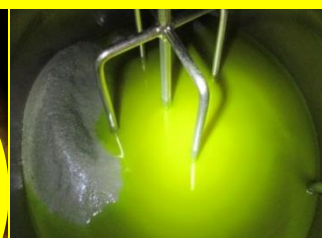
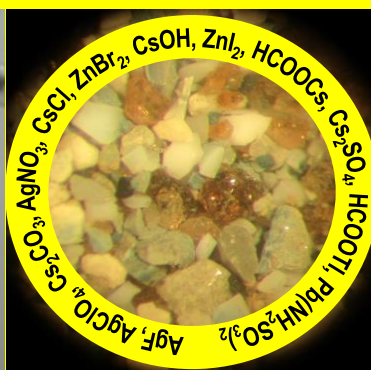


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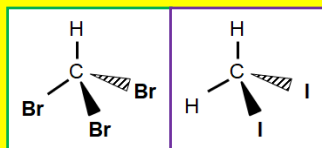
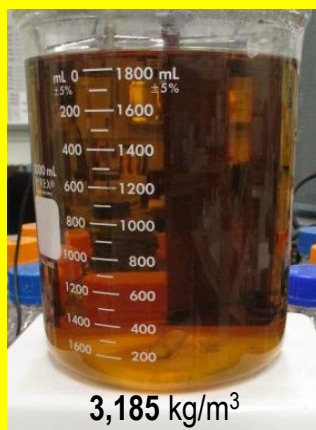
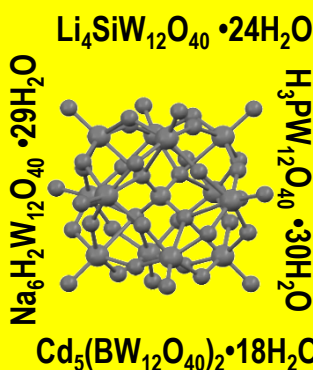
Heavy Liquids for the Separation of Minerals:

Their Preparation, Properties, and Uses



$\text{CHBr}_2\text{-CHBr}_2$

Cs_2WO_4 $\text{Cd}(\text{ReO}_4)_2$



François Cardarelli

**Heavy Liquids for the Separation
of Minerals:**

Their Preparation, Properties, and Uses

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Units Policy

In this monograph all the units of measure used for describing physical quantities and properties were those recommended by the *Système International d'Unités* (SI) except in some few instances where some units from the *US Customary System* (USCS) are used in conjunction. For accurate conversion factors between these units and the other non SI units (e.g., cgs, fps, Imperial, and US customary systems) please refer to the reference book of the same author:

CARDARELLI, F. (2005) *Encyclopaedia of Scientific Units, Weight and Measures. Their SI Equivalences and Origins*. Springer, New York, London, xxiv, 848 pages; ISBN 978-1-85233-682-0.

Books by the same author:

CARDARELLI, F. (2023) *Electrowinning Iron and Recycling Sulfuric Acid from Iron Sulfates: a Zero-Carbon Iron-Making Process*. Electrochem Technologies & Materials Inc., Montreal, Canada, xxviii, 471 pages, 181 tables, 140 color and black and white figures. ISBN 978-1-7775769-3-6.

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CARDARELLI, F. (2018) *Materials Handbook. A Concise Desktop Reference, Third edition*. Springer, Cham, London, New York. cxxxii, 2,254 pages, 150 black and white figures, 25 illustrations in color in two volumes. ISBN 978-3-319-38923-3.

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Preface

This concise monograph is primarily intended to describe the main physical and chemical properties of heavy organic liquids and dense aqueous solutions of inorganic salts used in mineralogical, metallurgical, and chemical laboratories worldwide for the separation by gravity of minerals, metallic ores, coal macerals, fossils, and gemstones, along with plastics, glasses, ceramics, and other synthetic materials. Moreover dense solutions of salts used in biology for the separation of nucleic acids, and other biological molecules of interest by density gradients centrifugation are also described.

The heavy liquids that are described in this monograph are heavy halogenated organic solvents, dense aqueous solutions of inorganic salts, low temperature molten salts, eutectic mixtures and heavy suspensions. Moreover, in order to be comprehensive, we have also included non-conventional heavy liquids rarely or never used in mineralogy but having some applications in other fields.

For several heavy liquids, it provides a detailed description of the laboratory methods and industrial processes utilized for their preparation along with the most efficient recovery and recycling techniques. Moreover, when available, the occupational health and safety information for toxic chemicals and hazardous compounds used as heavy liquids is also provided to ensure safe practices in the work place.

Finally, their potential utilization in others fields such as water-in-salts electrolytes, x-ray and radiographic contrast agents, radiation shielding, non-destructive testing (NDT), drilling fluids, ballasts and counterweights due to their high density are briefly described.

The information has been presented in such a form that mineralogists, chemists, geologists, paleontologists, biologists, metallurgists, mineral processing engineers, scientists, professors, and technologists will have access to relevant scientific and technical information supported by key data gathered from several disseminated sources from the scientific and technical literature.

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About the Author



Dr. François Cardarelli, President and Owner of the Canadian company *Electrobem Technologies & Materials Inc.*, is an industrial chemist with a strong physical-chemistry background and a doctorate in chemical engineering from the University Paul Sabatier (UPS) Toulouse III. He is the inventor and co-inventor of 16 patents, and the sole author of three reference handbooks published worldwide by Springer since 1996 and three professional monographs.

He has over 35 years of industrial experience in North America and Europe in developing electrochemical, chemical, and metallurgical processes for winning, refining or producing a variety of metals, alloys, and inorganic chemicals either from aqueous solutions or molten salts media.

A particular area of his professional expertise is the chemical, and electrochemical processing of mining residues, metallurgical wastes, and industrial effluents, the manufacture of industrial electrodes, the electrochemical production of vanadium electrolyte, the pyro- and hydrometallurgical production of vanadium, niobium, tantalum, and tungsten compounds and chemicals, and finally the manufacture of novel industrial materials. All these processes are covered by patents enforced in many jurisdictions.

Dr. François Cardarelli is a member in good standing of the following professional organizations and societies: *American Institute of Chemical Engineers* (AIChE) [Lifetime member], *American Chemical Society* (ACS), *Chemical Institute of Canada* (CIC), *Canadian Society for Chemical Engineering* (CSChE), *The Electrochemical Society* (ECS), *Mineralogical Society of America* (MSA), *Ordre des Chimistes du Québec* (OCQ), *The Oughtred Society* (OS), and *The Minerals, Metals and Materials Society* (TMS).

François Cardarelli

Heavy Liquids for the Separation of Minerals: Their Preparation, Properties, and Uses



This concise monograph is primarily intended to describe the main physical and chemical properties of heavy organic liquids and dense aqueous solutions of inorganic salts used in mineralogical, metallurgical, and chemical laboratories worldwide for the separation by gravity of minerals, metallic ores, coal macerals, fossils, and gemstones along with plastics, glasses, ceramics and other synthetic materials. Moreover dense solutions of salts used in biology for the separation of nucleic acids, and other biological molecules of interest by density gradients centrifugation are also described.

For several heavy liquids, it provides a detailed description of the laboratory methods, and industrial processes utilized for their preparation along with the most efficient recovery and recycling techniques. Moreover, when available the occupational health and safety information for toxic chemicals and hazardous compounds used as heavy liquids is also provided to ensure safe practices in the work place.

Finally, their potential utilization in others fields such as X-ray and radiographic contrast agents, radiation shielding agents, non-destructive testing (NDT), water-in-salt electrolytes, drilling fluids, ballasts and counterweights due to their high density are described. The information has been presented in such a form that mineralogists, chemists, geologists, paleontologists, biologists, metallurgists, mineral processing engineers, scientists, professors, and technologists will have access to relevant scientific and technical information supported by key data gathered from several disseminated sources.

The following topics are covered:

- Dense media separation of minerals and ores by the sink-float method, elutriation, fluidization, centrifugation and density gradients;
- Heavy halogenated organic solvents;
- Dense aqueous solutions of inorganic salts;
- Dense salts in non-aqueous solvents;
- Dense molten salts and eutectics;
- Suspensions of heavy solids;
- Liquid metals and low melting point alloys;
- Non-conventional heavy liquids;
- Other uses;
- Appendices;
- Bibliography.

