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Honorary note: Jan Drzymala – 70th birthday

Jan Drzymala was born on September 25, 1949 in Slawa, Lower Silesia/Lubusz Land, Poland. He graduated, with a M.Sc. degree in chemistry, from the Wroclaw University of Science and Technology in 1973 and obtained a Ph.D. degree in mineral processing under the supervision of Prof. J.S. Laskowski in 1977. In 1978/79 he spent 15 months as a Postdoctoral Research Engineer at the Department of Material Science and Mineral Engineering, University of California, Berkeley, USA, working with Professor D.W. Fuerstenau on selective flocculation in the silica/hematite system. Between 1979 and 1984 he was back in Poland and next he spent one year in the USA working on oil agglomeration with Prof. T. D. Wheelock and Dr. R. Markuszewski at the Chemical Engineering Department, Iowa State University, Ames, Iowa. He continued the research on oil agglomeration in Ames in 1988/90 (2 years), 1991 (3 months), 1994 (6 months), and 2000 (3 months). In 2001 he was a Visiting Professor at Laboratoire Environnement et Minéralurgie, Nancy, France (3 months) working with prof. J. Mielczarski. The President of Poland appointed him as a Full Professor in 2002. He has been employed, between 1973 and 2018, by the Wroclaw University of Science and Technology in Wroclaw, Poland. He was teaching undergraduate, graduate and postgraduate students mineral processing and chemistry. As the editor-in-chief of the Physicochemical Problems of Mineral Processing journal he managed to put on the list of journals in the Journal Citation Reports in 2009. He was also a co-editor of several peer-reviewed graduate students conference proceedings devoted to interdisciplinary topics in mining and geology as well as four annual volumes (2014-218) of Kuperschiefer (copper bearing carbonaceous Zechstein shale, in Polish lupek miedzionosny). He wrote a book on mineral processing entitled Foundations of theory and practice of minerallurgy (two editions in Polish, one in English, second English edition is currently in preparation). The first English version is available free of charge at http://www.dbc.wroc.pl/dlibra/docmetadata?id=2070 &from=publication. He supervised doctoral dissertations of Jacek Bigosinski, Krzysztof Pradel, Tomasz Ratajczak, Zaklina Konopacka, Hussin A.M. Ahmed, Przemyslaw B. Kowalczuk, wrote 17 doctoral evaluations and several opinions for promotion of Professors. He was a member of the International Advisory Committee of International Mineral Processing Council.

The most important contributions of Professor Jan Drzymala, many accomplished together with his co-workers, are presented below.

Prof. Drzymala got his MSc under the supervision of Prof. Serkies and published his first paper (J. Drzymala, J. Serkies, On the Lechosos Opals and Chrysoprases in the Weathering Zone of Serpentinites from Szklary (Lower Silesia), Bull. Acad. Sci., des Science de la Terrie, XXI, No. 2, 111-117(1973)) showing that green color silicas, occurring in the Szklary (Lower Silesia, Poland) weathering deposit, which were investigated by IR spectroscopy and X-ray techniques, can be present both as nickel-bearing microcrystalline quartz (chrysoprase), which presence was disputable, as well as nickel-bearing (lechosos) opals. After suicidal death of prof. Juliusz Serkies, he joined the newly created, by prof. J.S. Laskowski, mineral processing research and teaching group at the Wroclaw Technical University, working on mineral processing and surface properties of minerals. The result was his Ph.D. degree and publication (J. Drzymala, J. Lekki, J. Laskowski, Surface Dissociation Constants for Solid Oxide-Aqueous Solution System, 1979. Colloid and Polymer Sci., 257, 768-772) in which surface dissociation

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constants of surface hydroxyl groups of selected oxides, based on a thermodynamic derivation taking into account the surface charge/zeta potential of the solid/aqueous solution interface, were calculated.

In 1978 Prof. Drzymala was a postdoc working in the mineral processing group of D.W. Fuerstenau in Berkeley. He worked on separation of silica and hematite by selective flocculation. The results of investigations were published in three papers (J. Drzymala, D.W. Fuerstenau, Selective Flocculation of Hematite in the Hematite-Quartz-Ferric Ions-Polyacrylic Acid System. Part I. Activation and Deactivation of Quartz, Inter. Min. Process. Journal, 8, 265-277(1981); Part 2. Effect of Grinding and a Hydrofluoric Treatment on Selectivity of Flocculation, Int. J. Min. Proc., 129, 1-5, 2014; J. Drzymala, D.W. Fuerstenau, Adsorption of Polyacrylamide, Partially Hydrolyzed Polyacrylamide and Polyacrylic Acid on Ferric Oxide and Silica, Process Technol. Proc., (Flocculation in Biotechnology and Separation Science), 45-60 (1987).

In 1979 he returned from the USA and joined the research group of Dr. Janusz Lekki and Dr. Andrzej Luszczkiewicz, and worked on developing a technology of separation of magnetite from ilmenite and next purification to produce, accepted by industry, ilmenite concentrates from the Polish magnetite–ilmenite vanadium-rich ore from Krzemianka, located in northeastern Poland. It was established that the main obstacle to obtained the goal was the presence of hercynite and pleonaste, which were difficult to separate by oleate flotation. The following papers were published (J. Drzymala, A. Luszczkiewicz, P. Simiczyjew, Hercynite-Pleonaste from Ilmenite-Magnetite Rocks of Krzemianka (NE Poland). Miner. Polonica, 13(2), 33-40(1982); J. Drzymala, A. Luszczkiewicz, P. Simiczyjew, Flotation Study on Hercynite High-Hercynite Ilmenite Ore, Inter. Miner. Process. Journal 10, 289-296(183); A. Luszczkiewicz, J. Lekki, J. Drzymala, Difficulties Encountered During Upgrading of Polish Ilmenite-Magnetite Ore, Prace IMN, Gliwice, 3/4, 119-124(1983), in Polish).

To find the way of separation of hercynite from ilmenite and purify ilmenite concentrates it became necessary to look more closely into properties of the oleate-type flotation collectors used for this purpose. The result of individual investigations of Prof. Drzymala was a complete phase diagram of the oleic acid/water/NaCl vs. pH at 25 oC system published in: J. Drzymala, Chemistry of Oleic Acid-Water-NaCl System vs. pH at 25C. Surfactants in Solution, V7, K.L. Mittal Ed., Plenum Press, New York, 483-496 (1990). The diagram shows the areas of oleate ions, molecular forms, micelles and liquid crystals in the system. The surface properties of oleic acid were also investigated and described in J. Drzymala, An Estimation of the Surface Ionization Constant of Oleic Acid in Aqueous Sodium Chloride Solution, Colloid and Polymer Sci., 265, 613-618(1987). All his accomplishments regarding oleate were summarized in a monograph: J. Drzymala, Properties of Oleate Aqueous Solutions and Emulsions, Scientific Papers of IChNiMPR of Wroclaw University of Technology, 61, Monograph 29, 1-89(1990), in Polish. The monograph was used for a partial fulfilment of the requirements to receive the degree of Doctor of Science (D.Sc., habilitation).

In 1984 Prof. Drzymala was invited by Prof. T.D. Wheelock and Dr. Markuszewski to Iowa State University in Ames (USA) to work for a year on application of oil agglomeration for coal cleaning. Altogether he spent in Ames 4 years. The research and cooperation were very rewarding and fruitful. They published several papers on the mechanism of oil agglomeration in model and real agglomerating systems, and on application of pyrite depressants in the agglomerating systems. The important finding was a significant role of air in the process, which was named air-promoted oil agglomeration (J. Drzymala, R. Markuszewski, T.D. Wheelock, Influence of Air on Oil Agglomeration of Carbonaceous Solids in Aqueous Suspension, Inter. Miner. Process. Journal, 18, 277-286(1986); J. Drzymala, T.D. Wheelock, Air Promoted Oil Agglomeration of Moderately Hydrophobic Coals. 2. Effect of Air Dosage in a Model Mixing System, Coal Preparation, 18, 37-52 (1997)). Basing on the experimental observations, a new process was proposed, in which oil was completely replaced by air. The process was named air agglomeration (J. Drzymala, T.D. Wheelock, Air Agglomeration of Hydrophobic Particles, in: Processing of Hydrophobic Minerals and Fine Coal, J.S. Laskowski and G.W. Poling Editors, Canadian Institute of Mining, Metallurgy and Petroleum, Montreal, Canada, 1995). Another innovation was monitoring the course of oil agglomeration by turbidity measurements (J. Drzymala, T.D. Wheelock, Determining the Oil Agglomeration Characteristics of a Coal Suspension by Monitoring Turbidity Changes, 3rd International Conf. on Process. and Utiliz. of High-Sulfur Coals, Elsevier, Amsterdam, 289-300(1990)). The oil agglomeration investigation led to finding that dedecylphenol was a very efficient agglomerant for some oxidized carbonaceous materials (J. Drzymala, J.T. Gorke, T.D. Wheelock. A flotation Collector for the Separation of Unburned Carbon from Fly Ash, Coal Preparation, 25, 67-80 (2005)).

In 1989, together with Dr. Lekki, a method, called flotometry was invented. The method is based on monitoring flotation of different size fractions of particles for a long time of flotation to find the maximum yield, and next, the maximum size of floating particles. The flotometry method allows to find relationships between different parameters of flotation systems including recovery (yield), hydrophobicity, density, particle size. As a result also a distinction between true floatation and mechanical carryover is possible (J. Drzymala, J. Lekki, Flotometry-Another Way of Characterizing Flotation, J. Colloid Interface Sci., 130, 205-210(1989). J. Lekki, J. Drzymala, Flotometric Analysis of Collectorless Flotation of Sulfide Materials, Colloids and Surfaces, 44, 179-190(1990). He continued the flotometric investigations after Dr. Janusz Lekki left Wroclaw for Silesian Technical University. He published three papers providing relations between flotation parameters (J. Drzymala, Characterization of Materials by Hallimond Tube Flotation. Part 1: Maximum Size of Entrained Particles, Int. J Miner. Process., 42, 139-152(1994); Part 2: Maximum Size of Floating Particles and Contact Angle, Int. J. Miner. Process., 42, 153-167(1994) and erratum 43, 1995, 135; Part 3: Maximum Size of Floating and Interacting Particles, Int. J Miner. Process., 55, 203-218(1999). Many materials were tested by flotometry in the absence of any regents and the results were summarized in the paper of P.B. Kowalczuk, J. Drzymala, Contact Angle of Bubble with Immersed-in-Water Particle of Different Materials, Industrial and Engineering Chemistry Research, 50(7), 4207-4211 (2011). Flotometry was further developed by taking into account the dynamics of the process in different flotation machines using a machine constant. This was considered in a paper together with co-workers (P.B. Kowalczuk, O. Sahbaz, J. Drzymala, Maximum Size of Floating Particles in Different Flotation Cells, Minerals Engineering, 2011, 24(8), 766-771(2011)).

The natural flotation and flotometric contact angles of most hydrophobic materials (molybdenite, many sulphides, copper bearing shale) are much smaller than indicated by the sessile drop data. Their full flotation can be realized provided that a frother is used in flotation. It points to a great role of thin films in flotation and flotometric measurement. This issue requires further studies and is being considered by determination of energy barrier and activation energy in separation systems (J. Drzymala, Arrheniusan Activation Energy of Separation for Different Parameters Regulating the Process, Physicochem. Probl. Miner. Process. (Special issue to honor J.S. Laskowski) 54(4):1152–1158(2018)).

Water is essential in mineral processing operations, and hence understanding its interfacial properties, including the ice/water border, is very important. The electrical charge and potential of the ice/water interface play a role not only in mineral processing as a model for the oxide/water system but also in environmental phenomena including weather, especially thunderstorms. Early trials of Schulman and Perreira in 1964 to measure the zeta potential of ice were unsuccessful, until Prof. Drzymala's idea to use heavy ice suspended in water, allowing to create an equilibrium system between 0 and 3.8 oC . The idea was positively experimentally verified together with his coworkers and describe in the papers J. Drzymala, Z. Sadowski, L. Holysz E. Chibowski, Ice/Water Interface, Zeta Potential, Point of Zero Charge, and Hydrophobicity, J. Colloid Interface Sci., 220, 229-234 (1999); J. Drzymala, Study of the ice-water interface, Encyclopedia of Surface and Colloid Science, Arthur T. Hubbard (editor), Marcel Dekker, New York,4892-4898 (2002). The properties of the interfacial regions from the thermodynamic point of view were also considered by Prof. Drzymala together with Prof. Lyklema (†2017) for aqueous electrolyte solutions (J. Drzymala, J. Lyklema, Surface Tension of Aqueous Electrolyte Solutions. Thermodynamics, J. Phys Chem. A., 116(25), 6465-72, (2012)).

In mineral processing different methods of separation are used and the results are presented in numerous ways. To put some order in this aspect of mineral processing Prof. Drzymala, together with his at that time Ph.D. student Prof. P.B. Kowalczuk, proposed a system for that in a paper J. Drzymala, P.B. Kowalczuk, A Proposition for Symbolism of Non-ideal Separations Followed by Analytical Separations Used for Evaluation of Separation Efficiency, Mineral Processing and Extractive Metallurgy Review, Processing and Extractive Metallurgy Review, 32, 278-288 (2011). Unfortunately, the system has not been adopted by other researchers and no citations of this paper can be found in the Web of Science.

Prof. Drzymala proposed many types of graphical representations of separation results and the way to used them to find local and global efficiencies as a well as mathematical forms of separation curves. Although all the curves present the same experimental data, their usefulness is different. It was shown by Prof. Drzymala that recovery-recovery upgrading curve, now called the Fuerstenau curve or plot, is very convenient (J. Drzymala, Atlas of Upgrading Curves Used in Separation and Mineral Science and Technology, Physicochemical Problems of Mineral Processing, Part 1. 40, 19-29 (2006), Part 2., 41, 27-35 (2007), Part 3., 42 (2008) 75-84; J. Drzymala, H.A.M. Ahmed, Mathematical Equations for Approximation of Separation Results Using the Fuerstenau Upgrading Curves, Int. J. Miner. Process., 76, 55-65 (2005). The upgrading curves, especially the Fuerstenau curve, can be also generated by using kinetic data (A. Bakalarz, J. Drzymala, Interrelation of the Fuerstenau Upgrading Curve Parameters with Kinetics of Separation, Physicochemical Problem of Mineral Processing, 49(2), 443-451(2013)).

A great care must be observed when using statistics for evaluation of separation data in the form of separation curve due to different degree of x-y separation results parameters self-similarity. In case of the Fuerstenau plot the self-similarity is low, while for other curves is high (M. Duchnowska, J. Drzymala, Self-similarity of Upgrading Parameters Used for Evaluation of Separation Results, Int. J. Mineral. Processing, 106-109, 50-57(2012)). The upgrading curves are also useful for characterizing reagents used in flotation, including selectivity and power (P.B. Kowalczuk, J. Drzymala, Selectivity and Power of Frothers in Copper Ore Flotation, Physicochem. Probl. Miner. Process. 53(1), 515–523(2017)). In recent years he spent some time working with his research group on principles of flotation both from the kinetic and thermodynamic points of view. The principle idea regarding kinetics was that the main kinetic parameter is the process rate, not kinetic constants, providing information on the local, for a given time, kinetics. The numerous kinetic constants are parameters characterizing kinetics globally, regardless of time of the process (T. Ratajczak, J. Drzymala, P.B. Kowalczuk, Local and Global Assessment of Flotation Kinetics, E3S Web Conf., 8 (2016) 01033, Mineral Engineering Conference MEC2016, Swieradow-Zdroj, Poland, September P.B. Kowalczuk and J. Drzymala (Eds.), 25-28 (2016); J. Drzymala, T. Ratajczak, B.P. Kowalczuk, Kinetic Separation Curves Based on Process Rate Considerations, Physicochem. Probl. Miner. Process, 53(2), 983-995(2017)).

Prof. Drzymala together with his co-workers published several papers on Kupferschiefer, that is copper- and carbon-bearing shale. This component of the Zechstein-origin copper ore, which is mined and processed in Poland, creates numerous technological difficulties. Due to these works the properties of the shale are now well established (for instance J. Drzymala, P. Karwowski, K. Borowski, P.M. Pazik, P.B. Kowalczuk, 2017. A trail to classify Legnica-Glogow Copper Basin shale on the basis of carbonates, clays, organic carbon and copper contents was offered in the paper: Lupek miedzionosny III, Kowalczuk, P.B., Drzymala, J. (eds), WGGG PWr, Wroclaw, 52-58 (2017) (in Polish). The obtained results on shale are useful for improving technology of their processing and either considered or applied, including application of dextrin (J. Drzymala, J. Kapusniak, P. Tomasik, A method of Production of Copper Concentrates Rich in Chalcocite, Polish Patent PL 195693 B1, 2007)).

Worthwhile to mention are two additional accomplishments resulting from cooperation with others. One is a model of separation process (M. Brozek, J. Drzymala, Universal Delineation of Particle Separation Systems and Separation Results of Stratified Material, Separation Science and Technology, 44(8), 1657 – 1674, 2009) and the second is proving, among others, that not all completely wetting liquids of solid surface can be used as the reference material in the Washburn approach to determination of contact angle (P.B. Kowalczuk, J. Drzymala, Surface Flotation of Particles on Liquids. Principles and Applications, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 393 (2012), 81-85).

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