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(72) Inventeurs/Inventors:
MANRING, LEWIS EDWARD, US;
WEST, MICHAEL WENDELL JOHNSON, US
(73) Propriétaire/Owner:
E.I. DU PONT DE NEMOURS AND COMPANY, US
(74) Agent: BENNETT JONES LLP

(54) Titre : ESTERIFICATION DE POLYMERES RENFERMANT DES CARBOXYLATES
(54) Title: ESTERIFICATION OF CARBOXYLATE CONTAINING POLYMERS

(57) **Abrégé/Abstract:**

A process for esterifying a polymer containing carboxyl(ate) groups, by maintaining the polymer at 0 °C to 200 °C, where the counterion for the carboxylate groups is a selected ammonium or sulfoxonium ions. Such processes are useful for preparing improved films and coatings, particularly automotive coatings.

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(54) Title: ESTERIFICATION OF CARBOXYLATE CONTAINING POLYMERS (57) Abstract A process for esterifying a polymer containing carboxyl(ate) groups, by maintaining the polymer at 0 °C to 200 °C, where the counterion for the carboxylate groups is a selected ammonium or sulfoxonium ions. Such processes are useful for preparing improved films and coatings, particularly automotive coatings.		

TITLE

ESTERIFICATION OF CARBOXYLATE CONTAINING POLYMERS

BACKGROUND

5 This invention concerns a process for esterifying a
carboxylate containing polymer, by reacting selected
ammonium or sulfoxonium salts of the carboxylate groups
to effect esterification.

Carboxylate containing polymers are often used in
products that are in water solution, dispersion, or
10 emulsion, where the carboxylate groups may help
solublize or stabilize such mixtures. Such polymers are
used for coatings, adhesives, photo and thermal resists.
However, once the water is removed from the polymer, it
is often desirable to somehow remove or convert the
15 carboxylate groups into less polar moieties to reduce
the effect of water on the resulting polymer (e.g., less
water swell), or to help coalesce the polymer into a
uniform film by removing highly polar regions made up of
carboxylate salts. The removal or conversion of
20 carboxylate groups should take place when desired, after
most of the water has been removed, and the process
should preferably be efficient and proceed under
relatively mild conditions.

A. T. Lawson, et al., J. Chem. Soc., vol. 53,
25 p. 624-636 (1888) and R. C. Fuson et al., J. Am. Chem.
Soc., vol. 61, p. 1290 (1939), report that tetramethyl-
ammonium ions esterify certain carboxylate ions.
K. Yamauchi, et al., J. Org. Chem., vol. 44, p. 638-639
(1979) report that trimethylsulfonium hydroxide
30 esterifies carboxylic acids. Polymers are not mentioned
in any of these papers.

U.S. Patents 3,544,499, 3,804,797 and 3,903,056
describe the use of sulfonium salts of carboxyalate
containing polymers for making such polymers less

hydrophilic (more hydrophobic). No mention is made of the use of ammonium or sulfoxonium salts.

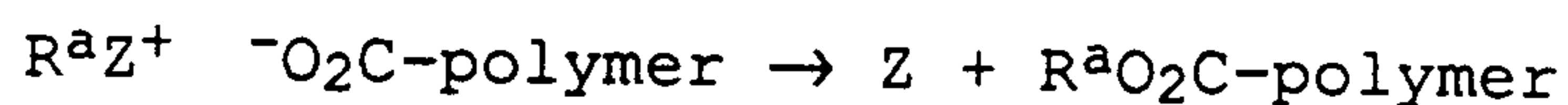
H. Ohtani, et al., J. High Res. Chromatog., vol. 14, p. 388-391 (1991) report the use of tetra-
5 methylammonium hydroxide as an alkylating agent to form methyl esters of the carboxylic acids residues present in liquid crystalline polyesters when such polyesters are analyzed by pyrolysis-gas chromatography. No
10 mention is made of esterifying a polymer which contains carboxyl(ate) groups.

SUMMARY OF THE INVENTION

This invention concerns a process for forming alkyl esters in polymers, comprising, maintaining a polymer containing carboxylate ions, whose counterions are
15 esterifying ammonium or sulfoxonium ions at a temperature of about 0°C to about 200°C. It has been found that when the counterion (positive ion) of the carboxylate anion is an ammonium or sulfoxonium cation the salt of the cation is relatively stable in water,
20 but efficiently esterifies the carboxylate group under relatively mild conditions in the substantial absence of water.

DETAILS OF THE INVENTION

The overall reaction which takes place during the
25 process can be represented by the equation



where R^a is alkyl or substituted alkyl, Z is a neutral
30 compound which contains all of the ammonium or sulfoxonium ion except the group R^a , and the starting carboxylate ion and final ester are bonded to a polymer.

None of the ammonium or sulfoxonium ions herein have a hydrogen atom attached to the atom that bears the
35 positive charge. Thus all the useful ammonium ions

herein are quaternary ammonium ions, not protonated ammonia or primary, secondary or tertiary amines. At least one of the groups attached to the atoms that bears the positive charge of the ammonium or sulfoxonium ion is an alkyl or substituted alkyl group. The alkyl group, and phenyl group if present, may be substituted by a group which does not interfere with the esterification reaction. In some instances (see below) the substituents may affect the reactivity of the onium ion towards esterification of the carboxylate group. Suitable substituents include, but are not limited to, alkyl, aryl, ether, halo, ester, and amino.

In the presence of large amounts of water or other strongly hydrogen bonding solvents such as alcohols, particularly the lower alcohols, the esterification reaction is slow or does not occur at detectable levels. It is believed that solvation of the ammonium or sulfoxonium ion and/or carboxylate ion by water or other hydrogen bonding compounds slows the esterification reaction. As the amount of water or other hydrogen bonding solvent decreases, the rate of the esterification reaction increases. It is difficult to remove the last traces of water from the carboxylate salts, since the water molecules (or other hydrogen bonding compounds) strongly solvate the carboxylate salts. Thus, it is believed that in most instances, the esterification reaction occurs in the "substantial absence" of water or other hydrogen bonding compounds, but the complete absence of water or other hydrogen bonding compounds is usually not attained while esterifying, and is probably not necessary.

The amount of water or other hydrogen bonding compounds that may be present during the esterification reaction depends on several interrelated factors, such as the inherent reactivities of the particular

carboxylate ion and the particular ammonium or sulfoxonium ion, and the temperature at which the process is carried out. The higher any particular reactivity, or the higher the temperature, the more
5 water may be present, and vice versa. The particular combination of conditions necessary for esterification for any given system is readily determined (see below), and some of these combinations are illustrated in the Examples herein.

10 The inherent reactivity of the carboxylate ion towards esterification by an ammonium or sulfoxonium ion is believed to be related to the pKa of the conjugate acid of the carboxylate ion. Thus, the higher the pKa of the conjugate acid in water, the more reactive the
15 carboxylate ion will be. It is therefore preferred if the conjugate acid of the carboxylate ion has a pKa of 0 or more, more preferably 2 or more.

An important factor affecting the reactivity of the ammonium or sulfoxonium ion is whether the groups
20 directly attached to the atom bearing the positive charge of the ion are relatively electron donating or electron withdrawing compared to an unsubstituted alkyl group. Thus, electron withdrawing groups such as phenyl, and p-chlorophenyl will make the ion more
25 reactive, and the more there are of such groups, the more reactive the ion will become. Electron donating groups such as p-N,N-dimethylaminophenyl and ethoxymethyl will tend to slow the rate of reaction of the ion. Extremely reactive ions will tend to react
30 with water to form alcohols and the corresponding neutral compound from the remainder of the ammonium or sulfoxonium ion.

It is believed that the relative reactivities of the (substituted) alkyl groups attached to the
35 positively charged atom of the ammonium or sulfoxonium

ion is similar to their relative reactivities in so called S_N2 displacements. Such relative activities are known to the art skilled, see for example J. B. Hendrickson, et al., "Organic Chemistry", 3rd Ed., McGraw-Hill Book Co., New York, 1970, p. 390, Table 10-5.

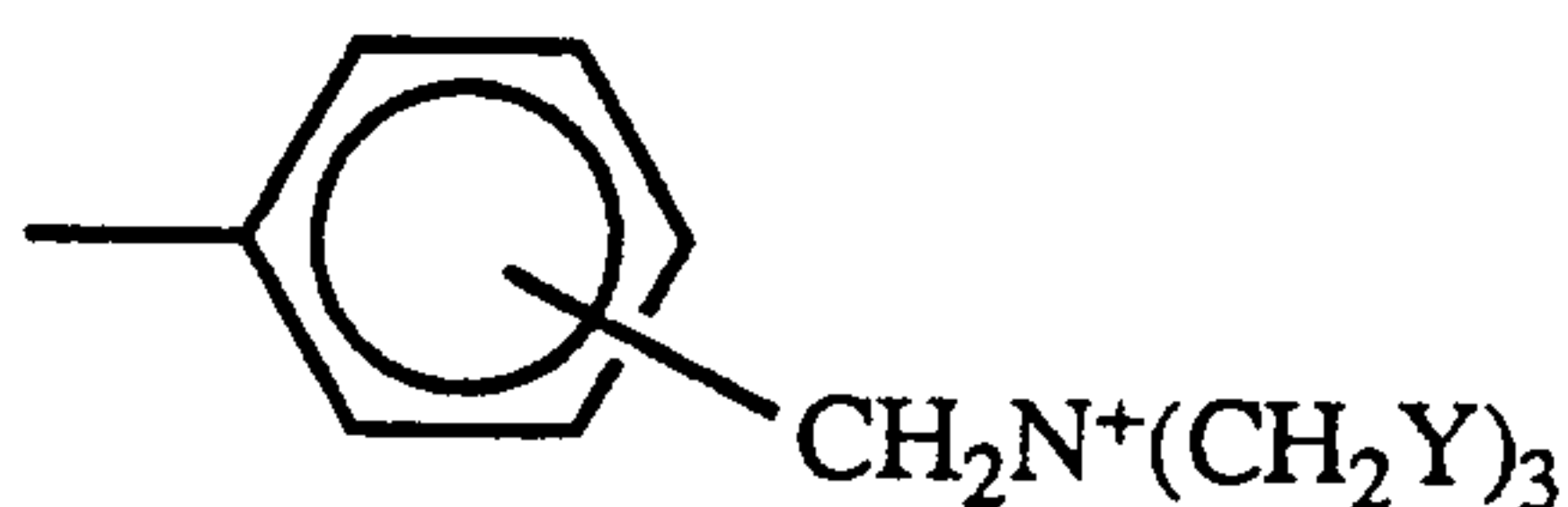
Ammonium or sulfoxonium ions that are significantly unstable in the presence of water are not included in the present invention. Ammonium or sulfoxonium ions that are too unreactive to esterify carboxylate ions in the substantial absence of water are also not included within the present invention. The following simple test may be used to determine if any particular ammonium or sulfoxonium ion is included within the present invention:

A random copolymer (0.2 g) made of about 33 mole percent methacrylic acid and about 67 mole percent ethyl acrylate is mixed with 2 mL of water, and an equivalent amount of a basic salt of the ammonium or sulfoxonium ion such as the hydroxide or bicarbonate (see Examples 1 and 9). The polymer is allowed to dissolve by stirring 12-24 hrs at ambient temperature. A film is made from the solution (if the polymer has precipitated from solution at this point, the ammonium or sulfoxonium ion is too reactive) of the polymer and an infrared spectrum is obtained, preferably without delay. If the polymer is not at least partially (20 mole percent) esterified at this point (the ammonium or sulfoxonium ion would be included herein if it was) the polymer may be heated at up to 180°C under nitrogen for up to 48 hr. If the polymer is not at least 20 mole percent esterified at this point (as judged from the IR spectrum, or more exactly by an acid-base titration of the polymer), the particular ammonium or sulfoxonium ion is not included herein. The techniques used in this determination,

including film formation, esterification, and measuring IR spectra, are illustrated in Examples 1 and 9.

Suitable types of cations that are useful herein include, but are not limited to, quaternary ammonium ions and sulfoxonium ions. Specific cations that are useful herein include, but are not limited to $R^1R^2R^3R^4N^+$ where R^1 , R^2 and R^3 are independently alkyl containing 1 to 6 carbon atoms and R^4 is phenyl or alkyl containing 1 to 6 carbon atoms; and $R^5R^6R^7SO^+$ where R^5 , R^6 and R^7 are independently alkyl containing 1 to 6 carbon atoms. Preferred specific cations are tetramethylammonium, phenyltrimethylammonium, trimethylsulfoxonium, and (methoxymethyl)triethylammonium.

Another preferred esterifying cation is $(YCH_2)_4N^+$ or $(YCH_2)_3SO^+$ wherein each Y is independently selected from the group consisting of hydrogen, alkyl containing 2 to 10 carbon atoms, aryl containing 6-12 carbon atoms, aralkyl containing 7 to 20 carbon atoms, alkaryl containing 7 to 30 carbon atoms, alkaryl containing 7 to 30 carbon atoms and substituted with one to 5 esterifying ammonium or sulfoxonium ions, and alkyl containing 3 to 30 carbon atoms substituted with 1 to 5 esterifying ammonium or sulfoxonium ions, and provided that no more than one of Y is hydrogen. These preferred esterifying cations which contain more than one esterifying ammonium or sulfoxonium ion are "poly-cations" (See the following paragraph.) Useful groups Y include, but are not limited to, $-CH_2CH_3$, $-CH(CH_3)_2$, $n-C_5H_{11}$, $-C(CH_3)_3$, phenyl, $CH_2C_6H_5$, $p-C_6H_4CH_3$ and



The ammonium and sulfoxonium cations of the invention may be included in molecules that contain one or more cations per molecule. If more than one cation is present per molecule, the "poly-cation" may act a
5 crosslinking agent if either the polymer and/or the "poly-cation" is tri- or higher functional. For example, assume an ammonium ion has the formula $A_3N^+XN^+A_3$, where each A is an alkyl group, and X is an alkylene group that is bound to (or connects) the two
10 nitrogen atoms. If both nitrogen onium ions were to esterify one carboxylate ion each, and the esterification in both cases were carried out by X, the polymer would become crosslinked, assuming each polymer chain has three or more esterified carboxylate ions. Thus, in
15 order to efficiently crosslink a polymer, the group(s) connecting the cations should preferably be more reactive towards esterification than the other groups bound to the cation atoms with the positive charges.

In one preferred embodiment the polymer has more
20 than two carboxyl(ate) groups and the ammonium or sulfoxonium ion is difunctional. This will cause crosslinking. In another preferred embodiment the ammonium or sulfoxonium ion is monofunctional. In this case, simple esterification of the carboxyl(ate) groups
25 takes place. In another preferred embodiment the polymer has two carboxyl(ate) groups, preferably end groups, and the ammonium or sulfoxonium ion is difunctional. In this instance, chain extension via esterification takes place.

30 Any polymer containing carboxyl(ate) groups from which the ammonium or sulfoxonium salt may be formed is useful in the instant process. By containing carboxyl(ate) groups means that these groups are bound to the polymer. In general, the carboxylate salts of
35 the ammonium or sulfoxonium ion may be formed by

reacting the carboxylic acid form of the carboxyl(ate) group with a basic salt of the ammonium or sulfoxonium ion such as the hydroxide or bicarbonate. This is most conveniently done in a solvent which dissolves the basic ammonium or sulfoxonium salt and swells or dissolves the polymer and/or its ammonium or sulfoxonium salt. For polymers with relatively high carboxyl(ate) content, water or the lower alcohols are usually suitable. Suitable types of polymers include, but are not limited to, acrylics, styrenics, polyesters, polyamides, polyimides, and polyolefins. Especially preferred polymers are acrylic and styrenic polymers, and acrylic-styrenic copolymers. The synthesis of carboxyl(ate) containing polymers suitable for use herein is known, and many of them can be bought.

By an acrylic polymer is meant a polymer wherein 10 mole percent or more of the repeat units are acrylic acid and/or methacrylic acid and their derivatives. By acrylic derivatives herein are meant common derivatives of carboxylic acids such as, but not limited to, esters, amides, acyl halides, carboxylate salts (including ammonium and sulfoxonium ion containing carboxylates) and nitriles.

By a styrenic polymer is meant a polymer wherein 10 mole percent or more of the repeat units are styrene, and/or alpha-methylstyrene and their derivatives. By derivatives are meant substituents on the phenyl ring such as methyl, halo, amino and carboxyl(ate). A polymer may contain a combination of acrylic and styrenic monomers.

The esterification process is carried out at a temperature of about 0°C to about 200°C, preferably about 15°C to about 150°C and most preferably about 25°C to about 130°C. The higher the temperature the faster the esterification reaction will proceed. The polymer

should be stable at the process temperature, and if the polymer is sensitive to oxygen at higher temperatures, an inert atmosphere, such as nitrogen, can be used.

The process described herein is useful in coatings, particularly coatings applied to metals, such as automotive coatings and appliance coatings. Carboxylate containing polymers are used in such coatings, particularly when the solvent is water based. The carboxylate groups in these polymers tend to make the polymers water soluble or at least help stabilize dispersions or emulsions of the polymers in the water. Carboxylate containing polymers may also be used as surfactants for stabilizing emulsions of other polymers. However, when the coating is applied these carboxylate groups tend to retard the coalescence of less polar polymers of the coating, and also usually make the coating itself more water sensitive. Therefore after the coating has been applied and substantially dried, it would be preferable if the carboxylate group could be converted to less polar groups. The instant process does that by converting the carboxylate groups to the less polar, less hygroscopic, ester grouping, while not affecting the carboxylate group before the coating is applied, since a large amount of water is then present. The esterification can be done under relatively mild conditions after the coating is substantially dry, the temperature required being dependent principally on the onium ion present, and the rate of reaction that is needed.

If an ammonium or sulfoxonium ion is used which is di- or higher functional the resulting coating, after esterification, may be crosslinked. This is sometimes desirable, since crosslinking often increases hardness and improves solvent resistance.

This invention also includes an aqueous based coating composition which comprises polymeric carboxylate groups wherein the counterion is an esterifying onium ion. All of the preferred compositions and preferred conditions described above for the esterification process apply also to this coating composition.

EXAMPLES

The following abbreviations are used in the examples:

MAA = methacrylic acid

MMA = methylmethacrylate

EA = ethylacrylate

TEPAOH = triethylphenylammonium hydroxide

15 TMPAOH = trimethylphenylammonium hydroxide

TMSOOH = trimethylsulfoxonium hydroxide

20 TMPAOH was prepared by addition of excess silver oxide to a solution of trimethylphenylammonium bromide in methanol. The concentration of TMPAOH (1.1 molar) was determined by dilution in water and titration with HCl (phenolphthalien end point).

The copolymer used in examples 1-10 contains 66% ethyl acrylate (EA) and 33% methacrylic acid (MAA). The initial copolymer (a suspension in water, 29.7% solids) has a molecular weight of >500,000. An FTIR of the initial polymer (cast on CaF₂ from methanol) shows relevant bands at 1735 cm⁻¹ (ethyl ester), 1705 cm⁻¹ (carboxylic acid) and 3100-3500 cm⁻¹ (OH from water and carboxylic acid).

30

EXAMPLE 1

To a small vial was added 1 mL water, 193 mg of the EA/MAA copolymer suspension (2.2×10^{-4} equivalents of carboxylic acid), and 200 mL of 1.1 M TMPAOH in methanol (2.2×10^{-4} equivalents of TMPAOH). Neutralization of

the carboxylic acid sites with TMPAOH made the polymer water soluble.

The carboxylate CO stretch of the neutralized polymer (film cast on CaF_2 from water) shifted from 1705 cm^{-1} to 1575 cm^{-1} . IR absorbance from 3100-3500 cm^{-1} is due to water retained in the ionic polymer. The IR also contained a shoulder at 3030 cm^{-1} due to the aromatic C-H groups in the TMPA cation.

Heat treatment of a film of TMPAOH neutralized polymer at 130°C for 30 minutes completely converted the TMPA-carboxylate to methyl ester. This fact was established by loss of the carboxylate band at 1575 cm^{-1} , increased ester absorbance at 1735 cm^{-1} (now a combination of methyl and ethyl ester) and loss of the residual water. The ester absorbance increased from 0.98 absorbance units to 1.67 absorbance units, consistent with complete conversion of the TMPAOH neutralized carboxylates to methyl ester groups. The dimethylaniline by-product diffused out of the film as evidenced by the loss of the shoulder at 3030 cm^{-1} .

EXAMPLE 2

A film similar to the one described in Example 1 was heated to 120°C in an FTIR instrument. Complete conversion of the TMPA-carboxylate to methyl ester occurred before the apparatus reached 120°C.

EXAMPLE 3

A film similar to the one described in Example 1 was heated to 100°C in an FTIR instrument. Complete conversion of the TMPA-carboxylate to methyl ester occurred in ~ 12 mins. The ester absorbance increased from 0.74 absorbance units to 1.14 absorbance units, consistent with complete conversion of the TMPAOH neutralized carboxylates to methyl ester groups.

EXAMPLE 4

A film similar to the one described in Example 1 was heated to 80°C in an FTIR instrument. The apparatus required about 5 mins. to heat from room temperature to 80°C and ~ 70% of the TMPA-carboxylate is converted to methyl ester in ~ 20 mins. The ester absorbance increased from 0.5 absorbance units to 0.7 absorbance units, consistent with complete conversion of the reacted TMPAOH neutralized carboxylates to methyl ester groups.

EXAMPLE 5

The TMPAOH neutralized EA/MAA copolymer solution described in Example 1 was heated to 100°C (boiling water) for 30 mins. under conditions where the solvent could not evaporate. A film of the heated solution was cast on CaF₂. The carboxylate CO stretch at 1575 cm⁻¹ had not changed in intensity relative to the unheated solution. This example demonstrated that the cationic esterification described in Examples 1-4 is preceded by film drying. Therefore, the aqueous polymer solution will have excellent shelf life and the esterification will not occur until the water is substantially removed.

EXAMPLE 6

A film similar to the one described in Example 1 was left at room temperature for 8 days. FTIR analysis indicated no conversion of the TMPA-carboxylate to methyl ester.

EXAMPLE 7

A film similar to the one described in Example 1 was placed under vacuum for 4 days at room temperature. During this period, ~ 40% of the TMPA-carboxylate is converted to methyl ester. The ester absorbance increases from 0.23 absorbance units to 0.27 absorbance units, consistent with complete conversion of the

reacted TMPAOH neutralized carboxylates to methyl ester groups.

EXAMPLE 8

To a small vial was added 1 mL water, 199 mg of the
5 EA/MAA copolymer suspension (2.3×10^{-4} equivalents of
carboxylic acid), and 450 mg of 10% TEPAOH in water
(2.3×10^{-4} equivalents of TEPAOH, purchased from Pfaltz
& Bauer). Neutralization of the carboxylic acid sites
with TEPAOH made the polymer water soluble.

10 Similar to when TMPAOH was added, the carboxylate
CO stretch of the neutralized polymer (film cast on CaF₂
from water) shifted from 1705 cm^{-1} to 1575 cm^{-1} . IR
absorbance from $3100\text{--}3500 \text{ cm}^{-1}$ is due to water retained
in the ionic polymer. The IR also contained a shoulder
15 at 3030 cm^{-1} due to the aromatic C-H groups in the TEPA
cation.

Heat treatment of a film of TEPAOH neutralized
polymer at 95°C for 30 mins. converted the TEPA-
carboxylate to ethyl ester. This fact was established
20 by 94% loss of the carboxylate band at 1575 cm^{-1} , an
increase in the ester absorbance at 1735 cm^{-1} and loss
of the residual water. The ester absorbance increased
from 0.98 absorbance units to 1.38 absorbance units,
consistent with efficient conversion of the TEPAOH
25 neutralized carboxylates to ethyl ester groups. The
diethylaniline by-product diffused out of the film as
evidenced by the loss of the shoulder at 3030 cm^{-1} .

EXAMPLE 9

30 TMPAOH could be converted to trimethylphenyl-
ammonium bicarbonate by passing CO₂ through the TMPAOH
solution. It is likely bicarbonate solutions will be
more stable than the hydroxides. Furthermore, under
normal storage conditions it is possible that TMPAOH
will be converted to the bicarbonate.

To a small vial was added 1 mL of 1.1 M TMPAOH and 1 drop of dilute phenolphthalien (in methanol). Crushed dry ice was added until the solution became colorless, indicative of TMPAOH being converted to trimethylphenyl-
5 ammonium bicarbonate.

To a small vial was added 1 mL water, 199 mg of the EA/MAA copolymer suspension (2.2×10^{-4} equivalents of carboxylic acid), and 0.200 mL of 1.1 M trimethylphenyl-
10 ammonium bicarbonate in methanol (2.2×10^{-4} equivalents of trimethylphenylammonium bicarbonate). Neutralization of the carboxylic acid sites with trimethylphenyl-
ammonium bicarbonate produced considerable gas (CO_2 released) and made the polymer water soluble.

Heat treatment of a film of trimethylphenylammonium
15 bicarbonate neutralized polymer at 96°C for 30 minutes completely converted the TMPA-carboxylate to methyl ester. This fact was established by loss of the
carboxylate band at 1575 cm^{-1} , an increase in the ester absorbance at 1735 cm^{-1} (now a combination of methyl and
20 ethyl ester) and loss of the residual water. The ester absorbance increased from 1.33 absorbance units to 2.0 absorbance units, consistent with complete conversion of
the trimethylphenylammonium bicarbonate neutralized carboxylate to methyl ester. The dimethylaniline by-
25 product diffused out of the film as evidenced by the loss of the shoulder at 3030 cm^{-1} .

EXAMPLE 10

TMSOOH was prepared by addition of excess silver
oxide to a solution of trimethylsulfoxonium iodide
30 (Aldrich) in water. The concentration of TMSOOH (0.15 molar) was determined by dilution in water and
titration with HCl (phenolphthalien end point).

To a small vial was added 680 mg of the EA/MAA
copolymer suspension (7.9×10^{-4} equivalents of
35 carboxylic acid), and 5 mL of 0.15 M TMSOOH in water

(7.5×10^{-4} equivalents of TMSOOH). Neutralization of the carboxylic acid sites with TMSOOH made the polymer water soluble.

As with the TMPAOH neutralized polymer, the
5 carboxylate CO stretch of the TMSOOH neutralized polymer (film cast on CaF_2 from water) shifted from 1705 cm^{-1} to 1575 cm^{-1} .

Heat treatment of a film of TMSOOH neutralized polymer at 95°C for 30 mins. converted the TMSO-
10 carboxylate to methyl ester. This fact was established by loss of the carboxylate band at 1575 cm^{-1} , and an increase in the ester absorbance at 1735 cm^{-1} .

EXAMPLE 11

(Methoxymethyl)triethylammonium chloride was made
15 by addition of 40 g triethylamine to 25 g of chloromethyl methyl ether in 130 mL dichloromethane. A 7.8 g portion of the resulting salt (dried under vacuum) was reacted in 40 mL water with 5.6 g silver oxide to produce after filtration a solution of (methoxymethyl)-
20 triethylammonium hydroxide, 0.92 M. The copolymer of Examples 1-10 (193 mg of a 30% solids mixture) was diluted by 1 mL water and neutralized with 238 mL of the hydroxide solution. A film was cast on a CaF_2 window, and IR showed the carboxylate band at about 1575 cm^{-1}
25 was comparable in absorbance to the ester band at 1735 cm^{-1} . After treatment at 95°C for 30 mins., the carboxylate band was apparently gone, and the ester band was relatively more absorbing. A similar sample kept at 80°C for 20 mins. was more than 90% reacted.

30 EXAMPLE 12

Benzyltrialkylammonium (alkyl = methyl, ethyl, n-propyl, and n-butyl) hydroxides were made from the corresponding halides using silver oxide, and used to neutralize the 66% ethyl acrylate/34% methacrylic acid
35 polymer described in Example 1. Films on CaF_2 were

heated at 120°C and periodically cooled and analyzed by FTIR in order to estimate the rate of disappearance of the carboxylate salt at ca. 1575 cm⁻¹. The reaction was close to first order in carboxylate, and the time for disappearance was about 130 minutes for alkyl = methyl, 10 minutes for alkyl = ethyl, 5 minutes for alkyl = n-propyl, and less than 3 minutes for alkyl = n-butyl.

EXAMPLE 13

Tetraalkylammonium (alkyl = methyl, ethyl, n-propyl, n-butyl, and n-pentyl) ions were tested as in Example 12. When the films were allowed to dry at 160°C for 20 minutes, the initial IR absorbance at ca. 1575 cm⁻¹ was unchanged for R = methyl, had decreased 30% for R = ethyl, and was entirely absent for all the other R groups. When dried at 120°C for 20 minutes, the peak had decreased 50% for R = ethyl, >90% for R = n-propyl, and was entirely absent for R = butyl. (R = methyl and n-pentyl were not tested at 120°C.)

EXAMPLE 14

1,4-Bis(bromomethyl)benzene (11.878 g) was reacted with 14.327 g tri-n-propylamine while dissolved in 74 grams of acetonitrile, and under reflux, for about 1 hour. The crude product was filtered off and recrystallized from acetone. Recrystallized dibromide salt was converted to bis-hydroxide by silver oxide in ethanol, to produce a 0.164 mM OH⁻/gram solution.

A paint was made from a combination of a commercial latex, ICI Neocryl A-640, 6.004 g, (believed to be a carboxyl containing acrylic-styrene resin) with a solution of coalescing agent and plasticizers (0.9547 g taken from a solution of 13.45 g 1-butoxy-2-propanol, 1.5529 g dibutyl phthalate, and 0.0253 g triethylamine), by titrating 1 gram of the resulting mixture with the bis-hydroxide solution described above (4.75 g required). Coatings from 0.15 mm thick wet-films,

applied by doctor knife, were placed on plastic panels, air-dried for 45 minutes, and further dried at 120°C for 20 minutes. Disks produced from the free films were observed to swell by a factor of 1.48 +/- 0.05 in diameter when placed in dichloromethane, in comparison to a control coating made without the bis-hydroxide, where dichloromethane dissolved the disk. Further heating (40 more minutes) decreased the swelling in dichloromethane to 1.45 +/- 0.01.

10

EXAMPLE 15

An analogous paint to that of Example 14 was made from the corresponding 1,3-bis(bromomethyl)benzene, i.e., the meta isomer. The corresponding paint was also crosslinked, showing a swelling of 1.51 +/- 0.03 times in methylene chloride.

15

EXAMPLE 16

Diisopropylethylamine was reacted with 1,4-bis-(bromomethyl)benzene to form the bis-quaternary salt. The recrystallized product was converted to its bis-hydroxide form, and used to neutralize Neocryl A640 as in Example 14. A film was baked at 120°C for 20 minutes, showing a diameter swell factor in dichloromethane of 1.85, decreasing to 1.81 +/- 0.02 after a further 20 minutes at 120°C.

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What is claimed is:

1. A process for forming alkyl esters in polymers, comprising neutralizing a polymer containing carboxylate ions with a compound containing ammonium or sulfoxonium counterions, and maintaining a neutralized polymer at a temperature of 0°C to 200°C in the substantial absence of water and other solvents capable of strong hydrogen bonding, provided that said ammonium or sulfoxonium counterions are substantially stable in the presence of water and further provided that none of the ammonium or sulfoxonium counterions have a hydrogen atom attached to the atom that bears the positive charge and that at least one of the groups attached to the atom that bears the positive charge of the ammonium or sulfoxonium counterions is an alkyl or substituted alkyl group.
2. The process as recited in claim 1 wherein said counterion is selected from the group consisting of ammonium ions of the formula $R^1R^2R^3R^4N^+$ where R^1 , R^2 and R^3 are independently alkyl containing 1 to 6 carbon atoms and R^4 is phenyl or alkyl containing 1 to 6 carbon atoms; and sulfoxonium ions of the formula $R^5R^6R^7SO^+$ where R^5 , R^6 and R^7 are independently alkyl containing 1 to 6 carbon atoms.
3. The process as recited in claim 1 wherein said counterions are selected from the group consisting of tetramethylammonium, phenyltrimethylammonium and trimethylsulfoxonium.
4. The process as recited in claim 1 wherein said counterions are di- or higher functional.
5. The process as recited in claim 4 wherein said counterions are difunctional.
6. The process as recited in claim 5 wherein said polymer contains 2 carboxylate ions.
7. The process as recited in claim 1 wherein said counterions are monofunctional.
8. The process as recited in claim 1 wherein said temperature is 15°C to about 150°C.

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9. The process as recited in claim 1 wherein said temperature is 25°C to about 130°C.

10. The process as recited in claim 1 wherein said carboxylate has a conjugate acid whose pKa is 2 or more.

5 11. The process as recited in claim 1 wherein said polymer is an acrylic or styrenic polymer or a acrylic-styrenic copolymer.

12. The process of claim 1 carried out in a film or coating.

13. The process of claim 1 carried out in an automotive coating.

10 14. An aqueous based coating composition which comprises a polymer containing carboxylate groups wherein a counterion is an esterifying ammonium or sulfoxonium ion and water, provided that said ammonium or sulfoxonium counterions are substantially stable in the presence of water and further provided that none of the ammonium or sulfoxonium counterions have a hydrogen atom attached to the atom that bears the positive charge and that at least one of the groups attached to the atom that bears the positive charge of the ammonium or sulfoxonium counterions is an alkyl or substituted alkyl group.

15 15. The composition of claim 14 wherein said polymer is an acrylic or styrenic polymer, or an acrylic-styrenic copolymer.

20 16. The composition of claim 14 in which said carboxylate groups are esterified by substantially removing said water, and maintaining the polymer at a temperature of about 0°C to about 200°C.

25 17. The composition as recited in claim 14 wherein said counterion is selected from the group consisting of ammonium ions of the formula $R^1R^2R^3R^4N^+$ where R^1 , R^2 and R^3 are independently alkyl containing 1 to 6 carbon atoms and R^4 is phenyl or alkyl containing 1 to 6 carbon atoms; and sulfoxonium ions of the formula $R^5R^6R^7SO^+$ where R^5 , R^6 and R^7 are independently alkyl containing 1 to 6 carbon atoms.

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18. The composition as recited in claim 14 wherein said counterion is selected from the group consisting of tetramethylammonium, phenyltrimethylammonium and trimethylsulfoxonium.

5 19. The composition as recited in claim 14 wherein said counterion is di- or higher functional.

20. The composition as recited in claim 19 wherein said counterion is difunctional.

21. The composition as recited in claim 20 wherein said polymer contains two carboxylate ions.

10 22. The composition as recited in claim 14 wherein said counterion is monofunctional.

15 23. The composition as recited in claim 14 wherein said esterifying ammonium ion is $(YCH_2)_4N^+$ or said esterifying sulfoxonium ion is $(YCH_2)_3SO^+$ wherein each Y is independently selected from the group consisting of hydrogen, alkyl containing 2 to 10 carbon atoms, aryl containing 6-12 carbon atoms, aralkyl containing 7 to 20 carbon atoms, alkaryl containing 7 to 30 carbon atoms, alkaryl containing 7 to 30 carbon atoms and substituted with one to 5 esterifying ammonium or sulfoxonium ions, and alkyl containing 3 to 30 carbon atoms substituted with 1 to 5 esterifying ammonium or sulfoxonium ions, and provided that no more than one of Y is hydrogen.