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(54) Titre : **MACROMOLECULE AMPHIPHILE ET SON UTILISATION**  
 (54) Title: **AMPHIPHILIC MACROMOLECULE AND USE**

(57) **Abrégé/Abstract:**

The present invention provides an amphiphilic macromolecule and use thereof. The amphiphilic macromolecules have structural units to adjust molecular weight and molecular weight distribution and charging property effects, high stereo-hindrance structural units, and amphiphilic structural units, are suitable for fields such as oil field well drilling, well cementation, fracturing, oil gathering and transfer, sewage treatment, sludge treatment and papermaking, etc., and can be used as an oil-displacing agent for enhanced oil production, a heavy oil viscosity reducer, a fracturing fluid, a clay stabilizing agent, a sewage treatment agent, a papermaking retention and drainage aid or a reinforcing agent, etc.



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## Abstract

The present invention provides an amphiphilic macromolecule and use thereof. The amphiphilic macromolecules have structural units to adjust molecular weight and molecular weight distribution and charging property effects, high stereo-hindrance structural units, and amphiphilic structural units, are suitable for fields such as oil field well drilling, well cementation fracturing, oil gathering and transfer, sewage treatment, sludge treatment and papermaking, etc., and can be used as an oil-displacing agent for enhanced oil production, a heavy oil viscosity reducer, a fracturing fluid, a clay stabilizing agent, a sewage treatment agent, a papermaking retention and drainage aid or a reinforcing agent, etc.

## **Amphiphilic macromolecule and use**

### **Technical Field**

This invention relates to an amphiphilic macromolecule and uses thereof, and this amphiphilic macromolecule is applicable to oilfield drilling, well cementing, fracturing, crude oil gathering and transporting, sewage treating, sludge treating and papermaking, and it can be used as intensified oil producing agent and oil displacing agent, heavy oil viscosity reducer, fracturing fluid, clay stabilizer, sewage treating agent, retention aid and drainage aid and strengthening agent for papermaking.

### **Background of the Invention**

The main function of the polymer used for tertiary oil recovery is believed to increase solution viscosity and decrease water permeability in oil layer, so as to decrease mobility ratio and adjust water injection profile, and thus to enhance oil recovery by increasing the conformance factor. The solution viscosity and stability of the viscosity are important indicators for determining polymer displacement characteristics, and also are the key problem for determining recovery effect. With the continuous increase of oilfield comprehensive water content, it becomes increasingly difficult to extract oil and keep stable production, thus the requirements on the polymer used for tertiary oil recovery also increase constantly.

Heavy oil recovery is a common problem worldwide. The heavy oil has characteristics of high viscosity, high gum asphaltene content or high wax content; heavy oil gathers up about 70% sulfur and 90% nitrogen of the crude oil, the light component which accounts for about 70% of the total heavy oil is the convertible section by using the current technology, but it is still difficult to convert it efficiently. The heavy component which accounts for about 20% of the total heavy oil is difficult to be converted directly by using conventional technology. The rest of the heaviest is 10% of bottom residue of the heavy oil, which is rich in over 70% of metals and over 40% of sulfur and nitrogen, it can't be converted effectively into light product. The heavy oil is not easy to flow in the formation, wellbore and oil pipeline. Furthermore,

since the oil-water mobility ratio is big, heavy oil can easily cause many problems such as rapid water breakthrough, high water content of produced fluid, and easy formation sand production. The process for heavy oil recovery can be mainly divided into recovery of liquid flooding (e.g., hot water flooding, steam huff and puff, steam flood and so on) and recovery of yield enhancement (e.g., horizontal well, compositing branched well, electric heating and etc). Chemical viscosity reducer can disperse and emulsify the heavy oil effectively, reduce the viscosity of the heavy oil remarkably and decrease the flow resistance of heavy oil in the formation and wellbore, which is significantly important for reducing energy consumption in the process of recovery, decreasing discharging pollution and enhancing heavy oil recovery.

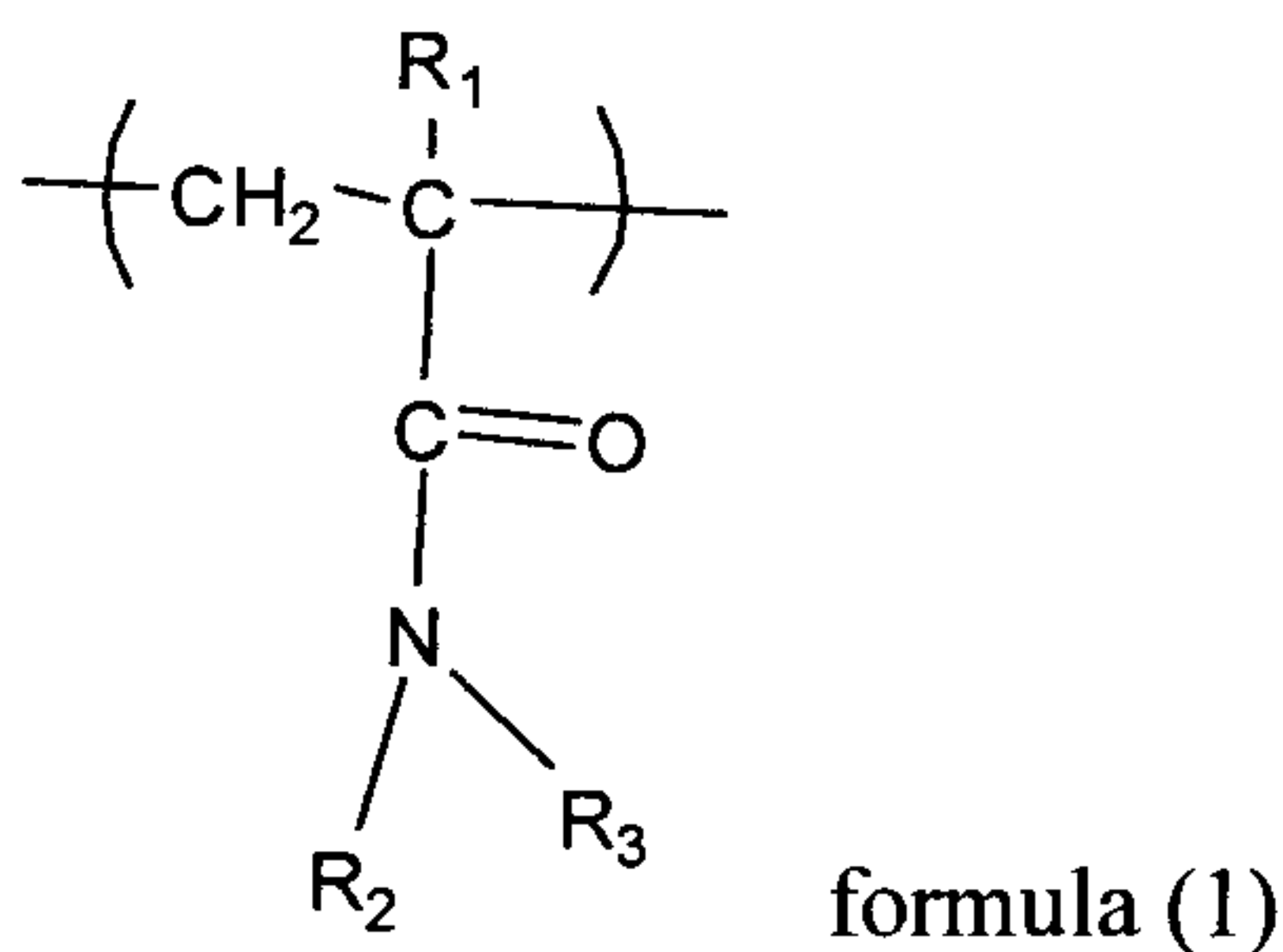
### **Brief Description of the Invention**

In the following context of this invention, unless otherwise defined, the same variable group, and molecular and structural formula have the same definitions..

The instant invention relates to an amphiphilic macromolecule, this amphiphilic macromolecule has repeating units as described below: a structural unit A for adjusting molecular weight, molecular weight distribution and charge characteristics, a highly sterically hindered structural unit B and an amphiphilic structural unit C.

In an embodiment, the structural unit A for adjusting molecular weight, molecular weight distribution and charge characteristics comprises (meth)acrylamide monomer unit  $A_1$  and/or (meth)acrylic monomer unit  $A_2$ . Preferably, the structural unit A includes (meth)acrylamide monomer unit  $A_1$  and / or (meth)acrylic monomer unit  $A_2$  simultaneously. In the art, the molecular weight of the amphiphilic macromolecule may be selected as needed, preferably, this molecular weight may be selected between 1000000-20000000.

Preferably, the (meth)acrylamide monomer unit  $A_1$  has a structure of formula (1):



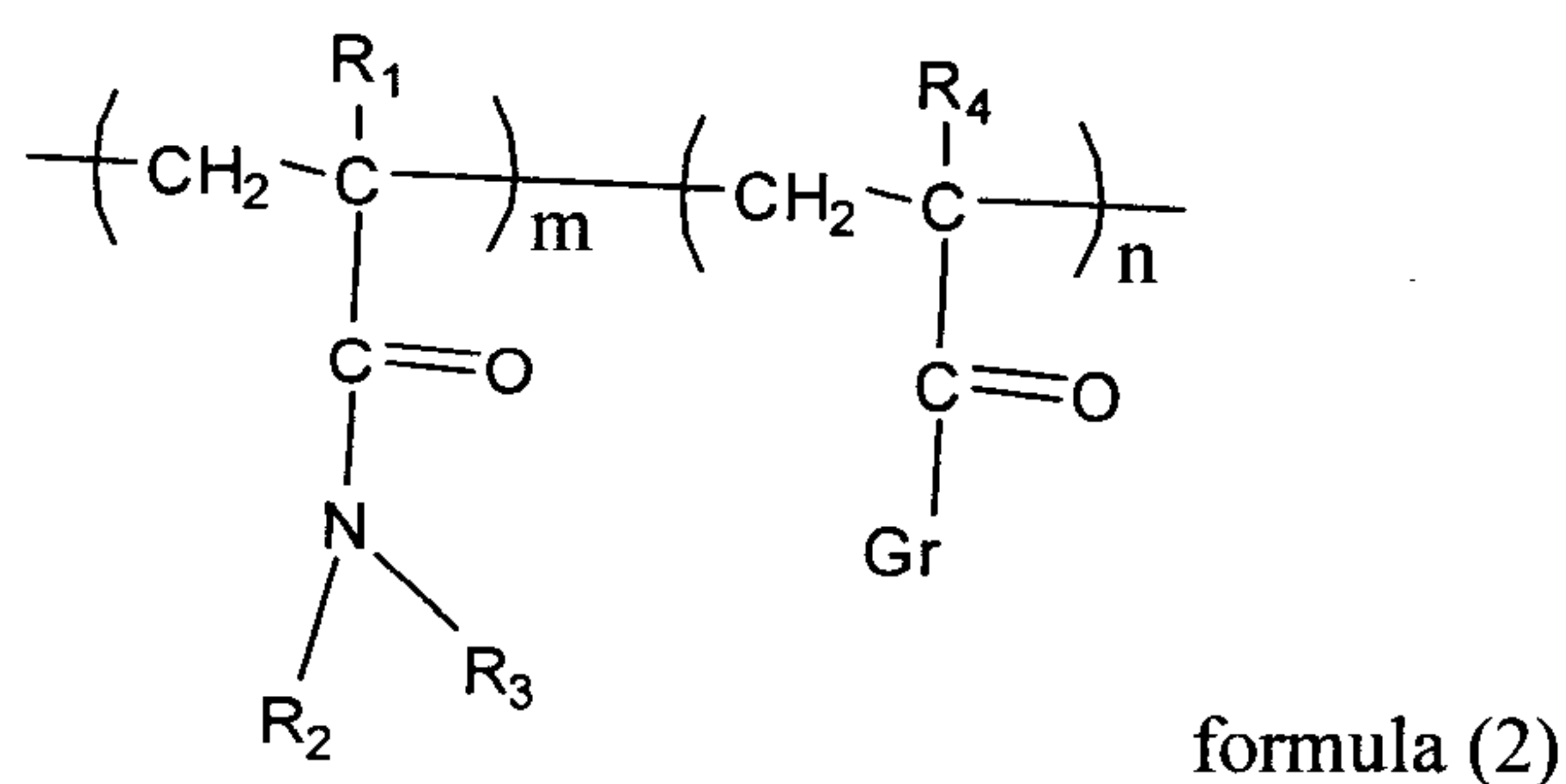
In formula (1), R<sub>1</sub> is H or a methyl group; R<sub>2</sub> and R<sub>3</sub> are independently selected from the group consisting of H and a C<sub>1</sub>-C<sub>3</sub> alkyl group; R<sub>2</sub> and R<sub>3</sub> are preferably H.

Preferably, the (meth)acrylic monomer unit A<sub>2</sub> is (meth)acrylic acid and/or (meth)acrylate. Preferably the (meth)acrylate is sodium methacrylate.

Preferably, the molar percentage of (meth)acrylamide monomer unit A<sub>1</sub> in the entire amphiphilic macromolecule repeating units is 70-99mol%; preferably 70-90 mol%, more preferably 72.85-78mol%.

Preferably, the molar percentage of (meth)acrylic monomer unit A<sub>2</sub> in the entire amphiphilic polymer repeat units is 1-30mol%; preferably 1-25mol%, and more preferably 20-25mol%.

In another embodiment, the structural unit A for the regulation of molecular weight, molecular weight distribution and charge characteristics has a structure of formula (2):



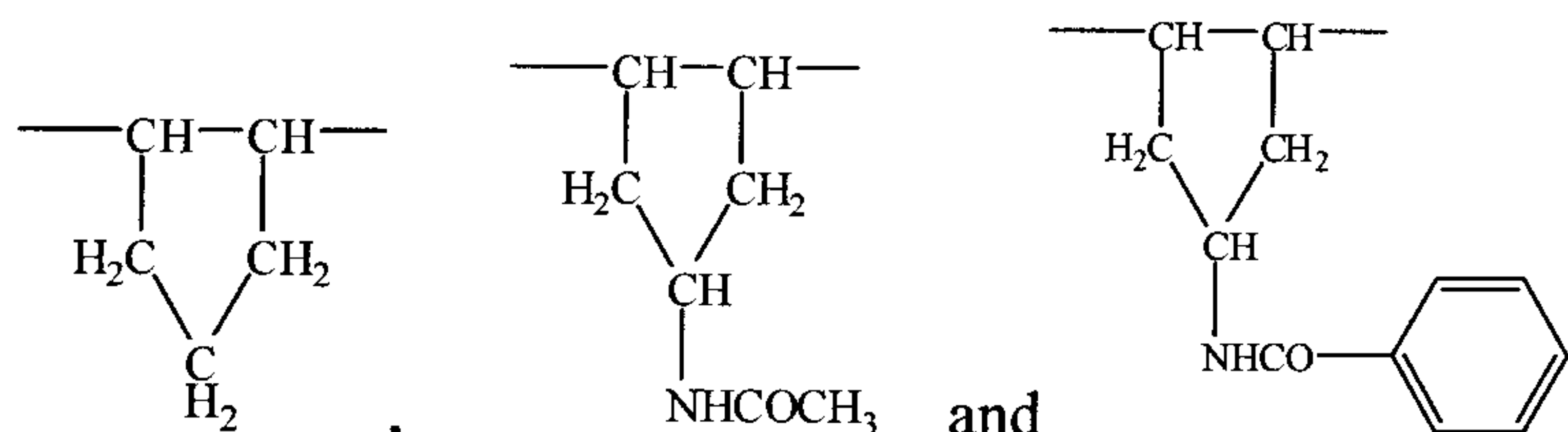
wherein, R<sub>1</sub> is H or a methyl group; R<sub>2</sub> and R<sub>3</sub> are independently selected from the group consisting of H and a C<sub>1</sub>-C<sub>3</sub> alkyl group; R<sub>2</sub> and R<sub>3</sub> are preferably H; R<sub>4</sub> is selected from H or a methyl group; Gr is -OH or -O<sup>-</sup>Na<sup>+</sup>; m and n represent the molar percentages of the structural units in the entire amphiphilic macromolecule repeating units, and m is 70-99mol%, preferably 70-90mol%, more preferably 72.85-78 mol%; n is 1-30mol%, preferably 1-25mol%, more preferably 20-25mol%.



and e are respectively integers from 0 to 17, preferably from 1 to 7; f is an integer from 2 to 8, preferably from 2 to 4; and X<sup>-</sup> is Cl<sup>-</sup> or Br<sup>-</sup>.

Preferably, the highly sterically hindered structural unit B comprises a structure G and a structure of formula (4).

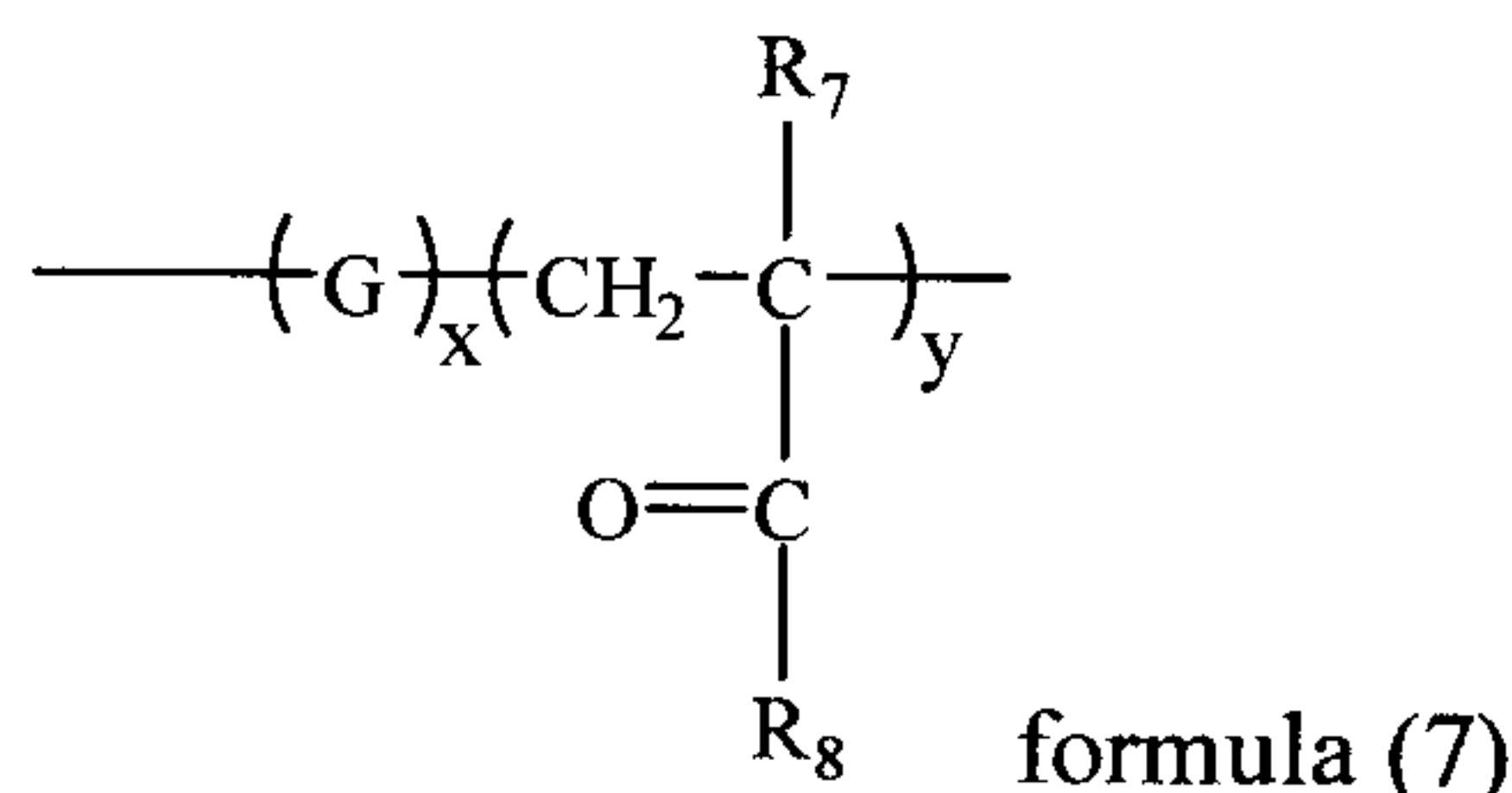
In another embodiment, the cyclic hydrocarbon structure formed on the basis of two adjacent carbon atoms in the main chain is selected from the group consisting of:



Preferably, the molar percentage of structure G of the highly sterically hindered structural unit B in the entire amphiphilic macromolecule repeating units is 0.02-2mol%; preferably 0.02-1.0mol%, more preferably 0.05-0.5 mol%.

Preferably, the molar percentage of the structure of formula (4) of the highly sterically hindered structural unit B in the entire amphiphilic macromolecule repeating units is 0.05-5mol%; preferably 0.1-2.5mol%, more preferably 0.1-1.0mol%.

In another embodiment, the highly sterically hindered structural unit B has a structure of formula (7):



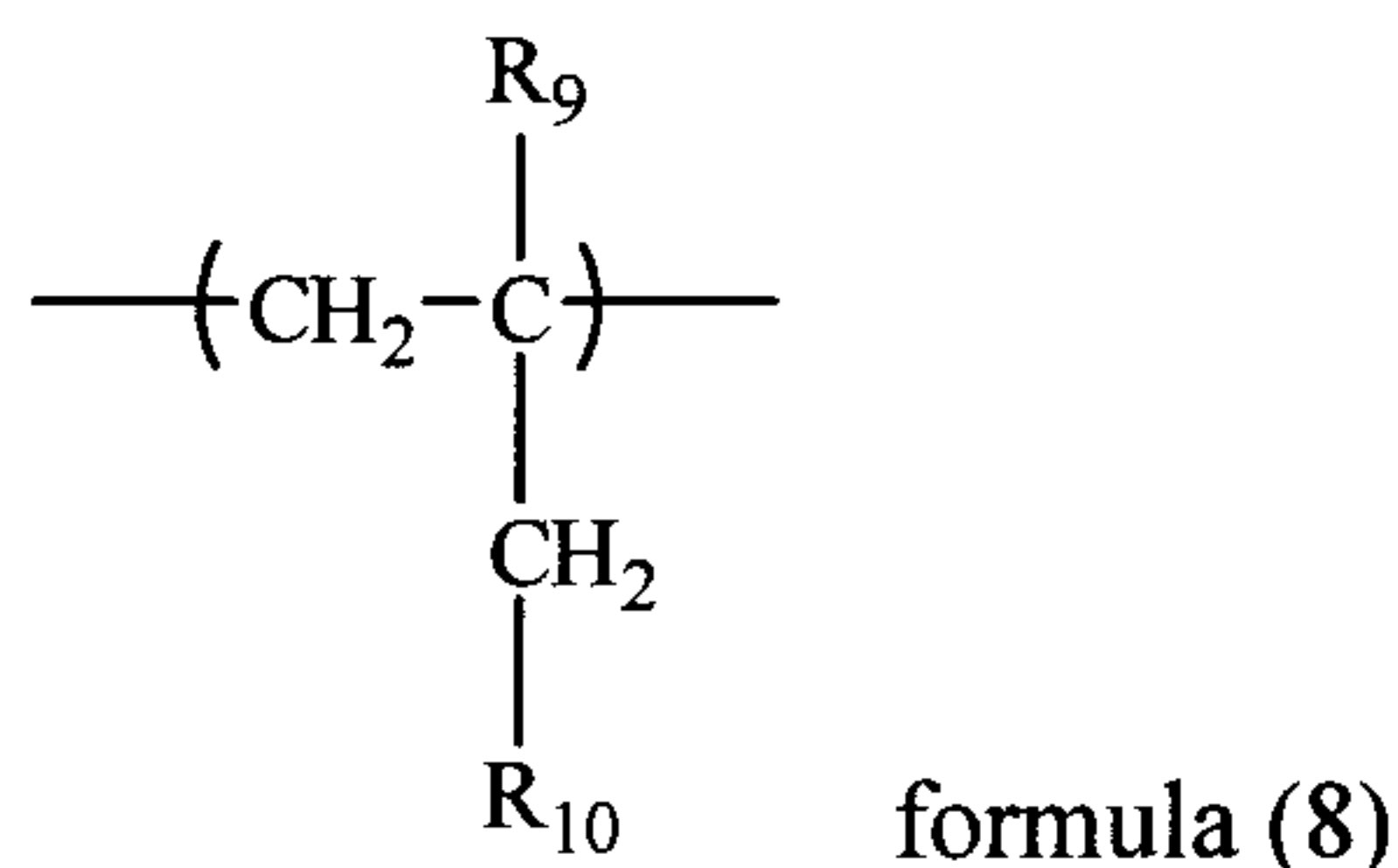
In formula (7), the definition on G is as described above, preferably the structure

of formula (3), ; the definitions

on R<sub>7</sub> and R<sub>8</sub> are as described in formula (4). x and y represent the molar percentages of the structure units in the entire amphiphilic macromolecule repeating units, and x is 0.02-2mol%, preferably 0.02-1.0mol%, more preferably 0.05-0.5mol%; y is

0.05-5mol%, preferably 0.1-2.5mol%, and more preferably 0.1-1.0mol%.

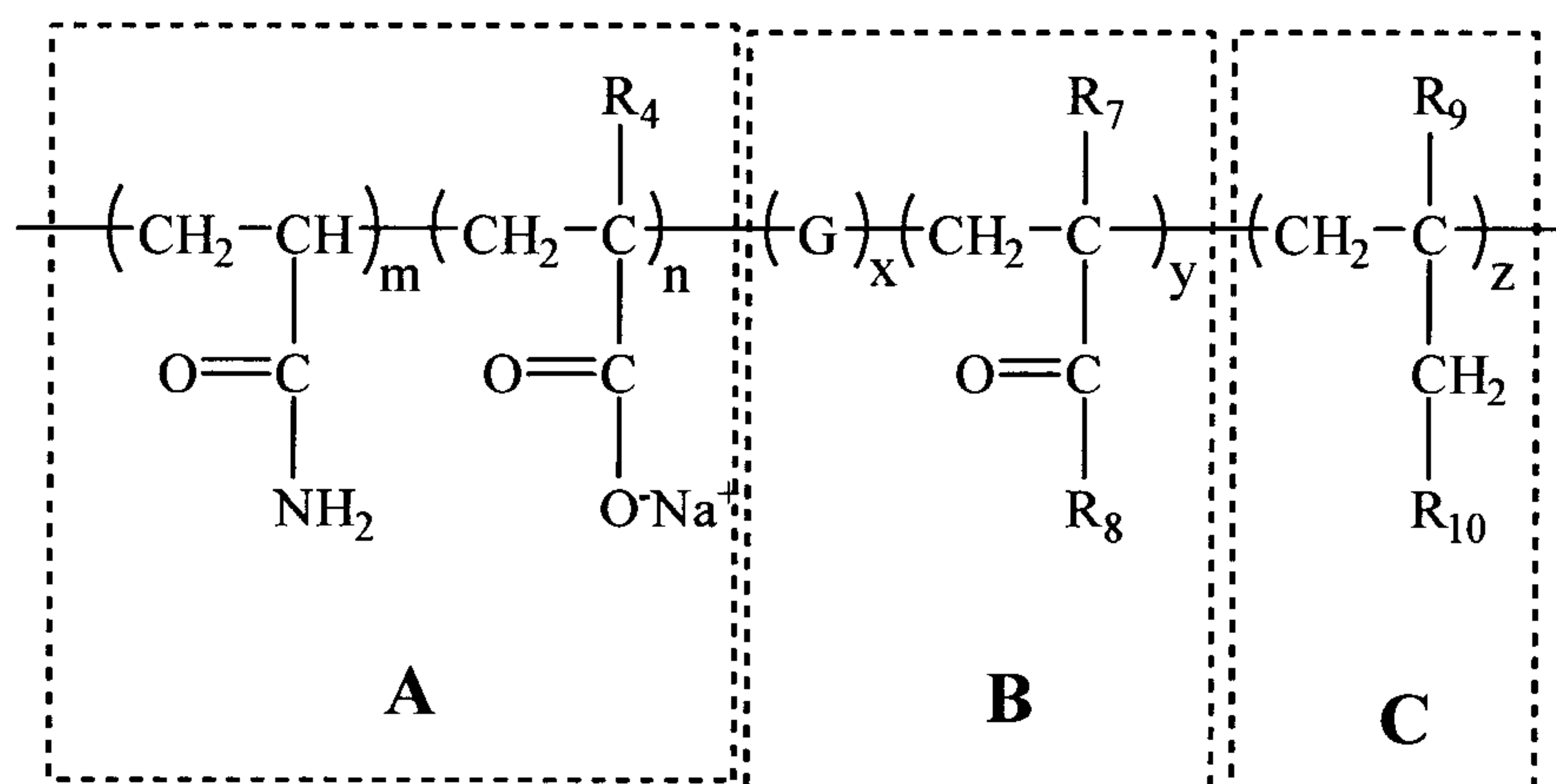
In another embodiment, the amphiphilic structural unit C has a structure of formula (8):



In formula (8), R<sub>9</sub> is H or a methyl group; R<sub>10</sub> is -N<sup>+</sup>(CH<sub>3</sub>)<sub>2</sub>(CH<sub>2</sub>)<sub>ξ</sub>CH<sub>3</sub>X<sup>-</sup>, -N<sup>+</sup>((CH<sub>2</sub>)<sub>σ</sub>CH<sub>3</sub>)<sub>3</sub>X<sup>-</sup> or -N<sup>+</sup>(CH<sub>3</sub>)((CH<sub>2</sub>)<sub>τ</sub>CH<sub>3</sub>)<sub>2</sub>X<sup>-</sup>; ξ is an integer from 3 to 21; σ is an integer from 2 to 9; τ is an integer from 3 to 15; X<sup>-</sup> is Cl<sup>-</sup> or Br<sup>-</sup>. Preferably, ξ is from 3 to 17, σ is from 2 to 5, τ is from 3 to 11.

Preferably, the molar percentage of amphiphilic structural unit C in the entire amphiphilic macromolecule repeating units is 0.05-10mol%; preferably 0.1-5.0mol%, more preferably 0.5-1.8mol%.

In another embodiment, the amphiphilic macromolecule has a structure of formula (9):

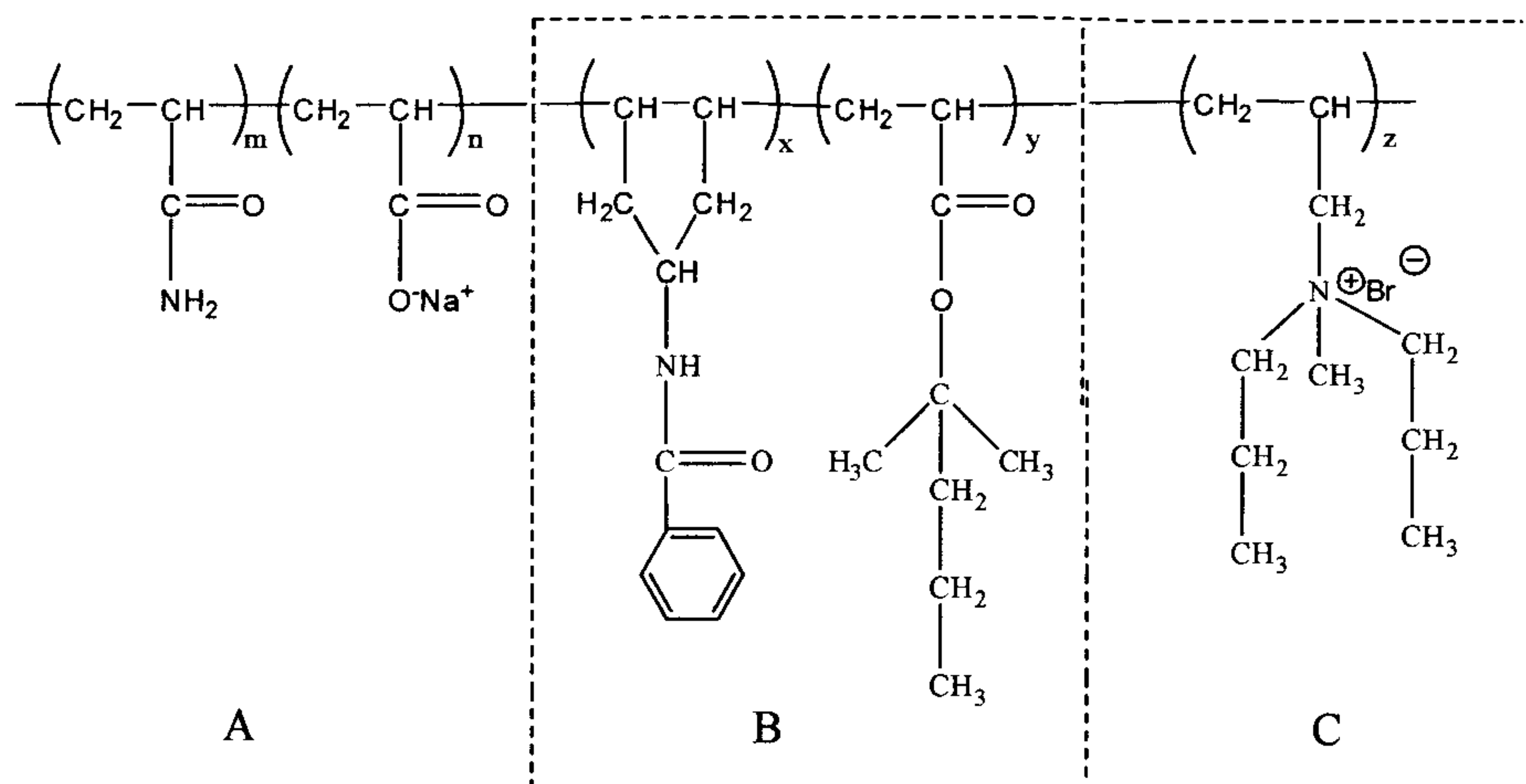
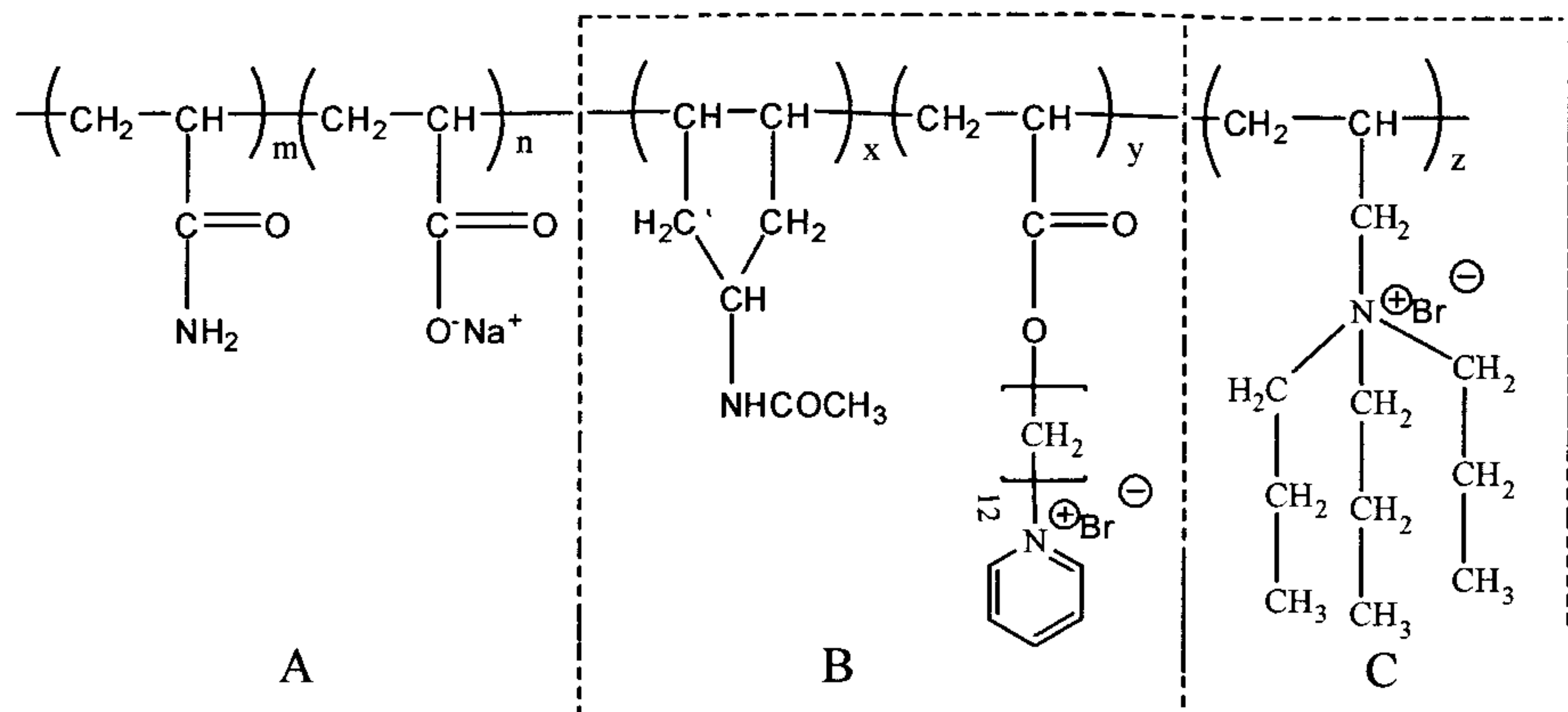
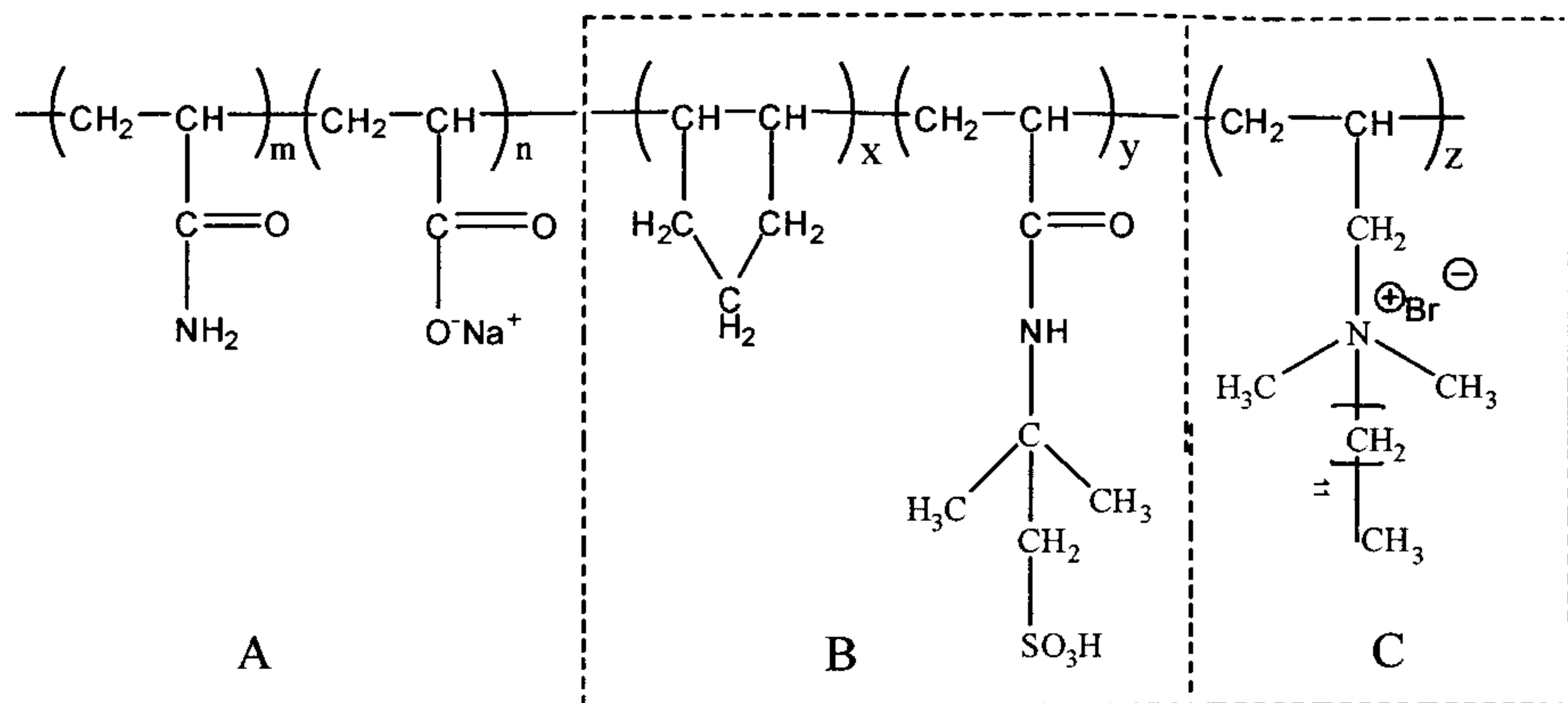


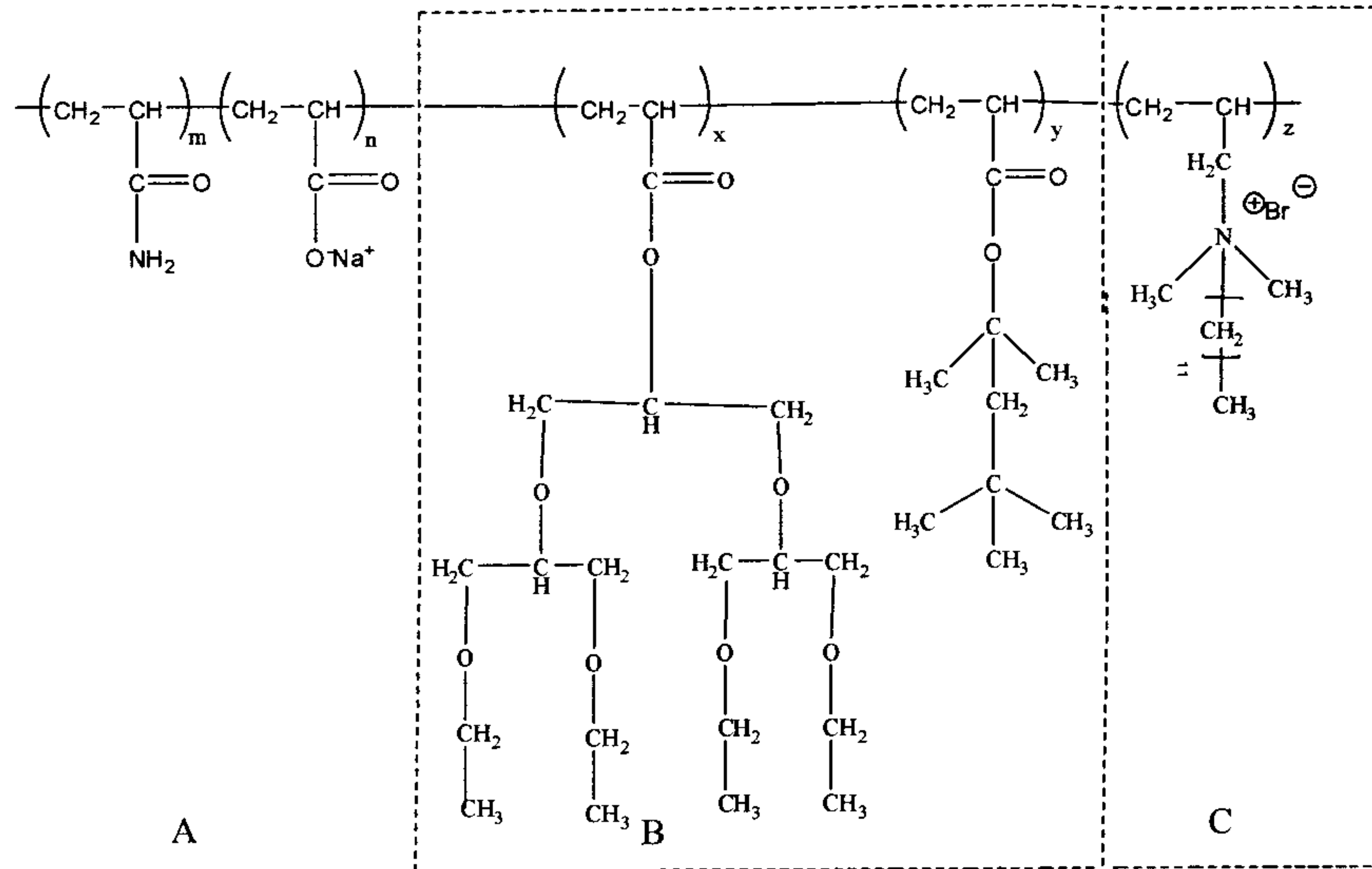
Formula (9)

In formula (9), the definitions on R<sub>4</sub>, m and n are as described in formula (2); the definitions on R<sub>7</sub>, R<sub>8</sub>, G, x and y are as described in formula (7); the definitions on R<sub>9</sub> and R<sub>10</sub> are as described in formula (8); z represents the molar percentage of this structural unit in the entire amphiphilic macromolecule repeat units, and z is 0.05-10

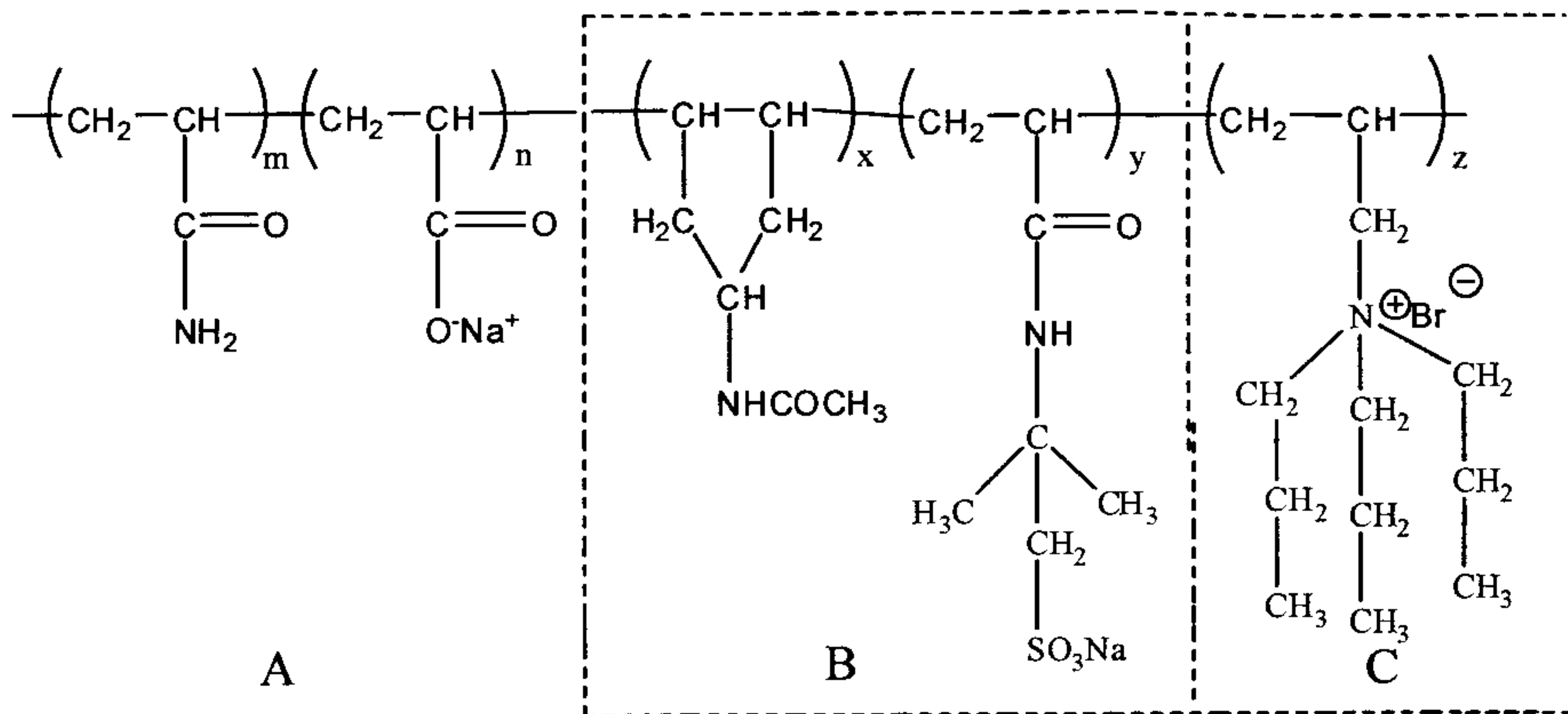
mol%, preferably 0.1-5.0mol%, more preferably 0.5-1.8mol%.

Specifically, this present invention provides a high molecular compound having a structure of formulas (I)-(X):

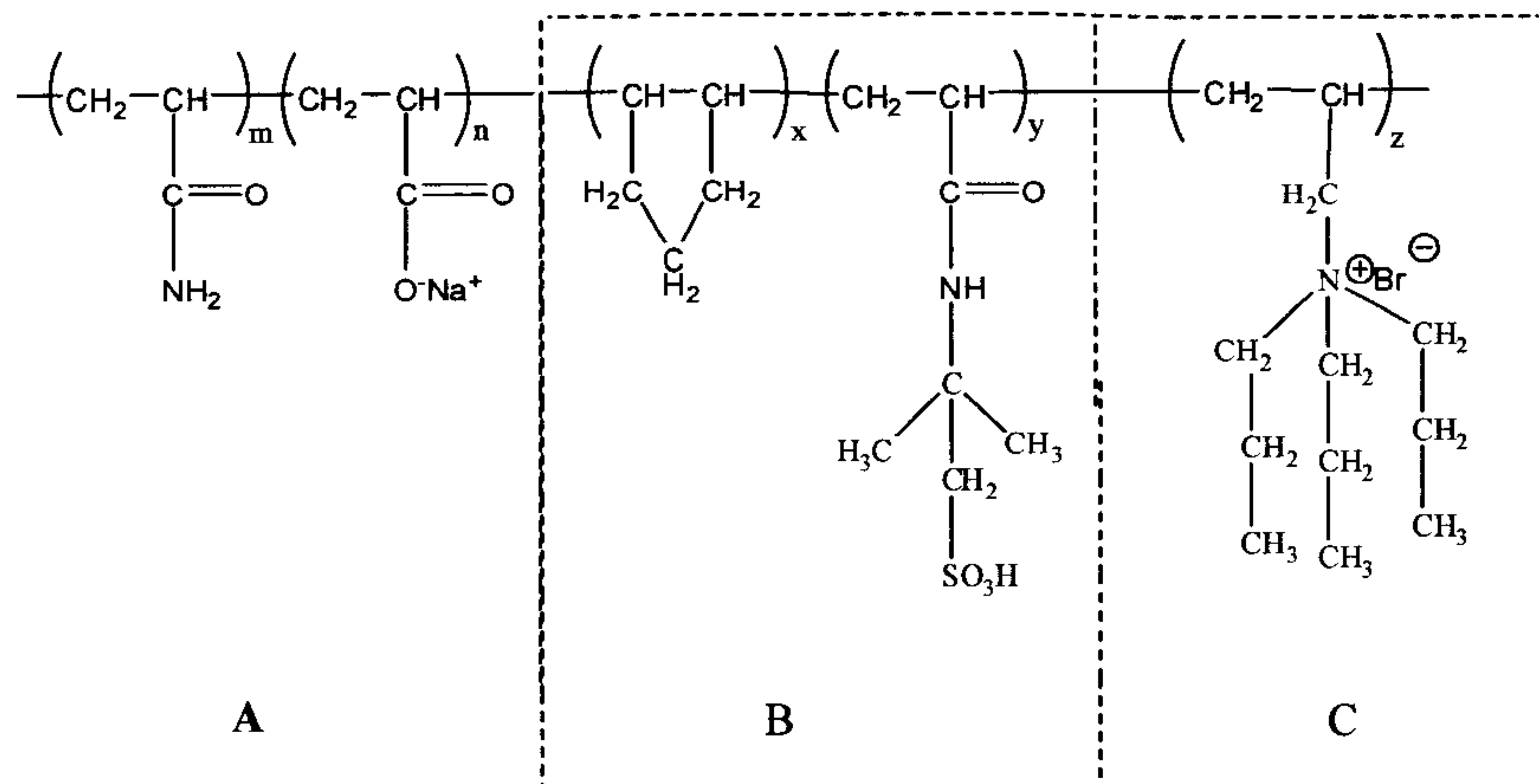




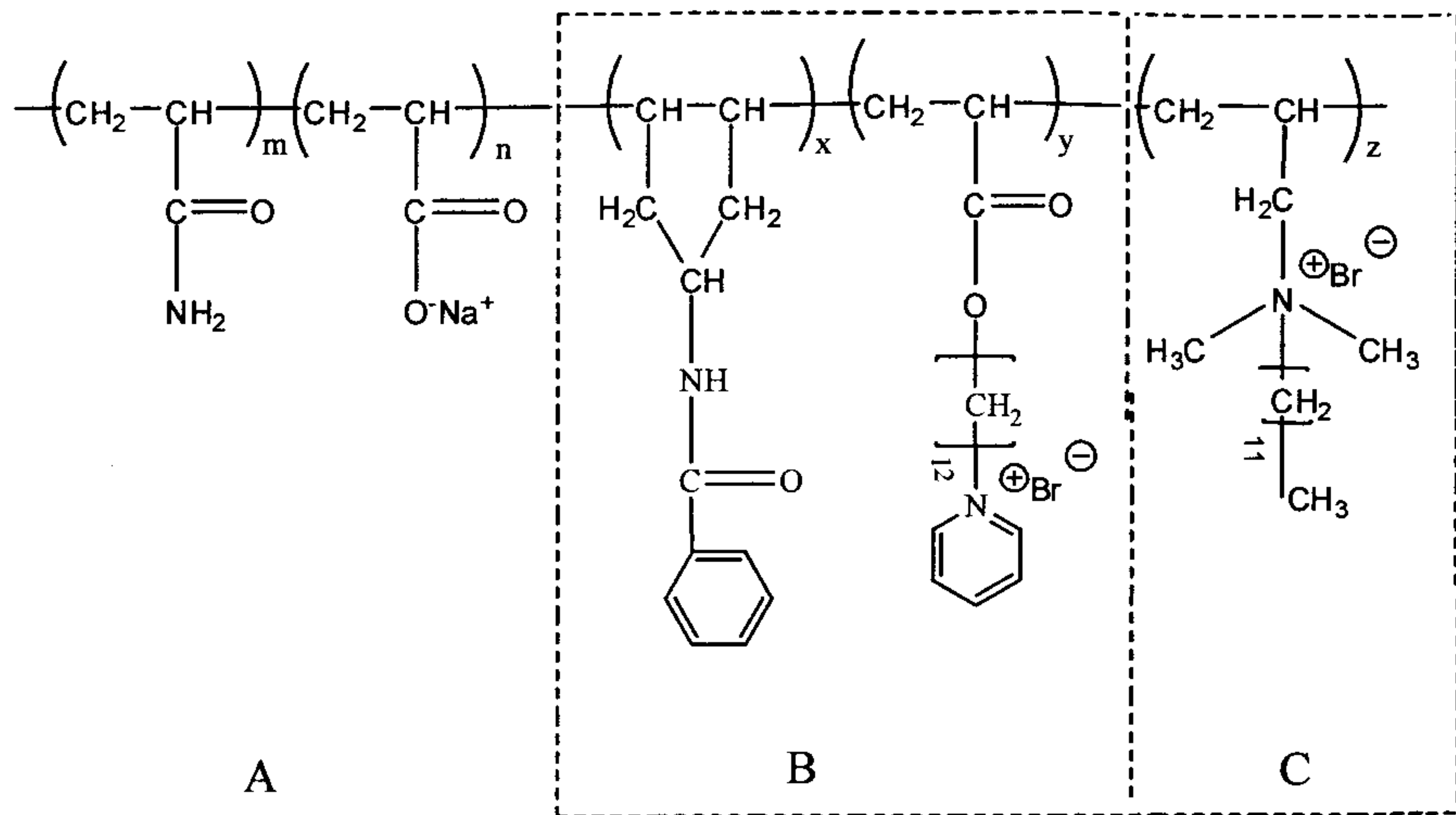
(IV)



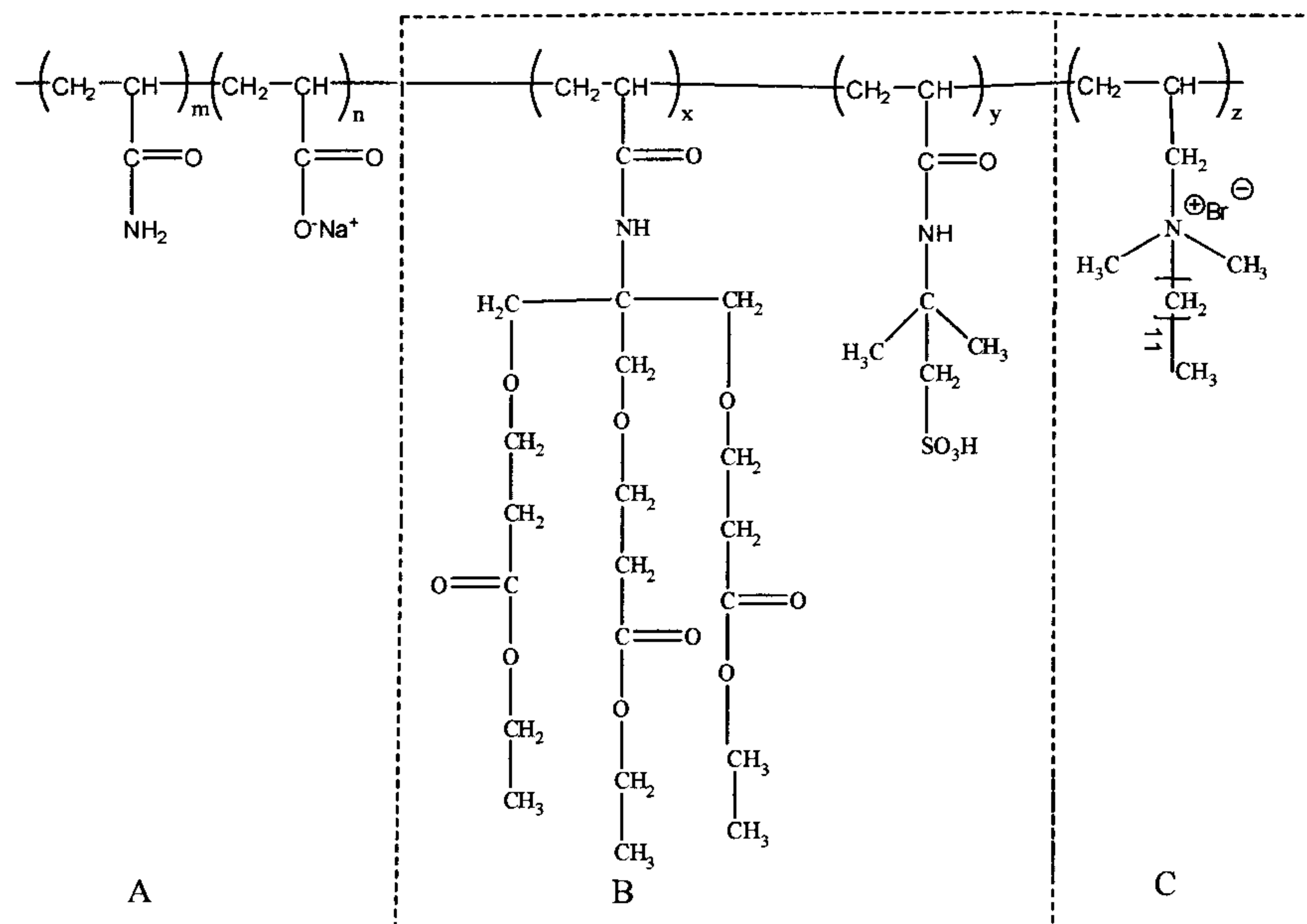
(V)



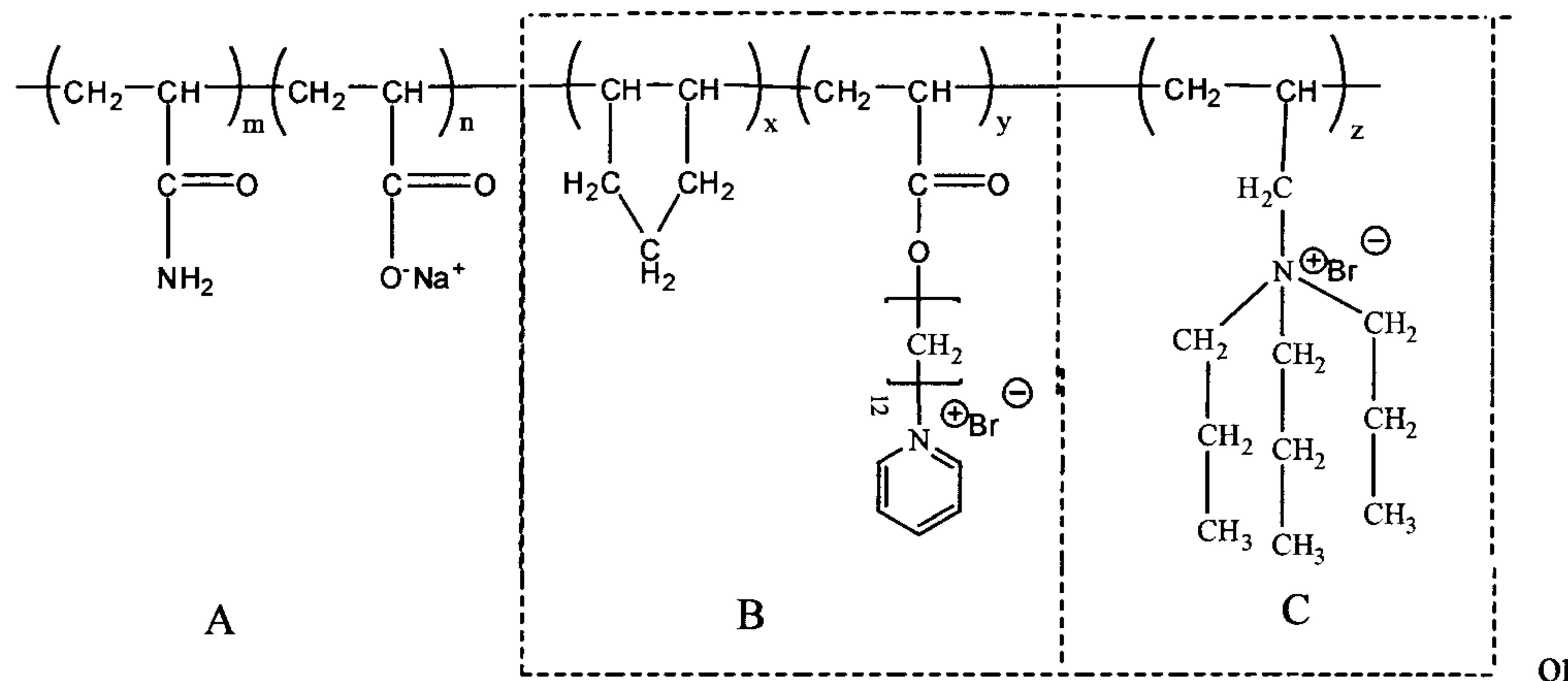
(VI)



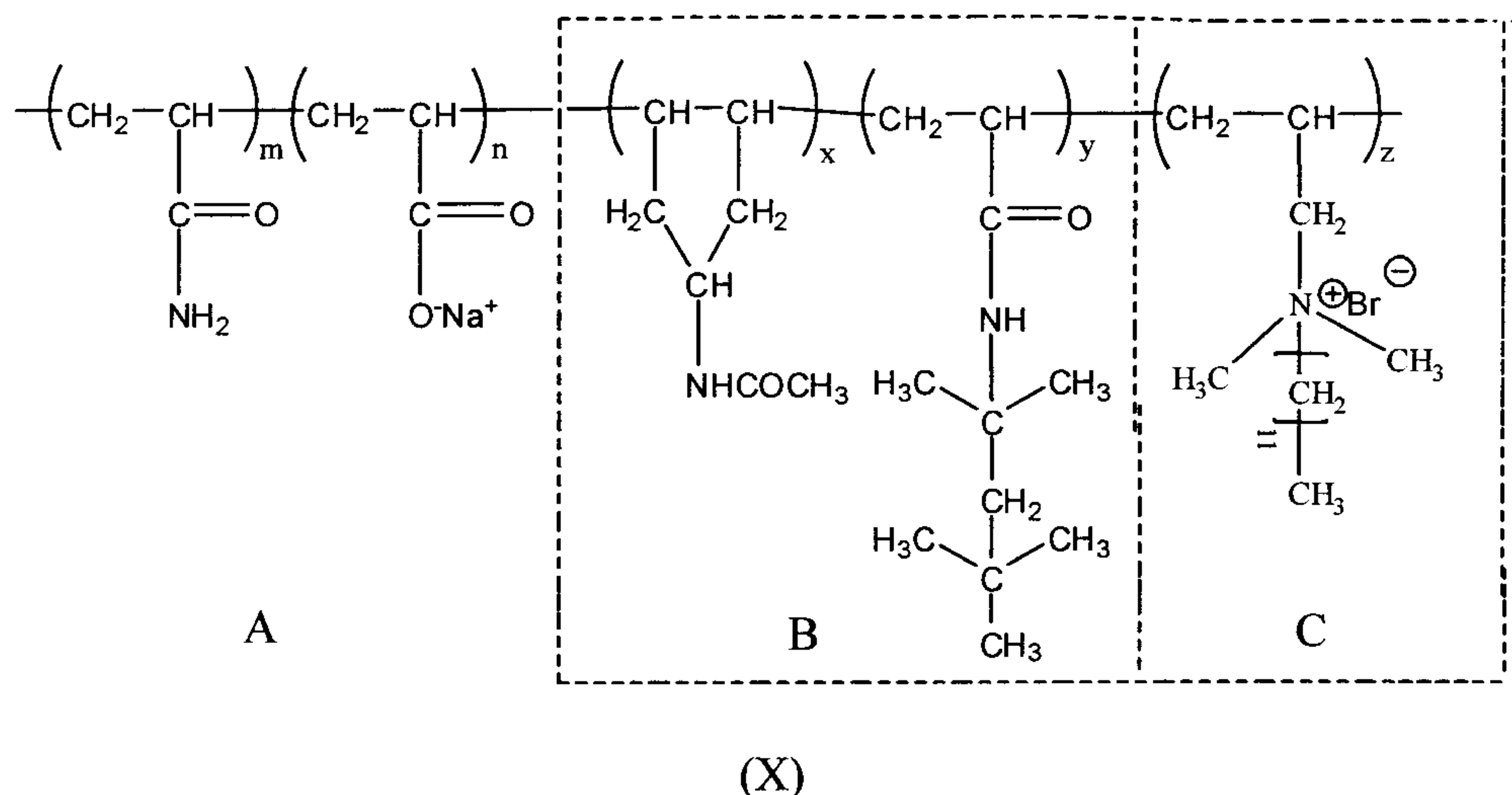
(VII)



(VIII)



(IX)



The molecular weight of the amphiphilic macromolecule described above is between 1000000 and 20000000; preferably between 3000000 and 13000000.

The measurement of the molecular weight  $M$  is as follows: The intrinsic viscosity  $[\eta]$  is measured by Ubbelohde viscometer as known in the art, then the obtained intrinsic viscosity  $[\eta]$  value is used in the following equation to obtain the desired molecular weight  $M$ :

$$M = 802[\eta]^{1.25}$$

The amphiphilic macromolecule according to this present invention can be prepared by known methods in the art, for example, by polymerizing the structural unit for adjusting molecular weight, molecular weight distribution and charge characteristics, the highly sterically hindered structural unit and the amphiphilic structural unit in the presence of an initiator. The polymerization process can be any type well known in the art, such as, suspension polymerization, emulsion polymerization, solution polymerization, precipitation polymerization, and etc.

A typical preparation method is as follows: the above monomers are each dispersed or dissolved in an aqueous system under stirring, the monomer mixture is polymerized by the aid of an initiator under nitrogen atmosphere to form the amphiphilic macromolecule. The so far existing relevant technologies for preparing an amphiphilic macromolecule can all be used to prepare the amphiphilic macromolecule of this invention.

All the monomers for preparing the amphiphilic macromolecule can be commercially available, or can be prepared on the basis of prior art technology directly, and some monomers' synthesis are described in details in specific examples.

### Description of Figures

Figure 1 depicts the relationship of viscosity vs. concentration of the amphiphilic macromolecules obtained from examples 1-5 of the invention in saline having a degree of mineralization of  $3 \times 10^4$  mg/L at a temperature of  $85^\circ\text{C}$ .

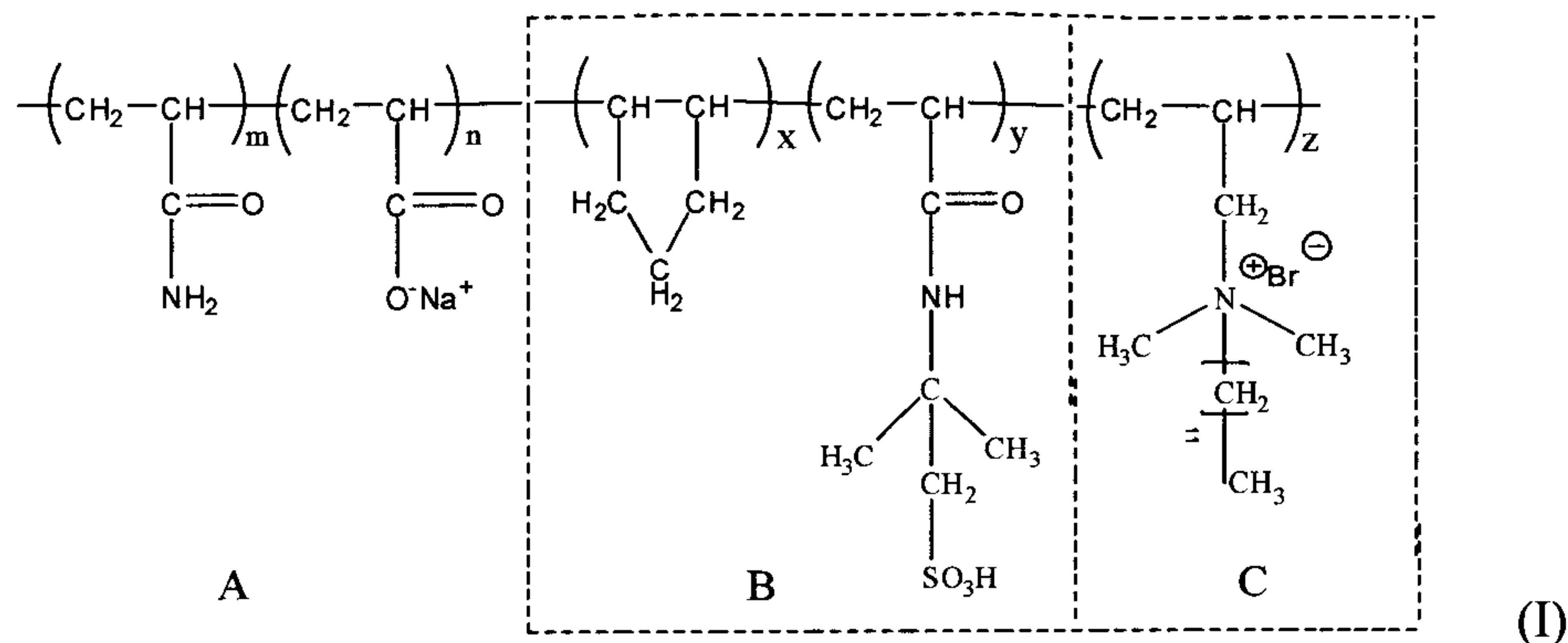
Figure 2 depicts the relationship of viscosity vs. temperature of the amphiphilic macromolecules obtained from the examples 1-5 of the invention in saline having a degree of mineralization of  $3 \times 10^4$  mg/L at the concentration of 1750mg/L.

### Detailed Description of the Invention

The present invention is further illustrated below by combining specific examples; however, this invention is not limited to the following examples.

#### Example 1

This example synthesized the amphiphilic macromolecule of formula (I):



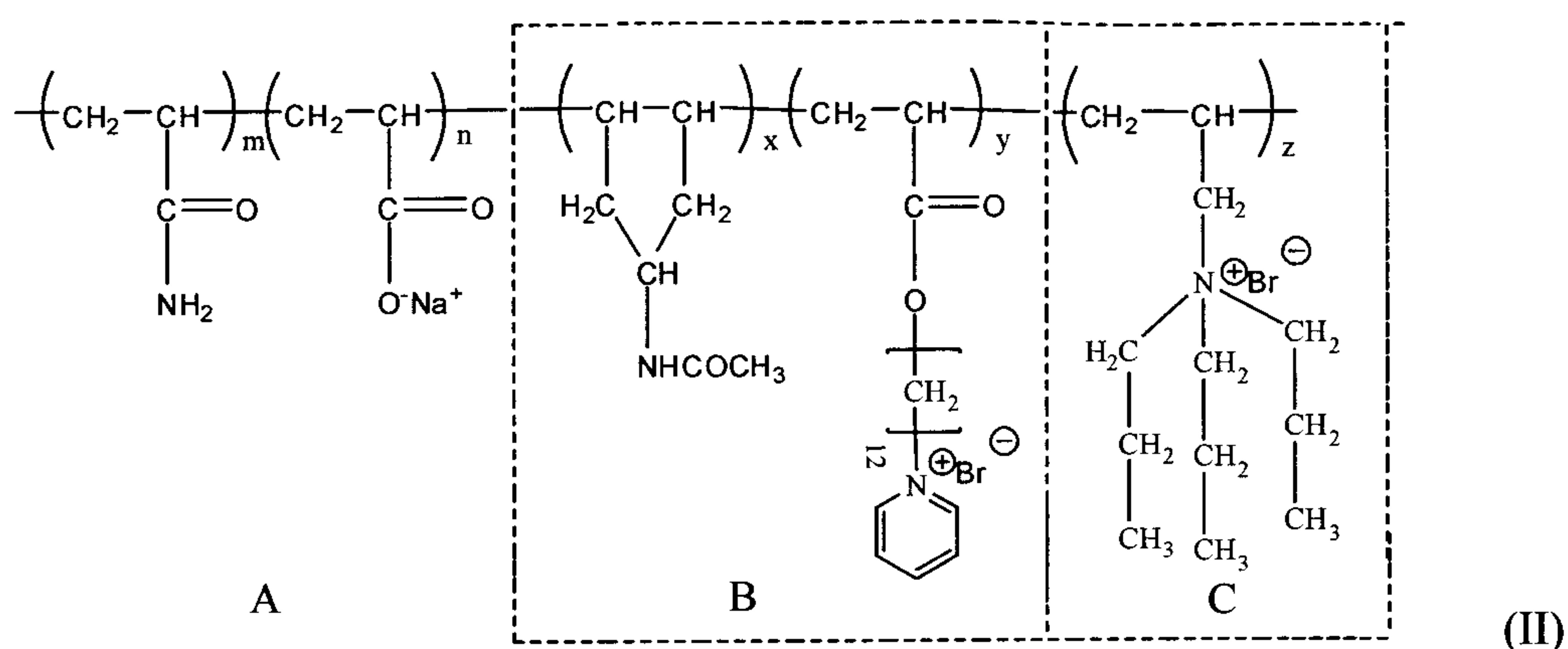
The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 75%, 23%, 0.15%, 0.65%,

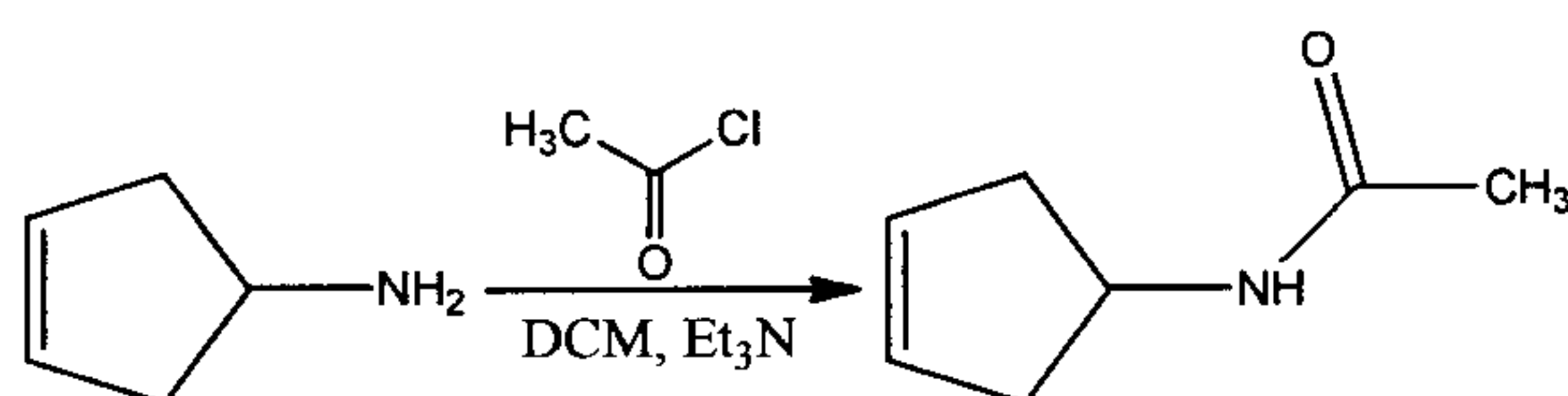
1.2% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 9, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 28°C; after 5 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $1160 \times 10^4$ .

### Example 2

This example synthesized the amphiphilic macromolecule of formula (II).



The synthesis route of the monomer  was as follows::



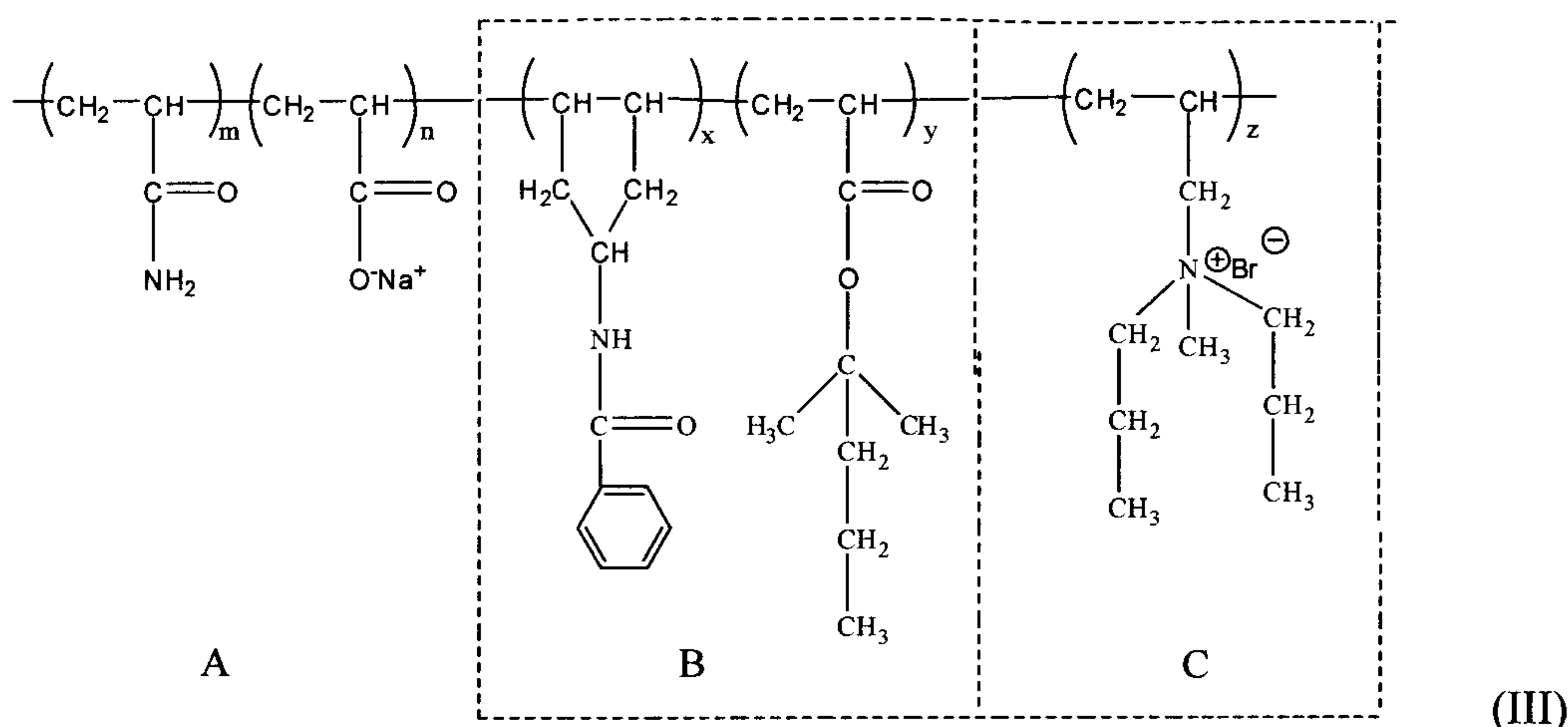
The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 75%, 24%, 0.15%, 0.1%,

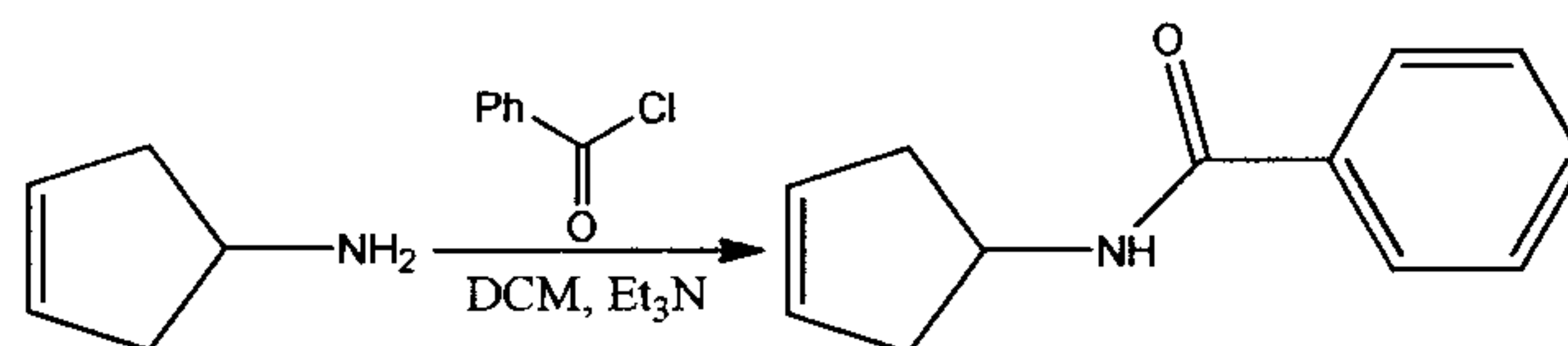
0.75% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 8, then nitrogen gas was introduced in for 40 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 25°C; after 5.5 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $730 \times 10^4$ .

### Example 3

This example synthesized the amphiphilic macromolecule of formula (III):



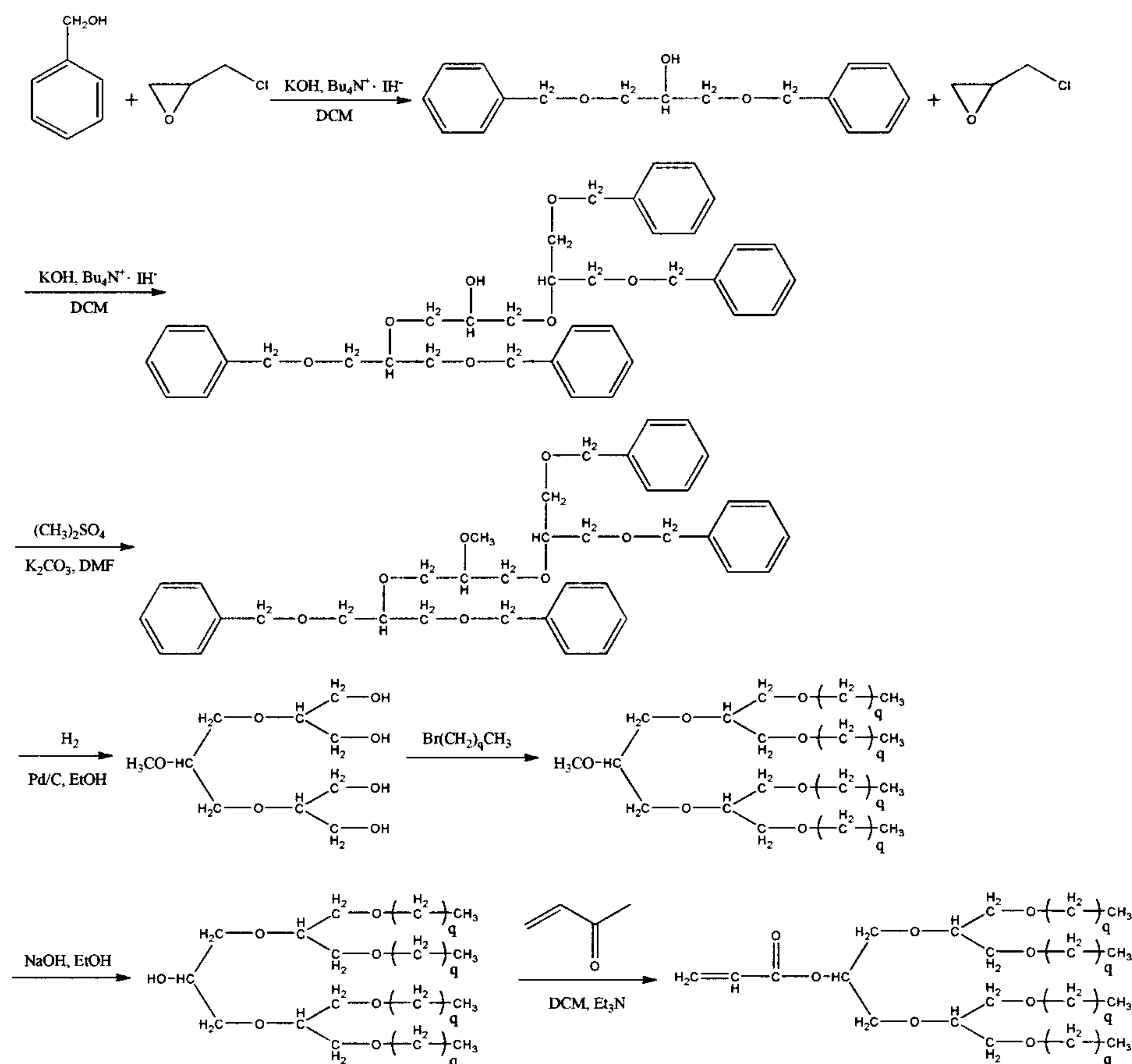
The synthesis route of the monomer  was as follows:



The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 77%, 21%, 0.25%, 0.25%,



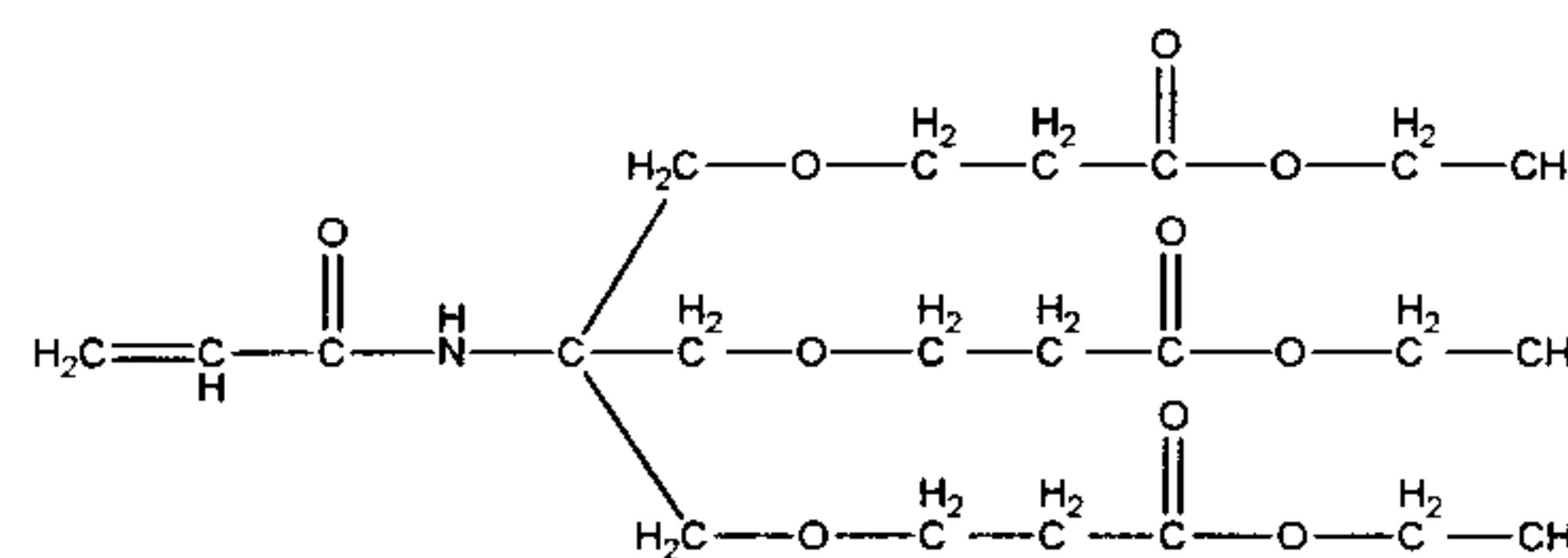
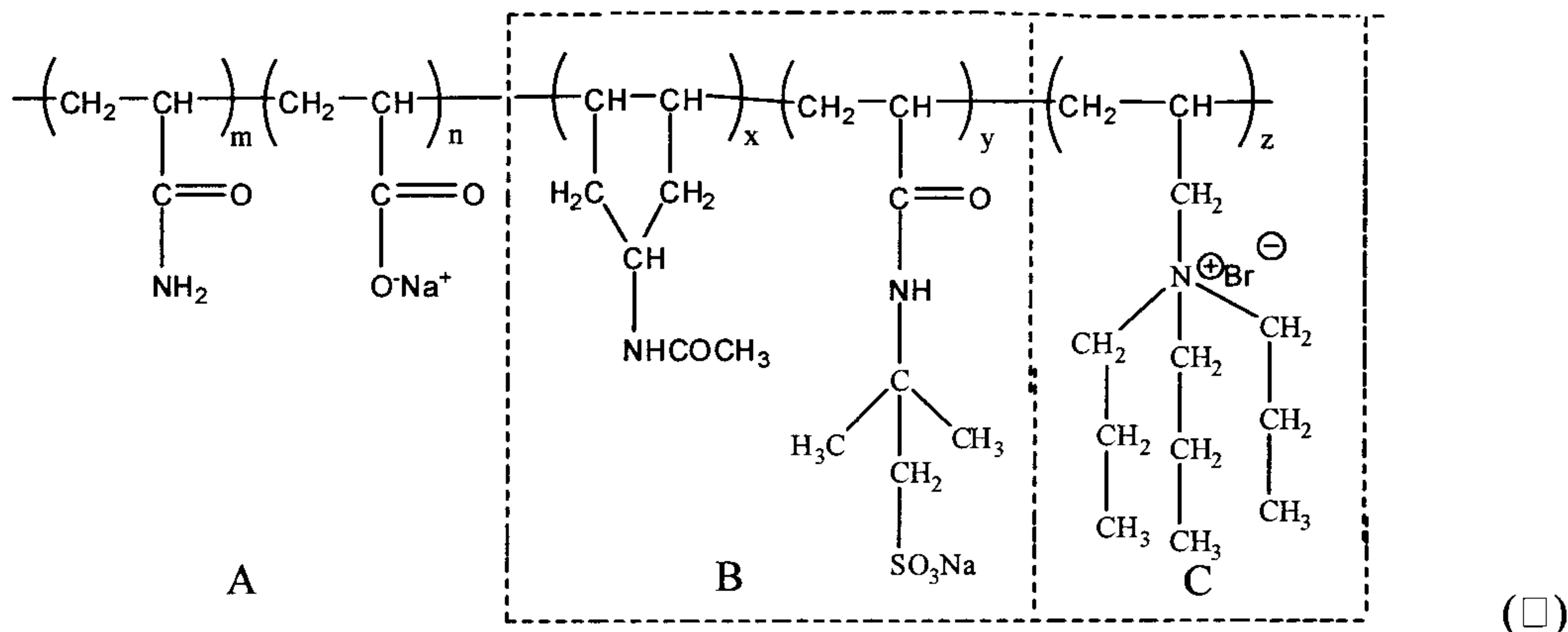


The synthesis of the amphiphilic macromolecule of this example was as follows:

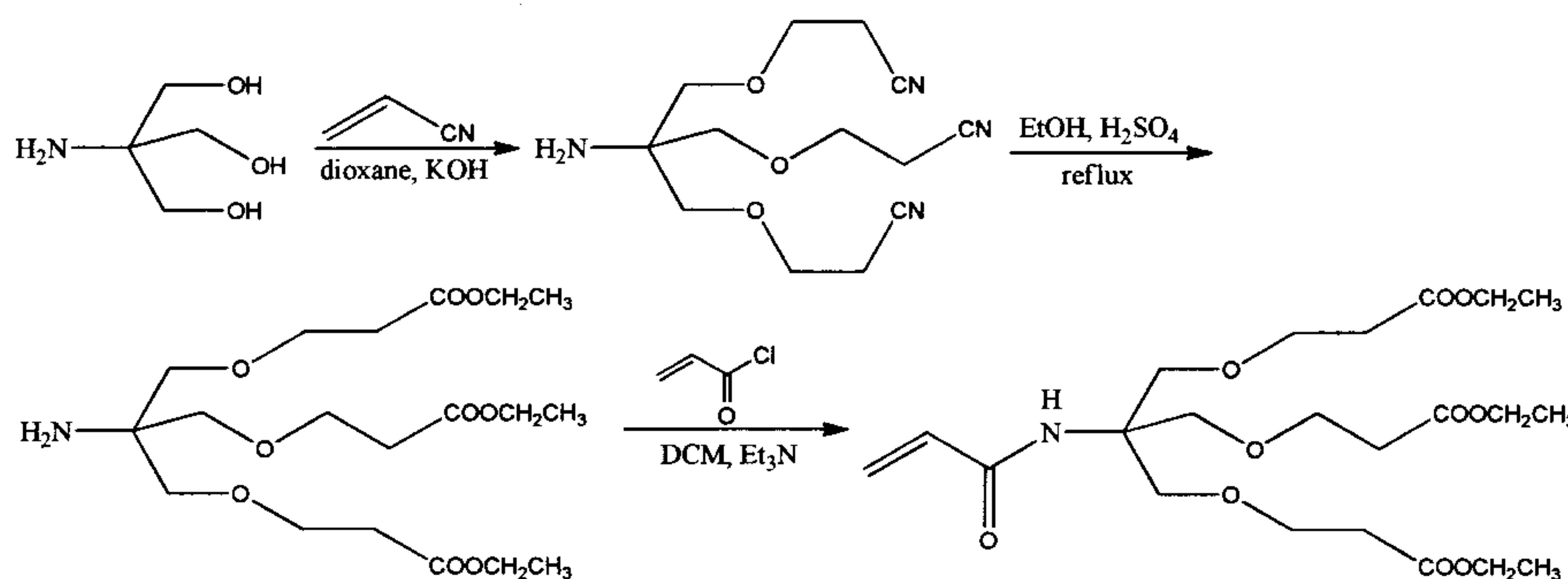
Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 75%, 23%, 0.05%, 0.15%, 1.8% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 9, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of  $28^{\circ}\text{C}$ ; after 5 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $460 \times 10^4$ .

**Example 5**

This example synthesized the amphiphilic macromolecule of formula (V):



The synthesis route of the monomer was as follows



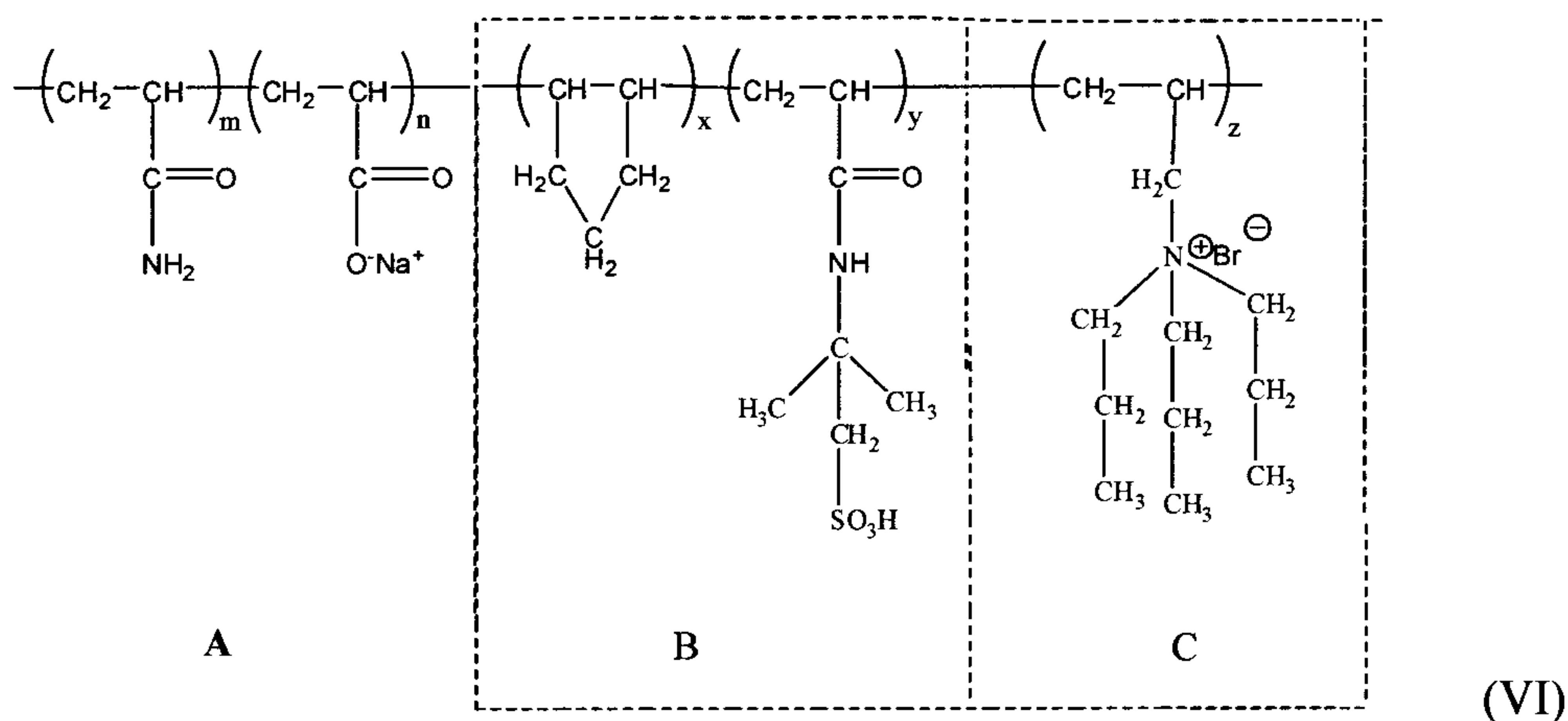
The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 78%, 20%, 0.2%, 1%, 0.8% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 10, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed.

The reaction was conducted at a temperature of 25°C; after 6 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $580 \times 10^4$ .

### Example 6

This example synthesized the amphiphilic macromolecule of formula (VI):

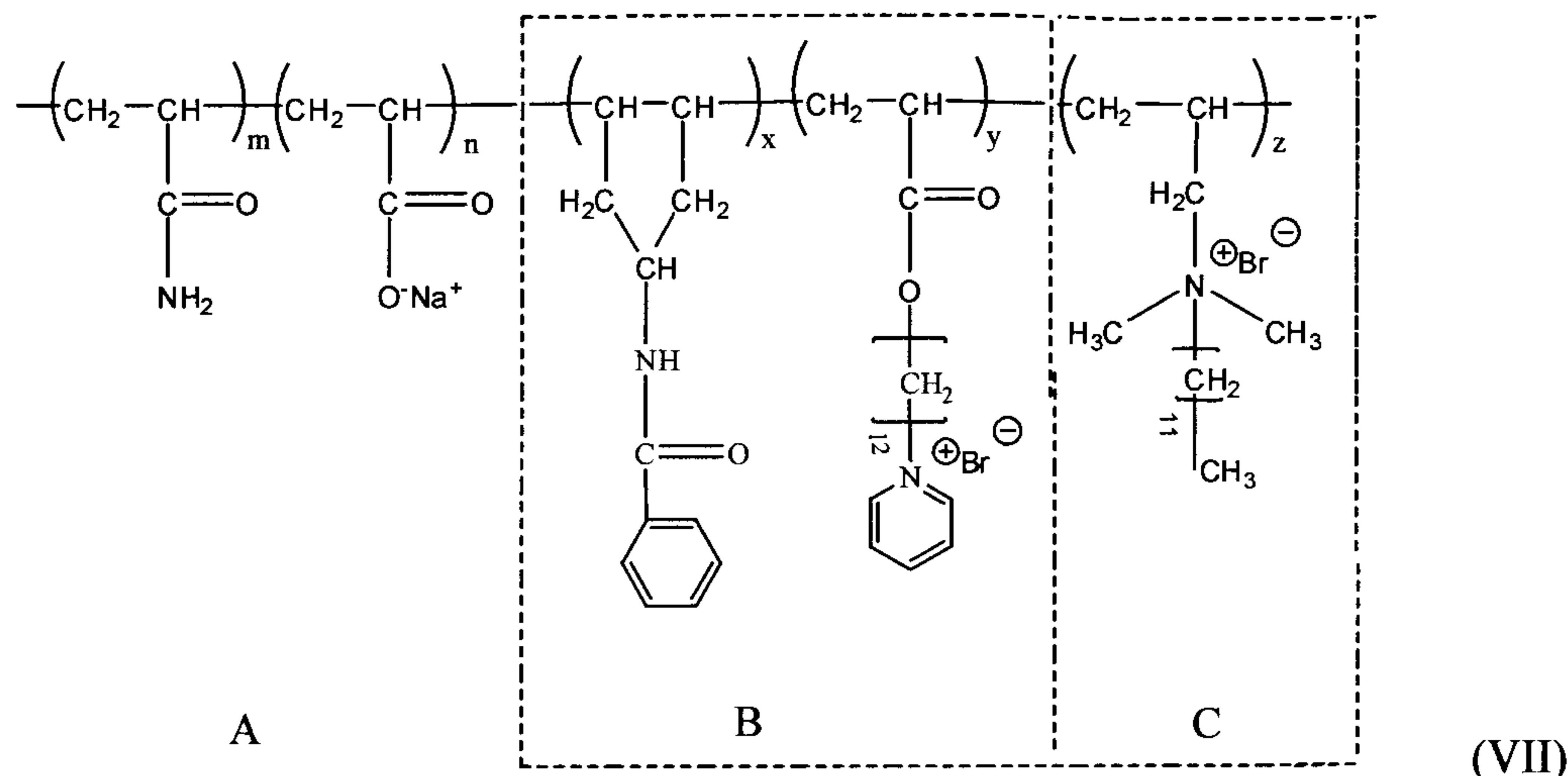


The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 73%, 24%, 0.5%, 1%, 1.5% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 8, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 55°C; after 3 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $770 \times 10^4$ .

**Example 7**

This example synthesized the amphiphilic macromolecule of formula (VII):

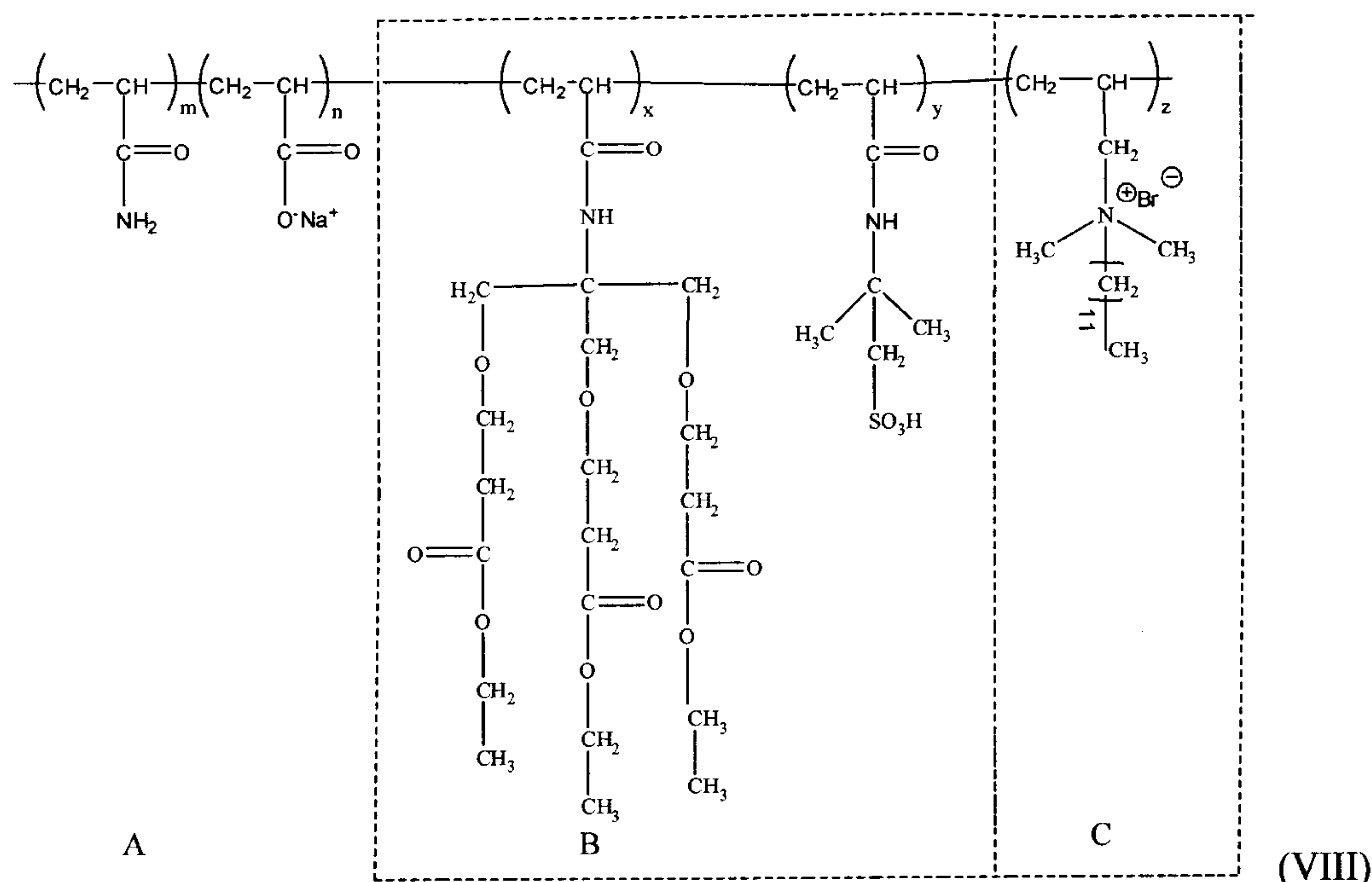


The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 77%, 22%, 0.25%, 0.25%, 0.5% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 9, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 55°C; after 2 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $920 \times 10^4$ .

**Example 8**

This example synthesized the amphiphilic macromolecule of formula (VIII):

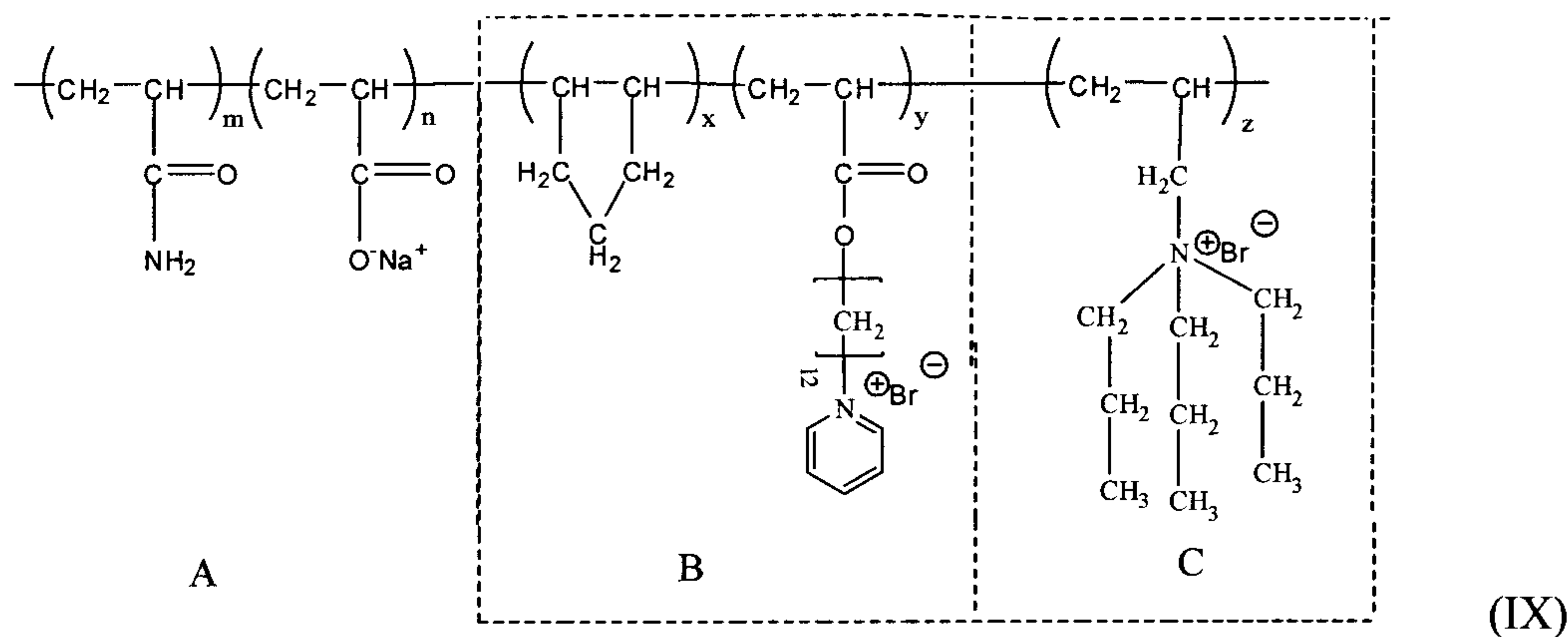


The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 72.85%, 25%, 0.15%, 1%, 1% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 10, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 55°C; after 3 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $430 \times 10^4$ .

### Example 9

This example synthesized the amphiphilic macromolecule of formula (IX):

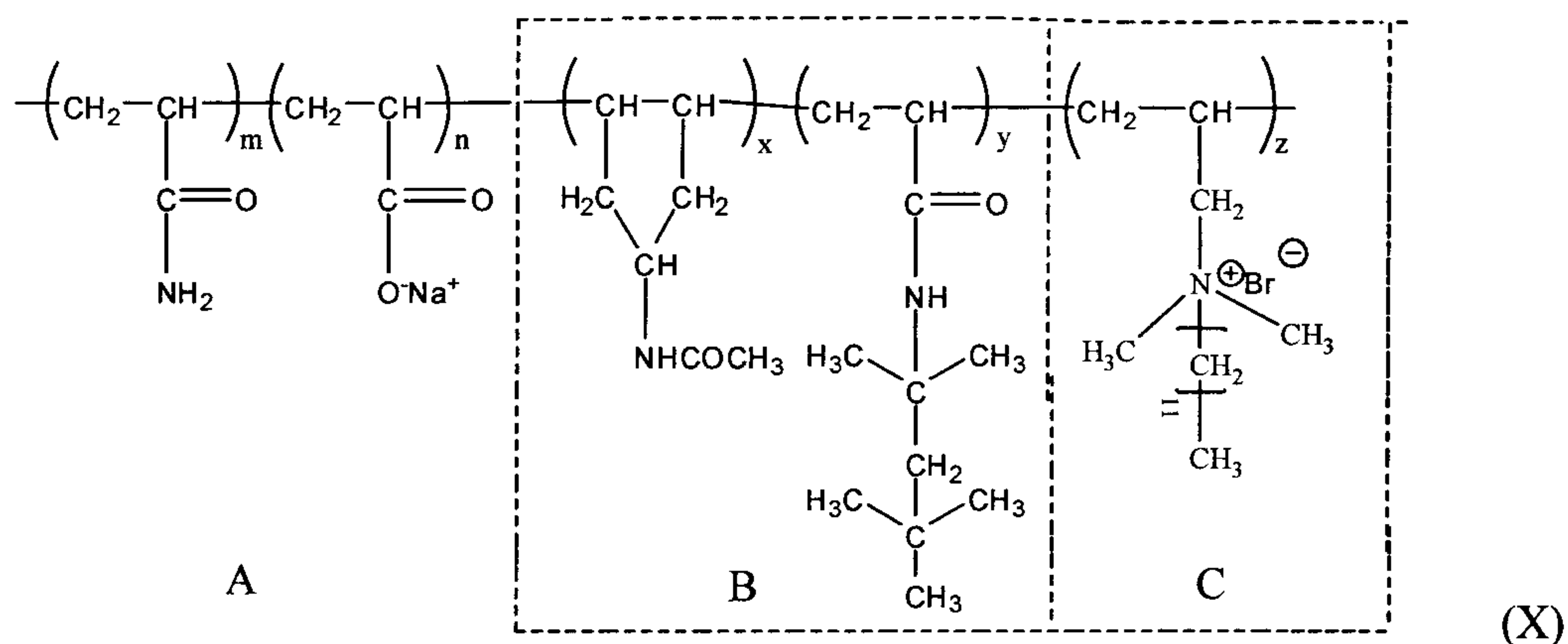


The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 75%, 23%, 0.25%, 0.25%, 1.5% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 8, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 50°C; after 2.5 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $690 \times 10^4$ .

### Example 10

This example synthesized the amphiphilic macromolecule of formula (X):



The synthesis of the amphiphilic macromolecule of this example was as follows:

Firstly, water, accounting for 3/4 of the total weight of the reaction system, was charged into a reactor, then various monomers, totally accounting for 1/4 of the total weight of the reaction system, were charged into the reactor as well, and the molar percentages  $m$ ,  $n$ ,  $x$ ,  $y$ ,  $z$  for each repeating units were 75%, 23%, 0.25%, 0.25%, 1.5% in succession. The mixture was stirred until complete dissolution, and a pH adjusting agent was then added in to adjust the reaction solution to have a pH value of about 8, then nitrogen gas was introduced in for 30 minutes to remove oxygen contained therein. An initiator was added into the reactor under the protection of nitrogen gas, and nitrogen gas was further continued for 10 minutes, then the reactor was sealed. The reaction was conducted at a temperature of 50°C; after 4 hours, the reaction was ended with a complete conversion. After the drying of the obtained product, powdered amphiphilic macromolecule was obtained. The molecular weight of the amphiphilic macromolecule was  $830 \times 10^4$ .

## Measurement Examples

### Measurement Example 1

Saline having a mineralization degree of  $3 \times 10^4$  mg/L was used to prepare amphiphilic macromolecule solutions with different concentrations, and the relationship between the concentration, temperature and the viscosity of the solution was determined. The results were shown in Figure 1 and Figure 2.

The figures showed that the amphiphilic macromolecule solutions of examples

1-5 still have favorable viscosifying capacity under the condition of high temperature and high degree of mineralization. The highly sterically hindered unit in the amphiphilic macromolecule reduced the rotational degree of freedom in the main chain and increased the rigidity of the macromolecule chain, which made the macromolecule chain difficult to curl and tend to stretch out, thus enlarging the hydrodynamic radius of the macromolecule; in the meantime, the amphiphilic structural unit associated each other to form the microdomain by intramolecular- or intermolecular- interaction, thus enhancing the viscosifying capacity of the solution remarkably under the conditions of high temperature and high salinity.

### Measurement Example 2

Testing method: Under a testing temperature of 25□, 25ml electric dehydration crude oil samples from three types of oilfields were added in a 50ml test tube with a plug, then 25ml aqueous solutions of amphiphilic macromolecule with different concentrations formulated with distilled water were added in. The plug of the test tube was tightened, then the test tube was shaken manually or by using an oscillating box for 80-100 times in horizontal direction, and the shaking amplitude should be greater than 20cm. After sufficient mixing, the plug of the test tube was loosed. Viscosity reduction rate for crude oil was calculated according to the following equation:

$$\text{Viscosity reduction rate(\%)} = \frac{\text{viscosity of crude oil sample} - \text{viscosity after mixing}}{\text{viscosity of crude oil sample}} \times 100$$

Table1 Experimental results of the heavy oil viscosity reduction of the amphiphilic macromolecule obtained from the example 6 to example 10 (oil-water ratio 1:1, 25□)

oil-water volume ratio (1:1)	oil sample	viscosity reduction rate(%)	oil sample	viscosity reduction rate(%)	oil sample	viscosity reduction rate(%)
test temperature (25°C)	1		2		3	
initial viscosity	1650	--	5100	--	16000	--

(mPa·s)							
Example 6	400mg/L	730	55.76	1750	65.69	7100	55.63
	600mg/L	470	71.52	1250	75.49	3250	79.69
	800mg/L	330	80.00	950	81.37	1850	88.44
	1000mg/L	295	82.12	820	83.92	1500	90.63
	1200mg/L	270	83.64	675	86.76	1225	92.34
Example 7	400mg/L	780	52.73	1800	64.71	7700	51.88
	600mg/L	590	64.24	1350	73.53	4200	73.75
	800mg/L	460	72.12	1100	78.43	2850	82.19
	1000mg/L	340	79.39	880	82.75	1900	88.13
	1200mg/L	300	81.82	790	84.51	1500	90.63
Example 8	400mg/L	820	50.30	1475	71.08	5650	64.69
	600mg/L	590	64.24	1200	76.47	3950	75.31
	800mg/L	450	72.73	850	83.33	2600	83.75
	1000mg/L	375	77.27	670	86.86	1450	90.94
	1200mg/L	330	80.00	620	87.84	1290	91.94
Example 9	400mg/L	780	52.73	1450	71.57	5800	63.75
	600mg/L	450	72.73	1150	77.45	4100	74.38
	800mg/L	360	78.18	850	83.33	2500	84.38
	1000mg/L	280	83.03	680	86.67	1570	90.19
	1200mg/L	260	84.24	620	87.84	1390	91.31
Example 10	400mg/L	710	56.97	1450	71.57	5270	67.06
	600mg/L	500	69.70	1050	79.41	3100	80.63
	800mg/L	410	75.15	830	83.73	1890	88.19
	1000mg/L	320	80.61	675	86.76	1200	92.50
	1200mg/L	270	83.64	650	87.25	950	94.06

Table 1 showed that the amphiphilic macromolecules of examples 6-10 had good

effects for viscosity reduction as to all three oil samples. With the increase of the concentration of the amphiphilic macromolecule solution, the viscosity reduction rate increased. And, when the concentration of the amphiphilic macromolecule solution was the same, the viscosity reduction rate increased with the enhancing of the viscosity of the oil sample. It was believed that the amphiphilic macromolecule could reduce the viscosity of the crude oil remarkably via a synergetic effect between the highly sterically hindered structural unit and the amphiphilic structural unit, which could emulsify and disperse the crude oil effectively.

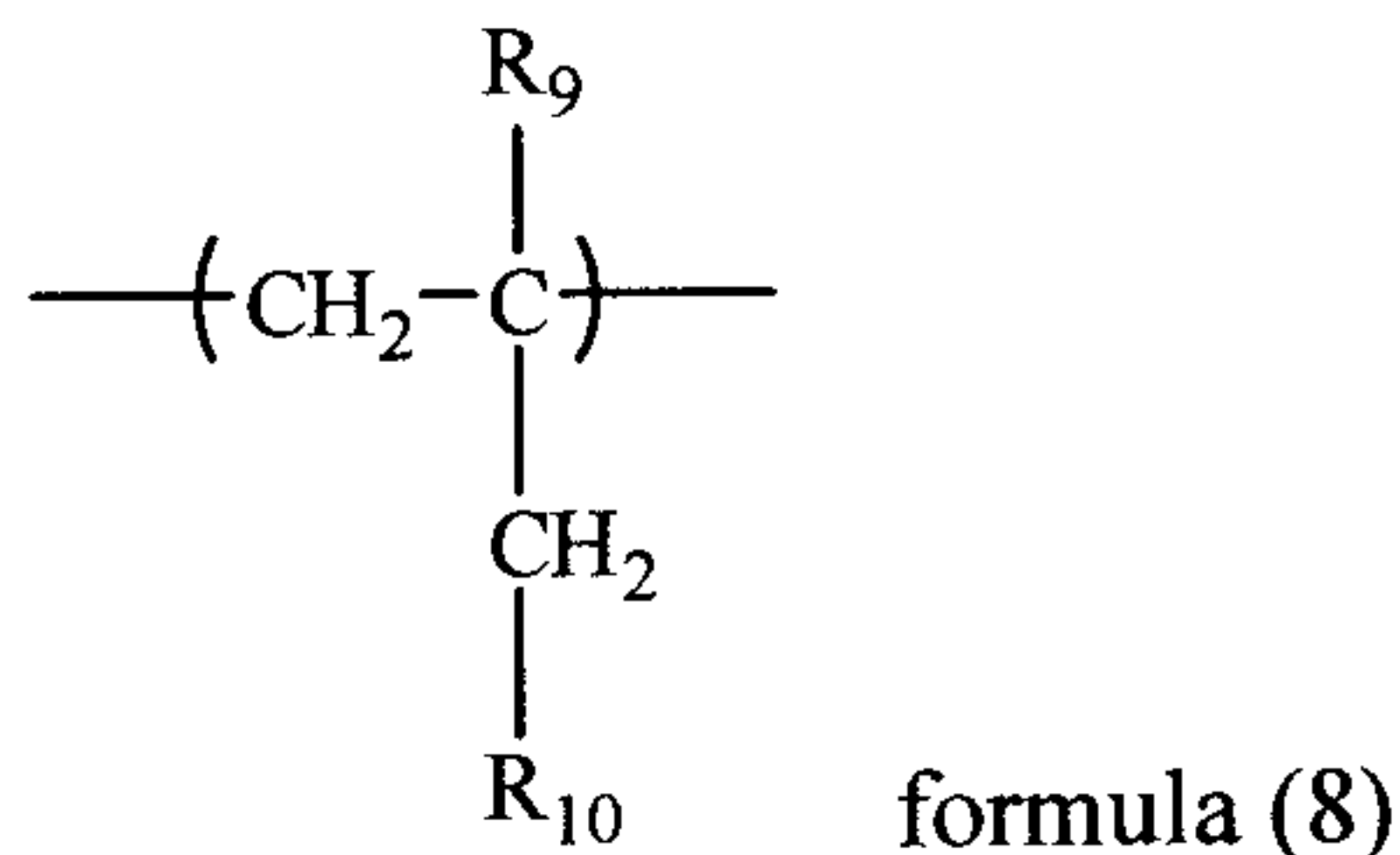
### **Industrial Application**

The amphiphilic macromolecule of this invention can be used in oilfield drilling, well cementing, fracturing, crude oil gathering and transporting, sewage treating, sludge treating and papermaking, and it can be used as intensified oil producing agent and oil displacing agent, heavy oil viscosity reducer, fracturing fluid, clay stabilizer, sewage treating agent, retention aid and drainage aid and strengthening agent for papermaking.

The amphiphilic macromolecule of this invention is especially suitable for crude oil exploitation, for instance, it can be used as an intensified oil displacement polymer and a viscosity reducer for heavy oil. When it is used as an oil displacement agent, it has remarkable viscosifying effect even under the condition of high temperature and high salinity, and can thus enhance the crude oil recovery. When it is used as a viscosity reducer for heavy oil, it can remarkably reduce the viscosity of the heavy oil and decrease the flow resistance thereof in the formation and wellbore by emulsifying and dispersing the heavy oil effectively.

What is claimed is:

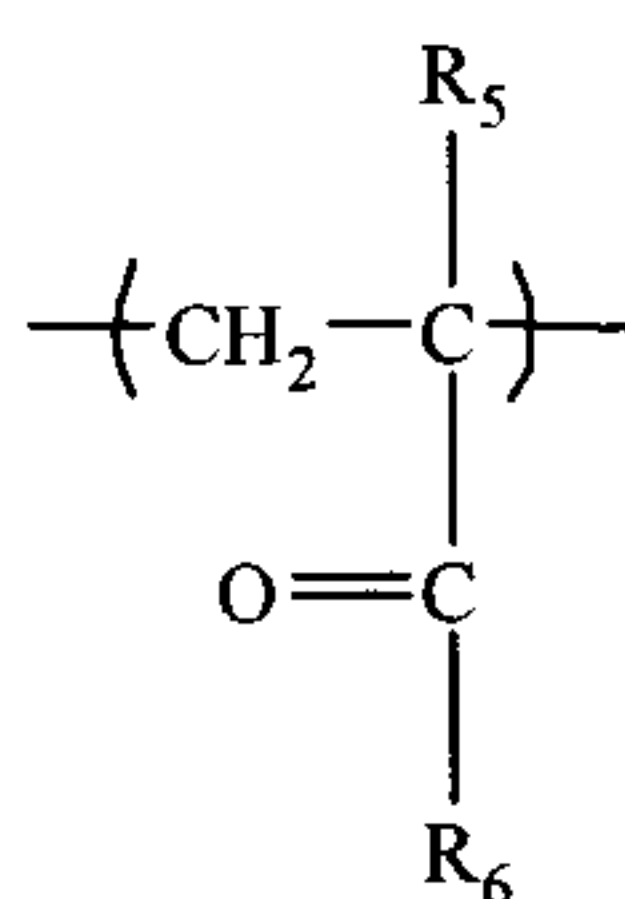
1. An amphiphilic macromolecule, characterized in that: as repeating units, it has a structural unit A for adjusting molecular weight, molecular weight distribution and charge characteristics, a highly sterically hindered structural unit B and an amphiphilic structural unit C, wherein the amphiphilic structural unit C has a structure of formula (8):



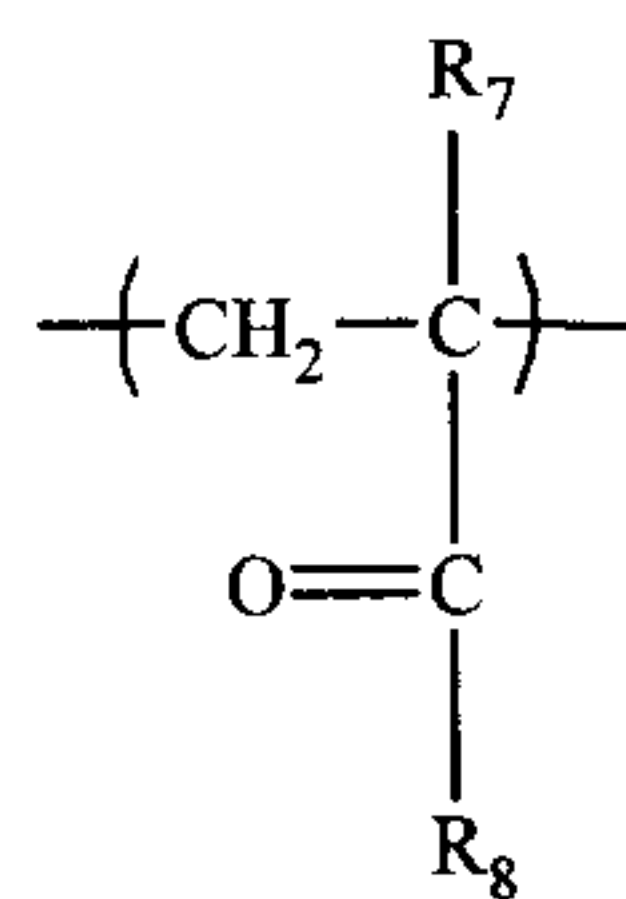
in formula (8), R<sub>9</sub> is H or a methyl group; R<sub>10</sub> is -N<sup>+</sup>(CH<sub>3</sub>)<sub>2</sub>(CH<sub>2</sub>)<sub>ξ</sub>CH<sub>3</sub>X<sup>-</sup>, -N<sup>+</sup>((CH<sub>2</sub>)<sub>σ</sub>CH<sub>3</sub>)<sub>3</sub>X<sup>-</sup> or -N<sup>+</sup>(CH<sub>3</sub>)((CH<sub>2</sub>)<sub>τ</sub>CH<sub>3</sub>)<sub>2</sub>X<sup>-</sup>; ξ is an integer from 3 to 21; σ is an integer from 2 to 9; τ is an integer from 3 to 15; and X<sup>-</sup> is Cl<sup>-</sup> or Br<sup>-</sup>.

2. The amphiphilic macromolecule as claimed in Claim 1, characterized in that, the structural unit A for adjusting the molecular weight, molecular weight distribution and charge characteristics comprises a (meth)acrylamide monomer unit A<sub>1</sub> and /or a (meth)acrylic monomer unit A<sub>2</sub>.

3. The amphiphilic macromolecule as claimed in Claim 1, characterized in that, the highly sterically hindered structural unit B contains a structure G, the structure G is a cyclic hydrocarbon structure formed on the basis of two adjacent carbon atoms in the main chain, or is selected from a structure of formula (3), and the highly sterically hindered structural unit B optionally contains a structure of formula (4):

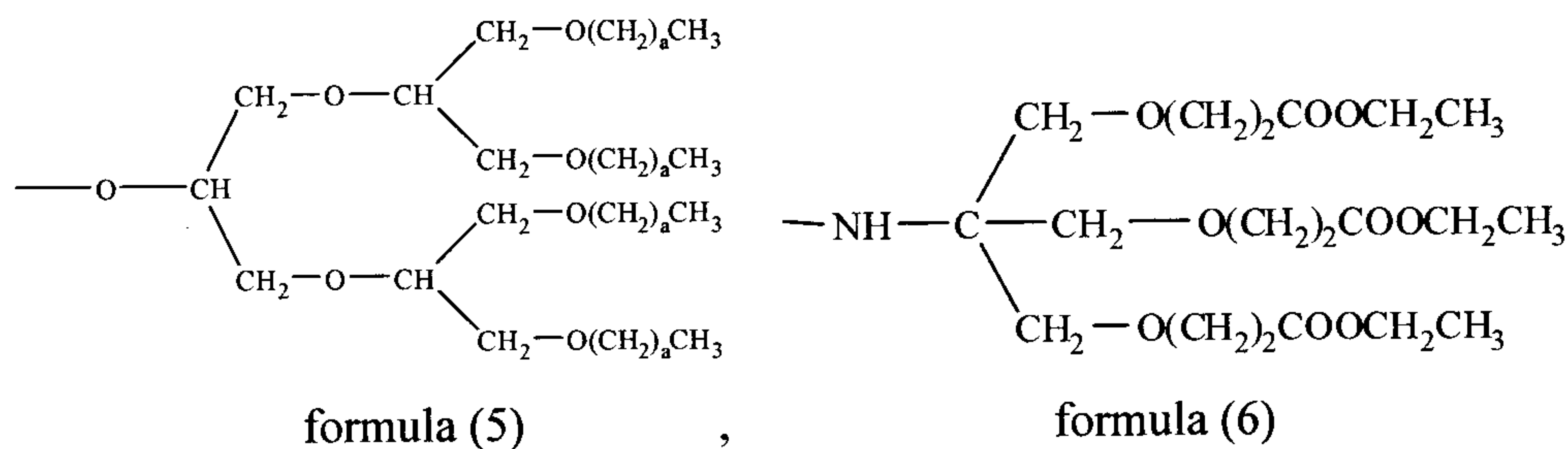


formula (3), and



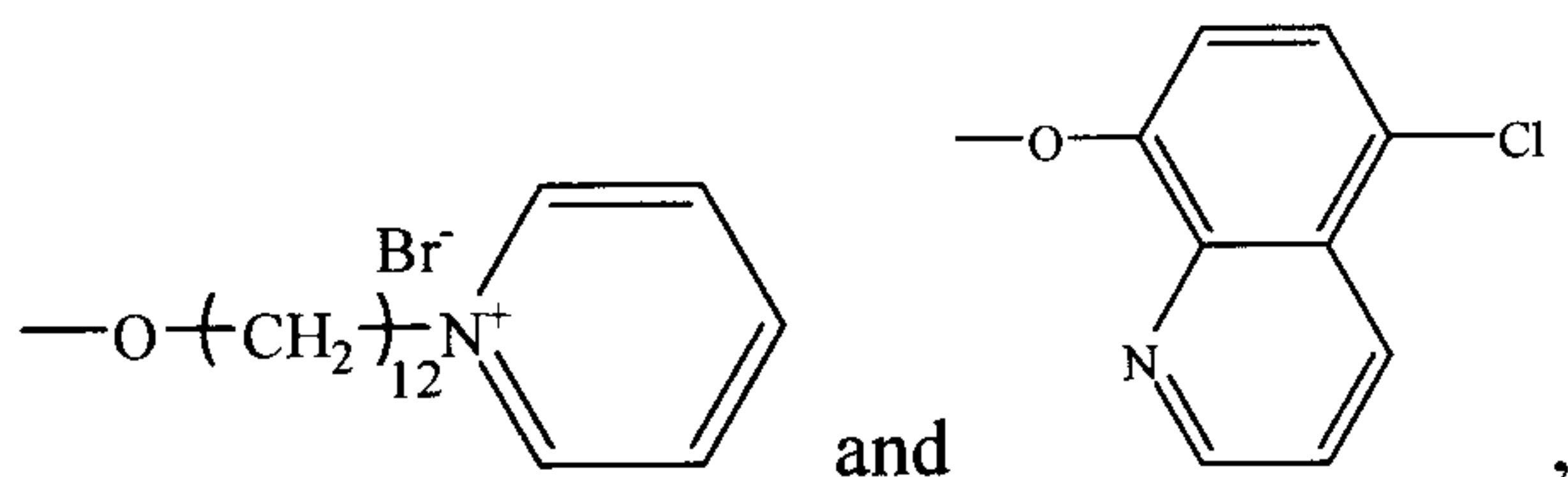
formula (4)

wherein in formula (3),  $R_5$  is H or a methyl group;  $R_6$  is a radical selected from the structures of formula (5) and formula (6),



in formula (5), a is an integer from 1 to 11,

in formula (4),  $R_7$  is H or a methyl group;  $R_8$  is selected from the group consisting of -NHPHOH, -OCH<sub>2</sub>Ph, -OPHOH, -OPhCOOH and salts thereof, -NHC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>SO<sub>3</sub>H and salts thereof, -OC(CH<sub>3</sub>)<sub>2</sub>(CH<sub>2</sub>)<sub>b</sub>CH<sub>3</sub>, -NHC(CH<sub>3</sub>)<sub>2</sub>(CH<sub>2</sub>)<sub>c</sub>CH<sub>3</sub>, -OC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>C(CH<sub>3</sub>)<sub>2</sub>(CH<sub>2</sub>)<sub>d</sub>CH<sub>3</sub>, -NHC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>C(CH<sub>3</sub>)<sub>2</sub>(CH<sub>2</sub>)<sub>e</sub>CH<sub>3</sub>, -O(CH<sub>2</sub>)<sub>f</sub>N<sup>+</sup>(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>PhX<sup>-</sup>,



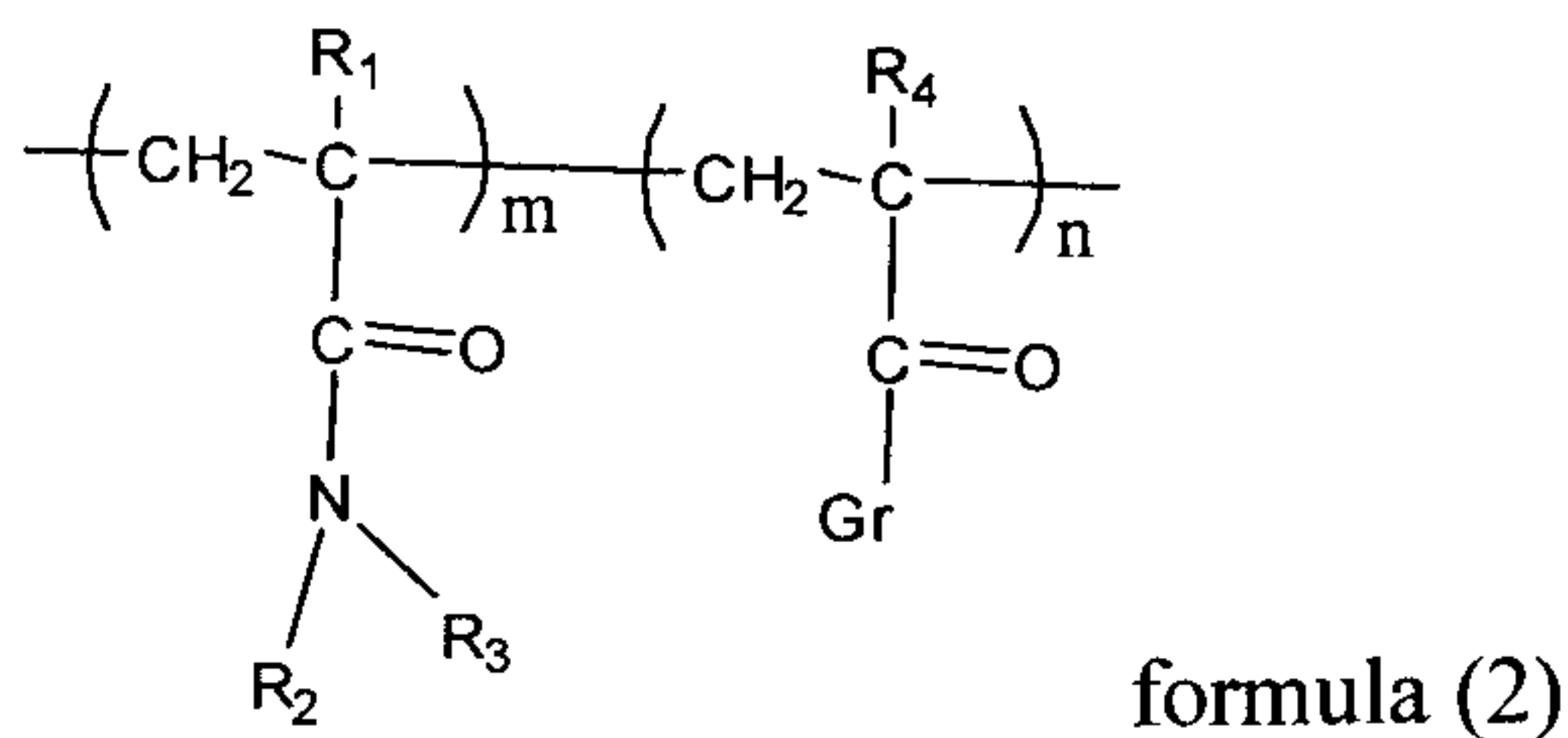
wherein b and c are integers from 0 to 21 respectively; d and e are integers from 0 to 17 respectively; f is an integer from 2 to 8; and X<sup>-</sup> is Cl<sup>-</sup> or Br<sup>-</sup>.

4. The amphiphilic macromolecule as claimed in Claim 2, characterized in that, based on 100 mol% of the entire amphiphilic macromolecule repeating units, the molar percentage of the (meth)acrylamide monomer unit A<sub>1</sub> is 70-99mol%; and the molar percentage of the (meth)acrylic monomer unit A<sub>2</sub> is 1-30mol%.

5. The amphiphilic macromolecule as claimed in Claim 3, characterized in that, based on 100 mol% of the entire amphiphilic macromolecule repeating units, the molar percentage of the structure G is 0.02-2mol%; and the molar percentage of the structure of formula (4) is 0.05-5mol%.

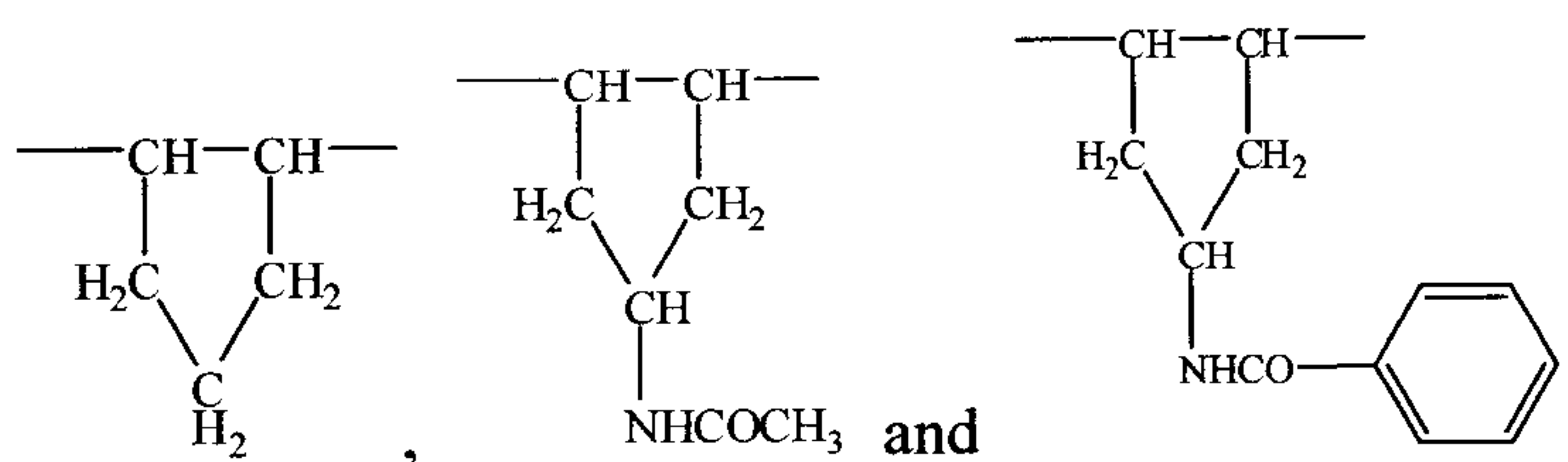
6. The amphiphilic macromolecule as claimed in Claim 1, characterized in that, based on 100 mol% of the entire amphiphilic macromolecule repeating units, the molar percentage of the structure of formula (8) is 0.05-10mol%.

7. The amphiphilic macromolecule as claimed in Claim 1, characterized in that, the structural unit A for adjusting molecular weight, molecular weight distribution and charge characteristics has a structure of formula (2);



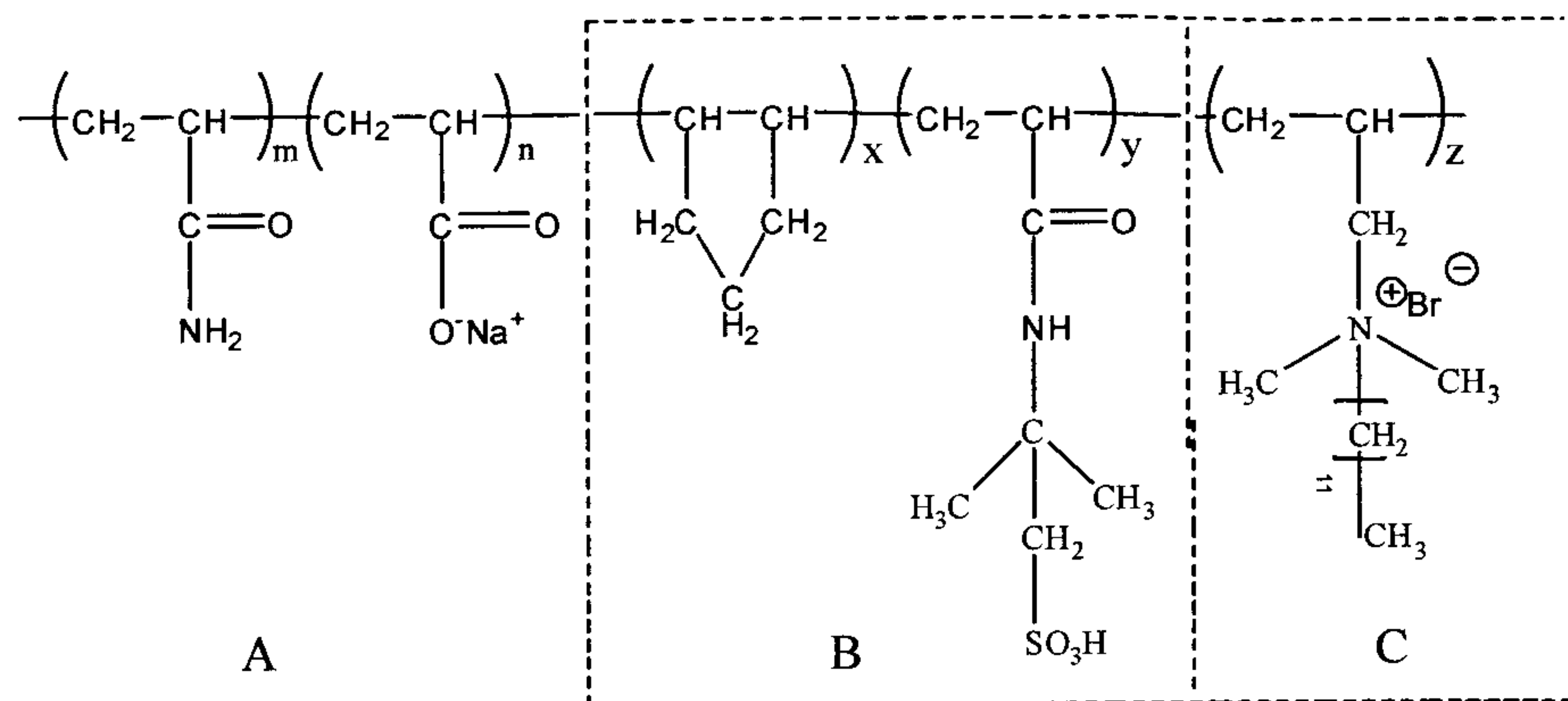
wherein in formula (2), R<sub>1</sub> is H or a methyl group; R<sub>2</sub> and R<sub>3</sub> are independently selected from the group consisting of H and a C<sub>1</sub>-C<sub>3</sub> alkyl group; R<sub>4</sub> is selected from the group consisting of H and a methyl group; Gr is -OH or -O<sup>-</sup>Na<sup>+</sup>; m and n represent the molar percentages of the structural units in the entire amphiphilic macromolecule, and m is from 70 to 99mol%; n is from 1 to 30mol%.

8. The amphiphilic macromolecule as claimed in Claim 3, characterized in that, the cyclic hydrocarbon structure formed on the basis of the two adjacent carbon atoms in the main chain is selected from the group consisting of:

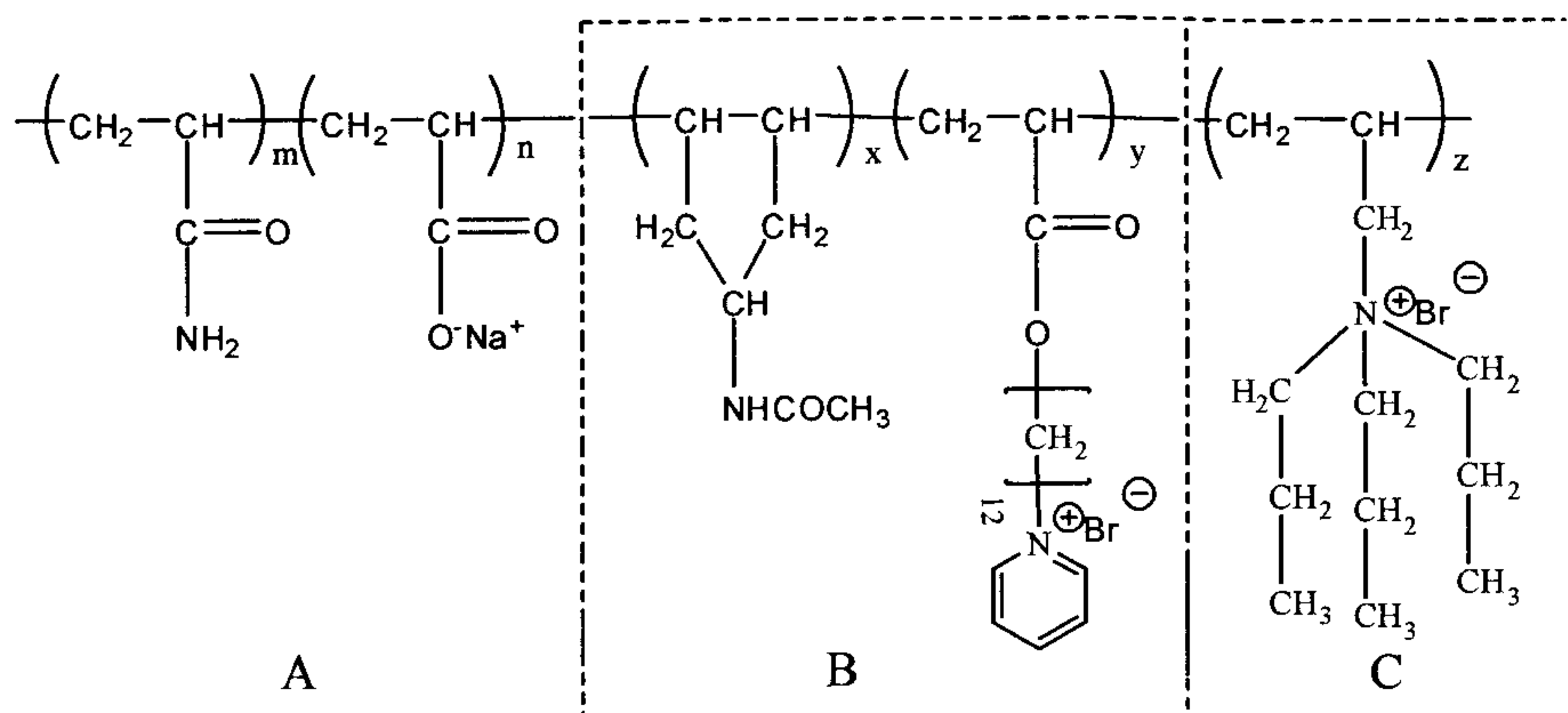


9. The amphiphilic macromolecule as claimed in Claim 1, characterized in that, the highly sterically hindered structural unit B has a structure of formula (7):

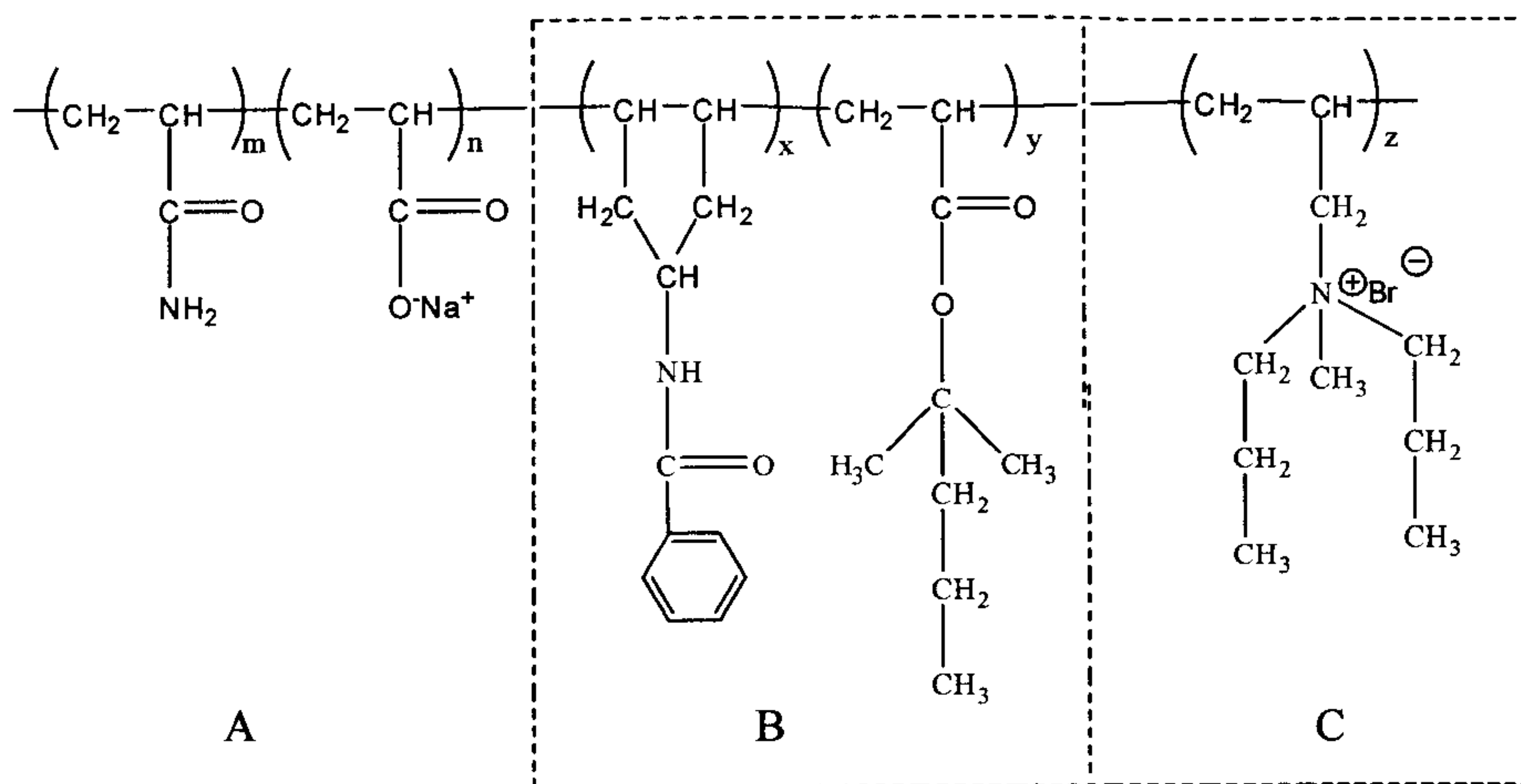




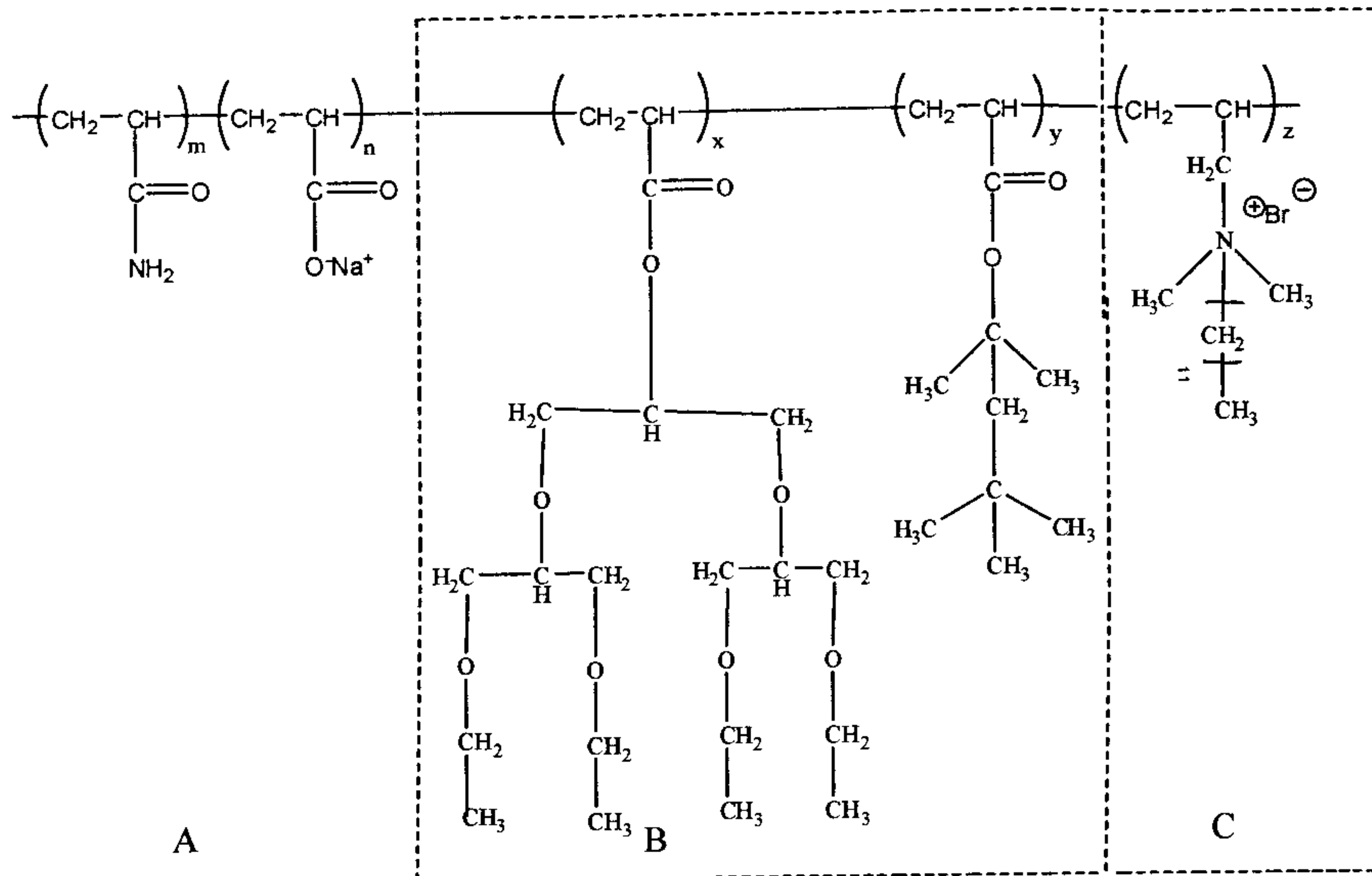
(I)



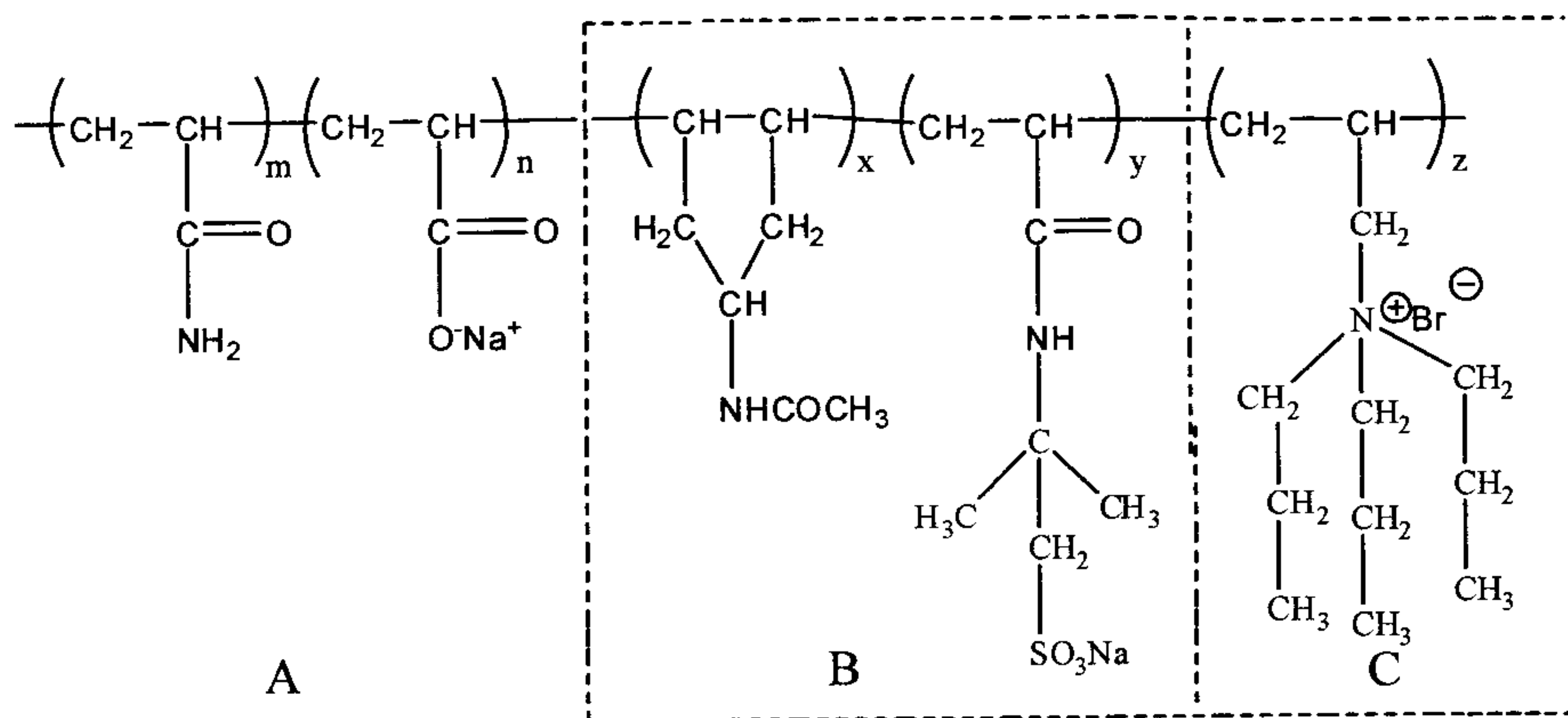
(II)



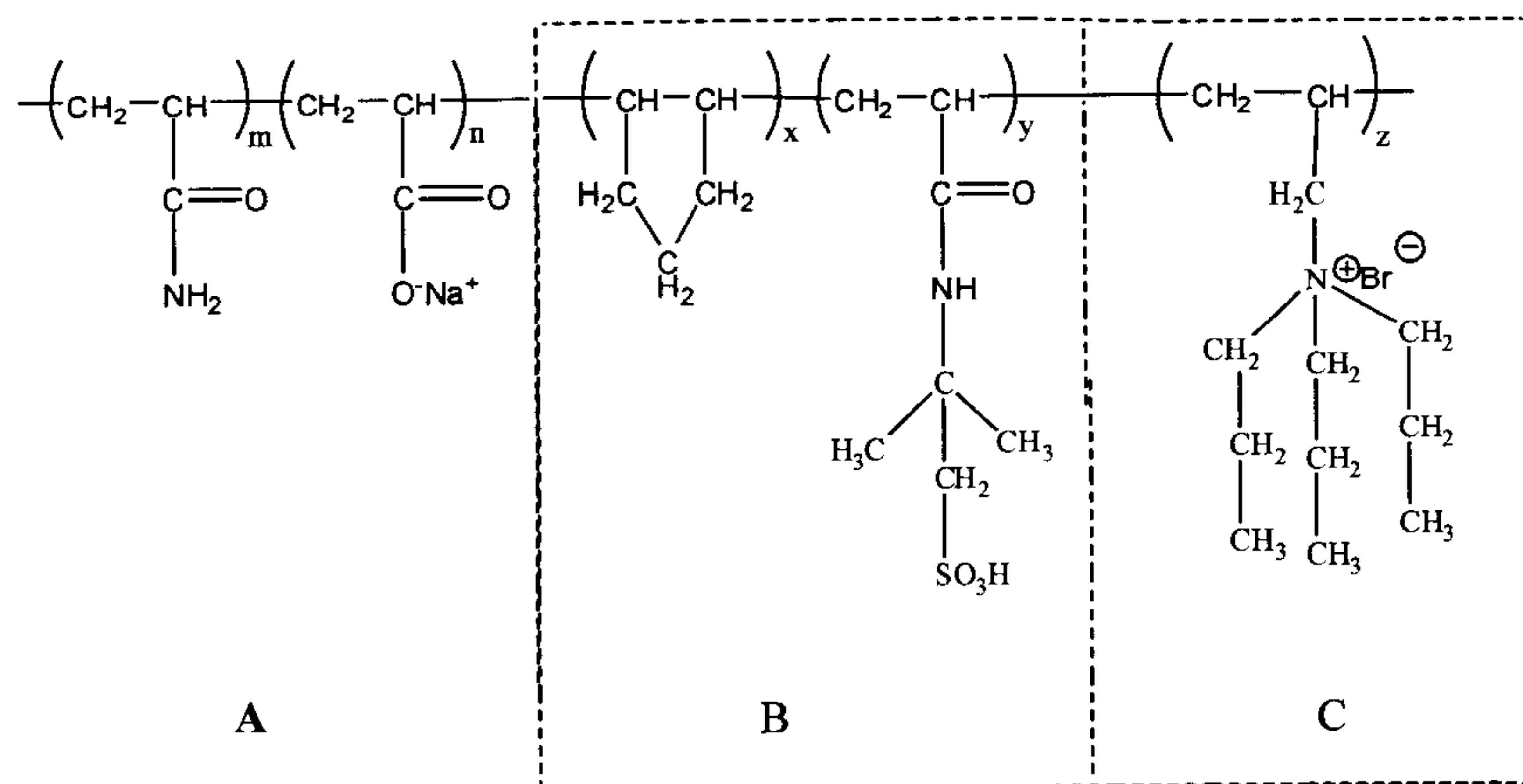
(III)



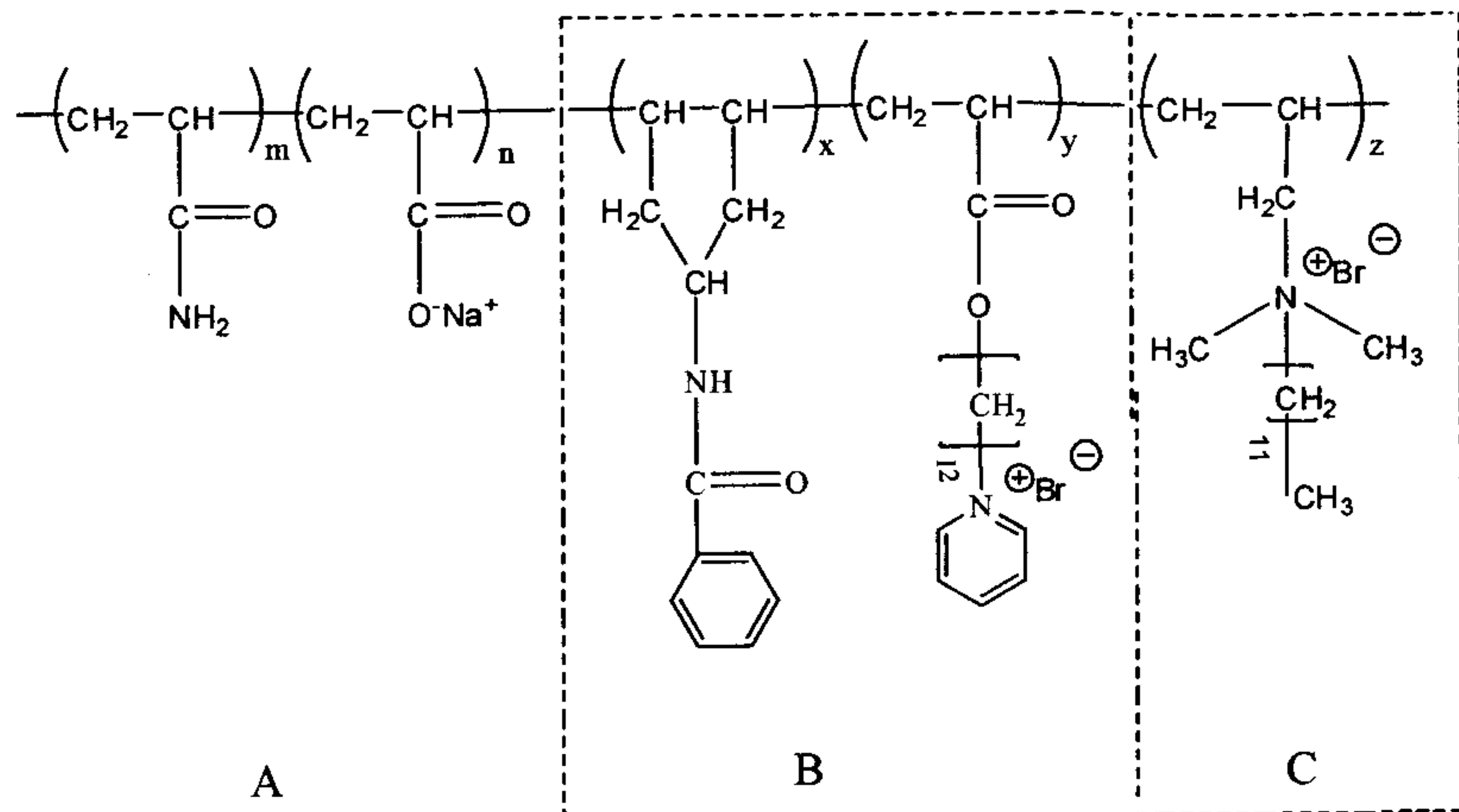
(IV)



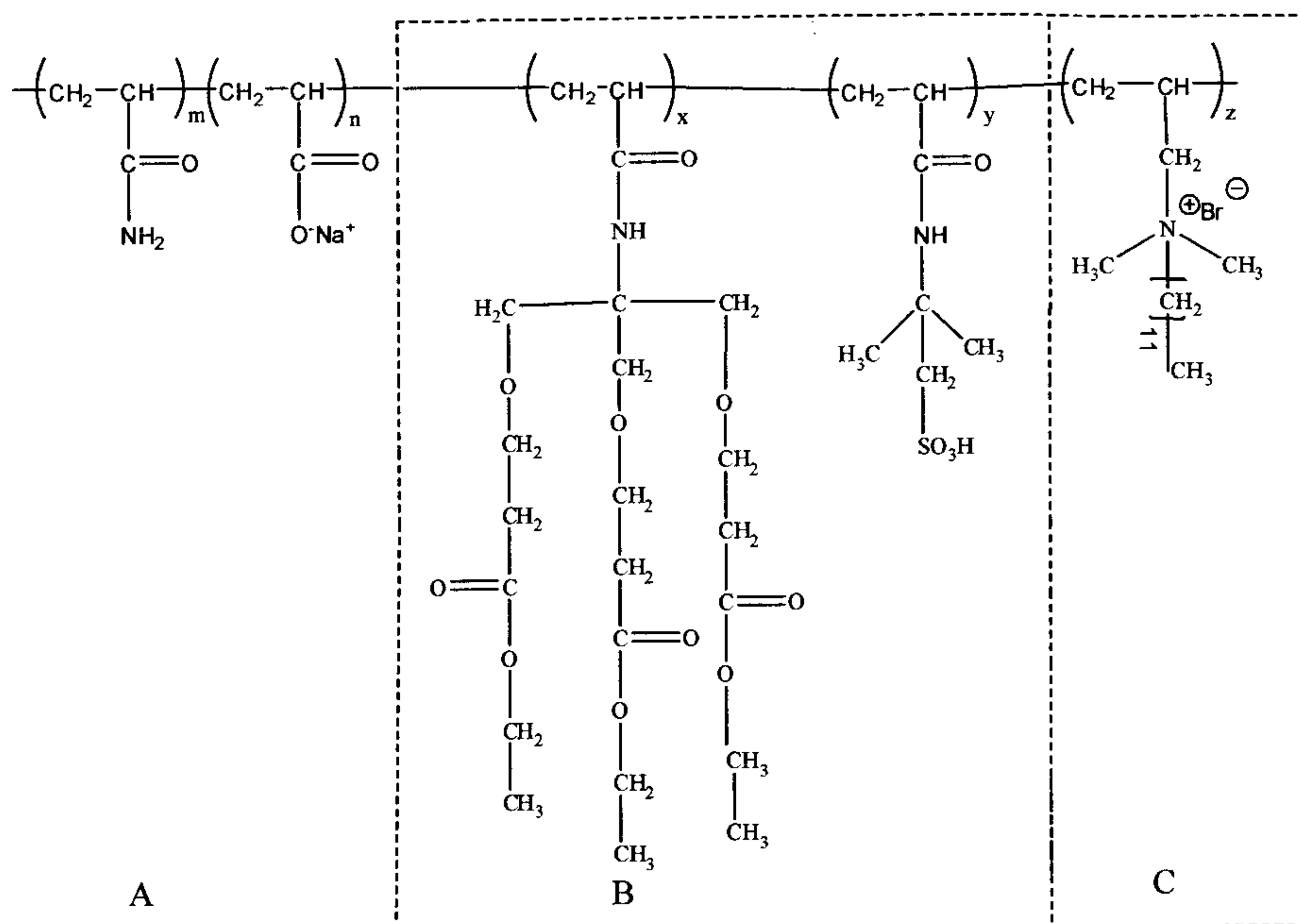
(V)



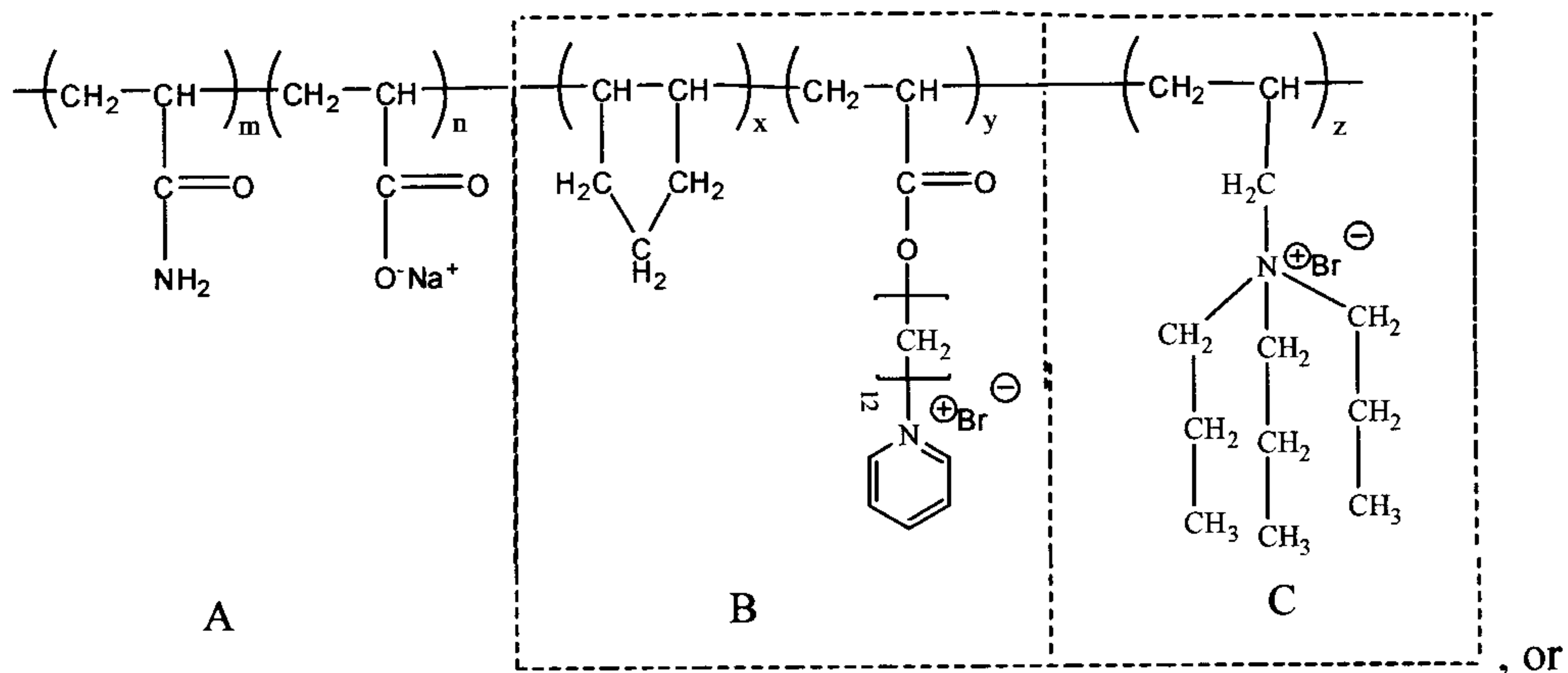
(VI)



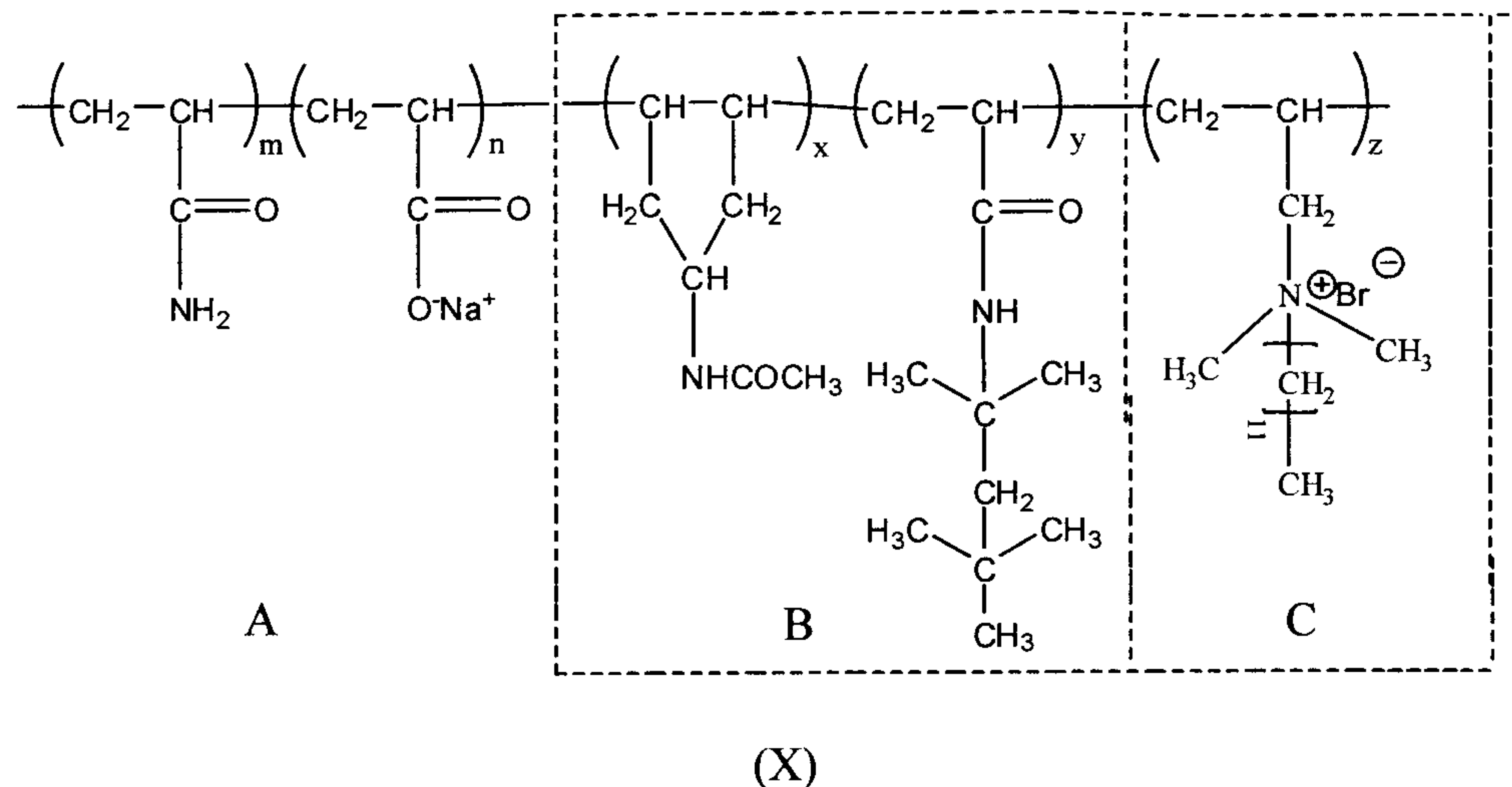
(VII)



(VIII)



(IX)



12. The amphiphilic macromolecule as claimed in any of Claims 1 to 11, characterized in that, it has a molecular weight of between 1000000-20000000.

13. Use of the amphiphilic macromolecule as claimed in any of Claims 1 to 12 in oilfield drilling, well cementing, fracturing, crude oil gathering and transporting, sewage treating, sludge treating and papermaking as intensified oil producing agent and oil displacing agent, heavy oil viscosity reducer, fracturing fluid, clay stabilizer, sewage treating agent, retention aid and drainage aid and strengthening agent for papermaking.

## Figures

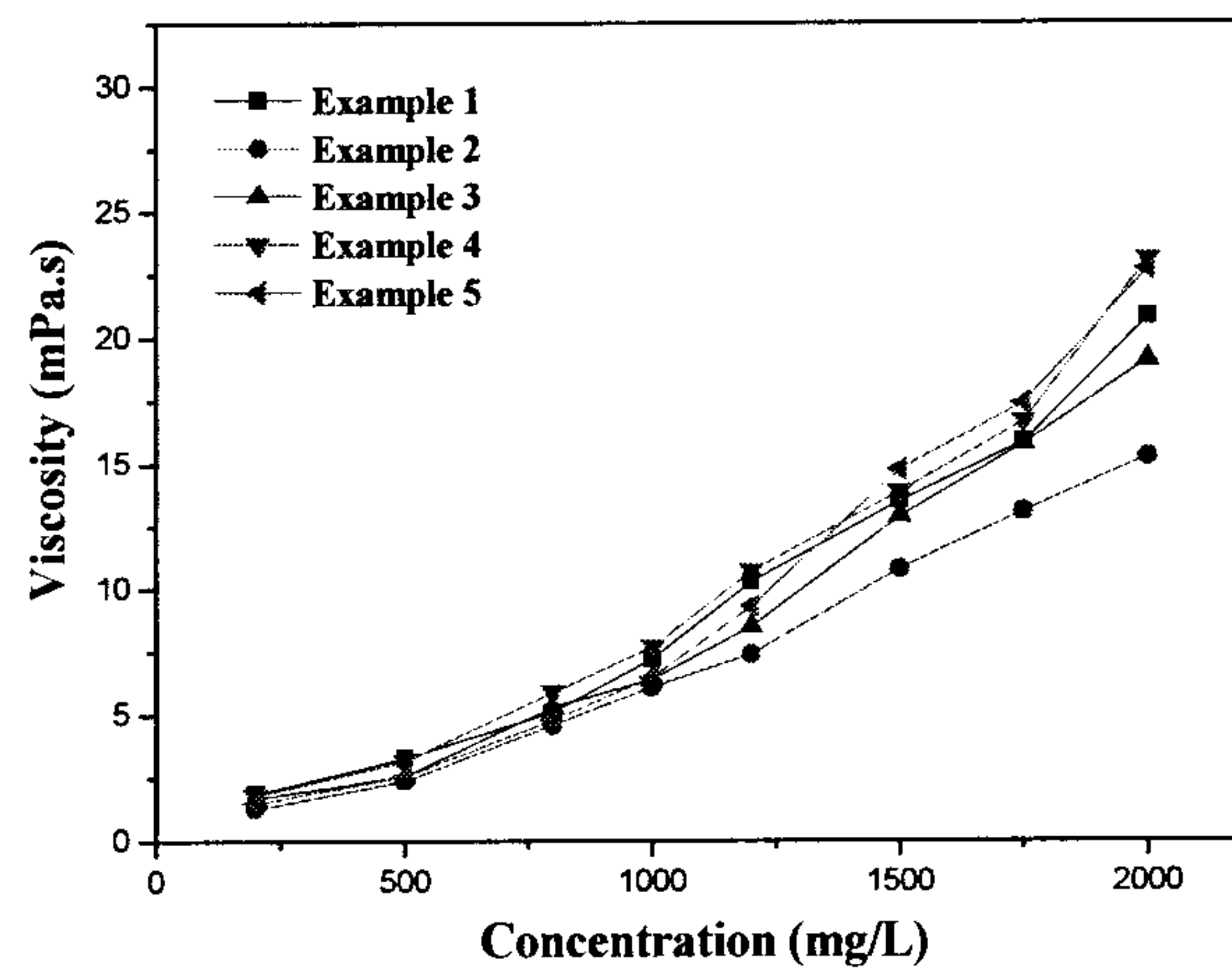


Figure 1: The relationship between the viscosity and concentration

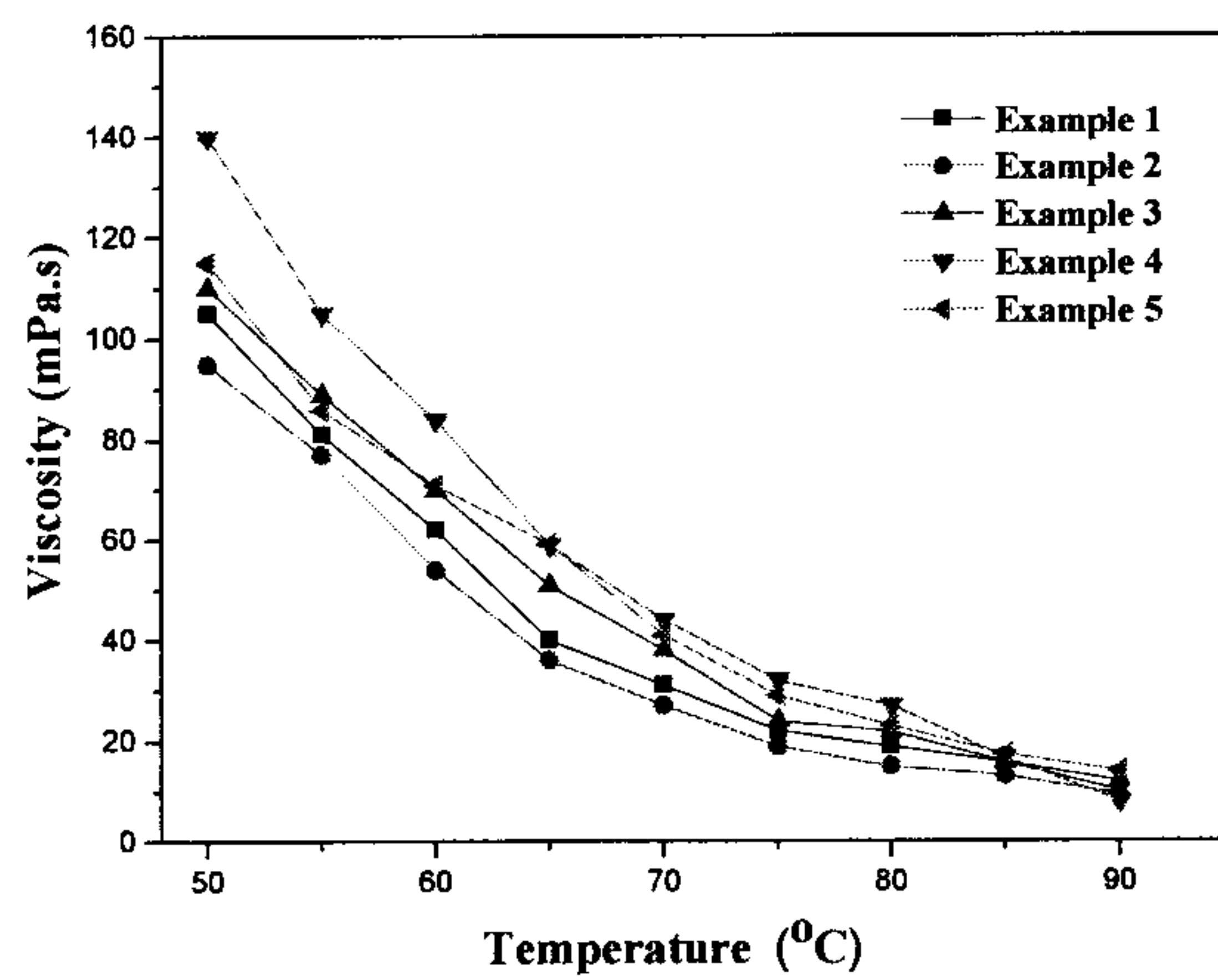


Figure 2: The relationship between the viscosity and temperature