

Synthesis of Amino-Functionalized Latex Particles by a Multistep Method

IRIS MIRABALLES-MARTÍNEZ,¹ A. MARTÍN-MOLINA,² F. GALISTEO-GONZÁLEZ,² JACQUELINE FORCADA³

¹Laboratorio de Inmunotecnología, Facultades de Ciencias y de Química, Universidad de la República, 11600-Avda, Alfredo Navarro, 3051 Montevideo, Uruguay

²Grupo de Física de Fluidos y Biocoloides, Departamento de Física Aplicada, Facultad de Ciencias, Universidad de Granada, Granada 18071, Spain

³Institute for Polymer Materials POLYMAT and Grupo de Ingeniería Química, Departamento de Química Aplicada, Facultad de Ciencias Químicas, Universidad del País Vasco/EHU, Apdo. 1072, San Sebastián 20080, Spain

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ABSTRACT: Cationic latex particles with surface amino groups were prepared by a multistep batch emulsion polymerization. In the first one or two steps, monodisperse cationic latex particles to be used as the seed were synthesized, and in the third step, two different amino-functionalized monomers [aminoethylmethacrylate hydrochloride (AEMH) and vinylbenzylamine hydrochloride (VBAH)] were used to synthesize the final functionalized latex particles. 2,2'-Azobisisobutyramidine dihydrochloride was used as the initiator, and different concentrations of two quaternary ammonium emulsifiers with hydrophobic chains of different lengths were examined. To characterize the final latexes yields were obtained gravimetrically, and particle size distributions and average particle diameters were determined by transmission electron microscopy and photon correlation spectroscopy. The amount of amino groups was determined by fluorimetry. The effect of the amino-functional monomer used on the final latexes and the colloidal behavior of the system were studied. The influence of the different conditions utilized to synthesize the latexes on the colloidal stability of the particles was evaluated in terms of the Fuchs stability ratio and electrophoretic mobility. High yields of the amino-functional monomers were obtained. Surface amino, amidine, and quaternary ammonium groups provided the cationic character. The colloidal stability behavior of the products obtained was compatible with their cationic character. © 2001 John Wiley & Sons, Inc. *J Polym Sci Part A: Polym Chem* 39: 2929–2936, 2001

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INTRODUCTION

In the search for new alternatives for the synthesis of latex particles and the preparation of ami-

no-functionalized latex particles suitable for binding synthetic peptides in immunoassays, we describe the synthesis of cationic latex particles with surface amino, amidine, and quaternary ammonium groups by a two- or three-step emulsion polymerization. Functionalized stable latex particles were prepared. In the first one or two steps, monodisperse cationic latex particles to be used as seed were synthesized, and in the third step

Correspondence to: J. Forcada (E-mail: qppfogaj@sq.ehu.es)

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the final functionalized latex particles were obtained. The effect of the amino-functional monomer used on the final latexes as well as the colloidal behavior of the system were investigated.

Several previous articles^{1–8} have described amino latex syntheses; however, the polymerization of an amino-functionalized monomer onto a seed previously synthesized with a cationic diazo initiator in the presence of a cationic emulsifier has not been researched. Cationic emulsifiers are not commonly used in emulsion polymerization. However, for practical reasons, in some circumstances they are the best option for the synthesis. To copolymerize cationic monomers, avoiding problems of lack of stability of the particles, both initiator and emulsifier should be cationic considering that to be useful for latex agglutination immunoassays, the particles must have good colloidal stability, be monodisperse, and (if necessary) have appropriate functional groups.

In a previous work,⁹ seeded copolymerizations of styrene and the amino-functionalized monomers, aminoethylmethacrylate hydrochloride (AEMH) and vinylbenzylamine hydrochloride (VBAH), were carried out to obtain monodisperse amphoteric amino-sulfate latex particles. The surface amino groups lend cationic character to the particles, whereas the emulsifier and initiator systems supply the anionic charge. The amount of functionalized monomer incorporated was similar in all the reactions carried out using a particular seed. The amount of amino groups obtained on the surface was enough to bond peptides, allowing good agglutination reactions and, therefore, adequate sensitivity in immunoassays. The colloidal stability of the latexes obtained was justified by their amphoteric character. The most stable latexes were obtained using the smallest seed, VBAH monomer, and the $K_2S_2O_8/Na_2S_2O_5$ initiator system.

In this work, we present the synthesis of polystyrene seed particles in the presence of cationic emulsifiers. Different concentrations of two quaternary ammonium emulsifiers with hydrophobic chains of different lengths were examined. To increase the surface-charge density of the seeds and then their electrostatic stabilization, the copolymerization of a quaternary ammonium methacrylate derivative onto the seeds was carried out. Finally, the amino-functional monomers and styrene were copolymerized onto previously synthesized cationic seeds.

MATERIALS AND METHODS

Styrene, freshly distilled under reduced pressure, was stored at $-20\text{ }^{\circ}\text{C}$ until use. The initiators 2,2'-azobisisobutyronitrile (AIBN) (Aldrich) or 2,2'-azobisisobutyramidine dihydrochloride (AIBA) (Aldrich) were used as supplied. Dodecyltrimethylammonium bromide (DTMAB, D) (Aldrich) and hexadecyltrimethylammonium bromide (HDTMAB, H) (Aldrich) were used as emulsifiers. 3-(Methacryloylamino)propyltrimethylammonium chloride (MA-NR₃) (Aldrich) was used as a comonomer, and AEMH and VBAH, synthesized as previously described,⁹ were the functional monomers in the polymerizations.

bis-(2-Hydroxyethyl)iminotris(hydroxymethyl) methane (bis-tris) (Sigma), tris(hydroxymethyl) aminomethane (tris) (Sigma), 2-amino-2-methyl-1-propanol hydrochloride (AMP) (Sigma), and sodium chloride (Merck) were used to prepare the buffers. Fluorescamine (Aldrich) and acetone (Aldrich), were used to determine the density of surface amino groups. Double deionized water was used throughout the work.

The experimental work was carried out in the following stages: (1) synthesis of monodisperse cationic particles to be used as seeds, (2) synthesis of the final amino-functionalized latex particles, and (3) latex characterizations.

Synthesis of Cationic Seed Particles

Monodisperse core polystyrene particles were synthesized by batch emulsion polymerization using the recipes and reaction conditions given in Table I. In the first column the nomenclature used for the latexes is shown. The first part is the name of the seed, separated by a dash from the name of the comonomer (MA-NR₃), if used, or the name of the functional monomer (AEMH or VBAH); the following number means that a different amount of comonomer was used in the recipe.

The influence of different reaction conditions used for producing the colloidal stability of synthesized final latexes was studied. The variables entailed the reaction temperature, the amount of initiator, the chain length of the quaternary ammonium emulsifier, the amount of emulsifier added, and the use of MA-NR₃ as a comonomer.

Reactions were carried out in a 1- or 2-L thermostated reactor fitted with a reflux condenser, stainless steel stirrer, sampling device, and nitro-

Table I. Recipes of the Polymerizations Carried out To Obtain the Cationic Seeds and Final Latexes

Latex	Water (g)	Seed (g)	Emulsifier (g)	Styrene (g)	MA-NR ₃ (g)	AEMH or VBAH (g)	AIBA (g)	T (°C)
8	400	—	0.5 (H) ^a	78	—	—	1.0 ^c	90
9	400	—	1.0 (H) ^a	78	—	—	1.0	70
10	400	—	1.5 (H) ^a	78	—	—	1.0	70
12	400	—	1.5 (H) ^a	78	—	—	1.5	70
14	400	—	0.36 (H) ^a	79.3	—	—	1.5	70
15	400	—	0.36 (H) ^a	78	—	—	1.5	90
16	400	—	0.36 (D) ^b	78	—	—	1.5	90
17	400	—	0.56 (D) ^b	78	—	—	1.5	90
18	400	—	1.73 (D) ^b	78	—	—	1.5	90
19	400	—	8.65 (D) ^b	78	—	—	1.5	90
20	670	—	0.60 (H) ^a	130	—	—	2.50	90
14/MA-NR ₃ -1	180	180	0.116 (H) ^a	3.15	1.10	—	0.09	70
14/MA-NR ₃ -2	180	180	0.172 (H) ^a	4.64	1.13	—	0.13	70
20/MA-NR ₃	485	320	0.525 (H) ^a	5.70	1.90	—	0.15	90
14/MA-NR ₃ -1/AEMH	5	325	—	2.0	—	0.74	0.05	70
14/MA-NR ₃ -2/AEMH	5	325	0.044	1.3	—	0.70	0.05	70
20/MA-NR ₃ -AEMH	242	161.40	0.263 (H) ^a	2.0	0.95	0.86	0.075	90
20/MA-NR ₃ -VBAH	242	161.40	0.263 (H) ^a	2.0	0.95	0.85	0.075	90

^a (H)-HDTMAB.^b (D)-DTMAB.^c AIBN.

gen inlet tube. The stirring rate was 250 rpm, and the reaction temperature (70 or 90 °C) was controlled. The reaction time was at least 12 h. The seeds (8–20) were synthesized in a single step, whereas for the seeds 14 and 20/MA-NR₃ an additional copolymerization step took place with the MA-NR₃ comonomer.

Synthesis of Final Functionalized Latex Particles

The recipes and reaction conditions used to obtain the final latex particles are described in Table I. The amino-functional monomers were synthesized as previously described.⁹ The reaction mixture was stirred at a rate of 250 rpm for 1 h at room temperature under an N₂ atmosphere. Once the reaction temperature (70 or 90 °C) was reached, the initiator solution was added. The reaction time was at least 6 h. The final latex was removed from the reactor, and the polymerization was quenched with hydroquinone.

Latex Characterizations

The mean particle diameters (d_p , nanometers) of the seeds and final latexes were determined by photon correlation spectroscopy (PCS, Coulter N4 Plus). The particle size distributions (PSD) were

determined by transmission electron microscopy (TEM, Hitachi H-7000 FA) on representative samples of N (used in Table II) particles and analyzed using the Bolero (AQ Systems) package. Number- (d_n), weight- (d_w), and volume-average (d_v) diameters as well as the polydispersity index (PDI) were calculated from PSD.¹⁰ After filtration of the latexes by means of glass wool to eliminate coagulum formed in the reaction, if any, the yield (Y%) defined as the solid content was determined gravimetrically.

The surface density of the amino groups was determined by fluorimetry.¹¹ The fluorescence titration method is based on the reaction of fluorescamine with the primary amino groups. The measurements were performed with a spectrofluorimeter (Shimadzu RF-540) equipped with a quartz cell for right-angle measurements. The particles were eliminated before the measurements by filtration through a polycarbonate Nuclepore 0.1- μ m pore size filter. Standard solutions of the functional monomers VBAH and AEMH were prepared in the range of 0.01–0.15 mg/mL. About 0.1 mL of standard or of 1:20 sample dilution was added to 2.9 mL of 0.1-M pH 9.5 borate buffer, followed by 1 mL of a 0.3-mg/mL solution of fluorescamine in acetone. Before the measurement, 1 mL of the mixture was taken and mixed with 2

Table II. Results of the Reactions Carried out to Obtain the Cationic Seeds

Latex	d_p (nm)	Y %	N	d_n	d_w	d_v	PDI
8	269	47.0	Polydispersity	—	—	—	—
9	88	90.0	Polydispersity	—	—	—	—
10	81	97.0	Polydispersity	—	—	—	—
12	95	83.0	Polydispersity	—	—	—	—
14	240	58.6	687	190.44	192.29	191.04	1.010
15	285	88.4	415	171.80	173.06	172.23	1.007
16	457	1.0	Not measured	—	—	—	—
17	399	16.2	599	335.72	351.52	341.97	1.047
18	203	40.2	360	171.99	178.00	175.06	1.035
19	54	80.2	Polydispersity	—	—	—	—
20	226	78.0	1036	180.74	184.15	182.02	1.019
14/MA-NR ₃ -1	249	91.4	331	204.73	205.20	204.89	1.002
14/MA-NR ₃ -2	248	92.0	1134	202.61	203.98	203.09	1.007
20/MA-NR ₃	210	100.0	Not measured	—	—	—	—

mL of borate buffer. The excitation wavelength was 393 nm, and the emission was measured at a wavelength of 477 nm.

To study the stability of the latexes, they were cleaned by the serum replacement method. The latexes were stored diluted at 0.1 mg/mL, and measurements of stability and electrophoretic mobility were carried out after 48 h. The measurements were performed at pH 6–10, and the ionic strength was adjusted between 2 and 500 mM by the addition of NaCl. The buffers used included bis-tris (2 mM of pH 6 and 7), tris (2 mM of pH 8 and 9), and AMP (2 mM pH 10).

The stability ratio (W) is a criterion for the stability of the colloidal system

$$W = \frac{k_r}{k_s} \quad (1)$$

where the rate constant k_r describes rapid coagulation, and k_s is the rate constant for the slow coagulation regime. Thus, the inverse of the stability ratio provides a measure of the effectiveness of collisions leading to coagulation.

In this work, the stability ratio was obtained experimentally from the rate constant of coagulation of the colloidal particles measured using the low-angle light scattering technique (nephelometry) developed by Lips and Willis,¹² where the total scattering intensity for a dispersion of identical primary particles with a time-varying distribution size is¹³

$$\frac{I(t, \theta)}{I_\theta(0)} = 1 + 2kn_s t \quad (2)$$

where $I_\theta(0)$ is the initial intensity of light scattered at angle θ , n_s the number of primary particles, and k is the rate constant.

The scattered light intensity at low angles increases linearly with time, and then an absolute coagulation rate can be obtained from the slope if the number of primary particles is known.

The aggregation was quantified by the intensity increment in scattered light using a noncommercial apparatus with a 10-mW He/Ne laser ($\lambda = 632.8$ nm) and a rectangular flow cell of 2 mm path length. Scattered light was monitored at an angle of 10° at a concentration of 4.0×10^{10} particles/mL. The initial slope was determined for an interval of 120 s. Electrophoretic mobility measurements were carried out in a ZetaPALS analyzer (Brookhaven Instruments Corp., Holtsville, NY) at a concentration of 2.0×10^{10} particles/mL.

RESULTS AND DISCUSSION

The purities of the functionalized monomers AEMH and VBAH were checked by ^1H NMR.

All the latexes were characterized by measuring the yields, the PSDs, and the colloidal stability. In the case of the final latexes, the surface densities of the amino groups were also measured.

In Table II the mean diameter of the particle obtained by PCS, the polymerization yields ($Y\%$), the total number of particles (N) measured to determine the PSDs, the calculated d_n , d_w , and d_v , and the PDI of the cationic seeds are listed. The PDI determinations showed that although

the PSD was wider after the second step of the polymerization, and in some cases the first step produced polydisperse latex particles, some of the cationic seeds can be considered monodisperse (PDI index lower than 1.05).¹⁴

The yields of the reactions presented in this work varied over a wide range. The yield was determined gravimetrically, and the coagulated polymeric material was not considered. Two different diazo initiators were examined, and the reactions were carried out at two different temperatures (90 and 70 °C). Latex 8 was the first attempt to obtain a cationic latex with the HDTMAB cationic emulsifier. However, the yield of the reaction was only 47%, mainly because of coagulation. Therefore, the amount of emulsifier was increased, and the nonionic initiator AIBN was replaced by its cationic analogue AIBA in the polymerization carried out to obtain latex 9. Even when the reaction to obtain latex 9 was carried out at a lower temperature, the yield of the reaction increased and the particle diameter decreased. A further increase of the emulsifier amount (latex 10) gave an even higher yield. Seeking a better electrostatic stabilization, in run 12 the amount of initiator was increased. However, the yield obtained was lower. This was possibly caused by the increase in the ionic strength as a result of the increase in the amount of initiator. A higher ionic strength favors the coagulation of the particles by compression of the electrical double layer and can modify the solubility of the emulsifier, which is also responsible for the size increase. So far, the latexes described were polydisperse, and a possible explanation for this fact could be the presence of very stable emulsifier micelles in the reaction medium. An increase in temperature from 70 to 90 °C (seeds 14 and 15) produced smaller particle sizes (the averages determined by TEM) and higher yields, as expected. The critical micelle concentration (cmc) value of DTMAb was assumed to be 1.4×10^{-2} M, and for HDTMAb, 9.5×10^{-4} M.¹⁵ Using a concentration of HDTMAb below the cmc, latexes 14 and 15, monodisperse particles, and yields depending on temperature were obtained.

Comparing seeds 15 and 16 in which HDTMAb emulsifier was replaced by the same amount of DTMAb, the diameter increased. However, the yield decreased dramatically (1.0%). For seeds 16–19, the concentration of DTMAb was selected to be 0.2, 0.3, 1, and 5 times the cmc, respectively. The series of latexes 16, 17, 18, and 19 showed that by increasing the amount of DTMAb, the

yield increased and the particle size decreased. However, to obtain a higher yield, the amount added had to be quite high (8.65 g = 5 cmc to obtain latex 19). The recipe for latex 20 was similar to that of latex 14, which was different from the reaction temperature (90 °C instead of 70 °C). As a result of this modification, a higher yield and lower particle size were obtained.

In the case of latexes 14/MA-NR₃-1 and 14/MA-NR₃-2, when the comonomer MA-NR₃ was used in the second step of the synthesis onto seed 14, a secondary particle nucleation was not observed by TEM (and the latexes remained monodisperse). The incorporation in a second step of comonomer MA-NR₃ did not produce polydisperse latexes. For latexes 14/MA-NR₃-1 and 14/MA-NR₃-2 as well as latex 20/MA-NR₃, the yields of the second step of the polymerization were higher than 91%.

The main objective of this work was to obtain stable latexes with functional amino groups. The cationic nature of these latexes suggests the best option for initiators and emulsifiers, if high stability is required, is to use initiator and emulsifier of the same type, either cationic or nonionic. After preliminary trials with AIBN, the initiator used was cationic AIBA.

The reaction temperature was increased from 70 to 90 °C with the objective of having a shorter interval for the decomposition of the initiator. A high amount of initiator (2–3 wt % with respect to the total amount of monomer) was also used in an attempt to impart a higher electrostatic charge on the surface of the particles.

One of the most important functions that emulsifiers have during the synthesis of latex by means of an emulsion polymerization process is to increase the solubility of monomers. Another function is to stabilize the new particles as they are formed. By increasing the level of emulsifier, colloidal stability of the particles increases and coagulation diminishes. The emulsifier also has a strong influence on the particle size.¹⁶

Cationic surfactants are the most adequate for this application, although they have not been frequently used in emulsion polymerization because they are not compatible with the negative charges derived from the usually used initiators and anionic surfactants.¹⁷ No anionic charges from either initiator, monomers, or surfactant were present on the surface of the latex particles synthesized in this work. The emulsifier used (DTMAb or HDTMAb) and the amount influence the product obtained because its chain length determines the cmc value and the nucleation stage of

Table III. Diameters and Surface Densities of the Amino Groups of the Final Latexes

Latex	d_p (nm) (PCS)	$\mu\text{Eq m}^{-2}$
14/MA-NR ₃ -1/AEMH	304	2.7
14/MA-NR ₃ -2/AEMH	232	1.4
20/MA-NR ₃ -AEMH	215	—
20/MA-NR ₃ -VBAH	216	2.3

emulsion polymerization. The emulsifier HDTMAB was replaced by DTMAB with the purpose of having most of the emulsifier in the aqueous phase rather than in the micelles and improving monodispersity and particle size control during the synthesis because the concentration of micelles determines the number of particles throughout Interval I of the polymerization.¹⁸ When HDTMAB was used at a high concentration (2.6 and 4 times the cmc) in the recipes to obtain latexes 9, 10, and 12, monodispersity was not obtained possibly because of the high stability of the micelles formed. When the amount of emulsifier was modified, both the yield and the PSD were modified. However, when DTMAB was used, the yields decreased drastically. Furthermore, when the yield was significant the latexes were monodispersen except for latex 19, the one having the highest amount of emulsifier in the recipe.

The cationic comonomer MA-NR₃ was used with the objective of giving additional electrostatic stabilization to the particles. The charge provided by this comonomer is not dependent on desorption phenomena as is the charge coming from the emulsifiers. The methacrylic group is responsible for the polymerization reaction,¹⁹ and the quaternary ammonium group gives the cationic charge to the particles. The yields for the shells (latexes 14/MA-NR₃-1, -2 and 20/MA-NR₃) formed onto the previously synthesized cationic cores were 91% or higher for all the reactions.

In Table III the values of the mean diameters (nm) determined by PCS and the surface density of amino groups ($\mu\text{Eq/m}^2$) of the final functionalized latex are summarized.

The surface density of the amino groups was determined by the fluorescamine method.¹¹ This fluorimetric method allows the interference as a result of the amidine groups on the surface-density determinations to be avoided. The amount of functionalized monomer incorporated is similar for all the reactions, as confirmed by the similar

values of surface densities of the amino groups. When the ratio between the total number of polymerized amino groups and the total amount of amino-functional monomer charged into the reactor was calculated, the percentages of the incorporated amino-functional monomers varied between 17 and 35%. These low values are compatible with the highly hydrophilic character of these monomers⁶ and are similar to previously obtained results by the N-succinimidyl 3-(2-pyridyldithio) tropionate method.^{9,20}

Colloidal stability is a very important characteristic for latex particles that are intended to be used to prepare reagents for immunoassays. If particles are not colloiddally stable, false positive results can be obtained in the immunoassays. In the synthesis of latexes, the type and amount of the emulsifiers used, among other factors, determine the colloidal stability of the final product. In this work, the colloidal stability was analyzed in terms of the Fuchs stability ratio (W) and the electrophoretic mobility of diluted samples.

When $\log_{10} W$ values are plotted versus $\log_{10} [\text{salt}]$, it is possible to determine the experimental stability domains of the colloid. As Reerink and Overbeek²¹ have shown with several approximations, a linear relationship exists between $\log_{10} W$ and $\log_{10} c_e$. Their treatment is based on the assumption that the value of the potential maximum in the interaction curve of two approaching spheres is approximately constant and neglects possible contributions from hydrodynamic interaction. The value of salt concentration where a limit aggregation state is achieved is usually referred to as the critical coagulation concentration (CCC).

In Figure 1 we observe a typical representation of $\log_{10} W$ as a function of $\log_{10} c_e$ and how the CCC may be determined from the extrapolation of the initial linear dependence. In such a way the stability domains and thereafter the CCC values were obtained for some representative samples of the three polymerization steps performed and presented in this work. In Table IV these measurements are summarized.

In the case of the initial seed, stabilized only by the amidine groups coming from the initiator (if we assume a practical removal of the emulsifier by the serum replacement cleaning process), and the first shell whose charged groups also include a polymerized quaternary ammonium emulsifier (latexes 20 and 20/MA-NR₃, respectively), CCC could only be determined at pH 6. At higher pH values, the colloidal stability of the latexes was so

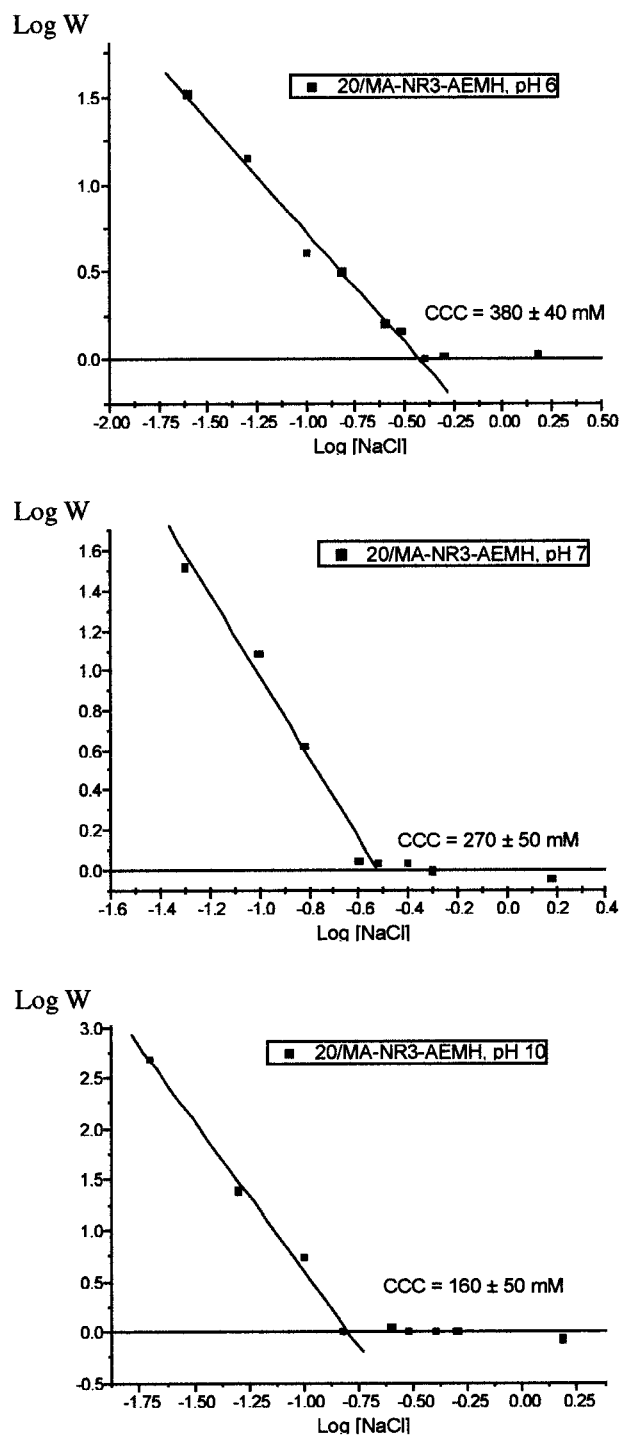


Figure 1. Log W versus log $[\text{NaCl}]$ of latex 20/MA-NR₃-AEMH at pHs 6, 7, and 10.

reduced even at low salt concentrations that it was not possible to determine a clear CCC value. We conclude that the amount (and effective pK_a value) of both kinds of cationic groups within this polymeric network is not enough to stabilize the colloidal particles at neutral and basic pHs.

Nevertheless, when these seeds are covered later on with the shell including functionalized amino groups (AEMH or VBAH), the stability of the resulting latex particles changes qualitatively as well as quantitatively. In the case of the latexes produced using latex 14 as the initial seed, the stability at pH 6 does not vary significantly from that observed on the seeds, but it clearly changes the behavior at higher pH values, where we can observe that at least at pH 7 CCC may be determined, although at pH 10 the CCC values are once again too low or not discernable.

In the case of the latexes produced using latex 20 as the initial seed, which differ from the others in the polymerization temperature, as well as in the inclusion of a different amino copolymer in the 20/MA-NR₃-VBAH latex, colloidal stability is clearly increased at all the studied pH values. Comparing the latexes prepared with the comonomer AEMH on both seeds, differing only in the polymerization temperature, we conclude this variable strongly affects the presence of charged groups at the surface. Because a significant variation in the amount of incorporated functional comonomer was not detected (Table III), it suggests that the increase in surface charge may be due to a faster decomposition of the initiator and then to an increased incorporation of charged free radicals onto the polymer chains.

When we study the electrophoretic mobility of these latexes (Fig. 2), we again observe increased values of mobility in the case of the latexes prepared with a higher temperature (those coming from seed 20), as could be expected from the differences in colloidal stability, and support the idea that this stabilization proceeds mainly from electrostatic interactions as a result of the surface-charged groups.

CONCLUSIONS

Multistep seeded emulsion copolymerizations of styrene with the cationic comonomer MA-NR₃

Table IV. Critical Coagulation Concentration (CCC, mM) of the Different Latexes

Latex	pH 6	pH 7	pH 8
20	190 \pm 50	—	—
20/MA-NR ₃	120 \pm 50	—	—
14/MA-NR ₃ -1/AEMH	140 \pm 50	100 \pm 30	—
14/MA-NR ₃ -2/AEMH	140 \pm 50	70 \pm 40	40 \pm 50
20/MA-NR ₃ -AEMH	380 \pm 50	270 \pm 50	160 \pm 50
20/MA-NR ₃ -VBAH	410 \pm 50	310 \pm 50	150 \pm 50

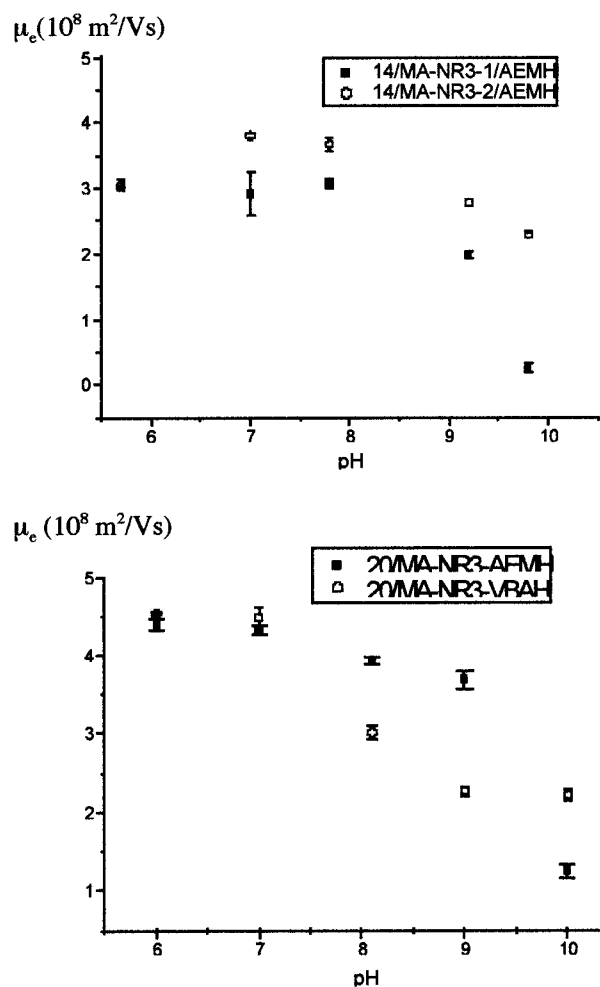


Figure 2. Electrophoretic mobility versus pH of the final latexes.

and the amino-functionalized monomers AEMH or VBAH were carried out to obtain cationic amino-containing latex particles. The initiator and emulsifiers used were also cationic. The amino, amidine, and quaternary ammonium surface groups imparted the cationic character to the particles. High conversions (yields) of the amino-functional monomers were achieved. High monodispersity was obtained for the majority of the latexes. The colloidal stability behavior of the products obtained was compatible with their cationic character and clearly increased when the copolymerization of the functional amino group was performed at high temperature, probably because of a faster decomposition of the initiator. The amount of surface amino groups of the final latexes was sufficient to bond peptides. The latex-peptide complexes formed were usable as immunoagents in immunoassays.

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