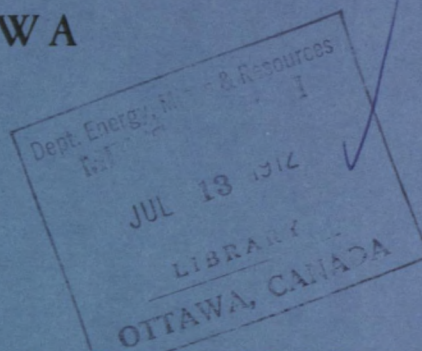


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*NOMENCLATURE IN THE SOLVENT
EXTRACTION FIELD*

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EXTRACTION METALLURGY DIVISION

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Nomenclature in the solvent extraction field

An attempt to define solvent extraction terms. The purpose is to avoid jargon which normally creeps into the terminology of any new field — some of which may be fine, but some of which is not always sufficiently descriptive. This article follows one by Ritcey on the use of solvent extraction for base metals published in the June 1969 issue of CMJ which prompted many enquiries from various parts of the world.

By A. W. ASHBROOK* and
G. M. RITCEY**

Over the last several years, the trend toward hydrometallurgical routes for treatment of ores and similar materials has resulted in considerable use of solvent extraction techniques. Solvent extraction processes for recovery of non-ferrous metals from solution have been adopted in several plants^(1,2), and the nuclear industry continues to expand such techniques for separation and recovery of radioactive products⁽²⁾.

The increasing amount of work being carried out in the field of solvent extraction in Canada and elsewhere has resulted in a parallel growth in the

number of papers published. It has become apparent, on reading the literature, that the terminology has become rather sloppy. It is not uncommon to find that the word solvent is used to describe two dissimilar liquids — extractant and diluent — in the same article.

It is surprising to note that the same situation arises even in the recommended nomenclature for liquid-liquid extraction in analytical chemistry⁽³⁾. Here, diluent is defined as "an inert organic solvent used to improve the properties of an extractant". There is also a distinction made between extractant and extracting agent, although they both appear to serve the same purpose.

To newcomers, plant operators, and those who are not expert in the field, such poor terminology can quickly result in confusion as to what is actually meant by a particular term or phrase.

If one reads the papers delivered at the International Solvent Extraction (ISE) Conference in The Hague, April 1971, the need for consistent terminology becomes evident. Further, a quick perusal of the Journal of Inorganic and Nuclear Chemistry, in which many papers on solvent extraction are published, confirms this need; it also emerges in discussions with other workers. In addition, at the ISE Conference, the chairman of the Solvent Extraction and Ion Exchange Group of the Society of Chemical Industry requested contributions on this topic. This short review of the solvent extraction nomenclature has been made for these reasons.

In this review, 82 of the approximately 140 papers presented at the ISE Conference were used. The results are given together with a suggested terminology for use in describing the various processes and stages. It should be noted that the terminology suggested is based on the use of solvent extraction as an industrial unit process.

The terms proposed are those generally in use in Canada, and to a large extent in the USA, in both commer-

cial and research operations.

The review

Because of inconsistencies in nomenclature used in the papers under review, the actual meanings of many of the terms can be obtained only from the context in which they are used. In order to indicate the actual meaning of these terms, it was necessary to use the reference terms given in the proposed nomenclature.

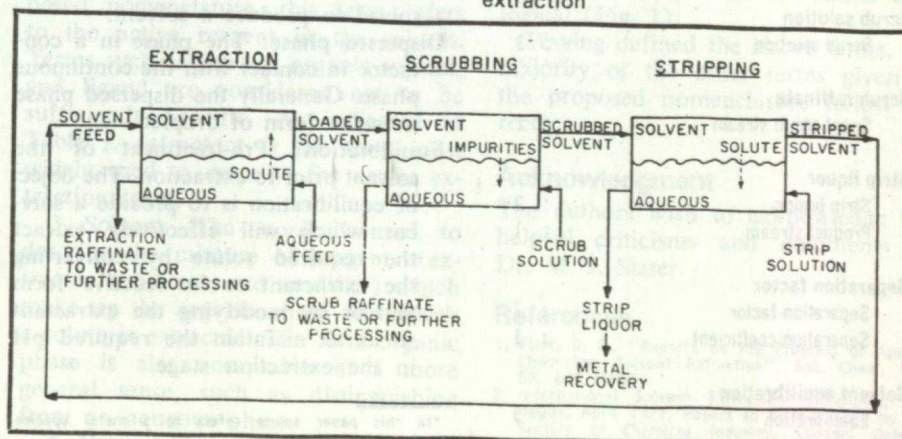
Results of the review follow. The 82 papers were from 17 countries and subject matter ranged from theoretical to descriptions of industrial processes. All papers were published in English.

Based on the authors' employment, the origins of the papers can be divided into (1) university (38 papers); (2) government agency (37 papers); (3) industry (7 papers). It was not clear in cases whether the employer was a government agency or university, therefore the individual totals for these two categories may not be correct. However, it is evident that the majority of papers presented were from non-industrial sources.

TABLE I Nomenclature used in papers given at the International Solvent Extraction Conference, The Hague, April 1971

Extraction coefficient, E	
Distribution coefficient	: 36
Distribution ratio	: 13
Extraction coefficient	: 7
Extraction constant	: 2
Symbols	
D : 32	E _A ^o : 4
E : 3	D _A ^o : 2
q : 3	m : 1
Extractant	
Extractant	: 21
Solvent	: 10
Extracting agent	: 3
Organic agent	: 1

Fig. 1 The general process of solvent extraction



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Organic solvent	: 1
Complex forming agent	: 1
Ligand	: 1
Solvent	
Organic phase	: 14
Solvent	: 8
Organic Solution	: 3
Extractant	: 1
Diluent	
Diluent	: 17
Solvent	: 13
Extraction isotherm	
Extraction isotherm	: 3
Distribution isotherm	: 2
Distribution curve	: 1
Extraction equilibrium curve	: 1
Extraction raffinate	
Raffinate	: 7
Effluent	: 1
Waste Solution	: 1
Aqueous phase	: 1
Loaded solvent	
Loaded solvent	: 5
Pregnant organic phase	: 1
Saturated organic phase	: 1
Solvent product	: 1
Stripped solvent	
Solvent raffinate	: 1
Spent solvent	: 1
Strip isotherm	
Backwash isotherm	: 1
Stripping	
Stripping	: 16
Back extraction	: 9
Backwash	: 3
Re-extraction	: 2
Scrubbing	
Scrubbing	: 20
Washing	: 1
Stripping	: 1
Strip solution	
Strip solution	: 4
Stripping agent	: 1
Back extractant	: 1
Scrub solution	
Scrub solution	: 3
Scrub raffinate	
Spent scrub stream	: 1
Strip liquor	
Strip liquor	: 2
Product stream	: 1
Separation factor	
Separation factor	: 7
Separation coefficient	: 1
Solvent equilibration	
Equilibration	: 7

Pre-equilibration	: 4
A/O or O/A ratio	
A/O flow rate	: 4
Flow ratio	: 2
Solvent-aqueous ratio	: 2
Volume ratio	: 1
Phase ratio	: 1
Antagonism	
Antagonism	: 2
Negative synergism	: 2

Terms in bold face are proposed; figures represent the number of times the term occurs in the 82 papers reviewed.

The confusion inherent in the current nomenclature of solvent extraction is evident from this review. In an attempt to resolve this problem, the authors propose the following: (Application of the proposed terms, used in describing the processes and solutions of a solvent extraction process, are shown in Fig. 1.)

Proposed nomenclature

Antagonism: Antonym of synergism.

A/O ratio: Refers to volume phase ratio of aqueous to organic phase; also expressed as O/A.

Aqueous feed: The aqueous solution feed to the extraction stage; it contains the solute* to be extracted.

Back-mixing: Deviation from an ideal (plug) flow pattern in a contactor.

Contactor: A device for dispersing and disengaging immiscible solutions. It may be single- or multi-stage.

Continuous phase: The coherent phase in a contactor.

Crud: The materials, resulting from agitation of an organic phase, an aqueous phase, and fine solid particles, that form a stable mixture. Crud usually collects at the interface between the organic and aqueous phases.

Countercurrent extraction: Solvent extraction in which the aqueous and organic phases flow in opposite directions in a contactor.

Diluent: The organic liquid in which an extractant and modifier are dissolved to produce a solvent.

Dispersed phase: The phase in a contactor in contact with the continuous phase. Generally the dispersed phase is in the form of droplets.

Equilibration: Pre-treatment of the solvent prior to extraction. The object of equilibration is to provide a solvent which will effectively extract the required solute by converting the extractant to its reactive form and/or by modifying the extractant so as to maintain the required pH in the extraction stage.

Extraction (distribution) coefficient: The ratio of total concentrations of solute (in whatever form) after contacting an aqueous and an organic solution under specified conditions.

analytical concentration of solute in the organic phase

$$E = \frac{\text{analytical concentration of solute in the organic phase}}{\text{analytical concentration of solute in the aqueous phase}}$$

Extraction (distribution) isotherm: The graphical representation of isothermal equilibrium concentrations of a solute in the aqueous and organic phases over an ordered range of conditions in extraction.

Extract: Used as a verb to describe the transferring of a solute between two immiscible liquids.

Extractant: The active organic reagent in the solvent primarily responsible for the extraction of a solute.

Extraction raffinate: The aqueous phase from which a solute has been removed by single- or multi-stage contacting with organic phase.

Flooding: The discharge of mixed phases from one or both exit ports of a contactor.

Loaded solvent: The organic solvent containing the maximum concentration of solute for the conditions under which extraction occurred.

Loading capacity: Refers to the saturation limit of a solvent for a solute or solutes.

Mixed solvent: A solution of more than one extractant in an organic diluent.

Modifier: A substance added to a solvent to increase the solubility of the extractant, or of salts of the extractant, or of the extracted solute-extractant species during extraction or stripping. Also added as an emulsion inhibitor.

Phase ratio: See A/O ratio.

Phase inversion: The change in a solvent extraction system when the dispersed phase becomes the continuous phase, or vice-versa.

Raffinate: The aqueous phase from which the solute has been removed; generally waste from the solvent extraction circuit.

Scrubbing: The selective removal of a contaminating solute from a loaded solvent prior to stripping. Also removal of solvent degradation products and non-strippable solute complexes from the solvent, usually after stripping.

Scrubbed solvent: The organic phase after removal of undesirable solutes.

Scrub solution: The aqueous solution used to contact the loaded solvent for removal of undesirable solutes.

Scrub raffinate: The aqueous phase after contacting the loaded solvent

*In this paper solute refers to a metal species.

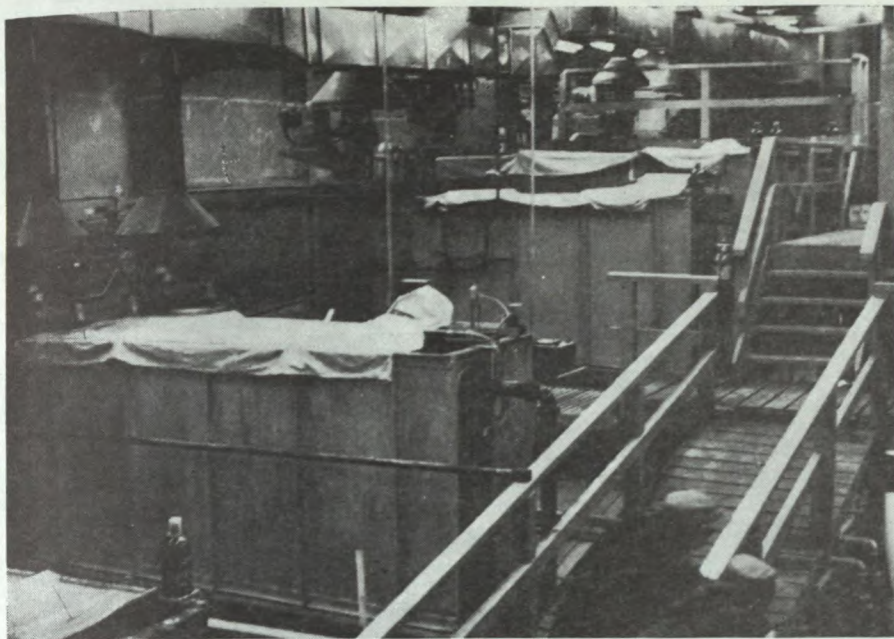


Fig. 2 Solvent extraction plant using mixer-settlers for the extraction of metals

with a scrub feed. Contains impurities removed during scrubbing.

Separation factor: The ratio of the extraction (distribution) coefficients of two metals being compared.

Settling: Separation of dispersed immiscible phases by coalescence or sedimentation.

Solvent extraction (SX): Separation of one or more solutes from a mixture by mass transfer between immiscible phases in which at least one phase is an organic liquid.

Solvent: A mixture of extractant, diluent, and in some cases, a modifier. The organic phase that preferentially dissolves the extractable solute from an aqueous solution.

Stage: A single contact (dispersion and disengagement). Also refers to a theoretical stage which is a contact that attains equilibrium conditions in a particular system.

Stripping: The removal of extracted solute from the loaded solvent. Selective stripping refers to separate removal of specific solutes from a solvent containing more than one solute.

Stripping coefficient(S): The reciprocal of the extraction coefficient. analytical concentration of solute in the aqueous phase.

$$S = \frac{\text{analytical concentration of solute in the aqueous phase}}{\text{analytical concentration of solute in the organic phase}}$$

Strip solution: The aqueous solution used to contact the loaded (or scrubbed) solvent to recover the extracted solute.

Strip isotherm: Similar to extraction isotherm but for stripping.

Strip liquor: The aqueous solution containing the solute recovered by stripping from a loaded solvent.

Stripped solvent: The solvent after removal of extracted solute by stripping.

Synergism: The co-operative and beneficial effect of two or more extractants that exceeds the sum of the individual effects.

Comments on the proposed nomenclature

Some of the proposed terms merit further explanation and justification.

1. Distribution or extraction coefficient. It is evident from Table I. that the term distribution coefficient (D) is most popularly used to describe the equilibrium distribution of a solute distributed between two immiscible liquids. Although the authors have a preference for extraction coefficient (E) because this term was found more useful from an industrial point of view, undoubtedly the term distribution coefficient will be more acceptable to the majority of workers in the solvent extraction field. The same situation obtains for either distribution or extraction isotherm.

2. Extractant. As defined in the proposed nomenclature, this term refers to the active reagent in the solvent. Terms such as solvent, organic solvent, and ligand are considered not to be sufficiently specific. As indicated in Table I, extractant is the term most widely used to describe the active extracting agent.

3. Solvent. The word is used to describe the mixture of reagents (extractants, diluent, and modifier) which make up the organic phase into which a solute is extracted. The term organic phase is also acceptable in a more general sense, such as distinguishing from an aqueous phase.

4. Diluent. Here again the use of

the word solvent to describe the organic liquid used to alter, for whatever reasons, the physical properties of extractants and modifiers is considered unsuitable. A distinction must be made between the various components of a solvent. Diluent is considered to express the function of the "inert carrier" used in the preparation of solvents.

5. Stripping. This is used in a general way to describe an aqueous phase having little or no direct influence on a particular solvent extraction circuit. Generally, it may be considered almost as a waste stream from the SX circuit. This is not to say, however, that a given raffinate may not be of importance in another part of the whole process of which the SX circuit is a unit process. For this reason, the aqueous solution obtained by stripping a loaded solvent cannot be referred to as a raffinate since it is of particular importance in a solvent extraction circuit. This solution is thus referred to as the strip liquor, and the aqueous solution which strips the loaded solvent is referred to as the strip feed (Fig. 1).

7. Loaded solvent. This term is preferred to loaded extract because the term stripped extract is somewhat misleading; the stripped extract is recycled to the extraction stage in a continuous process and becomes the solvent when it enters the extraction stage. Use of loaded solvent, hence stripped solvent, hence solvent, is then logical (Fig. 1).

Having defined the above terms, the majority of the other terms given in the proposed nomenclature follow directly.

Acknowledgment

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