



The interaction between positive and negative ions of surfactant in aqueous solution

Wenchang Zhuang*, Xiqiu Wang, Wenyong Zhu, Lin Tian

School of Chemistry and Chemical Engineering, Xuzhou University of Technology, Xuzhou 221018, China,
email: windchant@xzit.edu.cn (W. Zhuang)

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ABSTRACT

In order to find out whether the interaction between positive and negative ions is determined by the performance of surfactants, the interaction of anionic and cationic surfactants is introduced by testing the surface tension, interfacial tension, solubilization, compatibility, emulsification, ion distribution, etc. The test results show that the mixed solution of anionic and cationic surfactants can eliminate the repulsion between the same charge and form the attraction between the positive and negative charges, which is very conducive to the association between the two kinds of surfactant ions, at the same time, it can increase the hydrophobicity and improve the surface activity.

Keywords: Surfactant; Positive and negative ions; Interaction

1. Introduction

Observing a bottle of shampoo, we can find that the formula of shampoo is composed of many kinds of materials. The function of shampoo is not only related to the properties of each raw material in the formula, but also to the interaction between these raw materials. These interactions provide excellent properties for shampoos, such as decontamination, foam, wetting, and viscosity. Consumers' sense of these performances determines the success or failure of these products in the market. Therefore, it is very important for the formulator to understand the interaction between components [1].

Surfactant is a kind of substance that can change the interface state of the solution system. Since the earliest surfactant was put into the market, only a few new surfactants have appeared in the market. There are many kinds of classification methods for surfactants, one of

which is based on the charge of the organic part of surfactants. According to this classification method, surfactants can be divided into cationic (with a positive charge, such as stearyltrimethylammonium chloride), anionic (with a negative charge, such as lauryl sodium sulfate), non-ionic (without charge, such as lauryl polyoxyethylene (8) ether), and amphoteric (with both positive and negative charge, such as stearyldimethyl betaine) [2]. Among them, amphoteric surfactants are the focus of research in recent years. It has been found that under suitable conditions, the anionic/cationic surfactant mixture cannot precipitate, and because of the strong interaction, it can have an obvious synergistic effect, which greatly improves the surface activity.

This paper compares amphoteric surfactants with traditional surfactants. The interaction between positive and negative ions of surfactant in solution is studied, and it is found out whether the interaction is determined by the performance of surfactant.

* Corresponding author.

2. Experimental study on the interaction between positive and negative ions of surfactant in solution

Surfactant is a kind of substance that can change the interface state of the solution system obviously by adding a small amount of surfactant. It has fixed hydrophilic and lipophilic groups and can be aligned on the surface of the solution. Surfactant can reduce the surface tension of water by adsorbing on the gas–liquid interface or the liquid interface. Many surfactants can also aggregate into aggregates in bulk solution. The surfactants used in practice are never simple substances, but a variety of mixtures. Experience has proved that mixed surfactants often have higher surface activity than single surfactants. Therefore, it is of great theoretical and practical significance to study the interaction between positive and negative ions of surfactants in solution [3]. In the past, the research on mixed surfactants mainly focused on the influence of additives on surfactants, most of which were limited to the research on the same type of surfactant mixture, the mixture of surfactants and inorganic salts, and the mixture of surfactants and polar organics. However, the systematic study of mixed positive and negative ion surfactants is rarely concerned. It has reported the solution surface adsorption of cationic and anionic surfactants with the chain length of 12 carbons [4]. The results showed that the mixed positive and negative ion surfactants had very high surface activity, far more than the general single surfactant. It is generally believed that surfactant with chain length below 8 carbon has little surface activity and is not easy to form micelles. However, considering the strong interaction of positive and negative surfactants, it can be estimated that the mixed positive and negative surfactants with eight carbon (or even less than eight carbon) may also have a quite high surface activity; their adsorption on the solution surface may have a mutual promotion, and have special properties that a single surfactant does not have.

Positive and negative ion surfactants have high surface activity, but when their concentration is slightly higher than the critical micelle concentration, the solution becomes turbid, so its application is limited. In the past, it has been studied to improve the solubility of positive and negative ion surfactants in water by increasing their hydrophilicity and changing the size of their polarity head, or by adding non-ionic surfactants. At present, amphoteric surfactants, which have been widely used in biology, medicine, washing, chemicals, and other aspects, have good solubility in water, concentrated acid, alkali, salt solution, but their surface activity is not as good as positive and negative ion surfactants, so we should study the physicochemical properties of mixed aqueous solutions of these surfactants [5].

Based on the above research, this paper studies the interaction between positive and negative ions of surfactants in solution. The research is carried out in an experimental way, including the preparation of experimental samples, experimental reagents, experimental instrument, experimental methods, experimental results, and other parts. The following is a specific analysis.

2.1. Selection and preparation of experimental samples

Surfactants are characterized by asymmetric molecular structure. The whole molecule can be divided into two

parts, one is the lipophilic nonpolar group, which is also called hydrophobic group or lipophilic group; the other is the hydrophilic polar group, which is called hydrophilic group. Therefore, surfactants have amphiphilic properties, which are called amphiphilic [6].

Surfactants are amphiphilic molecules, which make them have two kinds of interface (surface) adsorption functions in an aqueous solution. Firstly, through “positive adsorption”, the surface tension of water can be reduced rapidly, reflecting the wetting and permeability of surfactant; secondly, through “micellization”, a large number of micelles can be formed in water and the interfacial tension between the two phases can be effectively reduced, so that liquid, solid and gas can exist stably in water, reflecting the emulsification, dispersion, foaming, solubilization, and other functions of surfactant [7]. Washing is a comprehensive process in which surfactants play various functions such as wetting, emulsifying, dispersing, foaming, and solubilizing.

According to the dissociation of surfactant molecules in water, it can be divided into four categories: anionic surfactant, a cationic surfactant, non-ionic surfactant, and amphoteric surfactant. This classification reflects the relationship between chemical structure and performance, but it is not clear with the actual performance. Its specific classification is as follows.

2.1.1. Anionic surfactant

Anionic surfactant, as the name implies, the hydrophilic group is anion is anionic. In medium to alkaline medium, anionic surfactant has a good application effect. The ionized part may be carboxylate, sulfonate, sulfate, and phosphate. It mainly includes carboxylic acid derivatives, sulfonates, sulfates, phosphates, *n*-acylamino-carboxylate anionic surfactants. It is often used as a detergent, wetting agent, emulsifier, and dispersant [8]. It cannot use with cationic surfactants as they will precipitate in aqueous solutions and lose their effectiveness. But it can be used with non-ionic surfactants.

2.1.2. Cationic surfactant

Cationic surfactants are mainly nitrogen-containing organic amine derivatives. Because the nitrogen atom in the molecule contains lone pair electrons, it can combine hydrogen bond with the hydrogen in the acid molecule to make the amino group positively charged. Therefore, they have good surface activity in acid medium, but they are easy to precipitate and lose surface activity in alkaline medium. In addition to the nitrogen-containing cationic surfactants, there are also a small number of sulfur, phosphorus, arsenic, and other elements of the cationic surfactants [9]. According to the chemical structure of cationic surfactants, they can be divided into four types: amine type, quaternary ammonium type, heterocyclic type, and Leucine type.

- Amine salt type

Amine salt type of cationic surfactant is the general term of primary amine salt, secondary amine salt, and tertiary amine salt surfactants. Their properties are very similar,

and many products are mixtures of primary and secondary amines. These surfactants are mainly salts formed by fatty amines and inorganic acids, which are only soluble in acid solutions. However, in the alkaline condition, amine salt is easy to react with alkali to form free amine, which reduces its solubility, so its application range is limited.

- Quaternary ammonium salt

Quaternary ammonium type of cationic surfactant is the most important type of cationic surfactant. Its properties and preparation method are different from the amine type. This kind of surfactant can be soluble in both acid and alkaline solutions. It has a series of excellent properties and good compatibility with other types of surfactants. Therefore, it is widely used.

- Heterocyclic type

The heterocycles in cationic surfactants are mainly morpholine, pyridine, imidazole, piperazine, and quinoline.

- Leucine type

According to different heteroatoms, cationic surfactants can be divided into N, P, As, S, I, and other elements, but this classification method is rarely used. According to the different positively charged atoms, the cationic surfactants also include LOX salt, matte salt, iodoroxy, and quinate compounds, etc.

2.1.3. Amphoteric surfactant

The molecules of amphoteric surfactants can be classified according to the anionic structure of their hydrophilic groups or their cations. According to its anionic structure, it can be divided into: carboxylate, phosphate, sulfate type amphoteric surfactants, and so on. The commercial significance is that the classification of carboxylate type amphoteric surfactants is easy to be confused with the classification of anionic surfactants according to its anionic structure, and cannot highlight its structural characteristics [10]. Therefore, the current classification is mainly based on its cation structure. It is generally divided into the following types:

- The cation part of amphoteric imidazoline derivatives is the imidazoline ring;
- The cationic part of the surface-active betaine is quaternary amine nitrogen;
- The cationic part of chloro acid surfactant is a primary amine or secondary amine nitrogen;
- Lecithin (α -phosphatidylcholine). The first three are synthetic surfactants, and lecithin is a natural surfactant.

2.1.4. Non-ionic surfactant

As the name implies, non-ionic surfactant has no charged group in the molecule and does not ionize in the aqueous solution. The lipophilic group in the molecule is high carbon fatty alcohol, alkylphenol, fatty acid, fatty amine, and oil, etc., while its water solubility comes from

the polyoxyethylene ether group and terminal hydroxyl group in the molecule. It mainly includes polyoxyethylene derivatives, alkylalcohol amides, polyol monofatty acid esters, alkyloxidanes, and *N*-alkylpyrrolidone [11].

The emulsifying effect of non-ionic surfactant is independent of the pH value of the solution. It has good acid and alkaline resistance and is little affected by salt and electrolyte. It is used in combination with other surface-active agents. It can be used as an emulsifier, cleaner, and solubilizer in a cosmetic formula.

Because the research object of this paper is the interaction between positive and negative ions of surfactants, the experimental object of this paper is amphoteric polymer surfactants. In order to ensure the accuracy of the experiment, amphoteric surfactants are synthesized [12].

The synthesis of amphoteric surfactants can be completed by three steps. Firstly, diethylamine hydrochloride reacts with epichlorohydrin to prepare the connecting group containing hydroxyl group, then reacts with dodecyl dimethyl tertiary amine to prepare the intermediate cation surfactant, and finally reacts with propionolactone to prepare the final product. The synthesis route is shown in Fig. 1 [13].

The specific synthesis steps of amphoteric surfactants are as follows:

- Preparation of connecting group: take 5.50 g diethylamine hydrochloride and dissolve it in 35 mL ethanol, and dissolve 10.18 g epichlorohydrin in 10 mL ethanol, slowly add epichlorohydrin solution to diethylamine hydrochloride solution, react at room temperature for 48 h and stop, evaporate the solvent under reduced pressure to obtain colorless viscous liquid.
- Synthesis of cationic surfactant (intermediate): dissolve the product of the previous step in 70 mL of ethanol and slowly add 16.00 g dodecyl dimethyl tertiary amine to react for 48 h; stop the reaction, the liquid is light yellow. After the solvent is evaporated under reduced pressure, it can obtain a light yellow oil-like liquid; recrystallization is carried out with ethanol/acetone mixed solvent, and a white powder-like solid is obtained [14].
- Synthesis of amphoteric surfactant (end product): dry the reaction solvent, add 10 g anhydrous CaCl_2 into 300 mL THF, stir for 24 h at room temperature, filter; after pre-water removal, add about 5.00 g sodium strip, stir at room temperature for 24 h, then heat to 65°C and reflux for 4 h; add a small amount of benzophenone, and turn the solution to become orange; dissolve 2 g of intermediate in 200 mL THIE, mix with N_2 , add 0.3 g NaH, and add 1 g of propionolactone. After refluxing reaction for 48 h, add the proper amount of ethanol, when there is no bubble, evaporate the solvent under reduced pressure to obtain red oily liquid.

Single anionic and cationic surfactants are purchased from the market as shown in Table 1.

2.2. Reagents and instruments

Many experimental instruments and reagents are needed to detect the interaction of positive and negative ions in the

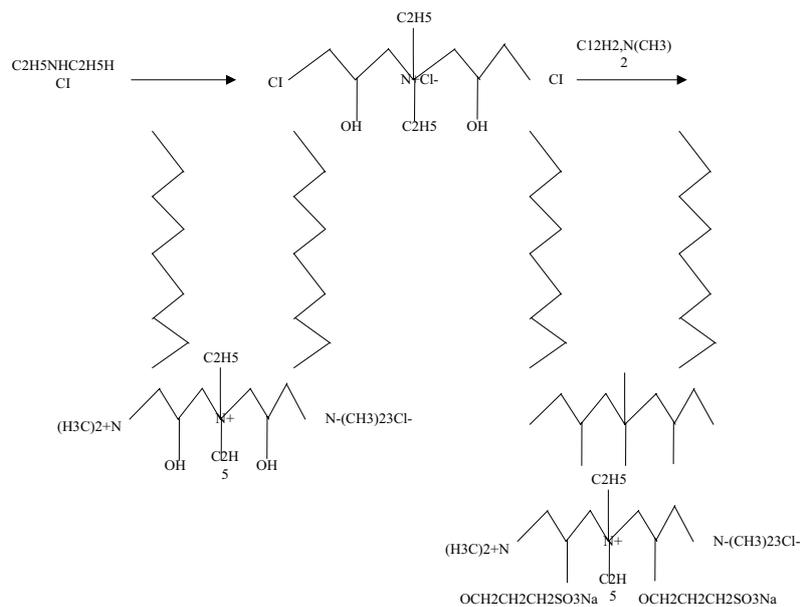


Fig. 1. Synthesis route of amphoteric surfactants.

Table 1
Comparison sample

Type	Surfactant name	Manufacturer	Molecular structure
Anionic type	Carboxylate	Shenyang Hongshan chemical raw material Co., Ltd. , (No. 19 Shengli North Street, Heping District, Shenyang City)	$\begin{array}{c} \text{CH}_3 \\ \\ \text{R}-\text{N}^+ - \text{CH}_2\text{CH}(\text{OH})\text{CH}_2 - \text{N}^+ - \text{R} \\ \qquad \qquad \qquad \\ \text{CH}_3 \qquad \qquad \qquad \text{CH}_3 \end{array}$
	Fluorine release agent	Shenyang Xinyi petrochemical plant	$\begin{array}{c} \text{CH}_3 \\ \\ \text{R}-\text{N}^+ - \text{CH}_2\text{CH}(\text{OH})\text{CH}_2 - \text{Cl}^- \\ \\ \text{CH}_3 \end{array}$
Cationic type	Ammonium salt	BASF Company (No. 8, Chuhua Road, Chemical Industry District, Shanghai)	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3-(\text{CH}_2)_{11}-\text{O}-\text{S}-\text{O}-\text{Na}^+ \\ \\ \text{O} \end{array}$
	Quaternary ammonium salt	Hercules Company	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3-(\text{CH}_2)_{11}-\text{O}-(\text{CH}_2\text{CH}_2)_2-\text{S}-\text{O}-\text{Na}^+ \\ \\ \text{O} \end{array}$

solution. The required experimental reagents, manufacturers, and purity of the reagents are shown in Table 2.

The experimental instruments used in this study are shown in Table 3.

2.3. Test methods and results

2.3.1. Surface tension measurement

2.3.1.1. Measurement method

The surface tension of the sample is measured by the surface tension meter. The measurement steps are as follows:

- Confirm that the tensiometer system is closed, put the sample into the sample container, and put it into the incubation bath.
- Put the platinum plate or platinum ring on the suspension inside the tensiometer, close the heat-resistant plexiglass door of the tensiometer, and loosen the balance lock on the tensiometer.
- Use the support knob to move the thermostatic container upward until the platinum ring or platinum plate is just above the liquid surface. After turning on the tensiometer switch or pressing the reset key, the tensiometer's force measurement system will self-calibrate.
- Press the menu on the screen to select the corresponding number key, select the desired measurement method, input the sample number, and then press the key system for full-automatic measurement after confirmation.
- The full-automatic measurement starts from the calibration of the balance, and the sound signal indicates the

end of the measurement. Press the key to confirm the end of the measurement, if the measurement needs to be carried out, press the START key again [15].

2.3.1.2. Measurement results

It can be concluded from Fig. 2 that the surface tension of the mixed system of amphoteric surfactants is lower than that of the single surfactant solution, so it has higher surface activity than that of the single surfactant, which shows that the electrostatic attraction between opposite ions in amphoteric surfactants makes the system have a strong ability to reduce the surface tension, that is, it has high surface activity.

The surface tension of an amphoteric surfactant system is lower than that of a single surfactant system. The main reason is that the attraction between positive and negative ions replaces the repulsive force between positive and negative ions, so the surfactant molecules are more closely arranged on the surface. The number of surfactant ions per unit area increases, the adsorption capacity is larger, and the surface energy is reduced to a greater extent, which is manifested in the reduction of surface tension on the macro level. Especially when the ratio of positive and negative ion surfactant molecules is 0, theoretically, almost no two surfactant molecules with the same charge are close to each other, so the system has the lowest surface tension at this time.

2.3.2. Interfacial tension measurement

The interfacial tension is measured by the interfacial tension meter.

Table 2
Reagents

Reagent	Manufacturer	Purity
Acrylic acid	Shanghai Lingfeng Chemical Reagent Factory (Huachi Road, Putuo District, Shanghai)	Chemically pure
Petroleum ether	Shanghai Lingfeng Chemical Reagent Factory (Huachi Road, Putuo District, Shanghai)	Chemically pure
Acetone	Sinopharm Chemical Reagent Co., Ltd.	Chemically pure
Second drunk	Guangdong Shantou Xilong Chemical Plant	Analytically pure \geq
Ammonium persulfate	Shanghai Lingfeng Chemical Reagent Factory (Huachi Road, Putuo District, Shanghai)	Analytically pure
Dodecyl dimethyl tertiary amine	China Pharmaceutical Group Shanghai Chemical Reagent Co., Ltd., (Beijing East Road, Shanghai) imported sub packaging, farco chemical supplies. Hongkong	Analytically pure
Diethylamine hydrochloride	Shanghai Hengda Fine Chemicals Co., Ltd., (Shanghai)	Analytically pure
Epichlorohydrin	Tianjin Damao Chemical Reagent Factory (Huaming Street, Dongli District, Tianjin)	Analytically pure
N-butanol	Zibo Chemical Reagent Factory (Longshan Road, Boshan District, Zibo City)	Analytically pure
Trichloroethyl methacrylate	Weihai Xinyuan Chemical Co., Ltd., (Zhuhai Road, Huancui District, Weihai City)	Analytical purity \geq 99%
Sodium chloride	Qingdao Chemical Reagent Factory (Qingdao)	Chemically pure
Secondary distilled water	–	–
Kerosene	Qingdao Chemical Reagent Factory (Qingdao)	–

Table 3
Instruments

Instrument	Manufacturer	Model
Electronic balance	Shanghai Hengping Instrument Factory (Shanghai)	MD100-1
Constant temperature water-bathing	Shanghai Medical Instrument Factory (Shanghai)	Accuracy is 0.1°C
Automatic interface tensiometer	Chengde precision laboratory machine Co., Ltd., (Chengde)	JZ-200A
FTIR infrared spectrometer	Nicolet, USA	Avatar-360
Rotary evaporator	Shanghai Jingsheng Scientific Instrument Co., Ltd., (Shanghai)	DDS-11A
Electric blast drying oven	Shanghai Experimental Device Factory Co., Ltd., (Shanghai)	101A-1
Transmission electron microscope	Produced by Japan Jeol Company (Japan)	JEM-100CX
Conventional glassware	Shanghai Medical Instrument Factory (Shanghai)	–
Electric blender	Shanghai Experimental Device Factory Co., Ltd., (Shanghai)	KD-100
Capillary viscometer	Shanghai Hengping Instrument Factory (Shanghai)	1834

2.3.2.1. Measurement method

Cleaning of instrument accessories

- It includes capillary, gasket, ring, pressure cap, and syringe cleaning. The order of the solvents used is water, acetone or petroleum ether, and ethyl alcohol, water. Gasket and ring shall not be washed with an organic solvent.

Sample loading

- First, use a microsyringe to inhale the oil sample, remove the air, insert the capillary tube filled with water sample, push it into the oil sample, and then quickly draw out the needle; use the syringe filled with a water sample to fill the capillary tube, then insert the capillary tube into the pressure cap with gasket and ring, finally dry the liquid inside and outside the pressure cap, and install it on the rotating shaft of the tensiometer.

Measurement

- First, turn on the power, make the motor rotate, then control the temperature, and then turn on the stroboscopic switch, move the reading microscope, adjust the focal length, and find the stretched oil column in the capillary; then, adjust the rotation speed to 8–12 ms rev⁻¹, use the reading microscope to measure the length of oil column. If the position of the oil column moves during reading, adjust the balance knob until the oil column does not move; if the length of the oil column is less than times of the diameter, measure the diameter of the oil column at the same time. Finally, use a density bottle to measure the density of oil sample and water sample at the same temperature, and use a refractometer to measure the refractive index of water sample to obtain the parameters for calculating the interface tension [16].

Calculation

- Calculate the interface tension as follows:

$$K = 1.233610^6 \frac{\Delta\rho \cdot D^3}{p^2 n^3} f(L/D) \quad (1)$$

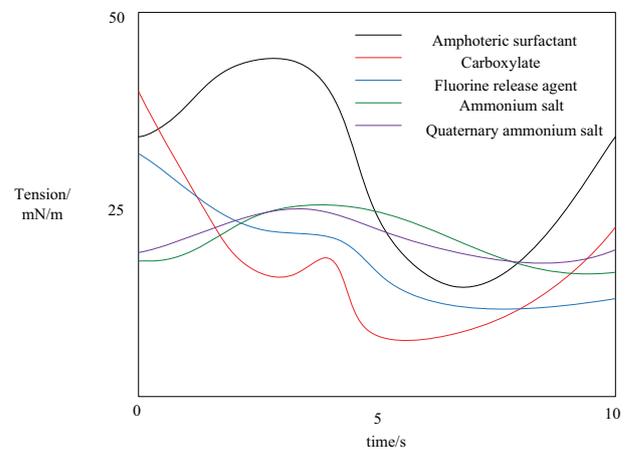


Fig. 2. Surface tension.

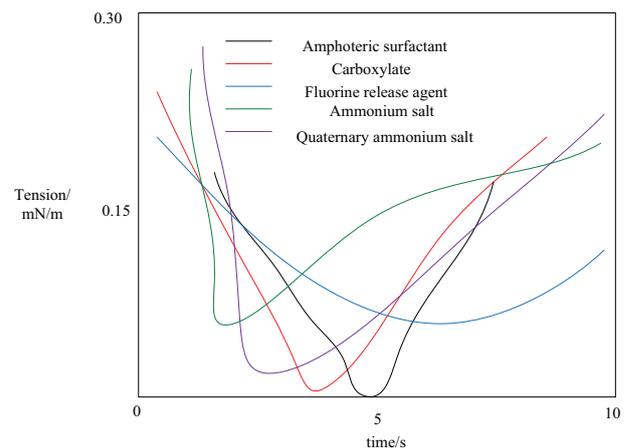


Fig. 3. Interfacial tension.

In Eq. (1), K is the interfacial tension, $\Delta\rho$ is the density difference of oil-water phase, L is the length of oil column, D is the diameter of oil column, p is the reciprocal of rotation speed, n is the refractive index of the water phase, and $f(L/D)$ is the correction factor.

2.3.2.2. Measurement results

It can be concluded from Fig. 3 that when there is only a single ionic surfactant molecule in the adsorption layer because the interaction between hydrophobic groups of surfactant molecules and oil molecules is very close to the interaction between hydrophobic groups in nature and strength, there are many oil phase molecules in the oil ice interface adsorption layer inserted between the hydrophobic group of the surfactant so that the adsorbed surfactant can be separated with the increase of the average area and the cohesive force between adsorbed molecules decreases. When the surfactant with opposite charge exists, the electrostatic attraction between the two kinds of surfactant with opposite charge makes the cohesive force between the adsorbed molecules increase, and the interfacial tension of the system decrease.

2.3.3. Solubilization determination

2.3.3.1. Measurement method

Take 2 mL 0.1 mol/L surfactant solution and put it into a 10 mL test tube, add quantitative solubilizer (ammonium persulfate) with a micro sampler, shake it, if it is transparent, continue to add solubilizer until it is opaque after shaking, which is the endpoint of solubilization, then calculate the molar ratio of solubilizer and surfactant:

$$r = 5 \times 10^3 \left(\frac{\rho}{M} \right) v \quad (2)$$

where ρ is the density of solubilizer; M is the molar mass of solubilizer; v is the volume of a solubilizer. The experiment is carried out at 40°C, and the error of the control experiment is less than 5% [17].

2.3.3.2. Measurement results

It can be seen from Table 4 that the molar ratio of amphoteric surfactants is close to 1:1, and the interaction between ions is weak, which indicates that amphoteric surfactants not only eliminate the repulsion between the same charges, but also form the attraction between the positive and negative charges, which is conducive to the interaction between the two surfactants, and at the same time increases the hydrophobicity. Therefore, the increase of adsorption on the surface (or interface) also makes the micelle easier to form and improves surface activity.

Table 4
Solubilization measurement

Surface active agent	Molar ratio r
Amphoteric surfactant	0.98:1.02
Carboxylate	0.74:0.82
Fluorine release agent	0.72:0.75
Ammonium salt	1.36:1.24
Quaternary ammonium salt	1.22:1.30

2.3.4. Compatibility measurement

2.3.4.1. Measurement method

The compatibility of amphoteric surfactants in this paper can be tested by measuring the viscosity of the mixture with viscometer. Viscometer is a physical analysis instrument for measuring the viscosity of fluid. The viscometer in this experiment is a capillary viscometer. It is a common viscometer. Its working principle is: the sample container (including the outflow capillary) is filled with the sample to be tested, which is in the constant temperature bath, and the liquid column height is h . When opening the cock, the sample begins to flow to the liquid receiver, at the same time, it starts to calculate the time until the sample liquid level reaches the scale line. The higher the viscosity of the sample is, the longer the time is Héloïse et al. [18]. Therefore, this time directly reflects the viscosity of the sample.

2.3.4.2. Measurement results

It can be seen from Fig. 4 that at the beginning, there is an obvious precipitation phenomenon, but with the



Fig. 4. Schematic diagram of anionic/cationic surface-active compatibility.

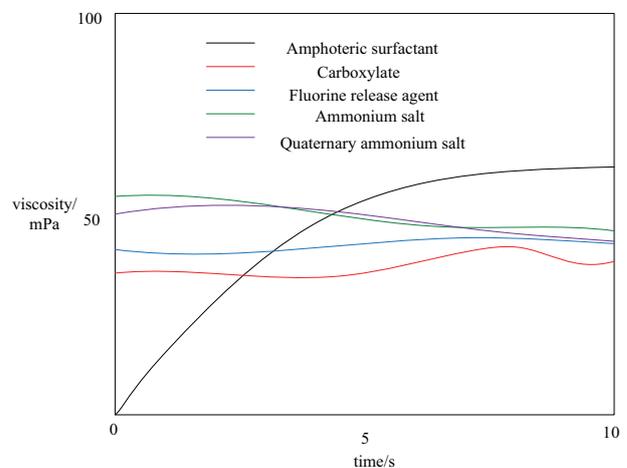


Fig. 5. Viscosity change with time.

passage of time, they start to dissolve each other, and finally, they are obviously mixed evenly; from Fig. 5, it can be seen that with the increase of time, the viscosity of amphoteric surfactants increases gradually, which also indicates that they start to dissolve each other. This indicates that the interaction between the positive and negative ions of surfactant begins.

2.3.5. Determination of emulsifying power

2.3.5.1. Measurement method

Take 40 mL of the sample with a pipette, put it into a small measuring cylinder with a plug of 100 mL, then take 40 mL of fire oil with a pipette and inject it into it, shake it tightly for 10 times, let it stand for 1 min, repeat it for 5 times; immediately straighten the measuring cylinder, start the stopwatch, stop the stopwatch immediately until

10 mL of the water phase is separated, record the required time (in seconds), take the average value for three times in parallel, and set it as *A* [19]; make a parallel emulsification test of standard activator (the method is the same as above), and set the phase separation time as *B*, then:

$$Y = B \times 100\% \tag{3}$$

2.3.5.2. Measurement results

Fig. 6 shows that the emulsification time of cationic surfactant is the shortest, the emulsification time of anionic surfactant is longer than that of cationic surfactant, and the emulsification capacity is better than that of cationic surfactant. In the mixed system of anionic and cationic surfactants, due to the effect of electricity, the surface activity of the mixed system increases, and the compactness of the film formed on the oil–water interface also increases, so as to achieve the effect of increasing the emulsification capacity. When the charge of anion/cation is nearly completely neutralized, the charge will disappear, the hydrophilic ability will decrease, the hydrophilic–lipophilic balance value will lose balance, and the emulsifying ability will also decrease.

2.3.6. Observation on ion distribution of surfactants

The distribution of ions in surfactants is observed by an ion analyzer. The ion analyzer is PXSJ-216F type ion analyzer made by Shanghai Leici [20]. The technical parameters of the analyzer are shown in Table 5.

The observation results are shown in Fig. 7.

From Figs. 7a–d, it can be seen that the ions in the single ion surfactant are in a monodisperse state, only a few molecules gather together due to the interaction between them. Careful observation can also be seen that there are a few larger particle size structures distributed in them, indicating that in the surfactant, the ions can interact with the water molecular monomer, but the interaction is not strong [21–23].

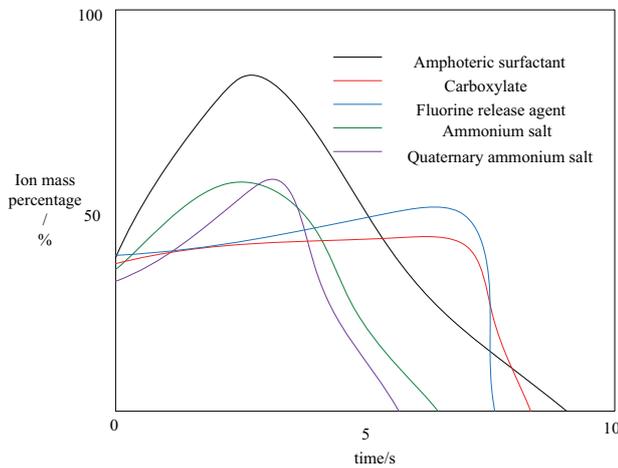


Fig. 6. Relation curve between ion mass percentage and emulsification time.

Table 5
Technical parameters of PXSJ-216F ion analyzer made by Shanghai Leici

Model	PXSJ-216F
Instrument level	0.001level
Measuring range	pH/pX (-2~20) pH; (0~14)pX
	MV (-1,999.9~1,999.9) mV
	Ion concentration (0~19,990), unit μg/L, mg/L, g/L, mol/L, and mmol/L
	Temperature (-5.0~110.0)°C
Resolving power	pH/pX 0.001 pH/pX
	MV 0.1 mV
	Concentration Four significant digits (indicated by scientific counting method)
	Temperature 0.1°C
Basic error	pH/pX ±0.002 pH/pX
	MV ±0.03% FS
	Ion concentration ±0.5%
	Temperature ±0.2°C
Power supply	DC universal power supply (9 VDC, 500 mA, and positive inside and negative outside)

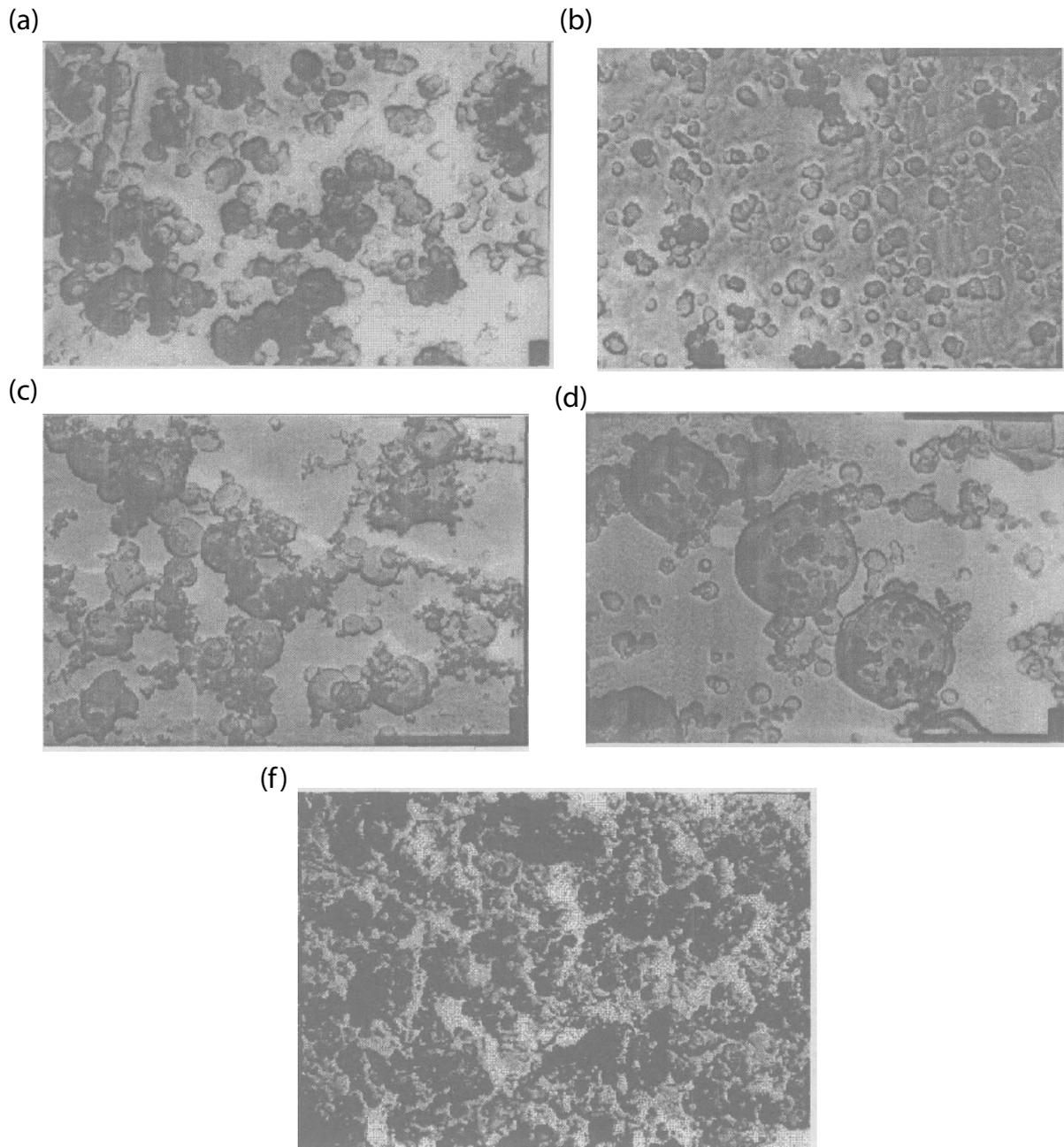


Fig. 7. Ion distribution of surfactant: (a) carboxylate, (b) fluorine release agent, (c) ammonium salt, (d) quaternary ammonium salt, and (e) amphoteric surfactant.

From Fig. 7e, it can be seen that the ions in amphoteric surfactant molecules show an aggregation state, indicating that the positive and negative ions of surfactant can attract each other, resulting in the swelling of polymer clusters [24–26].

3. Conclusions

In conclusion, the performance of anionic and cationic surfactants can be determined by their interaction. The formed complex not only determines their solubility in

water, but also determines the accumulation of complex on the surface, and ultimately affects the performance of surfactants. In order to search for the best performance of personal care formulations, the optimization of bisexual surfactants for foam, rinsing, wetting, and skin irritation may be a field worthy of research by the chemist.

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