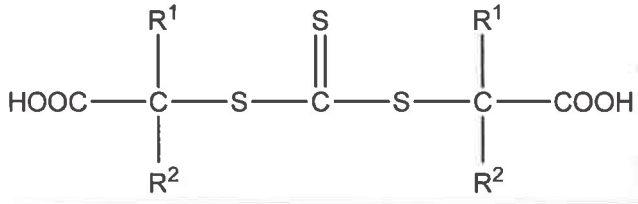
What is claimed is:

1. A method of chelating ions of hardness from a solution, wherein the method uses a polymer comprising (A) at least one water soluble chain transfer agent (CTA) - acid or CTA-acid salt and combinations thereof, wherein the water soluble CTA-acid comprises a thiocarbonate compound having the formula I

Formula I

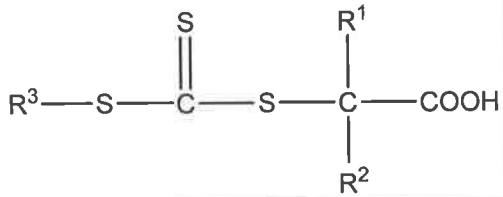


wherein

each of R^1 and R^2 is an alkyl group of four carbons or less or H,

so long as the sum of the number of carbon atoms present for all R^1, and R^2 in formula I together is less than four; or formula II

Formula II



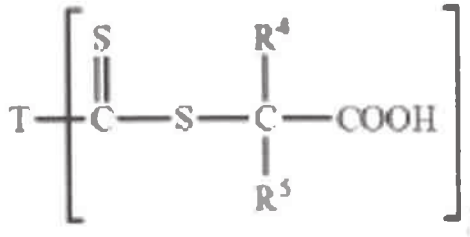
wherein

each of R^1 and R^2 is as defined above; and

R^3 is an alkyl group of four carbons or less, or H,

so long as the sum of the number of carbon atoms present for all R^1, R^2 and R^3 in formula II together is less than four; or formula III

Formula III



wherein

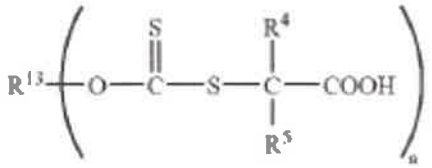
each of R^4 and/or R^5 substituents, independently, comprise an alkyl group having from 1 to 4 carbon atoms, or H;

j is 1 or 2, with the proviso that when j is 1, T is (--NR^6R^7); and when j is 2, T is a divalent radical having a nitrogen atom directly connected to each carbon atom of the two thiocarbonyl groups present;

R^6 and R^7, independently, are the same or different, and are H or a linear or branched alkyl having from 1 to 4 carbon atoms;

so long as the sum of the number of carbon atoms present for all R substituents in formula III together is less than four; or formula IV

Formula IV



wherein

each of R^4, and R^5 are as defined above

R^{13} is optionally substituted, and is a linear or branched alkyl having from 1 to 4 carbon atoms; and

a is 1 to 4;

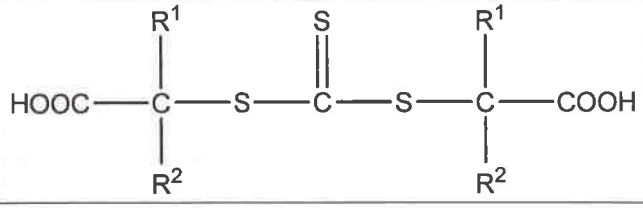
so long as the sum of the number of carbon atoms present for all R substituents in formula IV together is less than four:

(B) monomer units derived from at least one water soluble monomer, wherein the water soluble monomers comprise 2-Acrylamido-2-methylpropane sulfonic acid, acrylic acid, methacrylic acid, itaconic acid, maleic acid, fumaric acid, citraconic acid, mesaconic acid, (alkyl) acrylamide, and derivatives or salts thereof, or any combination thereof and optionally (C) monomer units derived from at least one water insoluble vinyl monomer, wherein the water insoluble monomers comprise of any polymerizable monomer that includes an alkyl group containing 1-18 carbon atoms consisting of a simple ester, a vinyl ester, a mono-allyl ether, styrene, derivatives thereof, or any combination thereof.

2. The method of any of claims 1 to 3 where the polymer is made up of 0.1 to 50 weight percent units derived from (A) and from 50 to 99.9 percent by weight of the combination of (B) and optional (C).

3. A polymer comprising (A) at least one water soluble CTA-acid or CTA-acid salt wherein the water soluble CTA-acid comprises of a thiocarbonate compound having the formula I

Formula I

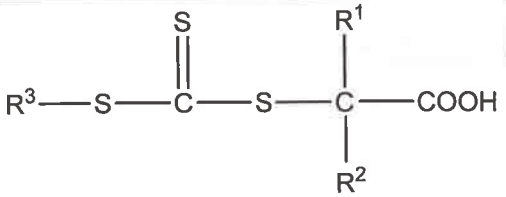


wherein

each of R^1 and R^2 is an alkyl group of four carbons or less or H,

so long as the sum of the number of carbon atoms present for all R^1, and R^2 in formula I together is less than four; or formula II

Formula II



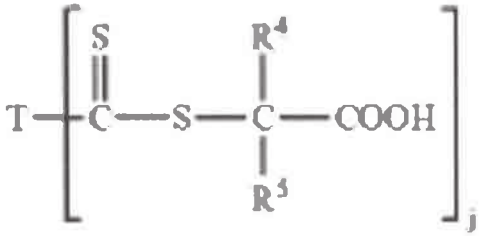
wherein

each of R^1 and R^2 is as defined above; and

R^3 is an alkyl group of four carbons or less, or H,

so long as the sum of the number of carbon atoms present for all R^1, R^2 and R^3 in formula II together is less than four; or formula III

Formula III



wherein

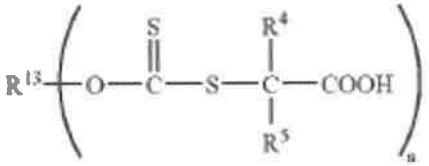
each of R^4 and/or R^5 substituents, independently, comprise an alkyl group having from 1 to 4 carbon atoms, or H;

j is 1 or 2, with the proviso that when j is 1, T is (--NR^6R^7); and when j is 2, T is a divalent radical having a nitrogen atom directly connected to each carbon atom of the two thiocarbonyl groups present;

R^6 and R^7, independently, are the same or different, and are H or a linear or branched alkyl having from 1 to 4 carbon atoms;

so long as the sum of the number of carbon atoms present for all R substituents in formula III together is less than four; or formula IV

Formula IV



wherein

each of R^4, and R^5 are as defined above

R^{13} is optionally substituted, and is a linear or branched alkyl having from 1 to 4 carbon atoms; and

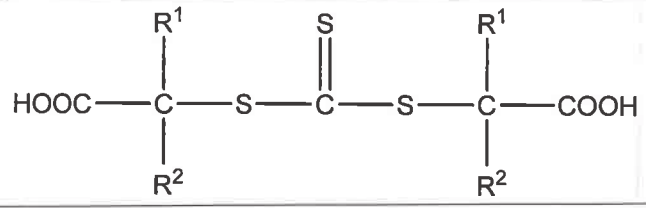
a is 1 to 4;

so long as the sum of the number of carbon atoms present for all R substituents in formula IV together is less than four:

(B) monomer units derived from at least one water soluble monomer, wherein the water soluble monomers comprise of 2-Acrylamido-2-methylpropane sulfonic acid, acrylic acid, methacrylic acid, itaconic acid, maleic acid, fumaric acid, citraconic acid, mesaconic acid, (alkyl) acrylamide, and derivatives or salts thereof, or any combination thereof and optionally (C) monomer units derived from at least one water insoluble vinyl monomer, wherein the water insoluble monomers comprise of any polymerizable monomer that includes an alkyl group containing 1-18 carbon atoms consisting of a simple ester, a vinyl ester, a mono-allyl ether, styrene, derivatives thereof, or any combination thereof.

4. The polymer of claim 3, wherein the CTA-acid portion of the water soluble CTA-acid salt comprises of a thiocarbonate compound having the formula I

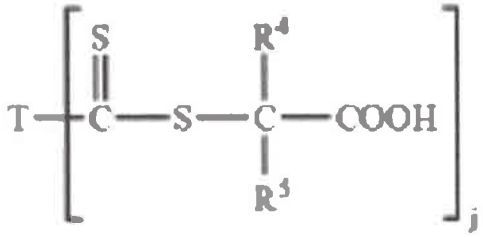
Formula I



wherein

R^1 and R^2, independently, are selected from a linear or branched alkyl having from 1 to 6 carbon atoms, a substituted alkyl having from 1 to 6 carbon atoms, substituted and unsubstituted aryl, R^1 and R^2 can form a substituted or unsubstituted cyclic ring having from 5 to 12 total carbon atoms; wherein said substituents, independently, are selected from an alkyl having from 1 to 6 carbon atoms, aryl, a halogen which can be the same or different, cyano, an ether having a total of from 2 to 20 carbon atoms, and a nitro group; or formula III

Formula III

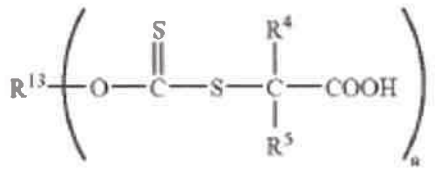


wherein

j is 1 or 2, with the proviso that when j is 1, T is (--NR^6R^7), and when j is 2, T is a divalent radical having a nitrogen atom directly connected to each carbon atom of the two thiocarbonyl groups;

R^4 and R^5, independently, are the same or different, are optionally substituted as defined for R^1 and R^2, and are selected from a linear or branched alkyl having from 1 to 12 carbon atoms, aryl having from 6 to 18 carbon atoms, R^4 and R^5 can form a substituted or unsubstituted cyclic ring having from 3 to 12 carbon atoms, wherein said substituents, independently, are selected from an alkyl having from 1 to 6 carbon atoms, aryl, halogen, cyano, an ether having a total of from 2 to 20 carbon atoms, a nitro group, and combinations thereof; wherein R^6 and R^7, independently, are the same or different, optionally substituted as defined for R^1 and R^2, and are selected from hydrogen, a linear or branched alkyl having from 1 to 18 carbon atoms, aryl, aryl alkyl having from 6 to 18 carbon atoms, optionally saturated or unsaturated, arylalkyl having from 7 to 18 carbons, alkenealkyl having from 3 to 18 carbon atoms, polyalkylene glycol ether having from 3 to 200 carbon atoms, and amine, or R^6 and R^7 can form a cyclic ring with the nitrogen atom having a total of 4 to 12 carbon atoms; or formula IV

Formula IV



wherein

R^4 and R^5 are as defined above;

R^{13} is optionally substituted, and is selected from linear or branched alkyl having from 1 to 12 carbon atoms, aryl optionally saturated or unsaturated, arylalkyl having from 7 to 18 carbon atoms, acyl, alkene, alkenealkyl having from 3 to 18 carbon atoms, an alkylene group, an alkoxyalkyl, polyalkylene glycol, polyalkylene glycol monoalkyl ether having from 3 to 200 carbon atoms, and 2-trifluoroethyl; wherein when R^{13} is optionally substituted the substituent is selected from alkyl having from 1 to 6 carbon atoms, aryl, halogen, a cyano group, an amino group, an alkene group, an alkoxycarbonyl group, an aryloxycarbonyl group, a carboxy group, an acyloxy group, a carbamoyl group, an alkylcarbonyl group, an alkylarylcarbonyl group, an arylcarbonyl group, an arylalkylcarbonyl group, a phthalimido group, a maleimido group, a succinimido group, amidino group, guanidimo group, allyl group, epoxy group, alkoxy group, an alkali metal salt, a cationic substituent, a hydroxyl group, an ether having a total of from 2 to 20 carbon atoms, nitro, sulfur, phosphorous, a carboalkoxy group, and combinations thereof; and "a" is 1 to 4.

5. The polymer of claim 3 or claim 4, wherein the salt comprises alkali or alkali earth metal hydroxide; alkali earth carbonate; mono-, di-, and/or tri-alkyl-substituted amine; and combinations thereof.

6. The polymer of any of claims 3 to 5 wherein the salt comprises of sodium hydroxide.

7. The polymer of any of claims 3 to 6 wherein the salt comprises of an alkylamine chosen from at least one of triethanolamine ("TEA"), ethanolamine, 2-(dimethylamino)ethanol, diethylamine, 2-(2-aminoethoxy)ethanol, 3-amino-1-propanol, N-(2-hydroxyethyl)ethylenediamine.

8. The polymer of any of claims 3 to 7 where the polymer is made up of 0.1 to 50 weight percent units derived from (A) and from 50 to 99.9 percent by weight of the combination of (B) and optional (C).