CLAIMS

1. A membrane obtainable from curing a composition comprising:
(i) a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

and optionally (ii) a curable compound having one ethylenically unsaturated group; wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25.

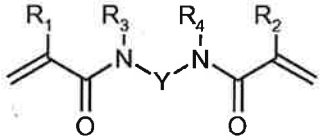
2. A membrane according to claim 1 wherein the composition further comprises a radical initiator.

3. A membrane according to any one of the preceding claims wherein the composition further comprises water or a mixture comprising water and a water-miscible organic solvent.

4. A membrane according to any one of the preceding claims wherein the (meth)acrylic groups in component (i) are (meth)acrylamide groups.

5. A membrane according to any one of the preceding claims wherein component (ii) further comprises an anionic group.

6. A membrane according to any one of the preceding claims wherein component (i) comprises a compound of the Formula (1):



Formula (1)

wherein:

R_1 and R_2 are each independently H or methyl;

R_3 and R_4 are each independently H or alkyl, or R_3 and R_4 together with the N atoms to which they are attached and Y form an optionally substituted 6- or 7-membered ring; and

Y is an optionally substituted and optionally interrupted alkylene or arylene group;

provided that the compound of Formula (1) has 1, 2, 3 or 4 sulphonic acid groups; and

provided that the compound of Formula (1) has a molecular weight which satisfies the equation:

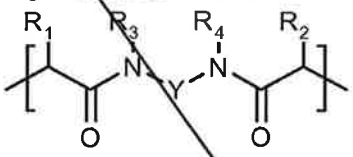
$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the compound of Formula (1); and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the compound of the Formula (1).

7. A membrane comprising a structural unit of Formula (1'):



Formula (1')

wherein:

R_1 and R_2 are each independently H or methyl;

R_3 and R_4 are each independently H or alkyl, or R_3 and R_4 together with the N atoms to which they are attached and Y form an optionally substituted 6- or 7-membered ring; and

Y is an optionally substituted and optionally interrupted alkylene or arylene group;

provided that the structural unit of Formula (1') has 1, 2, 3 or 4 sulphonic acid groups.

8. A membrane according to any one of the preceding claims having an IEC of at least 3.5 meq/g of total dry weight of the composition.

9. A composition comprising:

(i) 2 to 80 wt% of a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

(ii) 1 to 70 wt% of curable compound having one ethylenically unsaturated group;

(iii) 0 to 40 wt% of curable compound comprising at least two (meth)acrylic groups and being free from sulphonic acid groups;

(iv) 0 to 10 wt% of radical initiator; and

(v) 15 to 70 wt% of solvent;

wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25.

10. A composition according to claim 9 comprising:

(i) 4 to 70 wt% of curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

(ii) 10 to 60 wt% of curable compound having one ethylenically unsaturated group;

(iii) 0 to 30 wt% of curable compound comprising at least two (meth)acrylic groups and being free from sulphonic acid groups;

(iv) 0.1 to 10 wt% of radical initiator; and

(v) 25 to 45 wt% of solvent comprising water or a mixture comprising water and a water-miscible organic solvent;

wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.35.

11. A composition according to claim 9 to 10 wherein component (ii) further comprises an anionic group.

12. A composition comprising:

(i) 5 to 75 wt% of a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

(ii) 0 to 60 wt% of curable compound having one ethylenically unsaturated group;

(iii) 0 to 30 wt% of curable compound comprising at least two (meth)acrylic groups and being free from sulphonic acid groups;

(iv) 0.1 to 10 wt% of radical initiator; and

(v) 20 to 45 wt% of solvent;

wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25.

13. A process for preparing a membrane comprising the following steps:

a) applying a composition to a support; and

b) curing the composition to form a membrane;

wherein the composition comprises:

(i) a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

and optionally (ii) a curable compound having one ethylenically unsaturated group; wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25.

14. A process according to claim 13 wherein the composition is as defined in claim 9, 10, 11 or 12.

15. A process according to claim 13 or 14 wherein the curing is performed using electron beam or UV radiation.

16. A process according to any claim 15 wherein the composition is cured by irradiation with an electron beam or UV light for a period of less than 30 seconds.

17. A process according to any one of claims 13 to 16 wherein the composition is applied continuously to a moving support by means of a manufacturing unit comprising a composition application station, an irradiation source for curing the composition, a membrane collecting station and a means for moving the support from the composition application station to the irradiation source and to the membrane collecting station.

18. A process according to any one of claims 13 to 17 wherein the curable composition is applied to the support moving at a speed of over 5 m/min.

19. Use of a membrane according to any one of claims 1 to 8 for the separation or purification of liquids, vapours or gases.

20. An electrodialysis or reverse electrodialysis unit, a flow through capacitor device, an electrodeionization module, a continuous electrodeionization module, a fuel cell, a diffusion dialysis apparatus, a membrane distillation module or a membrane electrode assembly comprising one or more polymeric membranes according to any one of claims 1 to 8.

CLAIMS

1. A membrane obtainable from curing a composition comprising:
(i) a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

and optionally (ii) a curable compound having one ethylenically unsaturated group; wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25; wherein said curable compound has a molecular weight which further satisfies the equation: MW<(200 + 200n).

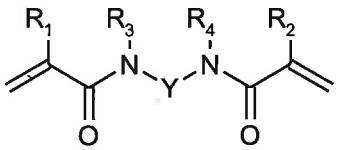
2. A membrane according to claim 1 wherein the composition further comprises a radical initiator.

3. A membrane according to any one of the preceding claims wherein the composition further comprises water or a mixture comprising water and a water-miscible organic solvent.

4. A membrane according to any one of the preceding claims wherein the (meth)acrylic groups in component (i) are (meth)acrylamide groups.

5. A membrane according to any one of the preceding claims wherein component (ii) further comprises an anionic group.

6. A membrane according to any one of the preceding claims wherein component (i) comprises a compound of the Formula (1):



Formula (1)

wherein:

R_1 and R_2 are each independently H or methyl;

R_3 and R_4 are each independently H or alkyl, or R_3 and R_4 together with the N atoms to which they are attached and Y form an optionally substituted 6- or 7-membered ring; and

Y is an optionally substituted and optionally interrupted alkylene or arylene group;

provided that the compound of Formula (1) has 1, 2, 3 or 4 sulphonic acid groups; and

provided that the compound of Formula (1) has a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

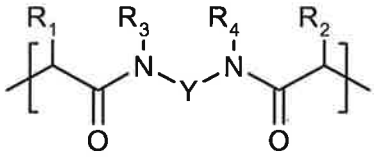
wherein:

MW is the molecular weight of the compound of Formula (1); and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the compound of the Formula (1)

wherein the compound of Formula (1) has a molecular weight which further satisfies the equation: MW<(200 + 200n).

7. A membrane according to claim 1 comprising a structural unit of Formula (1'):



Formula (1')

wherein:

R_1 and R_2 are each independently H or methyl;

R_3 and R_4 are each independently H or alkyl, or R_3 and R_4 together with the N atoms to which they are attached and Y form an optionally substituted 6- or 7-membered ring; and

Y is an optionally substituted and optionally interrupted alkylene or arylene group;

provided that the structural unit of Formula (1') has 1, 2, 3 or 4 sulphonic acid groups.

8. A composition comprising:

(i) a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

wherein said curable compound has a molecular weight which further satisfies the equation: MW<(200 + 200n)

(ii) a curable compound having one ethylenically unsaturated group;

(iii) a curable compound comprising at least two (meth)acrylic groups and being free from sulphonic acid groups;

(iv) a radical initiator; and

(v) a solvent;

wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25; and

wherein the composition comprises:

(a) 2 to 80 wt% of component (i), 1 to 70 wt% of component (ii), 0 to 40 wt% of component (iii), 0 to 10 wt% of component (iv); and 15 to 70 wt% of component (v); or

(b) 5 to 75 wt% of component (i), 0 to 60 wt% of component (ii), 0 to 30 wt% of component (iii), 0.1 to 10 wt% of component (iv); and 20 to 45 wt% of component (v).

9. A composition according to claim 8 wherein the solvent is water or a mixture comprising water and a water-miscible organic solvent.

10. A process for preparing a membrane comprising the following steps:

a) applying a composition to a support; and

b) curing the composition to form a membrane;

wherein the composition comprises:

(i) a curable compound comprising at least two (meth)acrylic groups and a sulphonic acid group and having a molecular weight which satisfies the equation:

$$MW < (300 + 300n)$$

wherein:

MW is the molecular weight of the said curable compound; and

n has a value of 1, 2, 3 or 4 and is the number of sulphonic acid groups present in the said curable compound;

and optionally (ii) a curable compound having one ethylenically unsaturated group;

wherein the molar fraction of curable compounds comprising at least two (meth)acrylic groups, relative to the total number of moles of curable compounds present in the composition, is at least 0.25, wherein said curable compound has a molecular weight which further satisfies the equation: MW<(200 + 200n).

11. A process according to claim 10 wherein the composition is as defined in claim 8 or 9.

12. A process according to claim 10 or 11 wherein the composition is cured by irradiation with an electron beam or UV light for a period of less than 30 seconds.

13. A process according to any one of claims 10 to 12 wherein the composition is applied continuously to a moving support by means of a manufacturing unit comprising a composition application station, an irradiation source for curing the composition, a membrane collecting station and a means for moving the support from the composition application station to the irradiation source and to the membrane collecting station.

14. Use of a membrane according to any one of claims 1 to 7 for the separation or purification of liquids, vapours or gases.

15. An electrodialysis or reverse electrodialysis unit, a flow through capacitor device, an electrodeionization module, a continuous electrodeionization module, a fuel cell, a diffusion dialysis apparatus, a membrane distillation module or a membrane electrode assembly comprising one or more polymeric membranes according to any one of claims 1 to 7.