

Dispersion Polymerization of Acrylamide in Aqueous Solution of Ammonium Sulfate: Synthesis and Characterization

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ABSTRACT: Dispersion polymerization of acrylamide (PAM) has been successfully carried out in aqueous ammonium sulfate media by using poly(acryloyloxyethyl trimethylammonium chloride) (PAOTAC) as the polymeric stabilizer and 2,2'-azobis(2-methyl propionamide) dihydrochloride (AIBA) as the initiator. The polymerization behaviors with varying concentrations of acrylamide, PAOTAC, AIBA, and ammonium sulfate were investigated. The reaction conditions for stable dispersion were concentrations of 5–10% for acrylamide, 0.6–1.8% for the stabilizer, $0.92\text{--}1.84 \times 10^{-4}$ mol/L for the initiator, and 24–30% for the salt. The resulting conversion–time curves were S-shaped, as is typically observed in polymerization. Polydisperse spherical particles were formed in the system. An image analyzer photographed the size of the dispersed particles and their distribution was measured. The mechanism and kinetics for the dispersion polymerization were discussed. © 2002 John Wiley & Sons, Inc. *J Appl Polym Sci* 83: 1397–1405, 2002

Key words: polyacrylamide; dispersion polymerization; aqueous solution; ammonium salt; poly(acryloyloxyethyl trimethylammonium chloride)

INTRODUCTION

Production of acrylic water-soluble polymers and copolymers provides many commercial applications. For example, they are used as flocculent for portable water and wastewater treatment in industries like mining, papermaking, tanning, and so forth. They are also used as adhesives. In these applications polymers of very high molecular weights are desired from the point of view of effectiveness and cost. However, these polymers

in dry form are difficult to dissolve. Moreover, their solutions are also difficult to handle or too dilute for applications because of their giving rise to gel. Methods of overcoming these problems of solution application have been proposed, one of which is to use inverse emulsion and inverse microemulsion (water in oil),^{1–3} and another is to use finely divided polymer dispersions in water or in mixtures of alcohol and water.^{4–7}

The dispersion polymerization of hydrophobic polymers in organic media was previously examined by many investigators such as Barrett,⁸ Almog,⁹ and Winnik.¹⁰ However, there exist only a few works on dispersion polymerization of water-soluble polymers in aqueous media. Pelton and coworkers^{6,7} prepared the hydrophilic latices of

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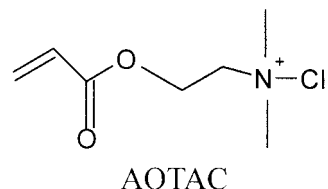
poly(*N*-isopropylacrylamide) (PNIPAM) in cross-linked form as well as copolymers of *N*-isopropylacrylamide and acrylamide. The monomers are soluble in the medium but the polymers are not. In aqueous *tert*-butyl alcohol media, Ray and Mandal^{4,5} carried out the dispersion polymerization of acrylamide using poly(vinyl methyl ether) (PAVE) as the polymeric stabilizer. According to our information, however, the dispersion polymerization of acrylamide in water without organic solvents has appeared in only a few patents.¹¹⁻¹³ Hence, for this system little is known about the effects of reaction variables. If water is the reaction medium, it has a number of practical advantages as the solution system. Using water involves a low fire risk and, in addition, it is free of odor and toxic effects.

Dispersion polymerization is a unique polymerization process, capable of forming particles of 0.1 to 15 μm in a single step.¹⁴⁻¹⁷ During dispersion polymerization the polymer precipitates from the originally homogeneous reaction mixture containing monomer, initiator, solvent, and stabilizer. The reaction medium is selected on the basis of not only its nonsolvent properties for the forming polymer but also its solubility properties for the stabilizer and its miscibility with the monomer. A proper salt added in water plays a big role on dispersion of polymers, especially for the water-soluble polymers. As the molecular weight of the polymer increases in a highly concentrated salt solution, the polymer precipitates as viscous gel particles. Such a system is obtained when the salt dissolved in the aqueous phase is capable of inducing the salting out.¹⁸⁻²¹

In the absence of the soluble stabilizer a single gummy lump of resin is frequently obtained: the stabilizer enables formation of stable colloidal latex particles. The mechanism of dispersion polymerization has been described as complex and ill understood. It has been common to assume that the stabilizer is surface active and protects the particles by adsorption and both steric and electrostatic stabilization.²²⁻²⁴ Besides the merely physical adsorption of stabilizer, it is known that grafting of stabilizer to the particle surface can possibly occur.^{8,16}

In this work, acrylamide (AM) was polymerized in aqueous ammonium sulfate media by using 2,2'-azobis(2-methyl propionamidine) dihydrochloride (AIBA) as the initiator and poly(acryloyloxyethyl trimethylammonium chloride) (PAOTAC) as the polymeric stabilizer. The stabilizer employed in this work is a polyelectrolyte with

quaternary ammonium, contrary to the nonionic stabilizer used in other works such as poly(vinyl methylether) (PVME),⁴ hydroxypropyl cellulose,^{9,25} polyvinylpyrrolidone.²⁶ In addition to the steric stabilization, the charged quaternary ammonium end groups in the polymer chains of PAOTAC are anticipated to enhance the stabilization of the latices by the electrostatic effect.



The formation of dispersions involves a number of processes, such as formation of oligomeric radicals, nucleation, adsorption of stabilizer to form stable particles, particle growth, coalescence of particles, and subdivision. Thus, when nucleation occurs in a short period of time at the start of the reaction, little or no coalescence occurs. For this reason, in a new image-analysis procedure, particles are deposited onto slides and viewed with transmitted light. During the polymerization, growth and distribution of particles could be observed.

The purpose of this work is to develop a method of preparing polyacrylamide in aqueous dispersions that do not require surfactants and organic solvents such as alcohol, and the resulting molecular weights of the polymer should be extremely high (10^6 g/mol). The solution polymerization and precipitation polymerization of acrylamide are also carried out and compared with the dispersion polymerization. Finally, some of our results on dispersion polymerization of acrylamide in aqueous solution are described and a kinetic model is discussed.

EXPERIMENTAL

Materials

The acrylamide (AM) monomer was purchased from Duksan Chemical Co. and was used either as received or after recrystallization from methanol. Ammonium sulfate (AS; Samchun Chemicals, EP) and 2,2'-azobis(2-methylpropionamidine) dihydrochloride (AIBA; Aldrich Chemicals, Milwaukee, WI) were used as received without further purification. AOTAC (dimethylaminoethyl acry-

Table I Results of Dispersion Polymerization of Acrylamide in Ammonium Sulfate Solution Using AIBA as the Initiator in the Presence of PAOTAC as the Stabilizer at 45°C^a

Experiment No.	AM (% w/v)	AS (% w/v)	PAOTAC (% w/v)	AIBA (10 ⁻⁴ mol/L)	M_w (10 ⁻⁶)	M_n (10 ⁻⁶)	MWD	Conversion (%)	PD (μm)
1	5			1.84	5.678	4.304	1.319	95	
2	5	30		1.84	5.514	2.072	2.661	90	
3	5	30	1.2	1.84	2.374	0.654	3.625	93	2.3 (2.0–3.7)
4-1	5	30	1.2	0.92	4.147	1.784	2.325	98	1.9 (0.9–3.1)
4-2	5	30	1.2	0.92	3.263	1.111	2.937	97	1.9 (1.5–2.9)
4-3	5	30	1.2	0.92	Aggregated				
5	5	30	1.2	1.38	2.495	1.021	2.887	96	2.0 (1.8–3.2)
3	5	30	1.2	1.84	2.374	0.654	3.625	93	2.3 (2.0–3.7)
6	5	30	1.2	2.3	2.352	0.53	4.436	94	2.8 (2.2–4.4)
4-1	5	30	1.2	0.92	4.147	1.784	2.325	98	1.9 (0.9–3.1)
7	7.5	30	1.2	0.92	5.933	2.617	2.267	96	2.3 (1.3–3.3)
8-1	10	30	1.2	0.92	6.977	2.862	2.438	99	2.6 (1.9–3.6)
8-2	10	30	1.2	0.92	6.088	2.066	2.947	95	3.1 (1.8–3.8)
8-3	10	30	1.2	0.92	Aggregated				
8-4	10	30	1.2	0.92	Aggregated				
9-1	7.5	24	1.2	1.38	5.934	2.239	2.65	95	2.5 (2.0–4.2)
9-2	7.5	24	1.2	1.38	5.107	2.358	2.166	93	2.7 (1.8–4.3)
9-3	7.5	24	1.2	1.38	Aggregated				
10	7.5	26	1.2	1.38	4.122	1.344	3.067	92	2.6 (1.9–3.9)
11	7.5	28	1.2	1.38	5.739	2.456	2.337	91	2.7 (2.0–4.5)
12	7.5	30	1.2	1.38	5.334	2.347	2.273	95	2.9 (1.4–5.8)
13	7.5	30	0.3	1.84	Aggregated				
14-1	7.5	30	0.6	1.84	6.527	2.243	2.91	89	4.2 (2.2–5.8)
14-2	7.5	30	0.6	1.84	Aggregated				
15	7.5	30	1.2	1.84	5.196	1.721	3.109	91	3.5 (2.6–5.4)
16	7.5	30	1.8	1.84	4.392	1.171	3.751	95	3.0 (2.5–5.6)
17-1	7.5	30	2.4	1.84	3.522	1.089	3.234	92	2.5 (2.2–4.8)
17-2	7.5	30	2.4	1.84	Aggregated				
17-3	7.5	30	2.4	1.84	Aggregated				

^a AM: acrylamide; AS: ammonium sulfate; PAOTAC: poly(acryloyloxyethyl trimethylammonium chloride); AIBA: 2,2'-azobis(2-methyl propionamide) dihydrochloride; PD: average of particle diameter (range of particle diameter).

late quaternary ammonium monomer) was obtained from CPS Chemicals (West Memphis, AR) as an aqueous solution (80%) inhibited approximately 600 ppm of hydroquinone monomethyl-ether and was purified by repeated extractions and crystallization from acetone. Poly(acryloyloxyethyl trimethylammonium chloride) (PAOTAC) was prepared from AOTAC in an aqueous solution using AIBA as initiator.^{22,29,30} PAOTAC had a Brookfield viscosity of 1.216×10^5 cps. The water used was triple distilled from NANO pure UV of Barnstead.

Procedure

Varying quantities of the ingredients (see Table I) were added to a 250-mL three-neck separable flask equipped with a stirrer, a reflux condenser, and a nitrogen inlet tube. After purging with N₂ and starting the temperature control, the poly-

merization was initiated by injecting the water-soluble initiator into the system. The polymerization was run at a constant temperature of 45°C. The agitation speed was fixed at 300 rpm in all experiments. The particles of polyacrylamide obtained were photographed by an image analyzer (Bum Mi Universe Co.) and a polarizing microscope (Olympus BH-2). The image analysis procedure consists of a calibration sequence for size and contrast to ensure high reproducibility, a neighborhood contrast thresholding algorithm, a particle selection criterion, and finally particle measurement. Using a reference slide and a contrast level predetermined by a software program for detecting the local contrast set the microscope illumination.

Polyacrylamide in aqueous solutions was separated by dialysis using porous cellulose acetate membrane and then was dried by lyophilization.

The molecular weight was determined from the analysis by Viscotek GPC with Tosoh G6000 columns using 0.3 mol/L acetic acid and 0.3 mol/L sodium acetate as solvent (TosoHaas, Montgomeryville, PA).

Conversion–time data were obtained by using a dilatometer. The aqueous solution of acrylamide was charged in a stirred bulb of about 40 cm³ of volume, and the height of liquid (mineral oil) in the attached capillary was measured with time. From the decrease of the volume of the system, the conversion with time was calculated by assuming that the conversion is proportional to the volume decrease. The final conversion of acrylamide was determined from the weight of the polymers obtained by precipitation in isopropyl alcohol.

RESULTS AND DISCUSSION

Comparison of Different Polymerization Methods

A dilatometric technique was used to obtain conversion–time data for the polymerization of acrylamide initiated by AIBA in water. A comparison of the rate of acrylamide polymerization for the solution (without salt and stabilizer), precipitation (without stabilizer), and dispersion polymerization is shown in Figure 1. The conversion versus time curve was typically S-shaped and the slope of the curve was proportional to the rate. In the dispersion polymerization, the rate of polymerization reached its maximum immediately after initiation and remained nearly constant up to 60–70% of conversion, followed by a decrease that could be described by first-order kinetics. The propagation rate is distinctly slower in the solution polymerization. The propagation rate in the precipitation polymerization is almost the same as or slightly slower than that in the dispersion polymerization, although the induction period is substantially longer (80–90 min). The difference in the rate of polymerization is probably the result of the difference of monomer diffusion in the three different systems.³¹ In the solution polymerization, the polymer chains will be highly stretched in the medium, which will act as diffusion barriers, and the viscosity of the system becomes very high. Therefore, diffusion of the monomer will be greatly hindered. Contrarily, in the dispersion polymerization the rate of monomer diffusion in the continuous phase to the dispersed particle surface will be fast, and the distance at

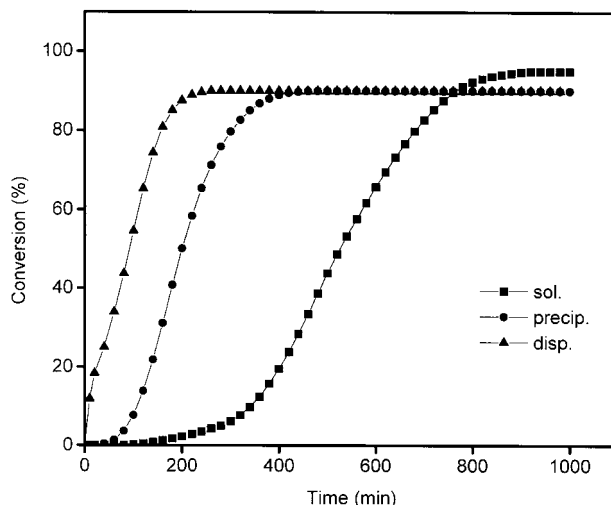


Figure 1 Comparison of rates of dispersion, precipitation, and dispersion polymerization of acrylamide: solution polymerization: 5% AM, 1.84×10^{-4} mol/L AIBA; precipitation polymerization: 5% AM, 30% $(\text{NH}_4)_2\text{SO}_4$, 1.84×10^{-4} mol/L AIBA; dispersion polymerization: 5% AM, 30% $(\text{NH}_4)_2\text{SO}_4$, 1.2% PAOTAC, 1.84×10^{-4} mol/L AIBA.

which the monomer should diffuse at a slower speed will be short only in the small particles. Hence, the rate of polymerization will be fast. In the precipitation system with uncontrolled aggregation, the particle size is relative bigger than in dispersion. Hence, the diffusion rate and accessibility of monomer is relatively slower than that in the dispersion system.

In Table I, the molecular weights are compared. The molecular weight of the polymer obtained by dispersion polymerization was significantly lower than that obtained by the solution and precipitation polymerization. This result is different from that of some other system where dispersion polymerization yields a higher molecular weight than that of solution polymerization. For the polymerization of methyl methacrylate, Barrett and Thomas³¹ suggested that the higher molecular weight by dispersion polymerization than that by solution polymerization is ascribed to restricted radical termination in the particles, either by isolation as in emulsion systems or by diffusion control as in bulk polymerization. However, this rationale does not seem to hold for the dispersion polymerization in this work: the radical termination appears to occur more frequently rather than to be restricted. Given that the dispersion system in this work is more complex, containing the stabilizer and salt, some other factors

may exert an influence on radical termination, which is discussed later.

Dispersion Polymerization

The polymerization results are summarized in Table I. Like most dispersion polymerization reported in the literature, the results were difficult to reproduce for some cases, especially for those attributed to aggregation. Strict control on stirrer speed and quality of the reagents are essential to obtain reproducible results. It can be seen that the aggregation is liable to occur with too low initiator concentrations, too high monomer concentrations, too low salt concentrations, and either too low or too high stabilizer concentrations. The coagulum took one of two forms: either a body of homogeneous gel of dissolved polymer or agglomerated lumps of the polymer sedimented from the medium. The aqueous dispersions prepared under proper conditions were stable, and no flocculation occurred even after a lapse of longer than 2 months.

Particle Size and Distribution

Figure 2 shows some representative micrographs of the dispersed particles, where it is seen that polydisperse spherical as well as oval particles were formed. The formation of oval particles suggests that coalescence of similar-size particles took place during the course of polymerization. From the pictures the particle size distributions were determined, as shown in Figure 3. The average particle diameters and the range of the particle sizes are given in Table I. The average particle size ranged from 2 to 4 μm , and most of the particles lay within 1 μm of the average particle size.

Effect of Initiator Concentration

Experimental sets 3 through 6 in Table I show the effects of the variation of initiator concentration from 0.92 to 2.3×10^{-4} mol/L, whereas the monomer and stabilizer concentrations were fixed at 5 and 1.2%, respectively. As is generally observed, the molecular weight of the polymers decreased with the increase of initiator concentration. The kinetic chain length ν of a radical chain polymerization is defined as the average number of monomer molecules consumed per each radical, which initiate a polymer chain. It is proportional to either the radical concentration or the polymerization rate.³⁰ Hence, increasing the polymerization

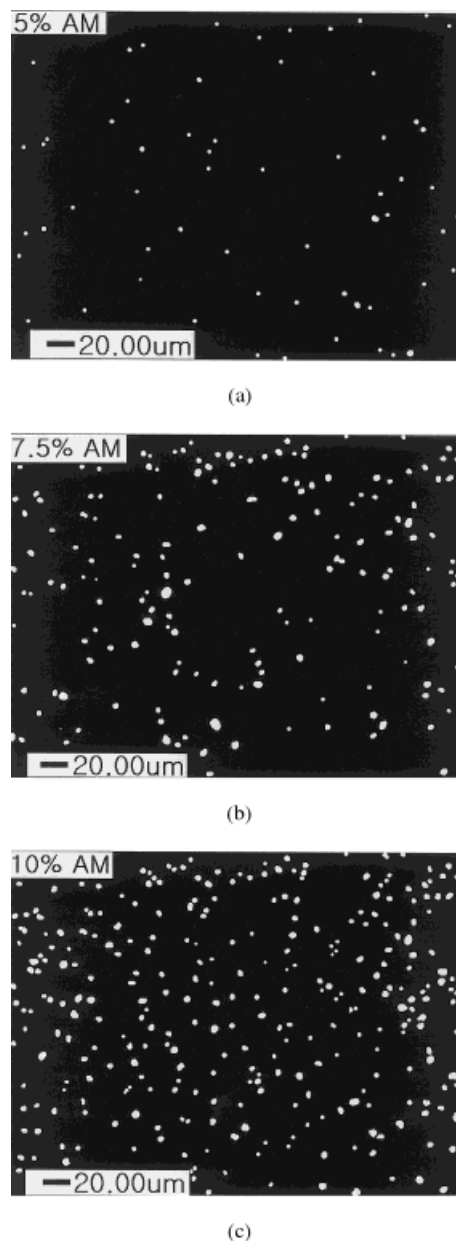


Figure 2 Micrographs (highly contrasted) of polyacrylamide dispersions prepared with different amounts of monomer: 30% AS, 1.2% PAOTAC, 0.92×10^{-4} mol/L AIBA. (a) 5% AM (experiment 4-1), (b) 7.5% AM (experiment 7), (c) 10% AM (experiment 8-1).

rate and initiator concentration in radical polymerization leads to smaller-size polymer molecules.

The particle size increased with the increase of the initiator concentration. This is in conformity with other previous dispersion polymerization experiments.^{17,32} Paine et al.³² argued that larger particles are obtained at high initiator concentra-

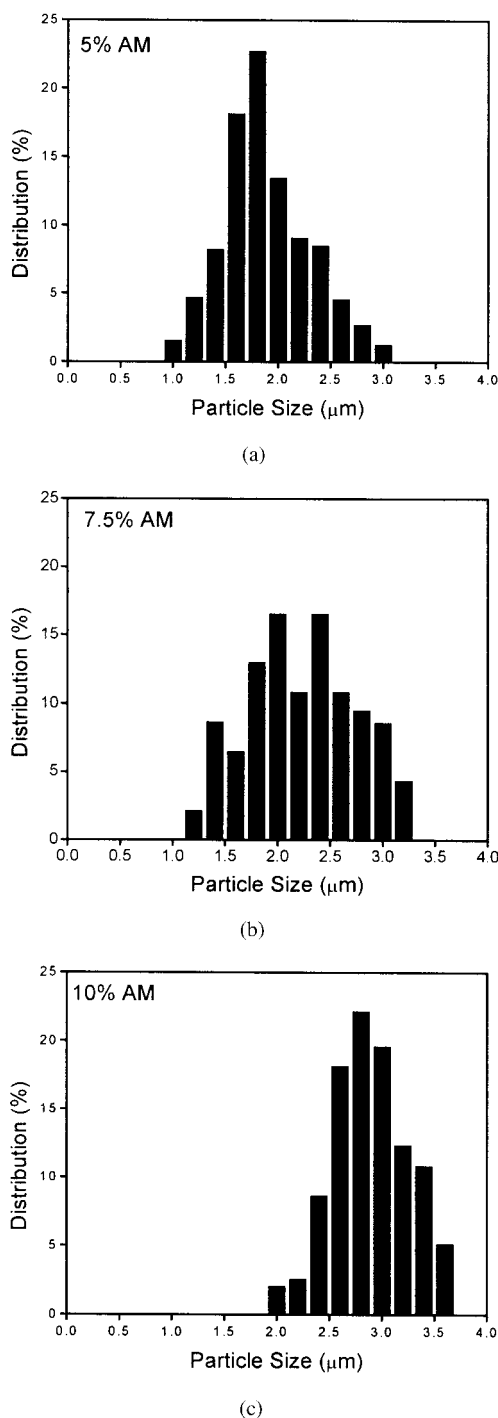


Figure 3 Distribution of particle size with different amounts of monomer: 30% AS, 1.2% PAOTAC, 0.92×10^{-4} mol/L AIBA. (a) 5% AM (experiment 4-1), (b) 7.5% AM (experiment 7), (c) 10% AM (experiment 8-1).

tions because lower molecular weight polystyrene is formed, making the grafted poly(*N*-vinylpyrrolidone) (PVP)–polystyrene(PS) more soluble and

less effective as a stabilizer. The adsorption of the grafted stabilizer on the particles would therefore be retarded, leading to larger size particles. On the other hand, Tseng et al.¹⁷ as well as Shen et al.³³ believed that a greater initiator concentration leads to a greater rate of generation of unstable oligomeric radicals or dead polymer molecules, in turn leading to a greater rate of coagulation and resulting in larger but fewer particles. When the generation rate of the oligomeric radicals is much faster than the adsorption rate of the stabilizer (attributed to the fast decomposition rate of the initiator), the oligomers would tend to aggregate and form larger particle nuclei of various sizes before enough stabilizers adsorb to stabilize them. In the same way, our result on the effect of the initiator concentration on the particle size is considered to support the view of Tseng et al.

Regarding the quantitative value of the exponent for the dependence of the particle diameter on the initiator concentration, the grafting mechanism of stabilization quantitatively developed by Paine³² predicts an exponent between -0.08 and 0.17 . The lower value is applicable for the case of adsorption of all grafts onto the particle surface as they are formed (full adsorption model), whereas the higher value is applicable for partial adsorption. The exponent in this work was about 0.3 , and hence it is considered that only a part of the grafts was adsorbed onto the particle in this system. The partial adsorption is more likely to be brought about when a better solvent for the polymer is employed.³² To make a comparison, an exponent value of 0.04 was reported for the dispersion polymerization of acrylamide in a *tert*-butyl alcohol (TBA)–water mixture.⁴ On the other hand, the exponent value of 0.4 was previously observed in other systems (dispersion polymerization of polystyrene),^{17,34} and one reason for this higher value may be postulated to be attributed to significant chain transfer to initiator.³²

Effect of Monomer Concentration

Experiments 4-1, 7, and 8-1 through 8-4 in Table I indicate that the molecular weight increased with the increase of the acrylamide concentration and the particle size also increased. As the monomer concentration was increased above 10%, stable dispersion could not be obtained when 1.2% PAOTAC and 2.76×10^{-4} mol/L AIBA were used.

Concerning the quantitative value of the exponent for the dependence of the particle diameter

on the monomer concentration, the grafting mechanism of stabilization quantitatively developed by Paine³² predicts an exponent of 0.67 for the case of the full adsorption model. For the case of the partial adsorption model, however, it is not easy to predict the exponent value because of an ill-defined term for the solubility parameter difference between the solvent and the graft. The exponent in this work was about 0.5. Unfortunately, however, this does not tell us which model may be applicable because of lack of information on the solubility parameter difference.

Effect of Salt Concentration

In experiments 9-1 through 12, the salt concentration was varied from 24 to 30%, whereas the monomer, stabilizer, and initiator concentrations were kept constant at 7.5%, 1.2%, and 1.38×10^{-4} mol/L, respectively. The effect of salt concentration did not seem to be strong either on the molecular weight of polymers or on the particle size. When the ammonium sulfate concentration was below 24%, dispersion polymerization could not be done successfully. Instead, unstable dispersion occurred with high yield of coagulum as a result of the poor salting-out effect. A concentration higher than 30% was practically difficult to employ because of the solubility limitation.

Effect of Stabilizer Concentration

In experiments 13 through 17-3, the stabilizer concentration was varied. One would expect from the simplest adsorption mechanism of stabilization by PAOTAC that the surface area stabilized would be proportional to the stabilizer concentration. Moreover, a low stabilizer concentration (0.3%) resulted in an agglomerate system, probably because of insufficient adsorption onto the polymerized phase. It was observed that increasing the stabilizer concentration up to a certain value provided more stable dispersion. When the stabilizer concentration was too high (above 2.4%), the dispersion became very unstable, giving agglomerated lumps separated from the medium. The presence of extra stabilizer molecules may make links between particles, leading to larger particles and ultimately inducing flocculation.

The decrease of particle size with an increase of stabilizer concentration is along the expected lines. With the fixed amounts of monomer and initiator, the rate of nucleation is given constant.

Then, under the same rate of nucleation, particles of polyacrylamide will be adsorbed fast to the stabilizer and a greater number of particles of smaller size will be stabilized. The theoretical analysis of Paine³² predicts an exponent of -0.5 for the dependence of the particle diameter on the stabilizer concentration for the grafting mechanism of stabilization by both the full and partial adsorption models. On the other hand, stabilization by the homopolymer adsorption mechanism suggests an exponent of -1 . The exponent in this work was about -0.3 , which is in conformity with that in an earlier work reported to be -0.3 .³⁴ To make a comparison, an exponent of -0.78 was reported in a dispersion polymerization of acrylamide using a TBA-water medium and PVME as the stabilizer.⁴ The exponent value in this work suggests that the stabilization is achieved by the grafting mechanism, probably by partial adsorption.

From the results in Table I, it is observed that the molecular weight of the polymers decreased with the increase of stabilizer concentration. This result is different from those of some other works. Ray and Mandal^{4,5} reported that the molecular weight increased with the increase of the stabilizer concentration. They explained that this was the result of the so-called gel effect. That is, with a higher concentration of the stabilizer, the greater number density of smaller particles ensures that they efficiently capture growing oligomeric radicals initiated in solution, leading to solid-phase polymerization of high molecular weight because of restricted radical termination in the gel particles. Thus, as the stabilizer concentration increases, the particle size becomes smaller and hence the rate of solid-phase polymerization becomes faster as a result of faster access of the monomer, thus leading to higher molecular weight. For the system in this work, however, it does not seem that the gel effect is significant. One difference is that TBA, a nonsolvent for PAM, was not used in this work. With regard to the access of the monomer into the PAM particles, it may be noted the PAM particles will undergo significant swelling by water and the monomer should find relatively easy entry into the swollen particles through the solvent channels.^{4,5}

It is well known that the molecular weight decreases by chain transfer.³⁵ In this work, the molecular weight obtained by dispersion polymerization was lower than that obtained by either solution polymerization or precipitation polymer-

ization, and the molecular weight decreased with increase of the stabilizer concentration. One marked difference between the three systems is the presence of the stabilizer. Therefore, one possible explanation is that the stabilizer used in this work, PAOTAC, might act as a chain-transfer agent, leading to lower molecular weight with increasing stabilizer concentration.

On the other hand, another factor may be considered. For the dispersion polymerization of acrylamide in which ammonium persulfate (APS) was used as the initiator, Ray and Mandal⁴ observed that the molecular weight decreased with increasing amount of TBA (decrease in polarity of the medium), although the particle size decreased. They proposed that the polymer radicals having negatively charged sulfate head groups might influence the rate of termination or the entry rate of oligomeric radicals into the particles.⁵ Because the stabilizer used in this work is a polyelectrolyte containing quaternary ammonium, the particles will be charged. The entry rate of oligomeric radicals, which was initiated by AIBA also containing quaternary ammonium in the solution phase, into the charged particles may be affected as a result of repulsion. As the stabilizer concentration increases, the repulsive force will become stronger and the entry rate will become slower. The probability that the polymer will be terminated in the solution phase will become greater. This is followed by the capture of the dead polymer molecules by the particles, which will lead to lower molecular weight. The molecular weight distribution became broader with increase of the stabilizer concentration, as shown in Table I, and this is considered to be consistent with the preceding discussion, regardless of which one of the two factors above is more plausible.

CONCLUSIONS

We examined the influence of the major reaction variables on the particle size and molecular weight of polyacrylamide prepared by PAOTAC stabilized in the aqueous solution of ammonium sulfate. We found the stable conditions for the dispersion polymerization of acrylamide: the concentrations were 5–10% for acrylamide, 0.6–1.8% for PAOTAC, $0.92\text{--}1.84 \times 10^{-4}$ mol/L for AIBA, and 24–30% for ammonium sulfate. The optimal conditions were determined to be as follows: 7.5% for acrylamide, 1.2% for PAOTAC, 1.84×10^{-4}

mol/L for AIBA, and 30% for ammonium sulfate. The aqueous dispersion was stable, and no flocculation occurred even after a lapse of longer than 2 months. The average particle size was between 2 and 4 μm ; M_w was $3\text{--}6 \times 10^6$ g/mol and M_n was $1\text{--}2 \times 10^6$ g/mol. The increase of initiator concentration and stabilizer concentration resulted in the decrease in molecular weight. The concentration of salt was not shown to significantly affect the molecular weight and the dispersity of the particles. The increase of acrylamide concentration led to increase of the molecular weight. The dependency of particle size on the initiator and stabilizer concentrations suggests that the particles may be primarily stabilized by the grafting mechanism of partial adsorption.

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