CLAIMS

What is claimed is:

1. A catalyst comprising: (a) at least one condensed phosphate anion selected from the group consisting of formulae (I), (II), and (III),

$$[P_nO_{3n+1}]^{(n+2)-} \quad (I)$$

$$[P_nO_{3n}]^{n-} \quad (II)$$

$$[P_{(2m+n)}O_{(5m+3n)}]^{n-} \quad (III)$$

wherein n is at least 2 and m is at least 1, and

(b) at least two different cations,

wherein the catalyst is essentially neutrally charged; and further, wherein the molar ratio of phosphorus to said at least two different cations is between about 0.7 and about 1.7.

2. The catalyst of claim 1, wherein said cations comprise:
(a) at least one monovalent cation; and
(b) at least one polyvalent cation.

3. The catalyst of any preceding claim, wherein said monovalent cation is selected from the group consisting of H^+, Li^+, Na^+, K^+, Rb^+, Cs^+, and mixtures thereof.

4. The catalyst of claim 2, wherein said polyvalent cation is selected from the group consisting of divalent cations, trivalent cations, tetravalent cations, pentavalent cations, and mixtures thereof.

5. The catalyst of claim 4, wherein said polyvalent cation is selected from the group consisting of Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+}, Sn^{2+}, Pb^{2+}, Ti^{3+}, Cr^{3+}, Mn^{3+}, Fe^{3+}, Al^{3+}, Ga^{3+}, Y^{3+}, In^{3+}, Sb^{3+}, Bi^{3+}, Si^{4+}, Ti^{4+}, V^{4+}, Ge^{4+}, Mo^{4+}, Pt^{4+}, V^{5+}, Nb^{5+}, Sb^{5+}, and mixtures thereof.

6. The catalyst of any preceding claim, wherein said condensed phosphate anions are described by formulae (I) and (II).

7. The catalyst of claim 6, wherein said catalyst comprises:
(a) $Ba_{2-x-s}K_{2x}H_{2s}P_2O_7$ or $Ca_{2-x-s}K_{2x}H_{2s}P_2O_7$ or $Mn_{1-x-s}K_{1+3x}H_{3s}P_2O_7$ or

$Mn_{1-x-s}K_{2+2x}H_{2s}P_2O_7$; and
(b) $(KPO_3)_n$;
wherein x and s are greater or equal to 0 and less than about 0.5 and n is a positive integer.

8. The catalyst of any preceding claim, wherein the molar ratio of phosphorus to the cations in said catalyst is between about 0.8 and about 1.3

9. The catalyst of any preceding claim, wherein the molar ratio of phosphorus to the cations in said catalyst is about 1.

10. The catalyst of any preceding claim, wherein said cations comprise:
(a) H^+, Li^+, Na^+, K^+, Rb^+, Cs^+, or mixtures thereof; and
(b) Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+}, Sn^{2+}, Pb^{2+}, Ti^{3+}, Cr^{3+}, Mn^{3+}, Fe^{3+}, Al^{3+}, Ga^{3+}, Y^{3+}, In^{3+}, Sb^{3+}, Bi^{3+}, Si^{4+}, Ti^{4+}, V^{4+}, Ge^{4+}, Mo^{4+}, Pt^{4+}, V^{5+}, Nb^{5+}, Sb^{5+}, or mixtures thereof.

11. The catalyst of any preceding claim, wherein said catalyst includes an inert support that is constructed of a material comprising silicates, aluminates, carbons, metal oxides, and mixtures thereof.

12. A method of preparing the catalyst of any preceding claim comprising mixing and heating at least two different phosphorus containing compounds, wherein each said compound is described by one of the formulae (IV) to (XXV), or any of the hydrated forms of said formulae:

$$M^{I}_{y}(H_{3-y}PO_4) \quad (IV)$$
$$M^{II}_{y}(H_{3-y}PO_4)_2 \quad (V)$$
$$M^{III}_{y}(H_{3-y}PO_4)_3 \quad (VI)$$
$$M^{IV}_{y}(H_{3-y}PO_4)_4 \quad (VII)$$
$$(NH_4)_y(H_{3-y}PO_4) \quad (VIII)$$
$$M^{II}_{a}(OH)_b(PO_4)_c \quad (IX)$$
$$M^{III}_{d}(OH)_e(PO_4)_f \quad (X)$$
$$M^{II}M^{I}PO_4 \quad (XI)$$
$$M^{III}M^{I}_{3}(PO_4)_2 \quad (XII)$$
$$M^{IV}_{2}M^{I}(PO_4)_3 \quad (XIII)$$
$$M^{I}_{z}H_{4-z}P_2O_7 \quad (XIV)$$

$M^{II}_{v}H_{(4-2v)}P_2O_7$ (XV)

$M^{IV}P_2O_7$ (XVI)

$(NH_4)_zH_{4-z}P_2O_7$ (XVII)

$M^{III}M^{I}P_2O_7$ (XVIII)

$M^{I}H_w(PO_3)_{(1+w)}$ (XIX)

$M^{II}H_w(PO_3)_{(2+w)}$ (XX)

$M^{III}H_w(PO_3)_{(3+w)}$ (XXI)

$M^{IV}H_w(PO_3)_{(4+w)}$ (XXII)

$M^{II}_{g}M^{I}_{h}(PO_3)_i$ (XXIII)

$M^{III}_{j}M^{I}_{k}(PO_3)_l$ (XXIV)

P_2O_5 (XXV)

wherein M^{I} is a monovalent cation; wherein M^{II} is a divalent cation; wherein M^{III} is a trivalent cation; wherein M^{IV} is a tetravalent cation; wherein y is 0, 1, 2, or 3; wherein z is 0, 1, 2, 3, or 4; wherein v is 0, 1, or 2; wherein w is 0 or any positive integer; and wherein a, b, c, d, e, f, g, h, i, j, k, and l are any positive integers, such that the equations: 2a = b + 3c, 3d = e + 3f, i = 2g + h, and l = 3j + k are satisfied.

13. The method of any preceding claim, wherein the molar ratio of phosphorus to the cations in said catalyst is about 1.

14. The method of any preceding claim, wherein said phosphorus containing compounds comprise a phosphorus containing compound of formula (IV), wherein y is equal to 1, and a phosphorus containing compound of formula (V), wherein y is equal to 2.

15. The method of any preceding claim, wherein said phosphorus containing compounds comprise:
    (a) KH_2PO_4; and
    (b) $CaHPO_4$ or $BaHPO_4$.

CLAIMS:

1. A catalyst comprising: (a) at least one condensed phosphate anion selected from the group consisting of formulae (I), (II), and (III),

$$[P_nO_{3n+1}]^{(n+2)-} \quad \text{(I)}$$

$$[P_nO_{3n}]^{n-} \quad \text{(II)}$$

$$[P_{(2m+n)}O_{(5m+3n)}]^{n-} \quad \text{(III)}$$

wherein n is at least 2 and m is at least 1, and

(b) at least two different cations,

wherein the catalyst is essentially neutrally charged; and further, wherein the molar ratio of phosphorus to said at least two different cations is between about 0.7 and about 1.7.

2. The catalyst of claim 1, wherein said cations comprise:

(a) at least one monovalent cation; and

(b) at least one polyvalent cation.

3. The catalyst of any one of the preceding claims, wherein said monovalent cation is selected from the group consisting of H^+, Li^+, Na^+, K^+, Rb^+, Cs^+, and mixtures thereof.

4. The catalyst of claim 2, wherein said polyvalent cation is selected from the group consisting of divalent cations, trivalent cations, tetravalent cations, pentavalent cations, and mixtures thereof.

5. The catalyst of claim 4, wherein said polyvalent cation is selected from the group consisting of Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+}, Sn^{2+}, Pb^{2+}, Ti^{3+}, Cr^{3+}, Mn^{3+}, Fe^{3+}, Al^{3+}, Ga^{3+}, Y^{3+}, In^{3+}, Sb^{3+}, Bi^{3+}, Si^{4+}, Ti^{4+}, V^{4+}, Ge^{4+}, Mo^{4+}, Pt^{4+}, V^{5+}, Nb^{5+}, Sb^{5+}, and mixtures thereof.

6. The catalyst of any one of the preceding claims, wherein said condensed phosphate anions are described by formulae (I) and (II).

7. The catalyst of claim 6, wherein said catalyst comprises:

(a) $Ba_{2-x-s}K_{2x}H_{2s}P_2O_7$ or $Ca_{2-x-s}K_{2x}H_{2s}P_2O_7$ or $Mn_{1-x-s}K_{1+3x}H_{3s}P_2O_7$ or $Mn_{1-x-s}K_{2+2x}H_{2s}P_2O_7$; and

(b) $(KPO_3)_n$;

wherein x and s are greater or equal to 0 and less than about 0.5 and n is a positive integer.

8. The catalyst of any one of the preceding claims, wherein the molar ratio of phosphorus to the cations in said catalyst is between about 0.8 and about 1.3

9. The catalyst of any one of the preceding claims, wherein the molar ratio of phosphorus to the cations in said catalyst is about 1.

10. The catalyst of any one of the preceding claims, wherein said cations comprise:

(a) H^+, Li^+, Na^+, K^+, Rb^+, Cs^+, or mixtures thereof; and

(b) Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+}, Sn^{2+}, Pb^{2+}, Ti^{3+}, Cr^{3+}, Mn^{3+}, Fe^{3+}, Al^{3+}, Ga^{3+}, Y^{3+}, In^{3+}, Sb^{3+}, Bi^{3+}, Si^{4+}, Ti^{4+}, V^{4+}, Ge^{4+}, Mo^{4+}, Pt^{4+}, V^{5+}, Nb^{5+}, Sb^{5+}, or mixtures thereof.

11. The catalyst of any one of the preceding claims, wherein said catalyst includes an inert support that is constructed of a material comprising silicates, aluminates, carbons, metal oxides, and mixtures thereof.

12. A method of preparing the catalyst of any one of the preceding claims comprising mixing and heating at least two different phosphorus containing compounds, wherein each said compound is described by one of the formulae (IV) to (XXV), or any of the hydrated forms of said formulae:

$$M^{I}_{y}(H_{3-y}PO_4) \quad (IV)$$

$$M^{II}_{y}(H_{3-y}PO_4)_2 \quad (V)$$

$$M^{III}_{y}(H_{3-y}PO_4)_3 \quad (VI)$$

$$M^{IV}_{y}(H_{3-y}PO_4)_4 \quad (VII)$$

$$(NH_4)_y(H_{3-y}PO_4) \quad (VIII)$$

$$M^{II}_{a}(OH)_b(PO_4)_c \quad (IX)$$

$$M^{III}_{d}(OH)_e(PO_4)_f \quad (X)$$

$M^{II}M^{I}PO_4$ (XI)

$M^{III}M^{I}_3(PO_4)_2$ (XII)

$M^{IV}_2M^{I}(PO_4)_3$ (XIII)

$M^{I}_zH_{4-z}P_2O_7$ (XIV)

$M^{II}_vH_{(4-2v)}P_2O_7$ (XV)

$M^{IV}P_2O_7$ (XVI)

$(NH_4)_zH_{4-z}P_2O_7$ (XVII)

$M^{III}M^{I}P_2O_7$ (XVIII)

$M^{I}H_w(PO_3)_{(1+w)}$ (XIX)

$M^{II}H_w(PO_3)_{(2+w)}$ (XX)

$M^{III}H_w(PO_3)_{(3+w)}$ (XXI)

$M^{IV}H_w(PO_3)_{(4+w)}$ (XXII)

$M^{II}_gM^{I}_h(PO_3)_i$ (XXIII)

$M^{III}_jM^{I}_k(PO_3)_l$ (XXIV)

P_2O_5 (XXV)

wherein M^{I} is a monovalent cation; wherein M^{II} is a divalent cation; wherein M^{III} is a trivalent cation; wherein M^{IV} is a tetravalent cation; wherein y is 0, 1, 2, or 3; wherein z is 0, 1, 2, 3, or 4; wherein v is 0, 1, or 2; wherein w is 0 or any positive integer; and wherein a, b, c, d, e, f, g, h, i, j, k, and l are any positive integers, such that the equations: $2a = b + 3c$, $3d = e + 3f$, $i = 2g + h$, and $l = 3j + k$ are satisfied.

13. The method of any one of the preceding claims, wherein the molar ratio of phosphorus to the cations in said catalyst is about 1.

14. The method of any one of the preceding claims, wherein said phosphorus containing compounds comprise a phosphorus containing compound of formula (IV), wherein y is equal to 1, and a phosphorus containing compound of formula (V), wherein y is equal to 2.

15. The method of any one of the preceding claims, wherein said phosphorus containing compounds comprise:

(a) KH_2PO_4; and

(b) $CaHPO_4$ or $BaHPO_4$.