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1.

a) $\overbrace{Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}}^{\text{oxidation}}$ (acidic conditions)

$+6\ -2 \quad +2 \quad +3 \quad +3$ (reduction)

For $Cr_2O_7^{2-}$:

Since O has oxidation number $= -2$, $(7)(O) + 2(Cr) = -2$

$7(-2) + 2(Cr) = -2$

$2(Cr) = 12$

$Cr = 6$, $\therefore$ Cr has oxidation number $+6$

Cr^{3+} means that Cr as a product, has an oxidation number of $+3$. Cr is reduced since it gains 6 electrons. (There are 2 Cr in the reactants)

$(3e^-/Cr)$, $(6e^-/2Cr)$

Fe loses an electron when its oxidation number changes from $+2$ to $+3$ (oxidized) $(1e^-/Fe)$

$Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$ (R: 3×2; O: 1×6)

Fe has to be multiplied by 6 to balance all 6 electrons.

$Cr_2O_7^{2-} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+}$ (Balance non-oxygen elements)

$Cr_2O_7^{2-} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$ (Balance oxygens)

$14H^+ + Cr_2O_7^{2-} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$ (Balance hydrogens by adding hydrogen ions)

$\rightarrow 14(+1) + (-2) + 6(+2) = 2(+3) + 6(+3) + 7(0)$ (Check if charges balance)

$24 = 24$ ✓

$\therefore 14H^+ + Cr_2O_7^{2-} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$ is the balanced reaction.

b) $\overbrace{S_5O_6^{2-} + ClO^- \rightarrow SO_4^{2-}}^{\text{oxidation}} + Cl^-$ (basic conditions)

$+2\ -2 \quad +1\ -2 \quad +6\ -2 \quad -1$ (reduction)

For $S_5O_6^{2-}$,

$\therefore$ O has oxidation number $= -2$, S has oxidation number: $6(-2) + 5(S) = -2$

$-12 + 5(S) = -2$

$S = +2$

For SO_4^{2-},

$\therefore$ O has oxidation number $= -2$, S has oxidation number: $4(-2) + S = -2$

$S = +6$

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1b) con't

Each S has a change in oxidation number of +2 to +6. Each S loses 4 electron
for a total of 20 electrons. (Oxidation)

$(4e^-/S)$, $(20e^-/5S)$

For ClO^-:

O has an oxidation number of -2, Cl has an oxidation number: $-2 + Cl = -1$

$Cl = +1$.

For Cl^-:

Cl has an oxidation number of -1.

Each Cl has a change in oxidation number from +1 to -1. Cl gains 2 electrons (reduced)

$(2e^-/Cl)$

O:

$\overset{+2}{S_5}O_6^{2-} \rightarrow \overset{+6}{S}O_4^{2-}$

$S_5O_6^{2-} \rightarrow SO_4^{2-} + 20e^-$ (Balance electron transfer)

$S_5O_6^{2-} \rightarrow 5SO_4^{2-} + 20e^-$ (Balance non-oxygen elements)

$14H_2O + S_5O_6^{2-} \rightarrow 5SO_4^{2-} + 20e^-$ (Balance oxygen with water)

$14H_2O + S_5O_6^{2-} \rightarrow 5SO_4^{2-} + 20e^- + 28H^+$ (Balance hydrogen with H^+)

$28OH^- + 14H_2O + S_5O_6^{2-} \rightarrow 5SO_4^{2-} + 20e^- + 28H^+ + 28OH^-$ (Balance H^+ with OH^-)

$28OH^- + S_5O_6^{2-} \rightarrow 5SO_4^{2-} + 20e^- + 14H_2O$ (Combine and cancel water)

R: $ClO^- \rightarrow Cl^-$

$ClO^- + 2e^- \rightarrow Cl^-$ (Balance electron transfer)

$ClO^- + 2e^- \rightarrow Cl^- + H_2O$ (Balance oxygen with water)

$2H^+ + ClO^- + 2e^- \rightarrow Cl^- + H_2O$ (Balance hydrogen with H^+)

$2OH^- + 2H^+ + ClO^- + 2e^- \rightarrow Cl^- + H_2O + 2OH^-$ (Balance H^+ with OH^-)

$H_2O + ClO^- + 2e^- \rightarrow Cl^- + 2OH^-$ (Combine + cancel water)

∵ oxidation reaction has $20e^-$ transferred and reduction reaction has $2e^-$ transferred,

multiply reduction reaction by 10 and add half-reactions:

(Cancel like terms)

$\cancel{20e^-} + \cancel{2}8OH^- + S_5O_6^{2-} + \cancel{10H_2O} + 10ClO^- \rightarrow 5SO_4^{2-} + \cancel{1}4H_2O + 10Cl^- + \cancel{20OH^-} + \cancel{20e^-}$

∴ $8OH^- + S_5O_6^{2-} + 10ClO^- \rightarrow 5SO_4^{2-} + 4H_2O + 10Cl^-$ is the balanced reaction in basic conditions

$8(-1) + (-2) + 10(-1) = 5(-2) + 4(0) + 10(-1)$

$-20 = -20$ ✓ Charges balance

1c) $\overbrace{Al + \underbrace{OH^- \rightarrow AlO_2^-}_{\text{oxidation}} + H_2}^{\text{reduction}}$ (basic conditions)

$\;\;\;\;\;\;\;0\;\;\;\;\;\;-2+1\;\;\;\;\;\;+4\;-2\;\;\;\;0$

For Al:

Al has an oxidation number of 0

Al in AlO_2^- has an oxidation number: $Al + 2(-2) = -1$ (oxygen has an oxidation number of -2)

$Al = +3$.

Al loses 3 electrons (oxidation) ($3e^-/Al$)

For H:

H has an oxidation number: $H + (-2) = -1$

$H = +1$ in OH^-.

H has an oxidation number $= 0$ in H_2.

Each H gains 1 electron (reduction) for a total of 2 electrons. ($1e^-/H$), ($2e^-/2H$)

$\overbrace{Al + 2OH^- \rightarrow AlO_2^- + H_2}^{R: 2\times 3}$

$\underbrace{Al + 2OH^- \rightarrow AlO_2^-}_{O: -3\times 2}$

Coefficients in front of Al and AlO_2^- are multiplied by 2 and coefficients in front of OH^- and H_2 are multiplied by 3 since $lcm(2,3) = 6$.

$2Al + 6OH^- \rightarrow 2AlO_2^- + 3H_2$ (Balance electrons)

$2Al + 6OH^- \rightarrow 2AlO_2^- + 3H_2 + 2H_2O$ (Balance O with water)

$4H^+ + 2Al + 6OH^- \rightarrow 2AlO_2^- + 3H_2 + 2H_2O$ (Balance H with H^+)

$\cancel{4OH^- + 4H^+} + 2Al + \cancel{6}OH^- \rightarrow 2AlO_2^- + 3H_2 + \cancel{2H_2O} + \cancel{4OH^-}$ (Balance H with OH^-)

$2H_2O + 2Al + 2OH^- \rightarrow 2AlO_2^- + 3H_2$ (Cancel like terms)

∴ The balanced reaction in basic conditions is:

$$2H_2O + 2Al + 2OH^- \rightarrow 2AlO_2^- + 3H_2$$

$2(0) + 2(0) + 2(-1) = 2(-1) + 3(0)$

$-2 = -2$ ✓ Charges balance!

1d) $\overset{+2\ -3+1}{Cu(NH_3)_4^{2+}} + \overset{+3\ -2}{S_2O_4^{2-}} \rightarrow \overset{+4-2}{SO_3^{2-}} + \overset{0}{Cu} + \overset{-3+1}{NH_3}$ (basic conditions)

oxidation

reduction

For Cu:

Cu has a +2 oxidation number in $Cu(NH_3)_4^{2+}$ (NH_3 has a total oxidation number of 0)

Cu has an oxidation number = 0 in Cu.

Cu gains 2 electrons (reduction) ($2e^-/Cu$)

For S: S has oxidation number: $2(S) + 4(-2) = -2$ in $S_2O_4^{2-}$

$S = +3$

S has oxidation number: $S + 3(-2) = -2$ in SO_3^{2-}

$S = +4$

Each S loses 1 electron (oxidation) ($1e^-/S$), Total: $2e^-/2S$

R: $Cu(NH_3)_4^{2+} \rightarrow Cu + NH_3$

$Cu(NH_3)_4^{2+} + 2e^- \rightarrow Cu + NH_3$ (Balance electron transfer)

$Cu(NH_3)_4^{2+} + 2e^- \rightarrow Cu + 4NH_3$ (Balance non-oxygen elements)

O: $S_2O_4^{2-} \rightarrow SO_3^{2-}$

$S_2O_4^{2-} \rightarrow SO_3^{2-} + 2e^-$ (Balance electron transfer)

$S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 2e^-$ (Balance non-oxygen elements)

$2H_2O + S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 2e^-$ (Balance O with water)

$2H_2O + S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 2e^- + 4H^+$ (Balance H with H^+)

$4OH^- + 2H_2O + S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 2e^- + 4H^+ + 4OH^-$ (Balance H^+ with OH^-)

$4OH^- + S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 2e^- + 2H_2O$ (Combine + cancel water)

Add half-reactions since electron gain/loss is already equal.

$\therefore Cu(NH_3)_4^{2+} + 4OH^- + S_2O_4^{2-} \rightarrow Cu + 4NH_3 + 2SO_3^{2-} + 2H_2O$

$+2 + 4(-1) + (-2) = 0 + 4(0) + 2(-2) + 2(0)$

$-4 = -4$ ✓ Charges balance!