site continued to list their research papers in the "Publications" web page as a numbered list of research articles without providing free access to the articles. Hopefully, therefore, the outcomes of this study will also assist in promoting the uptake of self-archiving among research chemists.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsomega.3c07037.

> Data set for journal citations and citation counts for the ten selected papers from *Chemical Communications* 50/2023 as well as references for the two papers published in *Scientific Reports* and in *Molecules* cited in the study (PDF)

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