commonly used as an emulsifier and solubilizer in pharmaceutical systems. Unlike the sulfonates, sulfates are susceptible to hydrolysis, resulting in the formation of long-chain alcohols; thus pH control is essential for solutions containing sulfate surfactants. The degree of water solubility is greatly influenced by the length of the alkyl chain and the presence of double bonds. Multivalent ions, such as calcium and magnesium, can significantly decrease the water solubility of anionic surfactants, even those with a small alkyl chain length. In addition, mixed micelles of binary surfactant mixtures consisting of nonionic/nonionic and cationic/nonionic surfactants have been studied including chain length effect of the hydrophobic moiety on solubility (Chatterjee et al., 2006).

Cationic Surfactants

Head groups of surfactants that ionize to yield a positive ion are classified as cationic. Some examples include amine, quaternary ammonium, and pyridiniumions. These surfactants are most commonly available as the halide salt form, for example, cetyltrimethylammonium bromide (CTAB), and are compatible with nonionic and amphotericin surfactants. Cationic surfactants cannot be used with anionic surfactants because they interact to form water-insoluble salts. Negatively charged substrates, such as skin, hair, glass, and many types of microorganisms strongly absorb positively charged surfactants. Quaternary amines retain their positive charge regardless of pH of solution. The use of cationic surfactants in pharmaceutical systems is generally limited to antimicrobial preservation. Their toxicity is due to the ability of cations to adsorb readily into cell membrane structures in a nonspecific manner, leading to cell lysis (including red blood cells), which destroy bacteria and fungi (Schott, 1995).

Zwitterionic Surfactants

Zwitterionic surfactants (such as amino acids, betaines, carnitines, and phosphatidylcholines) carry both a negatively and a positively charged moiety, and are pH-dependent. At high pH, they behave as anionic surfactants; at low pH, they behave as cationic surfactants; at intermediate pH values, they exhibit both anionic and cationic properties and have a neutral charge. Most of the molecules in this category are those containing carboxylate or phosphate groups as the anion and amino or quaternary ammonium groups as the cation. These long-chain amphoteric molecules are more surface active than ionic surfactants having the same hydrophobic groups, and are particularly useful as emulsifiers. Some examples include acrylic acid derivatives, such as alkylaminopropionic acids, substituted alkylamides, and phosphatides such as phospholipids. Phospholipids like lecithin are good emulsifiers for lipids and cholesterol. In the gastrointestinal tract, phospholipids combine with glycerides, fatty acids, and bile salts to form mixed micelles, which are effective solubilizers for cholesterol (Carey, 1983; Jin et at., 2014).

NONTRADITIONAL SURFACTANTS

Bile Salts

Salts of cholic acid and its derivatives are known as bile salts. Bile salts are unlike traditional surfactants in that they are rigid and have multiple polar moieties on one side of the molecule thus exhibiting surface activity.

Drugs

There are drug molecules themselves that resemble surfactant molecules with polar and nonpolar regions exhibiting surface-active properties. These drugs can thus self-associate and form small aggregates or micelles. Examples of drugs that are surface active include dexverapamil-HCl (Surakitbanharn et al., 1995), ibuprofen, and benzocaine.