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ANSWERS

1. (a) $Zn(s) + H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

$Zn \rightarrow Zn^{2+}$	write the half-reaction
$Zn \rightarrow Zn^{2+}$	balance all elements except O and H (Zn is balanced)
$Zn \rightarrow Zn^{2+}$	add water molecules to balance the oxygen (no oxygen)
$Zn \rightarrow Zn^{2+}$	add hydrogen ions to balance hydrogen (no hydrogen)
$Zn \rightarrow Zn^{2+} + 2\ e^-$	add electrons to balance the charge (this is the oxidation half-reaction because the electrons end up on the product side)
$Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-$	balanced oxidation half-reaction

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$H^+ \rightarrow H_2$	write the half-reaction
$H^+ \rightarrow H_2$	balance all elements except O and H (no other elements)
$H^+ \rightarrow H_2$	add water molecules to balance the oxygen (no oxygen)
$2\ H^+ \rightarrow H_2$	add hydrogen ions to balance hydrogen
$2\ e^- + 2\ H^+ \rightarrow H_2$	add electrons to balance the charge (this is the reduction half-reaction because the electrons end up on the reactant side)
$2\ e^- + 2\ H^+(aq) \rightarrow H_2(g)$	balanced reduction half-reaction

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Add the half-reaction equations (the electron transfer is balanced; 2 e^- in each half-reaction).

$$Zn(s) \rightarrow Zn^{2+}(aq) + \cancel{2\ e^-}$$
$$\cancel{2\ e^-} + 2\ H^+(aq) \rightarrow H_2(g)$$

$Zn(s) + 2\ H^+(aq) \rightarrow Zn^{2+} + H_2(g)$ overall balanced equation

1. (b) $HNO_3(aq) + Cu(s) \rightarrow NO_2(g) + Cu^{2+}(aq)$

$HNO_3 \rightarrow NO_2$	write the half-reaction
$HNO_3 \rightarrow NO_2$	balance all elements except O and H (N is balanced)
$HNO_3 \rightarrow NO_2 + H_2O$	add water molecules to balance the oxygen
$H^+ + HNO_3 \rightarrow NO_2 + H_2O$	add hydrogen ions to balance hydrogen
$e^- + H^+ + HNO_3 \rightarrow NO_2 + H_2O$	add electrons to balance the charge (this is the reduction half-reaction because the electrons end up on the reactant side)

$e^- + H^+(aq) + HNO_3(aq) \rightarrow NO_2(g) + H_2O(l)$ balanced reduction half-reaction

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$Cu \rightarrow Cu^{2+}$	write the half-reaction
$Cu \rightarrow Cu^{2+}$	balance all elements except O and H (Cu is balanced)
$Cu \rightarrow Cu^{2+}$	add water molecules to balance the oxygen (no oxygen)
$Cu \rightarrow Cu^{2+}$	add hydrogen ions to balance hydrogen (no hydrogen)
$Cu \rightarrow Cu^{2+} + 2\ e^-$	add electrons to balance the charge (this is the oxidation half-reaction because the electrons end up on the product side)

$Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$ balanced oxidation half-reaction

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Add the half-reaction equations after balancing the electron transfer.

reduction half-reaction × 2 = $\cancel{2\ e^-} + 2\ H^+(aq) + 2\ HNO_3(aq) \rightarrow 2\ NO_2(g) + 2\ H_2O(l)$

oxidation half-reaction × 1 = $Cu(s) \rightarrow Cu^{2+}(aq) + \cancel{2\ e^-}$

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overall balanced equation $2\ H^+(aq) + 2\ HNO_3(aq) + Cu(s) \rightarrow 2\ NO_2(g) + 2\ H_2O(l) + Cu^{2+}(aq)$

2. $CH_3OH(aq) + MnO_4^-(aq) \rightarrow CO_3^{2-}(aq) + MnO_4^{2-}(aq)$ (in basic solution)

$CH_3OH \rightarrow CO_3^{2-}$	write the half-reaction
$CH_3OH \rightarrow CO_3^{2-}$	balance all elements except O and H
$2\ H_2O + CH_3OH \rightarrow CO_3^{2-}$	add water molecules to balance the oxygen
$2\ H_2O + CH_3OH \rightarrow CO_3^{2-} + 8\ H^+$	add hydrogen ions to balance hydrogen
$2\ H_2O + CH_3OH \rightarrow CO_3^{2-} + 8\ H^+ + 6\ e^-$	add electrons to balance the charge
$8\ OH^- + 2\ H_2O + CH_3OH \rightarrow CO_3^{2-} + 8\ H^+ + 6\ e^- + 8\ OH^-$	to both sides, add OH^- to equal to number of H^+
$8\ OH^- + 2\ H_2O + CH_3OH \rightarrow CO_3^{2-} + 8\ H_2O + 6\ e^-$	combine OH^- and H^+ to make H_2O
$8\ OH^- + CH_3OH \rightarrow CO_3^{2-} + 6\ H_2O + 6\ e^-$	reduce water (remove 2 H_2O from both sides)

$8\ OH^-(aq) + CH_3OH(aq) \rightarrow CO_3^{2-}(aq) + 6\ H_2O(l) + 6\ e^-$ balanced oxidation half-reaction

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$MnO_4^- \rightarrow MnO_4^{2-}$	write the half-reaction
$MnO_4^- \rightarrow MnO_4^{2-}$	balance all elements except O and H (Mn is balanced)
$MnO_4^- \rightarrow MnO_4^{2-}$	add water molecules to balance the oxygen (oxygen is balanced)
$MnO_4^- \rightarrow MnO_4^{2-}$	add hydrogen ions to balance hydrogen (no hydrogen)
$e^- + MnO_4^- \rightarrow MnO_4^{2-}$	add electrons to balance the charge
$e^- + MnO_4^- \rightarrow MnO_4^{2-}$	there are no H^+ so no OH^- are added

$e^- + MnO_4^-(aq) \rightarrow MnO_4^{2-}(aq)$ balanced reduction half-reaction

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Add the half-reaction equations after balancing the electron transfer.

oxidation half-reaction × 1 = $8\ OH^-(aq) + CH_3OH(aq) \rightarrow CO_3^{2-}(aq) + 6\ H_2O(l) + \cancel{6\ e^-}$

reduction half-reaction × 2 = $\cancel{6\ e^-} + 6\ MnO_4^-(aq) \rightarrow 6\ MnO_4^{2-}(aq)$

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overall balanced equation

$$8\ OH^-(aq) + CH_3OH(aq) + 6\ MnO_4^-(aq) \rightarrow CO_3^{2-}(aq) + 6\ H_2O(l) + 6\ MnO_4^{2-}(aq)$$