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Editorial

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New Virtual Special Issue of Most-Cited Papers Posts: All-Time Greats and Contemporary Favorites

Industrial & Engineering Chemistry Research (I&ECR), with variations in title and format, has been publishing applied chemistry and chemical engineering research for over 100 years. I will use I&ECR to refer generally to any of the titles under which the journal has been published. It is the oldest chemical engineering journal. The first issue was published in 1909, well before most academic chemical engineering departments even existed. I&ECR was just the second journal launched by the American Chemical Society (ACS), which now publishes more than 45 journals. Just as ACS launched the *Journal of the American Chemical Society* to publish significant research of general interest to a broad readership of chemists, it subsequently launched I&ECR to showcase impactful chemical research with potential industrial application that would be of general interest within chemical engineering and applied chemistry. Our editors focus on this mission today as we strive to select, for publication, only the articles that meet this high standard, which is consistent with the journal's tradition of excellence. Today, I&ECR is the largest and most-cited journal in chemical engineering, thanks to its international reach. To celebrate both the historical contributions of I&ECR and its ongoing role in chemical research, we have assembled and posted a virtual special issue that contains the most-cited papers of all time and from the past five years (http://pubs.acs.org/page/iecred/history).

■ ALL-TIME GREATS

Given its history, international reputation, and global reach, the journal has published many landmark articles that have had an especially profound impact on engineering practice, engineering science, and engineering research. Table 1, which lists the 15 most cited I&ECR papers of all time (according to the *ISI Web of Science*, as of the date of this editorial), provides a set of these impactful articles.

Ten of the 15 papers on the list deal with compiling, correlating, or predicting thermodynamic and transport properties, primarily for gases and liquids.[1,3,6−11,13,15] Three provide engineering science analyses of phenomena associated with the fundamentals of adsorption, absorption, and heterogeneous catalysis.[5,12,14] The two remaining articles focus on key concepts regarding the behavior of surfaces.[2,4] Most of the papers are from North American authors, but three are from Europe.[10−12] Six of the 15 are from industrial research laboratories or include a coauthor from industry.[3,7−9,14,15] Five of the articles have a single author, and six others have two authors. Only four of the 15 have more than two authors.

The first paper in the list[1] has been cited more than 4700 times. It reports the development of the Peng−Robinson equation of state, which has found wide use in describing vapor−liquid equilibrium and the properties of the coexisting phases. This equation is commonly featured in thermodynamics textbooks when illustrating the utility of cubic equations of state and their ability to balance simplicity and accuracy.

The second paper[2] is Wenzel's 1936 contribution that deals with the wetting of solid surfaces. It has been cited more than 4400 times. This article identified that surface roughness was a critical factor in determining wettability of a surface. It also reported contact angle measurements for many different surface-fluid combinations. Homogeneous wetting of a non-ideal (rough) surface is now referred to as "Wenzel wetting". The article was cited just once during the first two years after it was published, and it was cited just five times during the first 10 years it was in print. Recently, however, this article is being cited more than 500 times every year. This work was recently identified[16] as a "sleeping beauty" article—one that was seemingly "asleep" for a long period of time prior to "waking up" in 2003. Of course, the quality of this article has not changed during this time, but rather a field of research arose (engineered surfaces) that recognized this article as providing a portion of the theoretical framework for current work. This "sleeping beauty" provides an example of why one cannot rely solely on citations in the near term to assess the significance of a research article.

The third paper provides the work by Redlich and Kister that introduced their well-known eponymous expansion for describing the excess free energy of liquid mixtures.[3] The article by Fowkes[4] demonstrated how quantifying the contribution of the London dispersion force to the surface free energy unified several fields of surface chemistry that had been previously considered unrelated. The article by Hall et al.[5] involves the fundamentals of fixed-bed adsorption and is notable in that it provided numerical solutions (in 1966) to many different scenarios. The sixth paper provides a method for predicting second virial coefficients and, hence, pressure−volume−temperature (*PVT*) behavior and properties for fluids in the absence of experimental equilibrium data.[6] Chapman et al.[7] introduced the Statistical Associating Fluid Theory (SAFT) equation of state, which has enjoyed broad use for representing the properties of fluids comprising associating molecules. Huang and Radosz[9] broadened the applicability of the SAFT equation of state, and Gross and Sadowski[11] used perturbation theory to develop their perturbed chain modification (PC-SAFT). The eighth-most-cited paper of all time is a compilation of vapor pressure data for more than 1200 pure organic compounds.[8] The tenth paper provides a modified UNIFAC model, which permits improved predictions of thermodynamic properties.[10]

The list also includes Danckwerts' introduction of surface renewal theory as a mechanism for gas absorption into a liquid,[12] an article on predicting gas-phase diffusion coefficients,[13] and one on calculating the thermal conductivity of mixtures of solids.[15] At No. 14 is the classic analysis by Thiele, showing how diffusion within a porous catalyst particle can influence the apparent rate of heterogeneously catalyzed

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Table 1. Most-Cited Papers in I&ECR History

ref	title	author(s)	publication year
1	A New Two-Constant Equation of State	D. Peng and D. B. Robinson	1976
2	Resistance of Solid Surfaces to Wetting by Water	R. N. Wenzel	1936
3	Algebraic Representation of Thermodynamic Properties and the Classification of Solutions	O. Redlich and A. T. Kister	1948
4	Attractive Forces at Interfaces	F. M. Fowkes	1964
5	Pore- And Solid-Diffusion Kinetics in Fixed-Bed Adsorption under Constant-Pattern Conditions	K. R. Hall, L. C. Eagleton, A. Acrivos, and T. Vermeulen	1966
6	A Generalized Method for Predicting Second Virial Coefficients	J. G. Hayden and J. P. O'Connell	1975
7	New Reference Equation of State for Associating Liquids	W. G. Chapman, K. E. Gubbins, G. Jackson, and M. Radosz	1990
8	Vapor Pressure of Pure Substances—Organic Compounds	D. R. Stull	1947
9	Equation of State for Small, Large, Polydisperse, and Associating Molecules	S. H. Huang and M. Radosz	1990
10	A Modified UNIFAC Model. 2. Present Parameter Matrix and Results for Different Thermodynamic Properties	J. Gmehling, J. Li, and M. Schiller	1993
11	Perturbed-Chain SAFT: An Equation of State Based on a Perturbation Theory for Chain Molecules	J. Gross and G. Sadowski	2001
12	Significance of Liquid-Film Coefficients in Gas Absorption	P. V. Danckwerts	1951
13	A New Method for Prediction of Binary Gas-Phase Diffusion Coefficients	E. N. Fuller, P. D. Schettler, and J. C. Giddings	1966
14	Relation between Catalytic Activity and Size of Particle	E. W. Thiele	1939
15	Thermal Conductivity of Heterogeneous Two-Component Systems	R. L. Hamilton and O. K. Crosser	1962

Table 2. Ten Most-Cited Papers Published in I&ECR since 2010

ref	title	authors	publication year
17	Post-Combustion CO_2 Capture Using Solid Sorbents: A Review	A. Samanta, A. Zhao, G. K. H. Shimizu, P. Sarkar, and R. Gupta	2012
18	Magnetically Separable $ZnFe_2O_4$–Graphene Catalyst and its High Photocatalytic Performance under Visible Light Irradiation	Y. Fu and X. Wang	2011
19	Thermophysical Properties of Pure Ionic Liquids: Review of Present Situation	S. Aparicio, M. Atilhan, and F. Karadas	2010
20	Ionic Liquids for Aromatics Extraction. Present Status and Future Outlook	G. W. Meindersma, A. R. Hansmeier, and A. B. de Haan	2010
21	State-of-the-Art of CO_2 Capture with Ionic Liquids	M. Ramdin, T. W. de Loos, and T. J. H. Vlugt	2012
22	Current Status of Metal–Organic Framework Membranes for Gas Separations: Promises and Challenges	M. Shah, M. C. McCarthy, S. Sachdeva, A. K. Lee, and H.-K. Jeong	2012
23	Preparation and Characterization of Membranes Formed by Nonsolvent Induced Phase Separation: A Review	G. R. Guillen, Y. Pan, M. Li, and E. M. V. Hoek	2011
24	Modified TiO_2 for Environmental Photocatalytic Applications: A Review	R. Daghrir, P. Drogui, and D. Robert	2013
25	Effect of Water Adsorption on Retention of Structure and Surface Area of Metal–Organic Frameworks	P. M. Schoenecker, C. G. Carson, H. Jasuja; C. J. J. Flemming, and K. S. Walton	2012
26	Biomedical Applications of Metal Organic Frameworks	S. Keskin and S. Kızılel	2011

reactions. Of course, this analysis and the modulus that Thiele introduced is now a standard component of chemical reaction engineering courses. This article was cited just four times during its first five years in print, so it provides yet another example of the initial citation rate not necessarily being an adequate measure of the impact of a research article.

CONTEMPORARY FAVORITES

Having highlighted several of the classic papers published by I&ECR over the years, I now want to shine the spotlight on the most frequently cited papers I&ECR has published in the last five years. Table 2 provides the 10 most-cited papers published since 2010, listed in order of number of citations received, as of the writing of this editorial. All of these articles have received at least 100 citations and all are ISI "Highly Cited" papers, meaning their citation count places them in the top 1% in their academic field. In addition, article 24 had been listed as a "Hot Paper", meaning that it had received enough citations in its first two years to be in the top 0.1% of its academic field.

While two-thirds of the All-Time Greats in Table 1 involved the prediction of thermodynamic and transport properties, primarily for gases and liquids, only one of the Contemporary Favorites[19] focuses on properties (for ionic liquids). Rather, the majority of Contemporary Favorites involve materials for separations and for catalysis. The materials of most recent interest are metal organic frameworks (MOFs), ionic liquids, membranes, and photocatalysts.

Three of these top-10 papers involve ionic liquids and their potential role as solvents for separations in the chemical processing industry.[19−21] Four others focus attention on issues related to the use of MOFs for separations and in biomedical applications such as drug delivery, imaging, and sensing.[17,22,25,26] Three of the papers provide reviews or overviews on membranes (polymers,[23] MOFs,[22] and ionic liquids[21]). The current emphasis in chemical engineering and applied chemistry research on environmental issues and sustainability is also readily evident as nearly all of the papers in Table 2 have a connection to environmental sustainability. These connections include CO_2 capture (by MOFs and by ionic liquids),[17,21,22] destroying organic pollutants via photocatalysis with visible light,[18,24] and reducing the environmental footprint of separations processes through the use of membranes and/or ionic liquids.[19,20,22,23,25]

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Overall, the topics appearing in Table 2 are consistent with the current research emphasis in chemical engineering on developing and using new materials (solvents, sorbents, membranes, catalysts) to meet pressing industrial and societal needs.

In addition to this difference in the major topics, the All-Time Greats and Contemporary Favorites differ in the composition of their authorship. None of the authors of Contemporary Favorites listed an industrial affiliation, in contrast with the All-Time Greats, where 40% of the articles were from industrial authors. The authors of the 10 Contemporary Favorites work in eight different countries, whereas the authors of the 15 All-Time Greats were from just the United States, Canada, Germany, and the United Kingdom. This broader, more geographically diverse author list for the Contemporary Favorites is fully consistent with I&ECR and chemical engineering research becoming increasingly global. Finally, I note that just 27% of the All-Time Greats had more than two authors, whereas this statistic is 80% for the Contemporary Favorites. This shift is consistent with research having become more collaborative and more team-based in recent years.

I trust that readers of this virtual special issue will enjoy taking this opportunity to look back at some of the All-Time Greats while also learning more about well-received recent papers.

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Notes

Views expressed in this editorial are those of the author and not necessarily the views of the ACS.

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