



Fifty years of inorganic biochemistry: Developments, trends, highlights, impact and citations

Jan Reedijk

Leiden Institute of Chemistry, Leiden University, PO Box 9502, 2300 RA Leiden, the Netherlands



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ABSTRACT

A brief historic overview and analysis is presented of the almost 9000 scientific articles that have appeared in the Journal of Inorganic Biochemistry (JIB) and its predecessor (Bioinorganic Chemistry), since 1973. This overview has a focus on the different topics, in particular on the different elements of the Periodic Table and on papers that have received very large numbers of citations. Over the whole period, copper has been the element occurring in most publications (almost 1800, which is 20%), followed by iron which occurs in some 12% of all papers. Other favorite elements are zinc, platinum and ruthenium. The worldwide origin of papers published in JIB has been analyzed as well, showing a quite evenly worldwide distribution, with just a few exceptions. Trends in selected scientific topics over time (first 10 years; last 25 years, last 10 years) are also discussed. Also authors and institutes with the largest number of papers published in JIB have been detected. The numerical information is based on an analysis of the Web of Science with a cutoff date around July 1, 2020.

1. Introduction

At a golden jubilee of an important journal it is worthwhile to look at the accomplishments of the past, and of course also to look ahead. In this paper I will look backwards and consider some statistics and developments of the journal. But first of all congratulations are due to the present editor, who has been serving the journal for almost 25 years, to the publishers and of course also congratulations to the groups of authors that have been sending regularly some of their best papers to the Journal of Inorganic Biochemistry (JIB).

A few years after my own PhD (1968) I started to become interested in the role of metal ions in living systems, be it the natural role, the curing role, or the application of bioinorganic principles in materials, catalysis and the environment. Like many of my colleagues in the field, I have regularly submitted research papers to JIB, and a total of 45 were published between 1980 and 2016. Having served on the editorial board since 1991, it is a pleasure to investigate the impact and use of the journal by authors since its beginning, and to describe a summary below.

The predecessor journal (*Bioinorganic Chemistry*; started by Gerhard Schrauzer) was really early in the recognition of the importance of the new, interdisciplinary field. In 1970 there was little more in the field than the few 3D structures of some metalloenzymes, and some early papers on metal-containing drugs. After the start of a Gordon Research Conference series, in 1962, initially called “Metals and Metal Binding in Biology” and in 1978 renamed to “Metals in Biology”, several initiatives

for workshops, meetings, summer schools and journals started worldwide. But it lasted till 1983 before the first “International Conference on Biological Inorganic Chemistry” (abbreviated as ICBIC; for the first two decades called “International Conference on Bioinorganic Chemistry”) was held (Florence 1983; initiated by Ivano Bertini, Bo Malmström, Harry B. Gray and Helmut Sigel). Later-on also Regional Bioinorganic/Biological Inorganic Chemistry Conferences (BICs) were initiated, like EuroBIC, AsiaBIC and LABIC (from Latin American countries).

In 1979 the scope of the first journal was widened, a new publisher was found, and the *Journal of Inorganic Biochemistry*, JIB, was born. The first editors of the refurbished journal were H. Allen O. Hill (Oxford University) and James F. Riordan (Harvard University), till 1996 when John Dawson took over the Editor-in-chief job. Currently the journal has obtained a stable position and has been successful in maintaining it, despite the fact that several regular inorganic chemistry journals, as well as biochemistry journals, started to encourage authors to submit research papers in this field, and also after a new journal entered the field, i.e. the Journal of Biological Inorganic Chemistry, abbreviated JBIC. In fact, JIB indeed has kept its strong position for a long period, as will be illustrated below.

2. Numerical information

An extensive research in the Web of Science (Clarivate Analytics) around July 1, 2020, has resulted in a number of interesting and

E-mail address: reedijk@chem.leidenuniv.nl.

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historically relevant data; a selection of the most relevant of these will be presented below. The Web of Science (WoS) started to cover “Bioinorganic Chemistry” only 2 years after the start of the journal “Bioinorganic Chemistry”, i.e. from 1973 onwards, till it changed its title in 1978; in total “*Bioinorganic Chemistry*” had published 255 articles covered by WoS.

NB: It is to be noted that in 2017 the Book Series: **Essays in Biochemistry**, includes 10 chapters under the title “Bioinorganic Chemistry”; these also are extracted into the Web of Science. These 10 titles are as yet hardly cited and do not disturb the results presented below.

The growth of the journal is clearly visible by looking at the number of papers. As the Web of Science only lists the “citable papers”, these numbers will be used in most of the Figures and Tables below. All papers in the journal have been classified into two fields used by the WoS, namely *Biochemistry and Molecular Biology*, and *Inorganic and Nuclear Chemistry*.

In the first decade 578 papers appeared, and in the last decade (2010–2020) this number is an impressive 2451, i.e. currently an average of some 245 articles per year. Over the whole period the journal had published (as measured till July 1, WoS) 8950 papers, from which 7329 had appeared in the last 25 years. The growth parallels the growth and the importance of the field. From the hundreds of authors, the top 4 who published most articles consists of: Henryk Kozłowski (as many as 91 articles), followed by Bernhard Keppler with 55 articles, Luigi Messori with 54 articles, and Isabel Moura with 53 articles. Another 12 authors all had between 40 and 50 articles published in JIB since its beginning.

In [Table 1](#) a selection of the publication and citation details is presented, including their variation over time, and a selection of classifications.

From all the 183,400 citations that JIB has received, the number of self-citations is quite low, namely just 4%. The most cited paper over the whole period has been cited 721 times, as shown in [Fig. 1](#). [Figs. 2, 3 and 4](#), show the highest cited papers in the other analyzed periods. The all-time most cited paper is that of Hartinger et al. from 2006 [1], followed by a review on Cd carcinogenesis, still receiving over 30 citations each year [2]. Even the 3rd ranked paper (from 1981; Doyle and Hoekstra, [3]) is still receiving a significant number of citations each year. The journal as a whole has received annually between 10,000 and 12,000 citations in the last decade.

Interestingly, the 4 most cited papers from the first decade have all remained popular, and it is also interesting to see in [Fig. 4](#) that these top-4 papers are still being cited up till today, i.e. even about 40–45 years after their first appearance [3,8–10].

Since 2007 the citation rates of any scientific journal are being quite accurately monitored by the WoS, and the figures for JIB have been pretty stable over the whole period, with all years having a (2-year) Journal Impact Factor (JIF) continuously above 3, and also the 5-year impact factor has been well above 3 since the start of its measurements by WoS (2007). In the recently introduced Citescore [11], the value of 6.0 also indices a leading position in the field, illustrating the constant

quality and impact of the journal since 2007. Also the number of papers in JIB since 2007 has remained rather constant, varying from just over 210 to 265 per calendar year.

Before 2007 many WoS measurements were less accurate, also for reasons of sometimes inconsistent definitions of papers that were considered as citable. In addition, for a few calendar years JIB had a few hundreds of conference papers included in a special issue of JIB, like in 2001 and 2003; these abstracts were largely taken from ICBIC conferences. In fact these abstracts in some way may disturb the statistics on the topics below, since such conference abstracts did not appear with their appropriate key words in WoS.

3. Popular elements

It is interesting to see what have been the most studied elements from the Periodic Table, not only over the whole period, but also over the first 10 years, the last 25 years and the most recent 10 years. Four elements have been really studied by many groups worldwide. These elements are highlighted in [Table 2](#), whereas the other elements for which over 100 papers have been published in the journal are listed in [Table 3](#). Some 20% of all papers that have appeared in JIB deal with copper, and 12% involve iron as the main topic of the paper.

As expected, early recognized metals in the bioinorganic field, i.e. Fe, Cu and Zn, appear as prominently present in all analyzed periods. It is interesting to see that the metal platinum and the topic cancer/anticancer, which were hardly present in the first decade, have grown tremendously in the most recent period. In total as many as 23 different elements of the Periodic Table (19 metals, 4 non-metals) are covered in at least 100 papers that appeared in JIB since 1973. It is also interesting to note that the h index for each of the 6 items in [Table 2](#) goes parallel with the number of total citations, illustrating a comparable impact for each of the 4 metals and 2 major topics.

From the non-metals, the top-4 elements appearing in key words and topics in the analysis of the WoS are S: 456, P: 390; Cl: 320; Br 240.

Apart from an increasing amount of metals being studied over the years, also a WoS search on anti-cancer and cancer has shown a very strong increase over the last 25 years, while very little of this topic was covered in the first 25 years. On the other hand, a frequently studied topic like oxidation/reduction has been present from the very beginning in the journal. Details of the two topics are also briefly mentioned in [Table 2](#).

In [Table 3](#) a list is presented of all elements for which at least 20 papers have appeared in JIB since 1973. There are also publications in JIB dealing with an additional 15 elements, with frequencies between 19 and 1.

In [Fig. 5](#) all the elements reported in the journal with their relative frequencies are listed color-coded in a Periodic Table format, allowing an easy graphical comparison, and again showing the wide occurrence of papers of almost all elements of the Periodic Table. As can be seen from the figure, as many as 39 metals occur more than 10 times in a JIB research paper.

Table 1

Publications details of the journals since 1973, i.e. the first year that the journal “Bioinorganic Chemistry” was covered by the WoS. Source: Web of Science July 1, 2020.

| Topic | 1973–2020 | 2010–2020 | 1995–2020 | 1973–1983 | Comment |
|--|--------------------|----------------|--------------------|------------------|---|
| Total citable papers | 8950 | 2451 | 7329 | 578 | Listed by WoS |
| Total full articles | 6549 | 2321 | 4990 | 534 | Listed by WoS |
| Total reviews | 178 | 83 | 173 | 2 | Listed by WoS |
| Other papers, notes & non-citable papers | Over 2000 | Over 250 | Over 500 | 32 | Only some of these listed by WoS do contribute to the journal impact factor (JIF) |
| Total citations with h index* | 183,400 h = 131 | 3634 h = 61 | 146,250 h = 125 | 14,700 h = 58 | Note: The h index for all papers amounts to 131 |

* When h = 131, it means that 131 articles were cited 131 times or higher.

How are these totals calculated?

| | 2016 | 2017 | 2018 | 2019 | 2020 | Total | Average Citations per Year |
|--|-------|-------|-------|-------|------|--------|----------------------------|
| Use the checkboxes to remove individual items from this Citation Report | | | | | | | |
| or restrict to items published between 1945 and 2020 Go | | | | | | | |
| | 10949 | 11356 | 11421 | 12089 | 5202 | 182615 | 3885.43 |
| 1. From bench to bedside - preclinical and early clinical development of the anticancer agent indazolium trans-[tetrachlorobis(1H-indazole)ruthenate(III)] (KP1019 or FFC14A) By: Hartinger, Christian G.; Zorbas-Seifried, Stefanie; Jakupec, Michael A.; et al. JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 100 Issue: 5-6 Pages: 891-904 Published: MAY 2006 | 60 | 58 | 33 | 59 | 15 | 721 | 48.07 |
| 2. Cadmium carcinogenesis in review By: Waalkes, MP JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 79 Issue: 1-4 Pages: 241-244 Published: APR 2000 | 40 | 47 | 40 | 33 | 17 | 586 | 27.90 |
| 3. OXIDATION OF NITROGEN-OXIDES BY BOUND DIOXYGEN IN HEMOPROTEINS By: DOYLE, MP; HOEKSTRA, JW JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 14 Issue: 4 Pages: 351-358 Published: 1981 | 8 | 10 | 12 | 15 | 6 | 514 | 12.85 |

Fig. 1. The top 3 most cited papers published in this journal since 1973; see [1–3]. WoS, July 1, 2020.

4. Geographic analysis

An international journal is expected to have contributions from all over the world. To check this in some detail, also a geographic analysis has been performed. As the WoS database contains for each paper the country names (i.e. 1, or more in collaborative projects) for each article is it possible to analyze this information and see from where the papers published in the journal originate from.

In Table 4, the countries from which 124 or more JIB papers are present in the database are listed. It should be noted that a paper authored by scientists from 2 or more countries, has been counted for each country. In total JIB has had authors from 98 different countries.

It is interesting to see that the worldwide distribution more or less parallels the overall chemical research activities over the years. The relatively high numbers of papers - given the population of the countries - reported for Italy, Australia, Portugal and Greece are noteworthy.

| | 2016 | 2017 | 2018 | 2019 | 2020 | Total | Average Citations per Year |
|--|------|------|------|------|------|-------|----------------------------|
| Use the checkboxes to remove individual items from this Citation Report | | | | | | | |
| or restrict to items published between 2010 and 2020 Go | | | | | | | |
| | 4249 | 5018 | 5679 | 6446 | 2942 | 35927 | 3266.09 |
| 1. Approaching tumour therapy beyond platinum drugs Status of the art and perspectives of ruthenium drug candidates By: Bergamo, A.; Gaiddon, C.; Schellens, J. H. M.; et al. JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 106 Issue: 1 Pages: 90-99 Published: JAN 2012 | 62 | 57 | 37 | 41 | 24 | 373 | 41.44 |
| 2. What do we know about the reduction of Pt(IV) pro-drugs? By: Wexselblatt, Ezequiel; Gibson, Dan JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 117 Pages: 220-229 Published: DEC 2012 | 30 | 27 | 26 | 30 | 14 | 185 | 20.56 |
| 3. Interaction of copper(II) with the non-steroidal anti-inflammatory drugs naproxen and diclofenac: Synthesis, structure, DNA- and albumin-binding By: Dimiza, Filitsa; Perdih, Franc; Tangoulis, Vassilis; et al. JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 105 Issue: 3 Pages: 476-489 Published: MAR 2011 | 23 | 15 | 24 | 27 | 8 | 179 | 17.90 |

Fig. 2. The top 3 most cited papers published in the last decade (2010–2020), see [4–6]. WoS, July 1, 2020.

| | 2016 | 2017 | 2018 | 2019 | 2020 | Total | Average Citations per Year |
|--|-------|-------|-------|-------|------|--------|----------------------------|
| Use the checkboxes to remove individual items from this Citation Report | | | | | | | |
| or restrict to items published between | 1995 | and | 2020 | Go | | | |
| | 10302 | 10791 | 10909 | 11474 | 4943 | 145499 | 5596.12 |
| 1. From bench to bedside - preclinical and early clinical development of the anticancer agent indazolium trans-[tetrachlorobis(1H-indazole)ruthenate(III)] (KP1019 or FCC14A) | | | | | | | |
| By: Hartinger, Christian G.; Zorbas-Seifried, Stefanie; Jakupec, Michael A.; et al. JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 100 Issue: 5-6 Pages: 891-904 Published: MAY 2006 | 60 | 58 | 33 | 59 | 15 | 721 | 48.07 |
| 2. Cadmium carcinogenesis in review | | | | | | | |
| By: Waalkes, MP JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 79 Issue: 1-4 Pages: 241-244 Published: APR 2000 | 40 | 47 | 40 | 33 | 17 | 586 | 27.90 |
| 3. High-valent iron in chemical and biological oxidations | | | | | | | |
| By: Groves, John T. JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 100 Issue: 4 Pages: 434-447 Published: APR 2006 | 21 | 31 | 30 | 33 | 10 | 444 | 29.60 |

Fig. 3. The top 3 most cited papers published in the last 25 years (1995–2020); see [1,2,7]. WoS, July 1, 2020.

From the institutes and universities the largest number of papers originate from the University of Wrocław (170 JIB papers contain this address), followed by the University of Florence (160 JIB papers contain this address).

5. Final remarks

Having analyzed the almost 9000 papers that have appeared in the Journal of Inorganic Biochemistry it is clear that a healthy and stable journal has been formed that now has matured, especially over the last

| | 2016 | 2017 | 2018 | 2019 | 2020 | Total | Average Citations per Year |
|--|------|------|------|------|------|-------|----------------------------|
| Use the checkboxes to remove individual items from this Citation Report | | | | | | | |
| or restrict to items published between | 1973 | and | 1983 | Go | | | |
| | 168 | 142 | 133 | 164 | 68 | 14700 | 312.77 |
| 1. OXIDATION OF NITROGEN-OXIDES BY BOUND DIOXYGEN IN HEMOPROTEINS | | | | | | | |
| By: DOYLE, MP; HOEKSTRA, JW JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 14 Issue: 4 Pages: 351-358 Published: 1981 | 8 | 10 | 12 | 15 | 6 | 514 | 12.85 |
| 2. CANCER MORTALITY CORRELATION STUDIES .3. STATISTICAL ASSOCIATIONS WITH DIETARY SELENIUM INTAKES | | | | | | | |
| By: SCHRAUZER, GN; WHITE, DA; SCHNEIDER, CJ BIOINORGANIC CHEMISTRY Volume: 7 Issue: 1 Pages: 23-34 Published: 1977 | 2 | 4 | 6 | 5 | 2 | 423 | 9.61 |
| 3. STRUCTURAL AND ELECTRONIC EFFECTS ON POLAROGRAPHIC HALF-WAVE POTENTIALS OF COPPER (II) CHELATE COMPLEXES | | | | | | | |
| By: PATTERSON, GS; HOLM, RH BIOINORGANIC CHEMISTRY Volume: 4 Issue: 3 Pages: 257-275 Published: 1975 | 2 | 2 | 4 | 3 | 1 | 295 | 6.41 |
| 4. ISOLATION OF A LOW-MOLECULAR WEIGHT ZINC-BINDING LIGAND FROM HUMAN-MILK | | | | | | | |
| By: LONNERDAL, B; STANISLOWSKI, AG; HURLEY, LS JOURNAL OF INORGANIC BIOCHEMISTRY Volume: 12 Issue: 1 Pages: 71-78 Published: 1980 | 3 | 0 | 0 | 0 | 1 | 184 | 4.49 |

Fig. 4. The top 4 most cited papers published between 1973 and 1983. See [3,8–10]. WoS, July 1, 2020.

Table 2

Papers dealing with the top 4 metallic elements in JIB, and their growths since 1983, and a few specific topics (cancer and anticancer; oxidation and reduction). Data from WoS, July 1, 2020.

| Element | 1973–1983 | Last 25 years | Last 10 years | 1973–2020 | Citations | h index |
|------------------------|-----------|---------------|---------------|-----------|-----------|---------|
| Cu | 90 | 1500 | 638 | 1777 | 46,615 | 90 |
| Fe | 33 | 1017 | 348 | 1153 | 27,549 | 74 |
| Pt | 15 | 644 | 283 | 728 | 19,882 | 65 |
| Zn | 35 | 590 | 267 | 691 | 17,392 | 62 |
| Cancer and anticancer | 8 | 1177 | 832 | 1201 | 32,343 | 76 |
| Oxidation or reduction | 38 | 1354 | 570 | 1488 | 37,550 | 84 |

Table 3

Number of papers in JIB (1973-present) dealing with the relevant elements of the Periodic Table (only those present in 20 or more papers are listed). Details about Cu, Zn and Pt are in Table 2. Not-listed elements are present in 20 or less papers published in JIB, since 1973. Source WoS, July 1, 2020.

| Element | 1973–2020 | Element | 1973–2020 | Element | 1973–2020 |
|---------|-----------|---------|-----------|---------|-----------|
| Ru | 498 | Cd | 199 | I | 41 |
| S | 456 | Mo | 138 | Si | 41 |
| P | 390 | Ag | 131 | Bi | 35 |
| Ni | 338 | Na | 130 | Ti | 35 |
| Al | 337 | Cr | 127 | As | 30 |
| Co | 324 | Mg | 100 | F | 32 |
| Cl | 320 | Se | 96 | B | 32 |
| V | 310 | Hg | 75 | Re | 31 |
| Mn | 243 | Gd | 57 | W | 30 |
| Br | 239 | Sn | 55 | Os | 26 |
| Ca | 243 | Pb | 50 | Li | 24 |
| Au | 211 | K | 46 | Sb | 22 |
| Pd | 201 | Ir | 43 | Tc | 20 |

25 years. Each year a rather constant number of 240 ± 20 articles has appeared, which on average are each cited quite frequently in the next two years, so that the Journal Impact Factor has been constant and well above 3. The Citescor [11], which also covers immediate citation and

Table 4

Distribution of JIB papers since 1973 over a variety of countries; only countries from which over 120 papers originate are listed. Source WoS, July 1, 2020.

| Country* | Papers in JIB | Country | Papers in JIB | Country | Papers in JIB |
|----------|---------------|-----------|---------------|-------------|---------------|
| USA | 2647 | France | 426 | Greece | 224 |
| Italy | 912 | Poland | 377 | Hungary | 192 |
| China | 701 | Australia | 312 | Netherlands | 160 |
| UK | 660 | Portugal | 302 | Sweden | 144 |
| Japan | 642 | Canada | 281 | Argentina | 132 |
| Germany | 510 | India | 276 | Switzerland | 125 |
| Spain | 486 | Brazil | 270 | Austria | 124 |

* Papers with authors from more than one country, do count for each country.

citation up to 4 years, has a value of 6.0 in 2019. The Journal has a stable position between related relevant “competing” journals, and the proportional contributions from authors worldwide, clearly illustrates this position. Common topics in the field of biological inorganic chemistry are all represented well.

Congratulations again to editor and staff, to authors and referees, for having generated and maintained a scientific journal in an important interdisciplinary research field. Of course I am happy to add my very best wishes for the future of JIB!

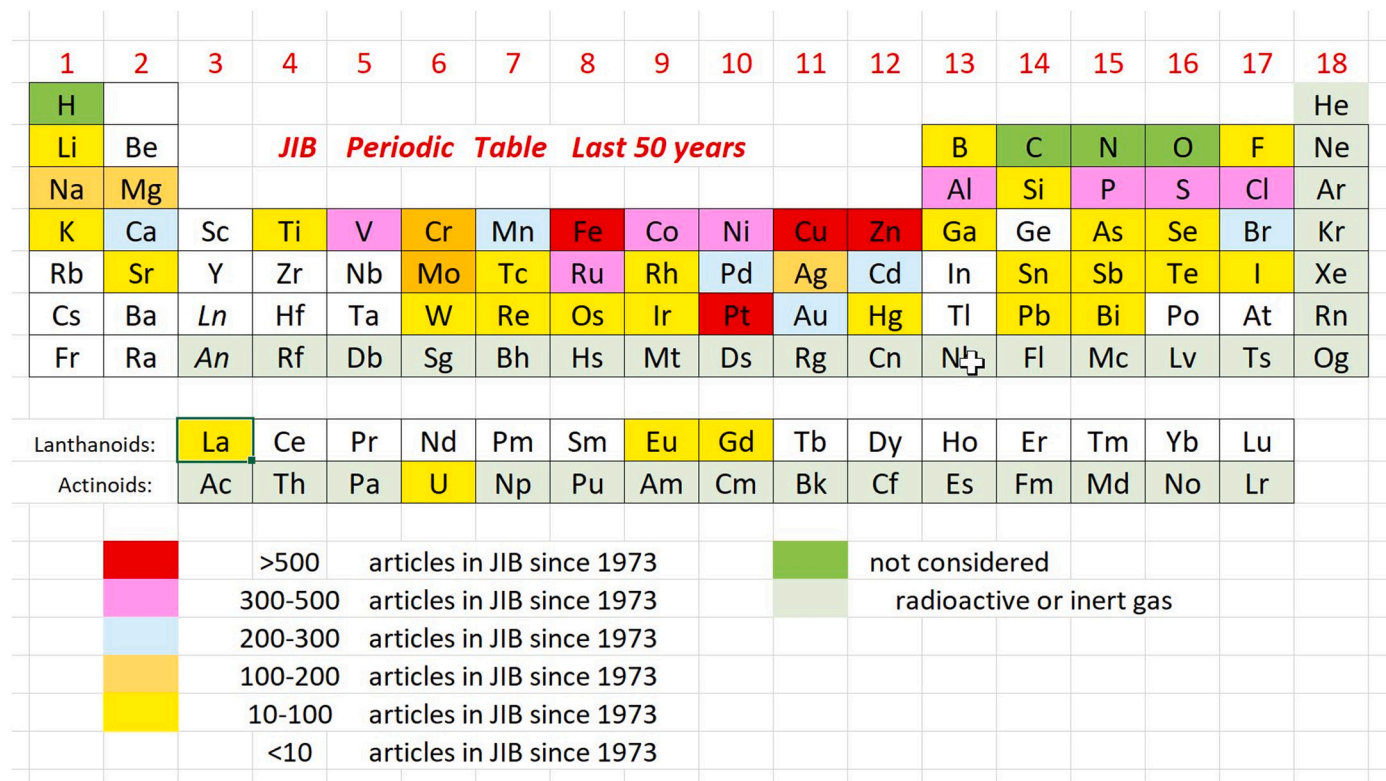


Fig. 5. Periodic Table illustrating the frequency of papers dealing with a certain element. Color codes are explained in the figure. Source WoS, July 1, 2020.

Declaration of competing interest

The author has no conflicts of interest.

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- [11] The **Citescore** is a relatively new indicator; it measures the average citations received per peer-reviewed document published in a specific journal. Citescore values are based on citation counts in a range of four consecutive years (e.g. 2016–2019) to peer-reviewed documents (articles, reviews, conference papers, data papers and book chapters) published in the same four calendar years, divided by the number of these documents published in the same four years. So the Citescore for JIB after the completion of the year 2019 = 5560 citations/927 papers = 6.0. This number is to be compared with for example *Inorg. Chem.* (8.0), *Dalton Trans.* (6.9), *Inorg. Chim. Acta* (3.9) and *Polyhedron* (3.9).