1. $HCl \rightarrow Cl^{1-}$

$CH_4 \rightarrow CH_3^{1-}$

$HSO_3^{1-} \rightarrow SO_3^{2-}$

$H_2SO_4 \rightarrow HSO_4^{1-}$

$NH_3 \rightarrow NH_2^{1-}$

$HClO_4 \rightarrow ClO_4^{1-}$

2. $HCl + H_2O \rightleftharpoons H_3O^{1+} + Cl^{1-}$ (a1, b2, a2, b1) — lies right acidic *

$HNO_3 + H_2O \rightleftharpoons H_3O^{1+} + NO_3^{1-}$ (a1, b2, a2, b1) — lies right acidic *

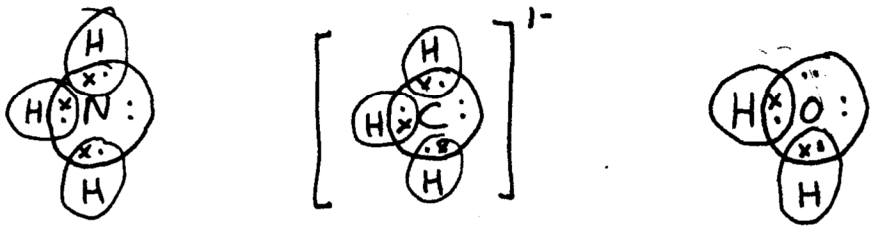
$H_2SO_4 + H_2O \rightleftharpoons H_3O^{1+} + HSO_4^{1-}$ (a1, b2, a2, b1) — lies right acidic *

$HClO_4 + H_2O \rightleftharpoons H_3O^{1+} + ClO_4^{1-}$ (a1, b2, a2, b1) — lies right acidic *

$H_2S + H_2O \rightleftharpoons H_3O^{1+} + HS^{1-}$ (a1, b2, a2, b1) — lies left acidic *

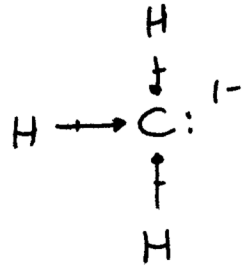
$H_3PO_4 + H_2O \rightleftharpoons H_3O^{1+} + H_2PO_4^{1-}$ (a1, b2, a2, b1) — lies left acidic *

* all acidic due to presence of H_3O^{1+}

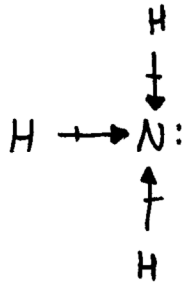
3. 

Note:

never dissociates

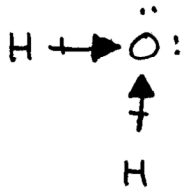


5% ionic character



20% ionic character

frequently dissociates



35% ionic character

← increased covalent character

→ increased ionic character

∴ increased likelihood of dissociation

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4. a) $\underline{NH_3}$ (b1) + $\underline{H_2O}$ (a2) ⇌ NH_4^{1+} (a1) + $\underline{OH^{1-}}$ (b2)

B.B. (b2 → a2)

lies left

~~base~~ basic

b) $\underline{CH_3^{1-}}$ (b1) + $\underline{H_2O}$ (a2) ⇌ CH_4 (a1) + $\underline{OH^{1-}}$ (b2)

B.B. (b1 → a1)

basic

lies right

* actually not an equilibrium (complete reaction)

c) $\underline{H_2O}$ (b1) + $\underline{H_2O}$ (a2) ⇌ H_3O^{1+} (a1) + $\underline{OH^{1-}}$ (b2)

B.B. (b2 → a2)

lies left

neutral

$[H_3O^{1+}] = [OH^-]$

d) $\underset{b1}{CH_3OH} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{CH_3OH_2^+} + \underset{b2}{OH^-}$ (B.B.) lies left basic

e) $\underset{b1}{Cl^{1-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HCl} + \underset{b2}{OH^{1-}}$ (B.B.) lies left basic

f) $\underset{b1}{SO_4^{2-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HSO_4^{1-}} + \underset{b2}{OH^{1-}}$ (B.B.) lies left basic

g) $\underset{b1}{S^{2-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HS^{1-}} + \underset{b2}{OH^{1-}}$ (B.B.) lies right basic

h) $\underset{b1}{NH_3} + \underset{a2}{HSO_3^{1-}} \rightleftharpoons \underset{a1}{NH_4^{1+}} + \underset{b2}{SO_3^{2-}}$ (B.B.) lies left

Note all of the above reactions form OH^- ions, all entities listed in 3 are basic

5. a) $HCl + H_2O \rightleftharpoons H_3O^{1+} + Cl^{1-}$ — lies right, acidic

(a1: HCl; b2: H_2O; a2: H_3O^{1+}; b1: Cl^{1-}; B.B.)

b) $H_2O + H_2SO_4 \rightleftharpoons H_3O^{1+} + HSO_4^{1-}$ — lies right, acidic

(b1: H_2O; a2: H_2SO_4; a1: H_3O^{1+}; b2: HSO_4^{1-}; B.B.)

c) $HSO_4^{1-} + H_3O^{1+} \rightleftharpoons H_2O + H_2SO_4$ — lies left, acidic

(b1: HSO_4^{1-}; a2: H_3O^{1+}; b2: H_2O; a1: H_2SO_4; B.B.)

d) $HS^{1-} + H_3O^{1+} \rightleftharpoons H_2S + H_2O$ — lies right, acidic

(b1: HS^{1-}; a2: H_3O^{1+}; a1: H_2S; b2: H_2O; B.B.)

e) $CH_3COOH + H_2SO_4 \rightleftharpoons CH_3COOH_2^{1+} + HSO_4^{1-}$

(b1: CH_3COOH; a2: H_2SO_4; a1: $CH_3COOH_2^{1+}$; b2: HSO_4^{1-})

??

these bases are too hard to compare

f) $HClO_4 + OH^{1-} \rightleftharpoons H_2O + ClO_4^{1-}$ lies right basic!!

B.B.

a1 b2 a2 b1

g) $NH_3 + HSO_3^{1-} \rightleftharpoons NH_4^{1+} + SO_3^{2-}$ lies right

B.B.

b1 a2 a1 b2

Note H_4O^{1+} does not form c) d)

NH_2^{1-} rarely forms g)

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7. a) $HCO_3^{1-} + H_2O \rightleftharpoons H_2CO_3 + OH^{1-}$ lies left

#1 b1 a2 a1 b2

B.B.

smaller gap

vs

#2 $HCO_3^{1-} + H_2O \rightleftharpoons CO_3^{2-} + H_3O^{1+}$ lies further left

a1 b2 b1 a2

* B.B.

larger gap

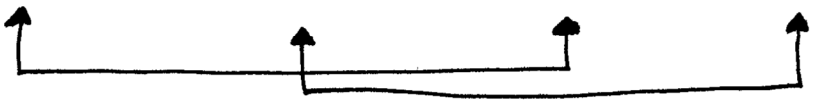
* the gap between CO_3^{2-} and H_2O is larger than the gap between OH^- and HCO_3^-

∴ equation #2 forms less H_3O^{1+} than equation #1 forms OH^- ∴ basic $[OH^-] > [H_3O^+]$

b) $\underline{H_2PO_4^{1-}} + H_2O \rightleftharpoons H_3PO_4 + \underline{OH^-}$ lies left

b1 a2 a1 b2

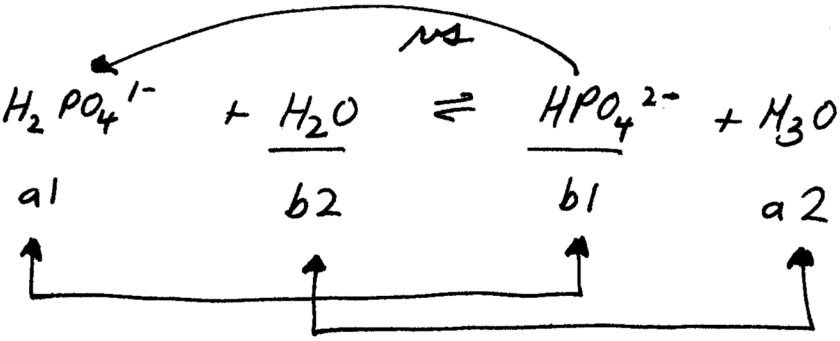
#1



vs

$H_2PO_4^{1-} + \underline{H_2O} \rightleftharpoons \underline{HPO_4^{2-}} + H_3O^{1+}$ lies left

#2 a1 b2 b1 a2



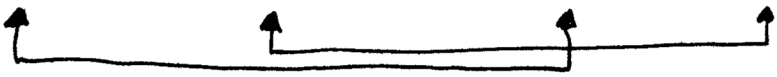
given that this question tells you that the resulting solution is acidic, one would assume that the gap between OH^- and $H_2PO_4^{1-}$ is larger than the gap between HPO_4^{2-} and H_2O.

c) large gap

$\underline{HSO_4^{1-}} + H_2O \rightleftharpoons H_2SO_4 + \underline{OH^{1-}}$ lies left (more)

b1 a2 a1 b2

#1

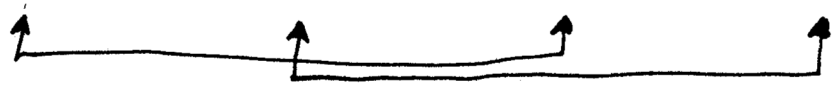


vs

smaller gap

$HSO_4^{1-} + \underline{H_2O} \rightleftharpoons \underline{SO_4^{2-}} + H_3O^{1+}$

#2 a1 b2 b1 a2 lies left



gap between OH^{1-} and HSO_4^{1-} is larger than the gap between SO_4^{2-} and H_2O. Therefore $[H_3O^{1+}] > [OH^{1-}]$

$\therefore$ acidic (#2 predominates)

d) $NH_4^{1+} + H_2O \rightleftharpoons H_3O^{1+} + NH_3$ — lies left

a1 b2 a2 b1

acidic

e) $HS^{1-} + H_2O \rightleftharpoons H_2S + OH^{1-}$ — lies left

#1 b1 a2 a1 b2 (smaller gap)

$HS^{1-} + H_2O \rightleftharpoons S^{2-} + H_2O$ — lies left (more)

#2 a1 b2 b1 a2 (large gap)

∴ equation #1 predominates ∴ basic $[OH^-] > [H_3O^+]$

f) $HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^{1-} + OH^{1-}$ — lies left

#1 b1 a2 a1 b2

vs

$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^{1+}$ — lies left (more)

#2 a1 b2 b1 a2

If basic (given) #1 predominates $[OH^-] > [H_3O^+]$

g) $\underset{b1}{S^{2-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HS^{1-}} + \underset{b2}{OH^{1-}}$ lies left, basic

h) $\underset{b1}{CO_3^{2-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HCO_3^{1-}} + \underset{b2}{OH^{1-}}$ lies left, basic

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example a) + b) point out that the salt of an acid is itself a base – dissociate first!!!

8. a) $Na_2CO_3 \longrightarrow \underset{\text{inactive}}{2Na^{1+}} + \underset{\text{active}}{CO_3^{2-}}$

B.B.

$\underset{b1}{CO_3^{2-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HCO_3^{1-}} + \underset{b2}{OH^{1-}}$ lies left, basic

b) $Na_2S \longrightarrow \underset{\text{inactive}}{2Na^{1+}} + \underset{\text{active}}{S^{2-}}$

B.B

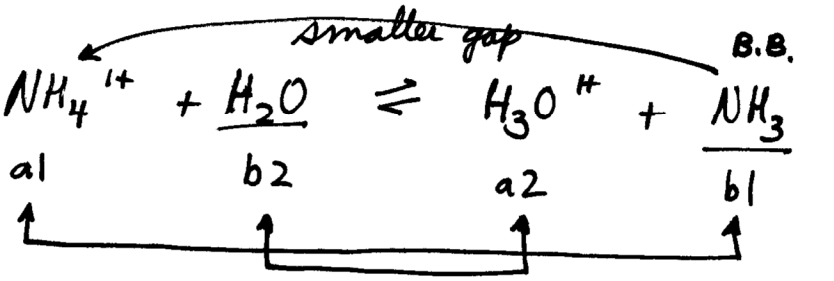
$\underset{b1}{S^{2-}} + \underset{a2}{H_2O} \rightleftharpoons \underset{a1}{HS^{1-}} + \underset{b2}{OH^{1-}}$ lies right, basic

c) $FeCl_3 \longrightarrow \underset{\text{active}}{Fe^{3+}} + \underset{\text{inactive}}{Cl^{1-}}$

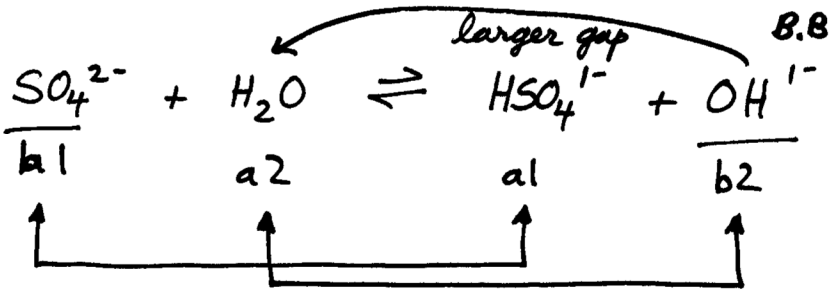
$\underset{\text{lewis acid}}{Fe^{3+}} + 6\underset{\text{lewis base}}{H_2O} \rightleftharpoons Fe(OH)_3 + 3H_3O^{1+}$ acidic

d) $(NH_4)_2SO_4 \rightarrow \underset{\text{active}}{2NH_4^{+}} + \underset{\text{active}^*}{SO_4^{2-}}$ ← not really, but if it were !!

#1



#2



1 predominates ∴ acidic

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e) $Al_2(SO_4)_3 \rightarrow \underset{\text{active}}{2Al^{3+}} + \underset{\text{active}^*}{3SO_4^{2-}}$

$Al^{3+} + 6H_2O \rightleftharpoons Al(OH)_3 + 3H_3O^{+}$

this reaction predominates ∴ acidic

yes! easier this way ↙

* SO_4^{2-} is not very active (could be classified inactive)

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f) $MgSO_4 \rightarrow \underset{\text{active}}{Mg^{2+}} + \underset{\text{active}^* \text{ (inactive)}}{SO_4^{2-}}$

$Mg^{2+} + 4H_2O \rightleftharpoons Mg(OH)_2 + 2H_3O^{+}$ ∴ acidic

g) $KHCO_3 \rightarrow K^{1+} + HCO_3^{1-}$

inactive amphiprotic (active)

smaller gap B.B.

#1 $\underset{b1}{HCO_3^{1-}} + H_2O \rightleftharpoons H_2CO_3 + \underset{b2}{OH^{1-}}$ lies left

a2 a1

larger gap B.B.

#2 $HCO_3^{1-} + \underset{b2}{H_2O} \rightleftharpoons \underset{b1}{CO_3^{2-}} + H_3O^{1+}$ lies left (more)

a1 a2

$[OH^{1-}] > [H_3O^{1+}]$ therefore basic

$\therefore$ #1 predominates $\therefore$ basic

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h) $AgNO_3 \rightarrow Ag^{1+} + NO_3^{1-}$

active inactive

$Ag^{1+} + 2H_2O \rightleftharpoons AgOH + H_3O^{1+}$ acidic

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i) $NH_4I \rightarrow NH_4^{1+} + I^{1-}$

more active

$NH_4^{1+} + H_2O \rightleftharpoons H_3O^{1+} + NH_3$ acidic

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j) $NaHSO_4 \rightarrow Na^{1+} + HSO_4^{1-}$

inactive active

$HSO_4^{1-} + H_2O \rightleftharpoons H_2SO_4 + OH^{1-}$ lies left (more)

large gap

$[H_3O^{1+}] > [OH^{1-}]$ therefore acidic

$HSO_4^{1-} + H_2O \rightleftharpoons SO_4^{2-} + H_3O^{1+}$ lies left

small gap

predominates $\therefore$ acidic