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Minerals Engineering 18 (2005) 139–149

MINERALS ENGINEERING

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# An overview of the use of chemical reagents in mineral processing

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Received 5 August 2004; accepted 7 September 2004

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## Abstract

The predominant reagents used in the mineral processing industry are reviewed and their mode of action briefly described. Inorganic, naturally derived organic and synthetic organic reagents, both old and new, all play a large part in successful processing particularly in froth flotation and in solid–liquid separation. The drive for new and improved reagents is both technical and environmental and reflects the ever evolving challenges of the industry.

*Keywords:* Agglomeration; Dewatering; Flocculation; Flotation reagents; Solvent extraction

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## 1. Introduction

The term ‘reagent’ has a dictionary definition of ‘an agent that produces chemical reactions’ or ‘a substance which acts on another in a chemical reaction’. The word ‘reagent’ (Fr. reactif; Gr. reagens; Sp. reactivo) entered into the English language in the 1800s.

The mineral processing and hydrometallurgical industries use a vast number of reagents ranging from bulk commodity inorganics to specialty synthetic polymers and extractants. The purpose of the paper is to illustrate the diversity of the reagents utilised and to give a brief description of how and where they are used.

Excepting the inorganic bulk reagents, the three largest volume categories of customised chemicals are polymeric flocculants and coagulants, flotation frothers and sulphide mineral flotation collectors. Consumption of these reagents is expected to grow by 2–3% per annum in the near future.

## 2. Inorganic reagents

The highest volume bulk inorganic reagents used in mineral processing are lime and sulphuric acid. Lime is a panacea throughout the industry, being used for pH adjustment, coagulation, heavy metal precipitation, causticisation and depression of pyrite in flotation. Sulphuric acid is also used for pH adjustment but more importantly for the leaching of oxide copper, lateritic nickel, zinc calcine, titanium dioxide from ilmenite and uranium minerals. Two other chemicals used in large tonnages are sodium (or calcium) cyanide and caustic soda. The former is a universal leachant for gold, first used for cyanidation in New Zealand in 1898, and is occasionally used in flotation, as described below; the latter is used for pH adjustment in several processes and for the leaching of alumina from bauxite in the Bayer process.

Many other inorganic reagents are used in the mineral processing industry, albeit at smaller amounts than those above. However, locally and specifically they can be very important for efficient processing. A summary of some and their primary uses are given in Table 1.

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doi:10.1016/j.mineng.2004.09.015

Table 1
Some inorganic reagents and their primary functions in mineral processing

| Reagent | Primary function |
|---|---|
| Sodium cyanide | Pyrite and sphalerite depressant |
| Sodium silicate | Slimes dispersant |
| Sodium fluorosilicate | Fluorite and silicate depressant |
| Zinc sulphate | Sphalerite deactivator |
| Copper sulphate | Sphalerite activator |
| Sodium sulphite | Pyrite, sphalerite and oxidised galena depressant |
| Potassium dichromate | Galena depressant |
| Potassium permanganate | Arsenopyrite and pyrrhotite depressant |
| Sodium hydrosulphide | Sulphidizer for oxide and weathered minerals |
| Soda ash | pH adjustment in lead flotation |
| Sulphuric acid | Fatty acid collector removal in phosphate flotation |
| Ammonia | Nickel leachant |
| Hydrogen peroxide | Oxidant for gold cyanidation |
| Lead nitrate | Additive in gold cyanidation |
| Alum | Clarification |
| Polyaluminium chloride | Clarification |
| Ferric chloride | Clarification |
| Zinc dithionite | Bleaching agent |
| Sodium hypochlorite | Cyanide destruction |
| Sodium ferrocyanide | Anti-caking agent |

## 3. Flotation reagents

It is estimated that approximately 2 billion tonnes of ore are treated by froth flotation annually. Thus, the flotation process consumes a huge amount of reagents in the form of collectors, frothers, depressants and modifiers.

### 3.1. Flotation frothers

Frothers are neutral molecules consisting of a medium chain length hydrocarbon entity and a polar group(s) entity. This gives the molecule dual affinity to water and air. The hydrophobic contribution is not as strong as in collectors, described below. The polar groups of frothers are always hydroxyl—usually in the form of alcohol or glycol. Frothers typically have HLB values (hydrophile–lipophile balance) in the range 6–8, Leja (1981). The primary mechanism of frother action is to reduce air/water interfacial tension so a foam will form.

The simplistic view of a frother is to provide a froth that holds the floated mineral at the surface of the aerated pulp, so that it can be scraped off into the concentrate and not fall back into the pulp.

However, although this is the simplistic function, the frother can have other interactions during the process of froth flotation:

- The frother can co-adsorb with collector at the mineral/water interface. Being a neutral molecule, this co-adsorption can lower the collector dosage at which hemi-micelle formation occurs and thus promote flotation.
- In bulk solution, the frother molecules cohabit with collector ions in micelles. This lowers the collector's CMC due to reduction of electrostatic repulsion between its polar, ionised heads, making micelle formation more energetically favourable.
- Frother molecules co-adsorb with collector ions in the skins of bubbles.
- The frother can be intentionally used to solubilise or emulsify water-insoluble collectors.
- The frother has a major effect on the rate (kinetics) of flotation.
- Selectivity continues to occur in the froth; the type of frother controls this.
- The type and dosage of frother control the bubble size distribution in the pulp.

The degree to which each phenomenon occurs or predominates, depends on the system.

The molecular structures of the more common flotation frothers are shown in Fig. 1. Generally, the water-insoluble alcohol based frothers are very selective whereas the water-soluble glycol based ones are stronger in their action. However, these are broad generalisations and much system dependency is evident in the suitability of flotation frothers.

A regional preference or dependency is shown with frothers like pine oil and TEB whereas MIBC and polypropylene glycol ethers tend to be more universal.

### 3.2. Sulphide collectors and promoters

In contrast to the non-sulphide mineral collectors discussed below, sulphide collectors are all based on divalent sulphur and the majority have shorter hydrocarbon chains, C5 being maximum. One interpretation of this is that sulphide surfaces already have a degree of hydrophobicity in their natural state.

The flotation of sulphide minerals is extensive worldwide (copper, lead, zinc, nickel), and in terms of tonnage, they represent the largest mineral group processed by froth flotation. Alkyl xanthates are by far the largest volume reagents used and they form the so-called 'workhorse' of sulphide collectors. The next largest group of collectors are the dithiophosphates. Many other specialised sulphydryl (thiol) collectors have been developed. The more common sulphide collectors and the more specialised ones are shown in Figs. 2 and 3. A fairly common property to most of these reagents is that they have characteristic odours, instantly recognisable when entering a mill.

In many cases a combination of two sulphide collectors, a xanthate and a dithiophosphate for example, give optimum grade and recovery efficiency for a particular

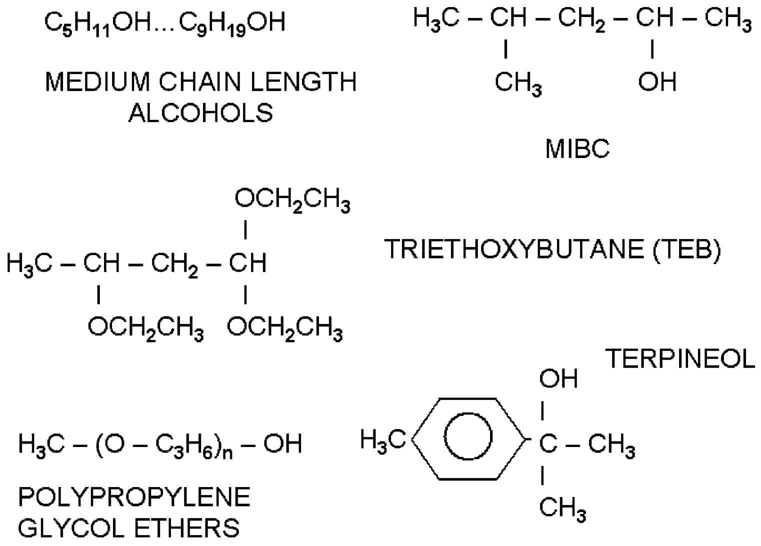

Fig. 1. Common flotation frothers.

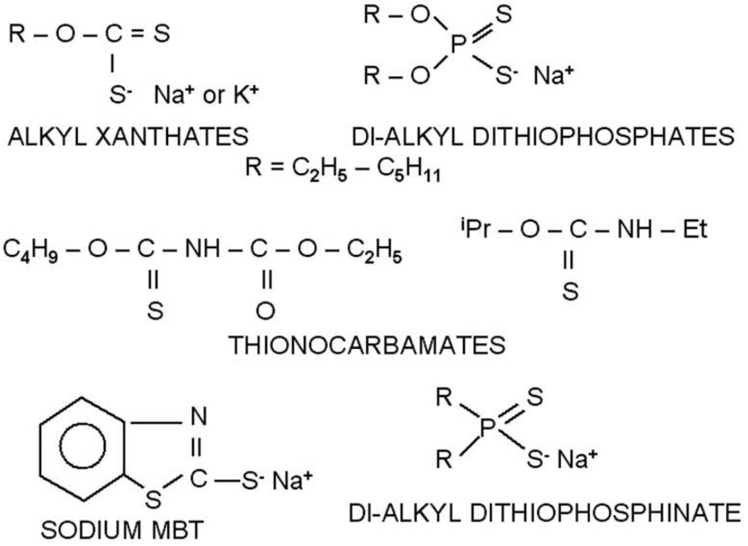

Fig. 2. Sulphide collectors (1).

circuit. Often the metallurgical challenge is to maximise the valuable sulphide recovery with minimum flotation of pyrite. Collector suites are selected to achieve this in many circumstances.

Reagent usage in a typical copper–zinc flotation circuit is shown in Fig. 4. the flowsheet employs sphalerite deactivation and activation, pyrite depression, potassium amyl xanthate collector and two frothers.

Some milestones in sulphide flotation are shown in Table 2. It is interesting to note that the two most used collectors, namely xanthates and dithiophosphates were devised almost 80 years ago.

### 3.3. Fatty acid collectors

Fatty acids are mixtures of long hydrocarbon chain carboxylic acids. The hydrocarbon chain is hydrophobic, while the polar carboxyl group is hydrophilic and this amphiphilic nature gives surfactant properties to the molecule. Fatty acid collectors are usually self-frothing and do not require a separate frother.

The main applications are in phosphate and fluorite flotation with minor applications including the removal of iron oxide contamination from glass sands.

The carboxyl group, being a weak acid, is undissociated at acidic pH values but dissociates in alkaline media to the carboxylate anion:

$$\mathrm{RCOOH} + \mathrm{OH}^- = \mathrm{RCOO}^- + \mathrm{H_2O}$$

When used as a flotation collector, the sodium salt of the fatty acid is usually prepared by adding caustic soda to the make up tank or relying on the alkaline conditions in the flotation circuit. This saponification process produces the carboxylate soap. Fatty acid neutral molecules

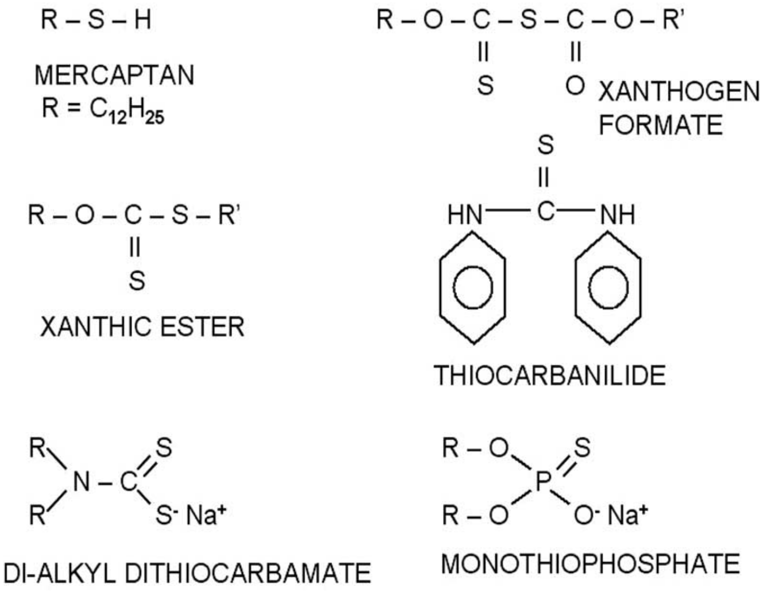

Fig. 3. Sulphide collectors (2).

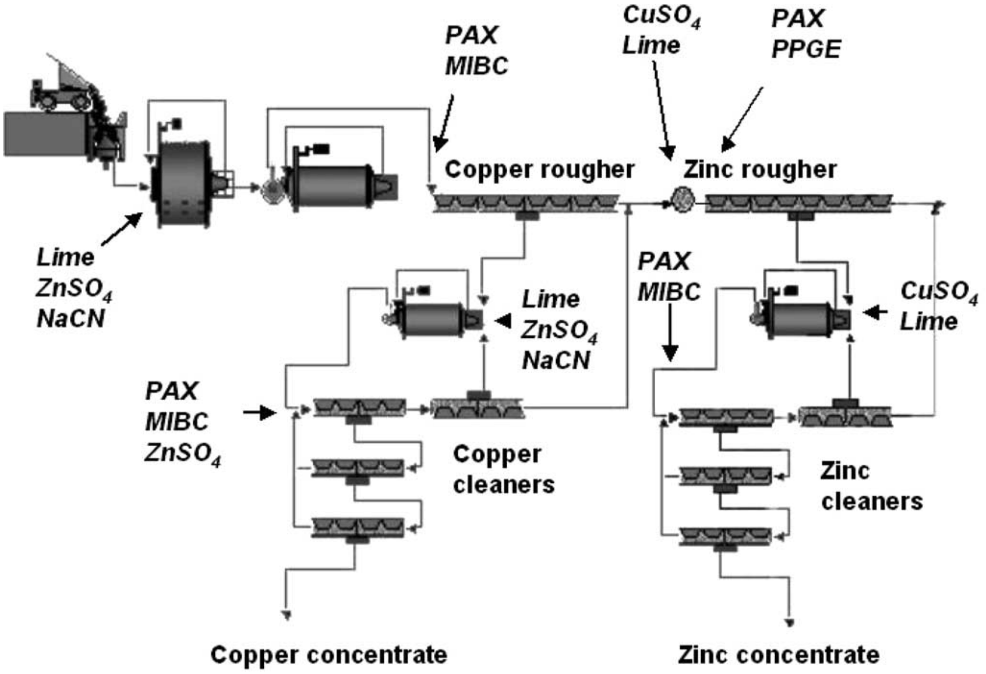

Fig. 4. Reagent use in a copper–zinc flotation circuit.

are quite insoluble in water, particularly the high homologues, and this neutralisation increases solubility considerably, hence providing a greater concentration of anions for flotation.

Fatty acids used in flotation are natural mixtures of various carboxylic acids extracted from vegetable and animal fats and oils. The actual composition depends on the natural source; vegetable sources are more popular than animal-derived products nowadays.

The great majority of fatty acid collectors nowadays are based on tall oil (TOFA = tall oil fatty acid). Tall oil fatty acids are derived from pine wood liquors in the Kraft process.

The active components of tall oil fatty acids are based on C18 fatty acids. Linoleic is usually the most prevalent constituent, oleic is second and then saturated stearic acid. Tall oil fatty acids have one potential drawback—rosin acids or abietic acid content (sometimes

Table 2
Milestones in sulphide flotation

| Date | Invention |
|---|---|
| 1898/1900 | Elmore vacuum process treating copper ores in Wales |
| 1901 | Potter process at Broken Hill, Australia, treating zinc ore |
| 1905 | Sulphidisation of oxidised ores with sodium sulphide |
| 1906 | Sulman and Picard patent |
| 1912 | Sodium dichromate used as galena depressant |
| 1913 | Sulphur dioxide used as sphalerite depressant |
| 1913 | Copper sulphate used as sphalerite activator |
| 1922 | Sodium cyanide used as sphalerite and pyrite depressant |
| 1924 | Sodium sulphite used as sphalerite depressant |
| 1925 | Keller and Lewis patent xanthate collectors |
| 1926 | Whitworth patents dithiophosphate collectors |
| 1954 | Harris patents thionocarbamate collectors |

called resin acids). Rosin acids or their soaps do not adsorb onto the mineral surfaces but concentrate in the froth; high rosin acid contents can lead to poor selectivity. The rosin acid content of tall oil should be kept to a minimum to give selective flotation collector properties.

### 3.4. Non-sulphide anionic collectors

These collectors are used, in the main, to float industrial minerals and some oxide metallic minerals. The common thread amongst all of them is that they are anionic collectors. Structures of the more important collectors are shown in Fig. 5.

Some of these products are now of historic interest only, while some have found specialised niches. The collectors are used for the flotation of barite, cassiterite and removal of iron and titanium contaminants from glass sands and kaolin. Some of these collectors have found important use in the flotation of hard-rock phosphates (carbonatite deposits).

Many of the collectors display typical 'surfactant' properties—critical micelle concentration, Krafft Point, emulsifying properties, detergency, medium hard water tolerance and self-frothing. Many of the water-soluble products reduce air/water and water/oil interfacial tensions considerably and can be used as co-collectors and emulsifiers for fatty acids. Virtually all the types are supplied as sodium salts which increases their water solubility.

### 3.5. Amine-based cationic collectors

Several categories of these collectors exist:

- Fatty amines $RNH_2$ ($R = C_{12}$–$C_{24}$)—solids/pastes
- Fatty diamines $RNH(CH_2)_3 \cdot NH_2$ ($R = C_{12}$–$C_{24}$)—solids/pastes
- Ether amines $R{-}O{-}(CH_2)_3 \cdot NH_2$ ($R = C_8$–$C_{13}$)—liquids
- Ether diamines $R{-}O{-}(CH_2)_3 \cdot NH(CH_2)_3 \cdot NH_2$—liquids
- Amine condensates and morpholines

The fatty amines/diamines and ether amines/diamines are supplied as, or prepared on site as, the acetate or chloride quaternary salts by partially neutralising with acetic or hydrochloric acid.

The major use of fatty amines and fatty diamines is as collectors for sylvite in potash flotation.

Ether amines and ether diamines are more selective and show better water-dispersibility. Their major use is as a silica collector in the reverse flotation of iron ore (hematite and magnetite taconite ores).

Both fatty and ether amines and diamines are used as collectors for silicate minerals.

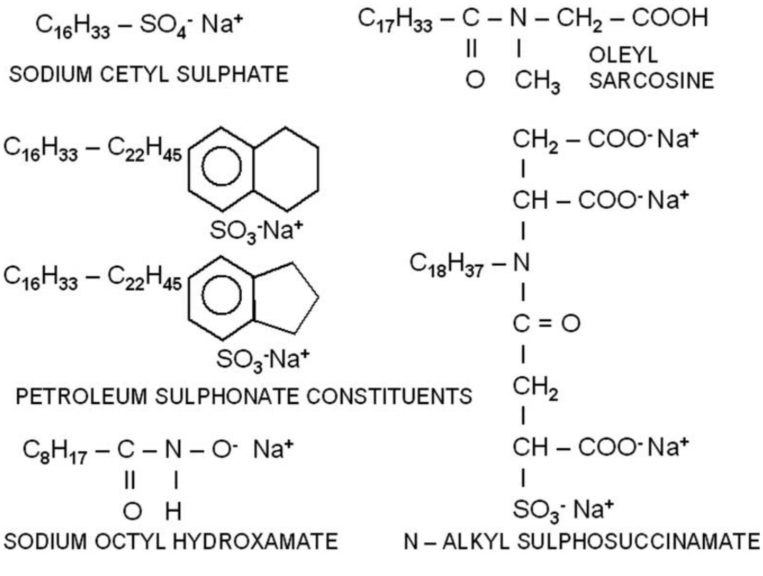

Fig. 5. Non-sulphide anionic collectors.

Amine condensates resist high sulphate levels and are used in phosphate flotation processes where roughing collector fatty acid is scrubbed from the surface with sulphuric acid for subsequent reverse cleaning with the amine. *N*-coco morpholine is used as a halite collector in the reverse flotation of potash.

### 3.6. Naturally derived organic flotation depressants

A simple classification is as follows:

- Polysaccharides:
  - Guar
  - Starch, dextrin
  - CMC (sodium carboxymethyl cellulose, a cellulose derivative)
- Polyphenols (tannins):
  - Quebracho
  - Mimosa (wattle bark extract)
  - Lignin (sodium lignosulphonate)

Virtually all depressants are based on multi-OH groups (hydroxyl or phenolic) in the molecule or ion or carboxyl groups to a lesser extent. Mechanisms include blocking or blinding of the gangue surface, thus preventing collector adsorption and adsorption onto and rendering hydrophilic, truly hydrophobic minerals e.g. CMC on talc. Often, a large hydration shield is built up. In addition, some depressants act as dispersants and reputedly froth modifiers.

Many natural depressants are derivatised. However, many of the properties of the 'parent' molecule are maintained and determine to some extent the derivative's behaviour.

Table 3 summarises parent polysaccharide structural features. Guar is often used underivatised and hence the information is of direct importance, Mackenzie (1986).

Guar is a galactomannan obtained from the seed of a small legume, *Cyamopsis tetragonolobus*, grown in Pakistan, India and South Africa. The intensity of grinding determines molecular mass. It is a very climate-sensitive crop and its price fluctuates due to crop yield, which in turn, depends on seasonal rainfall in the growing fields.

Guar is a non-ionic polymer of molecular mass in the order of 250,000 Da with about 450 repeating chain units.

Guar has a long, rigid, straight chain of mannose units linked by β(1–4) linkages. Simple side chains of galactose come off the mannose chain by α(1–6) linkages. The theoretical mannose to galactose ratio is 2:1 i.e. the galactose branches come off every alternate mannose unit, as shown in Fig. 6.

The positioning of the OH groups is important. In the mannose groups they are all in *cis* position (same side) and there are some *cis* OH groups in the galactose groups. This positioning means they can reinforce each other and promote efficient hydrogen bonding.

Starch consists of two components - linear amylose and branched amylopectin, the formulae of which are shown in Fig. 7. Amylose is a linear chain of glucose molecules, linked by α(1–4) bonds. OH groups on the glucose units are in the *trans* position so cannot reinforce each other in hydrogen bonding. The linear chain forms a helix with the length of each turn being six glucose units. Amylopectin has no definite structure except that it is highly branched and derived from short 20–25 anhydroglucose unit chains of amylose connected to each other by α(1–6) linkages.

The amylose:amylopectin ratio depends on the source of the starch and determines properties to some extent along with the degree of cross-linking.

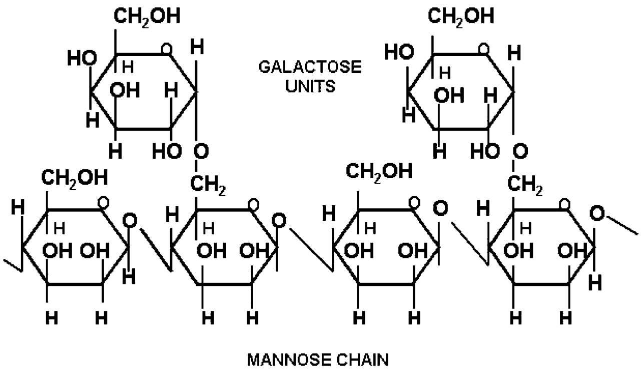

Fig. 6. Galactomannan structure of guar.

Table 3
Characteristics of some polysaccharide molecules

| Molecule | Molecular mass, Da | Glucosidic linkage | Hydroxyl position | Chain structure | Hydrogen bonding |
|---|---|---|---|---|---|
| Guar | 250,000 | β | *Cis* | Linear mannose with galactosidic branches | *Cis* OH groups reinforce H-bonding |
| Amylose starch | 40,000–65,000 | α | *Trans* | Unbranched, flexible helix | Many OH groups face inwards on helix and H-bonding not reinforced |
| Amylopectin starch | 10,000–100,000 | α | *Trans* | Highly Branched | Branched structure sterically hinders alignment in H-bonding |
| Cellulose | 250,000–1,000,000 | β | *Trans* | Rigid linear chain | H-bonding not reinforced due to *trans* position of OH groups |

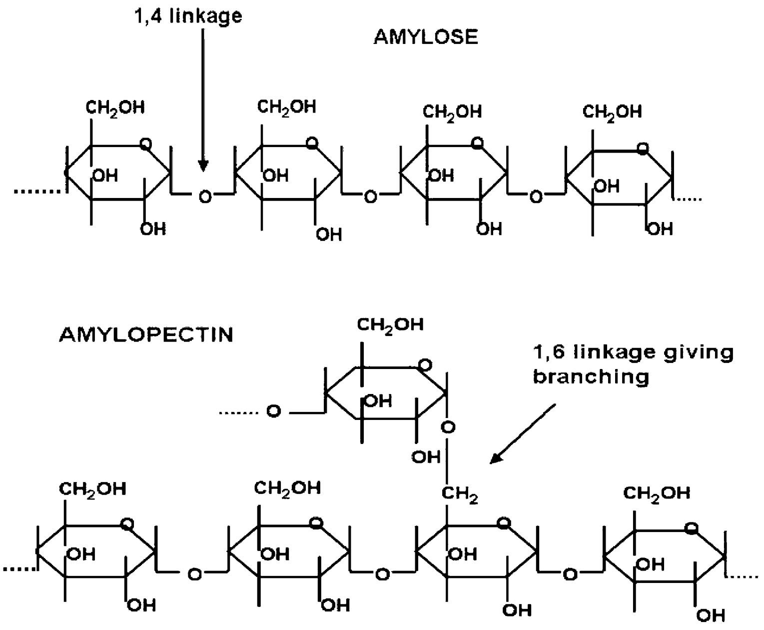

Fig. 7. Components of starch.

Starch is insoluble in cold water due to chains aligning themselves alongside each other and interacting via hydrogen bonding. Boiling or causticisation breaks this down and solubilises the starch.

Cold water soluble starches have been boiled, gelatinised or oxidised and then re-precipitated.

Starch is non-ionic with a slight anionic character. Anionic and cationic derivatives are available using carboxyl and amine groups respectively.

It has been proposed that minute traces of phosphate groups in potato starch are responsible for its affinity to hematite.

Sources of starch are potato, farina and corn (maize).

Dextrin is the product of heat and acid treatment of starch. The starch is broken down and repolymerisation of the hydrolysed fragments into highly branched molecules gives dextrin, which is cold water soluble.

Sodium CMC is prepared by the action of sodium hydroxide and mono-chloracetic acid on cellulose. Cellulose is a linear polymer of anhydroglucose and sources are wood or cotton, mainly the former. Some of the OH groups of the cellulose are replaced by $OCH_2COO^-Na^+$ at the sixth position in the glucose formula, as shown in the structural formula of sodium CMC given in Fig. 8.

Three parameters that determine the performance of sodium CMC are:

1. The purity: some products have residual sodium chloride from the reaction.
2. Molecular mass: quoted in terms of 1% or 2% solution viscosity
3. The average number of ether groups (carboxymethyl) substituted into one glucose unit. This is known as the degree of substitution (DS) and varies generally from 0.65 to 1.00. Cellulose has three OH groups per anhydroglucose unit. If one of these is reacted then the DS is 1.0.

Starch, usually causticised, or as dextrin, are good depressants for hematite, calcite and apatite. Large amounts of starch are used in the reverse flotation of iron ore.

CMC and Guar are clay blinders in potash flotation and talc depressants in nickel and PGM circuits.

Further uses of sodium CMC are described later in the paper.

Polyphenols, derived from trees differ from polysaccharides in that the OH groups are phenolic ($pK_a = 9.2$–$9.9$) rather than alcoholic ($pK_a > 12$).

An approximate structure for quebracho is shown in Fig. 9.

Quebracho is derived from the heartwood of the hardwood trees *Shinopsis balansae* and *Shinopsis lorentzii*, which grow in Argentina, Brazil and Paraguay. The name quebracho means ‘axe breaker’ in local dialect and refers to the hardness of the wood. The material is leached from the wood at temperatures over 100 °C and the resultant 10% solution is evaporated to a 95% powder under vacuum.

This raw powder is water-soluble at pH levels > 8. Good grades are treated with bisulphite which introduces sulphonate groups and makes the quebracho water-soluble at all pH levels.

Wattle bark extract or mimosa is a similar product and is obtained from the bark of *Acacia mollissima* by a similar treatment.

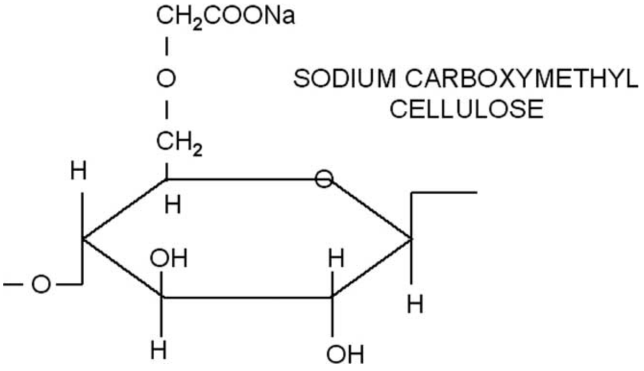

Fig. 8. Sodium carboxymethyl cellulose (simplified).

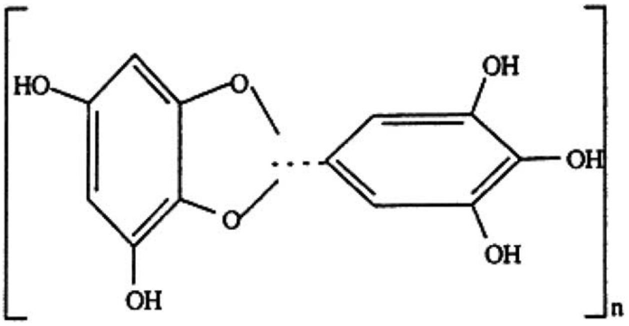

Fig. 9. Approximate structure of raw quebracho (*n* = 1–200).

Quebracho is used as a depressant for calcite, dolomite and siderite, often in fluorite flotation.

Sodium lignosulphonate is obtained by the sulphite and Kraft processes (alkaline sodium sulphide destruction of softwood). Sodium lignosulphonate has been used as a depressant for carbonaceous material and also to depress copper and iron sulphides in molybdenum recovery; it also has dispersant properties.

The structure of lignosulphonic acid is shown below. The product is sold as the sodium salt and is anionic in character (see Fig. 10).

## 4. Solvent extractants

Solvent extractants represent highly specialised reagents, not of high volume use but of high value, and there usage is increasing faster than many other reagents. Over 2 million tonnes of copper metal are produced annually by SX technology mainly from 'oxide' copper ores. The increasingly important lateritic nickel processes also employ technology that is dependent on solvent extraction.

The extractants used for copper are of the chelating type and contain very copper-specific ligands. They are generically hydroxyoximes, with the earlier versions based on ketoximes, like benzophenone oxime, with the more recent ones being based on aldoximes (salicylaldoxime).

Cobalt separation from nickel uses phosphinic acid based extractants. The structures of extractants are shown in Fig. 11.

A generic flowsheet for solvent extraction, solvent stripping and electrowinning of copper is shown in Fig. 12 to illustrate terminology and 'typical' solution tenors in aqueous and non-aqueous process streams.

## 5. Polymeric synthetic reagents

The vast majority of synthetic polymers used in mineral processing and hydrometallurgy are based on acrylic chemistry. The polymers are very versatile in terms of molecular architecture and as such have found many uses in the industry. Since their inception in the 1960s, rapid growth in their use has been witnessed. Some of the more general applications are described here, although many less common functions are found throughout the minerals industry.

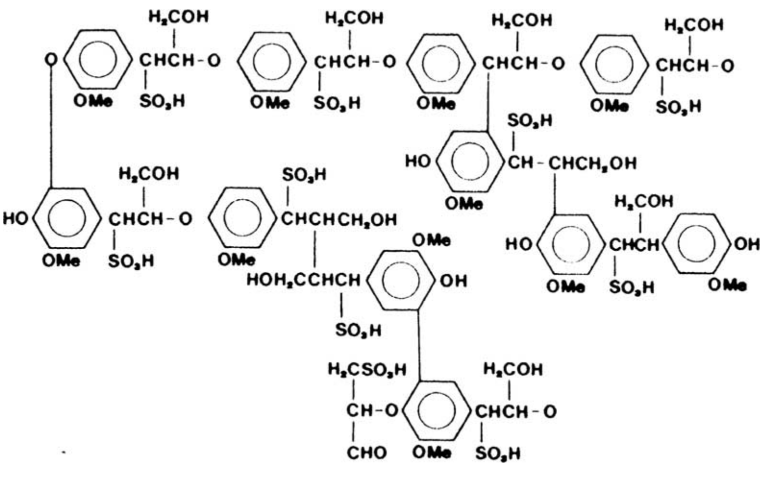

Fig. 10. Lignosulphonic acid.

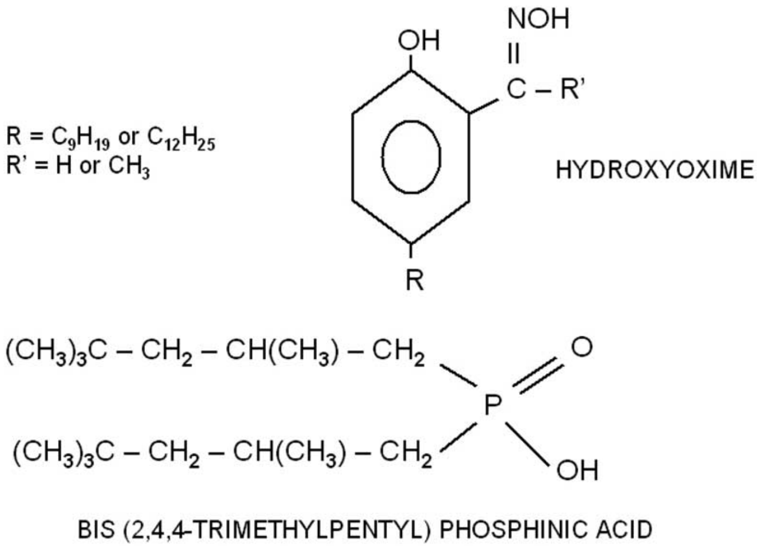

Fig. 11. Solvent extractants for copper and cobalt–nickel.

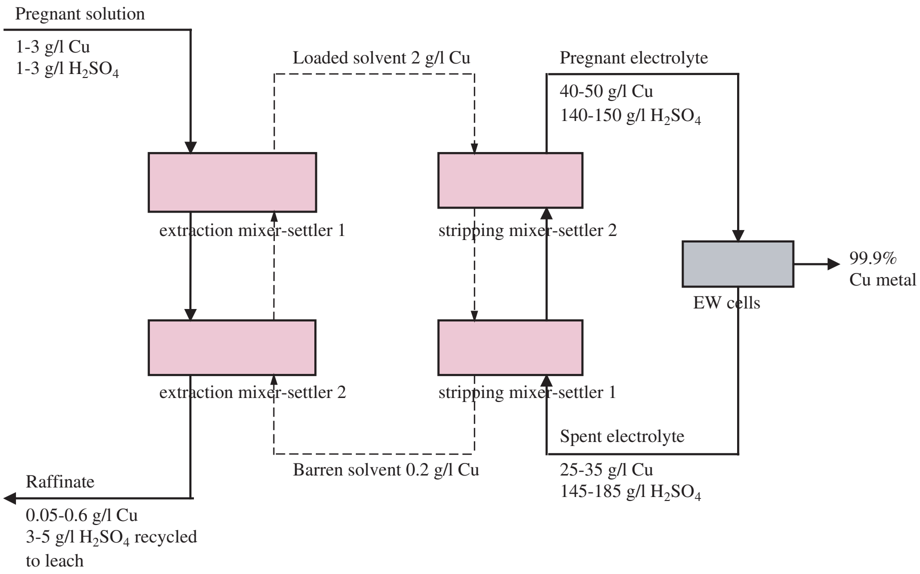

Fig. 12. Solvent extraction circuit for copper.

### 5.1. Flocculants and coagulants

Flocculants based on polyacrylamide represent the largest category of organic reagents, Pearse (2003). The polyacrylamide molecule can be tailored to virtually every mineral processing solid–liquid separation condition. Substitution in the polyacrylamide chain of various cationic and anionic functional groups gives a spectrum of reagents that will effectively treat all slurry environments from mono-mineralic to multi-mineralic, low to high suspended solids, low to high dissolved solids and low to high pH. Manipulation of molecular mass from 5 million to 25 million Da allows successful application to be made on all solid–liquid separation equipment—clarifiers, thickeners, filters of all types and centrifuges. New developments are on-going with these reagents, Pearse et al. (2001). Along with the polyamine and polyDADMAC (diallyldimethyl ammonium chloride) primary coagulants, described below, polyacrylamide-based flocculants account for over 90% of the mineral processing flocculant market.

The entities of acrylic chemistry used in common types of flocculant are shown in Fig. 13. Acrylamide is polymerised by vinyl addition to give non-ionic polyacrylamide. Sodium acrylate is co-polymerised with acrylamide to give anionic flocculants, while DMAEA

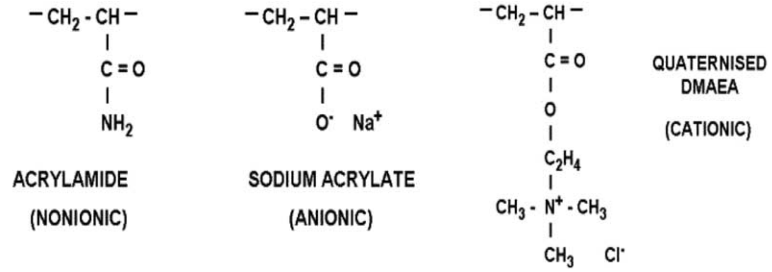

Fig. 13. Monomer entities which copolymerise to form acrylamide-based flocculants.

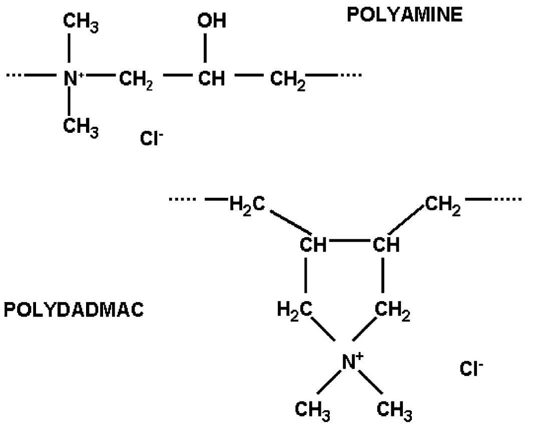

Fig. 14. Structures of synthetic coagulants.

(dimethylaminoethyl acrylate) is used with acrylamide to give cationic products.

As mentioned, the main coagulants used in the minerals industry today are based on polyDADMAC (diallyldimethyl ammonium chloride) and quaternised polyamines. Structures are shown in Fig. 14. These products are often known as primary coagulants as they are usually used prior to the addition of a polyacrylamide-based flocculant. Both types are highly cationic and of low molecular mass (<1MDa). The primary mechanism involved with these products is charge neutralisation, although bridging occurs in a secondary mode. Many of the inorganic coagulants used in the minerals industry previously have been replaced by synthetic coagulants.

### 5.2. Agglomerating agents (binders)

Replacement or partial substitution of bentonite binders for iron ore pelletisation is offered by polymers based on polyacrylamide or sodium carboxymethyl cellulose. Synthetic binders can provide improvements in wet and dry strength of pellets and can be designed to give superior anti-spalling and surface properties. In addition, the use of synthetic binders prevents silica being added to the pellets, which is critical where direct reduction is involved in iron and steel making.

The use of synthetic binders is increasing into other non-iron concentrate applications and includes other agglomerating methods such as briquetting of various substrates.

### 5.3. Dispersants and grinding aids

These reagents provide an opposite effect to flocculants whereby they adsorb onto the surface of minerals and disperse them as individual particles. Many of these reagents are based on low molecular mass polymers of sodium polyacrylate (see Fig. 13). Applications include dispersion of kaolin slips for paper coating and ceramics manufacture, mineral pigment dispersion and modification of the rheological properties of high clay content gold ores.

Grinding aids work by dispersion in that they reduce the viscosity of mineral slurries in grinding mills. This can allow efficient comminution of slurries at a higher solids content than normal thus allowing greater throughputs or the use of a smaller number of mills.

### 5.4. Antiscalants

In many operations that use lime, calcium carbonate or calcite scaling can be a major problem. For example, in gold processing, restriction in pipe flow, screen scaling and precipitation in activated carbon pores lead to processing inefficiencies. Also, in heap leaching operations, blockage of sprinklers can occur.

Where sulphuric acid is used intentionally for leaching or is generated by oxidising sulphide minerals, gypsum scale can form in an analogous manner to calcium carbonate scale.

Down time can be prevented and process efficiencies improved by the use of low addition levels of antiscalants to the various process streams. The majority of antiscalants are based on sodium polyacrylate of low molecular mass (<10,000 Da); some have an additional phosphonate component. Antiscalants work at sub-stoichiometric dose levels keeping the potential scalants in solution and preventing precipitation. A combination of crystallising nuclei destruction, agglomerate dispersion and crystal deformation preventing adhesion are the proposed mechanisms of operation of antiscalants.

In addition to direct application in mineral processing and hydrometallurgical process streams, antiscalants are extensively used in associated mine site power and heat generating facilities.

### *5.5. Rheology modification and tailings stabilisation*

An emerging technology, based on the versatility and scope for manipulation of the polyacrylamide and other synthetic polymer molecules, is centred around pumpable high solids slurries and stackable tailings that progressively dewater. Reduction of tailings dam footprint and increased dam life are major benefits of this technology.

## 6. Miscellaneous uses of reagents

Some reagent uses not described are listed in Table 4.

Table 4
Miscellaneous uses of reagents in mineral processing and hydrometallurgy

| Reagent type | Reagent type |
|---|---|
| Dust suppressants | Biocides |
| Surfactant dewatering aids | Emulsifiers |
| Antifoams | Cathode smoothing aids |
| Solvent diluents or carriers | Levelling agents |
| Extender oils | Mist suppressants |
| Wetting agents | Heavy metal precipitants |

## 7. Conclusions

The mineral processing and hydrometallurgical industries use an extensive range of inorganic, naturally derived organic and synthetic organic reagents, mainly in froth flotation and solid–liquid separation. Some reagents emerged in the early years of those processes and have stood the test of time; others are new or emerging and reflect the ever evolving challenges of the industry. The new and improved reagents reflect response to both technological and environmental requirements.

The large volume inorganic reagents that are used include lime and sulphuric acid, best described as bulk chemicals. Of the more specialised reagents, the largest volume chemicals are flocculants and coagulants, flotation frothers and sulphide mineral collectors. The most specialised high value reagents, although of lower volume, are solvent extractants. The more specialised reagents are predicted to increase in volume by 2–3% annually over the next few years.

In addition to the high volume reagents, there is a plethora of other chemicals that play essential roles in mineral processing and hydrometallurgy.

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