Ausmelt Limited, a Melbourne based technology company, claims to have changed mineral flotation forever. According to Dr Terry Hughes, principal geochemical consultant, Ausmelt, the company's development of a steric hydroxamate collector, called AM2, for oxidised base metal minerals, free metals and metal oxides, represents a major improvement in mineral processing. In particular, oxidised copper minerals in run-of-mine ore, tailings or waste streams can now be effectively recovered by flotation by blending AM2 reagent with conventional sulphide collectors.

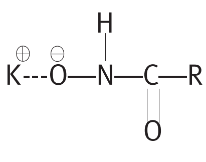
AM2 – a hydroxamate flotation collector reagent for oxides and oxidised mineral systems

By Dr Terry C Hughes, Ausmelt Chemicals Pty Ltd.

Ausmelt Limited has developed and patented a range of alkyl hydroxamates for use as collector reagents in mineral flotations systems. The most effective reagent is potassium n-octyl hydroxamate, termed AM2, which has been manufactured in multi-tonne quantities using an environmentally friendly aqueous based reaction route. AM2 has a stabilised hydroxamate structure which results in strong and selective surface chelation during its application as a flotation reagent. It is used as a 20% solution in dilute potassium hydroxide as a flotation collector for oxidised base metal sulphides, precious metals (Ag, Au, PGM) plus copper metal and lithophile metal oxides. Extensive trials have shown that AM2 is synergistic with sulphide collectors and has great promise for upgrading oxidised minerals and mine tailings. As such its development represents a major advance in flotation technology.

Hydroxamates are anionic collectors which have been known for many years. They behave as weak acids with a pKa between 9 and 10. Although these reagents are most effective at high pH (above 10.5) they have been shown to improve metal recovery in pulps with pH ranging from 7 to 10. The typical hydroxamate derivative is shown below.

K alkyl (R) hydroxamate



R = n C8-C10

The metallurgical applications and flotation testwork carried out by Ausmelt Limited has focused on copper to date, essentially for commercial reasons. Mineralogical associations of copper with gold, molybdenum and other base metals have shown similar grade/recovery improvements when AM2 is used providing some ore oxidation has occurred.

Extensive toxicological investigations on AM2 were carried out by NICNAS (National Industrial Chemicals Notification and Assessment Scheme, Australia) to ensure the safe handling and use of the hydroxamate reagents. This resulted in NICNAS granting a commercial registration for Ausmelt to manufacture and distribute AM2 (AM2 NICNAS Code is NA/917).

The Development of Hydroxamate Flotation Reagents

Numerous investigations into metal losses to tailings in the flotation process showed that at times the losses were due to liberated metal bearing minerals not being collected by the existing reagent suite. In some instances this was due to the oxidation of the mineral surface either during weathering of the ore deposit or tarnishing during the mining and handling process. Conventional collectors, eg. xanthates and thiophosphates typically do not perform well on oxidised surfaces, indicating that an oxide specific flotation collector is required to maximise recovery.

Initial investigations with fatty acids (C8/C10 saturated fatty acids or C18 oleic acid) showed some promise. However, problems of excessive frothing and major loss of selectivity due to general gangue flotation caused by reactions with dissolved Ca and Mg ions led to an investigation of hydroxamates as selective flotation reagents.

The Metallurgical Importance of the AM2 Chemical Structure

Ausmelt's AM2 reagent has been examined by Fourier transform infra red spectroscopy (FTIR), electron spray mass spectrometer (ESMS), thermal gravimetric analysis (TGA), nuclear magnetic resonance (NMR), and elemental analysis and its activity has been correlated in relation to flotation performance results.

The novel structural features of AM2 combined with a hydrophobic tail make the reagent highly effective as a selective collector of oxidised metal minerals in the froth flotation process. The tail promotes bubble attachment while the hydroxamate part selectively attaches to the oxidised metal surface by chelation. AM2 when prepared in paste form is made ready to use by simply dissolving it in a 1-2% KOH solution.

The AM2 reagent is also found to be an effective collector for some minerals at a pH well below that of its pKa, eg. it recovers tin as cassiterite (SnO2) in the pH range from 4 to 5. In this instance, the reagent might have relatively less solubility, however, the reagent functionality should still be accessible in reactive chelating mode. It is possible the zeta potential of the tin mineral (~4.5) induces AM2 adsorption at a faster rate at lower pH. Since the AM2 reagent has limited solubility at pH4-5 it is not able to form the reactive aggregate as occurred at higher pH in the case of copper recovery. It is found that with increasing temperature from 20 to 30°C there is a significant improvement in tin recovery process which may be offset in part by increasing the more soluble C-6 content of AM2.

The Importance of Hydroxamate Flotation in Copper Beneficiation

Figure 1 shows diagrammatically the changing chemistry with depth in a typical deposit of copper mineralisation. It should be noted that copper (Cu) levels are significantly enhanced by oxidative supergene enrichment. This is as a result of primary sulphide mineral oxidation resulting in the mobilisation of Cu ions and their precipitation in the supergene zone. Most of the Cu minerals are in the zone of secondary sulphide enrichment ore sulphides and can be recovered with conventional reagents. Minerals such as chalcocite are readily surface oxidised and may require a modification to the reagent regime such as the addition of hydroxamate, to effect their complete recovery.

In the zone of oxidised enrichment, oxides and metallic copper can be found. In this zone, which is often stockpiled "for treatment later or heap or dump leaching", hydroxamates are really needed. In particular AM2 is able to recover chrysocolla which is seen to be a performance test for novel Cu flotation reagents.

Figure 2 shows the flotation recovery of chrysocolla using AM2 at various pH's with added soluble copper (as CuSO4).

Flotation results shown in Figure 3 were obtained using run of mine chrysocolla rich samples with various reagent compositions. AM2 was used in 1% KOH solution with conventional sulphide reagents. However for experimental purposes the AM2 reagent was modified such that the cis:trans hydroxamate ratio was altered to increase the trans component and therefore decrease the collector efficiency of the hydroxamate reagent for the chrysocolla. The results are shown in Figure 3.

Reagent 1 is fresh AM2 in 1% KOH.

Reagent 2 is AM2 treated with 5% acetic acid filtered and dissolved in 1% KOH.

Reagent 3 is AM2 acidified with 2% H2SO4 filtered and dissolved in C10/C12 n-alkyl alcohol.

The feed material possessed a particle size of P80 100ì at the flotation cell pH was 9.5-10.5.

Flotation of Oxidised Polymetallic Ore

A further oxidised Cu, Pb, Zn and Ag ore from North Queensland was tested with AM2. Mineralogically the sample consists of the following:

Copper Minerals

Chalcocite (including digenite), malachite, native copper, covellite, chalcopyrite, cuprite, pyrite, hematite (+ magnetite), goethite, cuprite, and rare bornite.

Gangue Minerals

Quartz, biotite mica, siderite, feldspar and probably minor talc.

Flotation test results are shown below in Figure 4. A marked improvement in recovery is shown when AM2 is used with the thionocarbamates. The initial Cu concentration is increased from 33.5% when using thionocarbamates alone to 35.5% with AM2 and the final Cu recovery increases from 52.0% to 75.2%.

Conclusion

AM2 is a new mineral flotation reagent aimed at the cost effective recovery of oxidised or weathered base metals, sulphides, precious metals or oxide metals (lithophiles). Losses of metal values in mineral processing are often caused, in part, by surface oxidation. AM2 targets these valuable minerals which are not recovered by conventional thiol based collectors. Extensive testwork both in metallurgical laboratories and at mine sites, in particular, for Cu and Cu/Au deposits has been carried out. This has shown the value of AM2 as a scavenge or secondary collector, acting synergistically with conventional sulphide collecting reagents. For fully oxidised ores AM2 can be used alone and has shown an excellent performance for difficult to float minerals such as chrysocolla.

Other areas of application of AM2 are as follows:

- Recovery of metal values from base metal tailings dams.
- Removal of oxidised Cu (acid or cyanide soluble) prior to Au cyanidation.
- Concentration of fully oxidised Cu ores prior to acid leach, solvent extraction and electrowinning of the Cu.
- Recovery of fine Au or PGMs.
- Flotation beneficiation of lithophile metals, eg. Sn, Be, Ti, Zr, Hf, Ta, Nb, U and REE.
- Simplification of conventional flotation circuits by removing the need for reducing agents (MBS) or complexes (cyanide)
- Developing selective oxidation as a means of increasing metal flotation selectivity.

In summary AM2 represents the development of a novel flotation collector which can be applied to a wide range of ores and minerals many of which, have not in the past, been beneficiated in a cost effective way by flotation techniques. □

Figure 1:

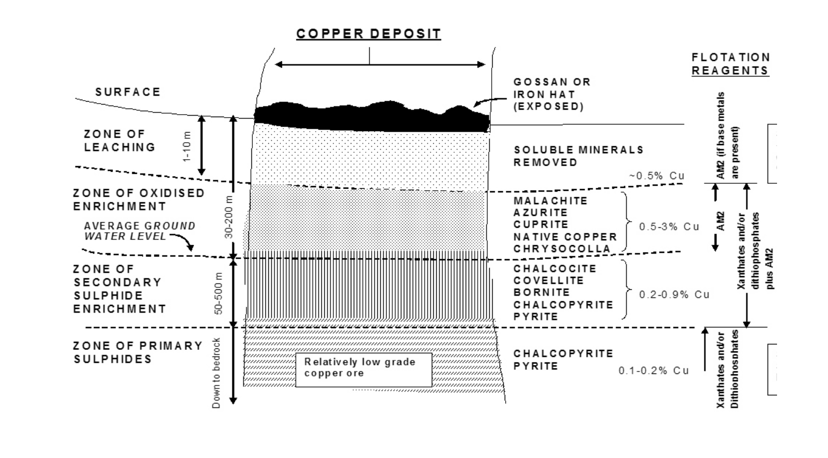


Figure 2:

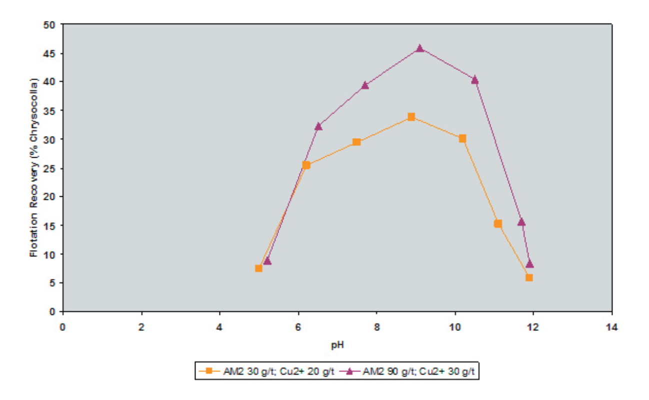


Figure 3:

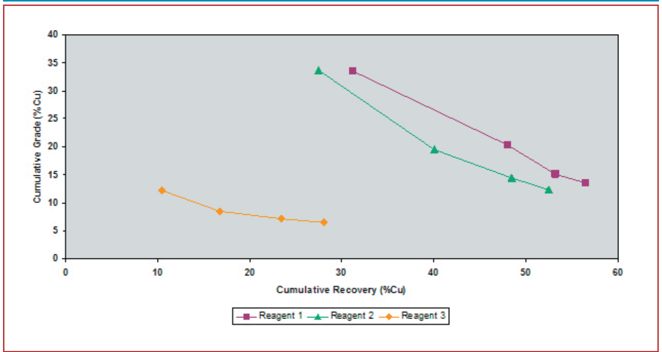


Figure 4: