REDOX Review
Key

1. Oxidation — the loss of one or more electrons by a substance.
   Reduction — the gain of one or more electrons by a substance.

2. Redox Reaction (aka Oxidation-Reduction Rxn): a process in which one or more electrons are transferred between reaction partners.

3. Oxidation half-reaction: $Al \longrightarrow Al^{3+} + 3e^-$
   * Al is Reducing agent
   Reduction half-reaction: $Cu^{2+} + 2e^- \longrightarrow Cu$
   * Cu^{2+} is Oxidizing agent

   Net Ionic Redox Equation:

   $$2Al + 3Cu^{2+} \longrightarrow 2Al^{3+} + 3Cu$$

4. $BrO_3^- + 6H^+ + 5e^- \longrightarrow \frac{1}{2} Br_2 + 3H_2O$ $E^\circ = +1.48 V$
   $H_2S \longrightarrow S_{(s)} + 2H^+ + 2e^-$ $E^\circ = -0.14 V$

   COMPLETE:
   $2BrO_3^- + 2H^+ + 5H_2S \longrightarrow Br_2 + 6H_2O + 5S_{(s)}$ $E^\circ_{TOTAL} = 1.34 V$

   Rxn is <u>spontaneous</u>

   O. agent = BrO_3^- (acidified)
   R. agent = H_2S

5. a) MnO_4^-: $O = -2$; $Mn = +7$ b) H_2SO_3: $O = -2$; $H = +1$; $S = +4$
   c) Fe_3O_4: $O = -2$; $Fe = \frac{8}{3}$ d) $BaCr_2O_7$: $O = -2$; $Ba = +2$; $Cr = +6$.
   e) C_3H_8: $H = +1$; $C = -\frac{8}{3}$ f) $HClO_4$: $O = -2$; $H = +1$; $Cl = +7$
   g) P_4: $P = 0$

6. a) NO; most double replacement rxns are <u>not</u> REDOX rxns. Also, oxidation #s of species involved do <u>not</u> change.
   b) YES; Na changes from 0 to +1 (oxidized)
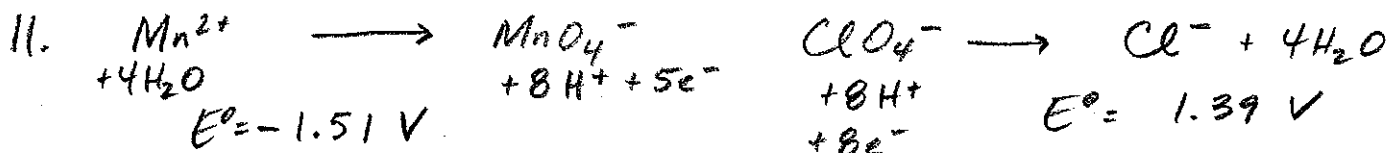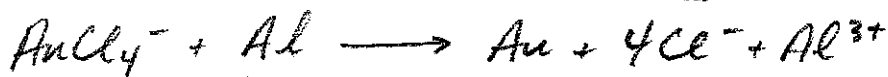   Mg changes from +2 to 0 (reduced)

7. Gold (Au)   * see table.

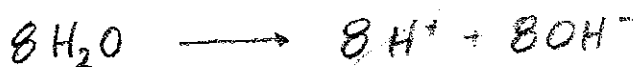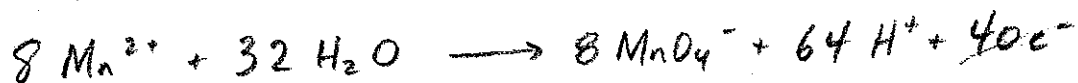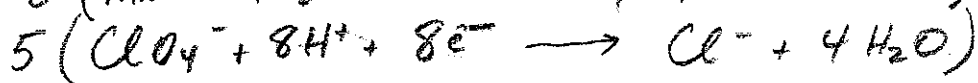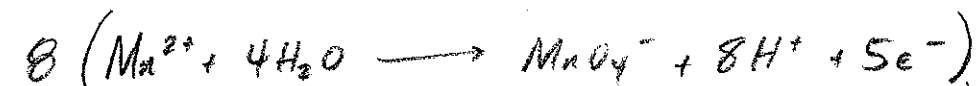8. Nickel (Ni) as it is lower in the Reducing Agents' column.

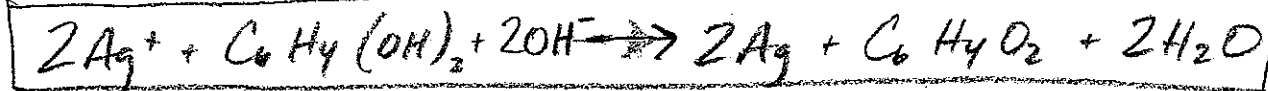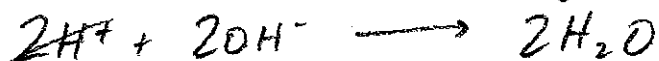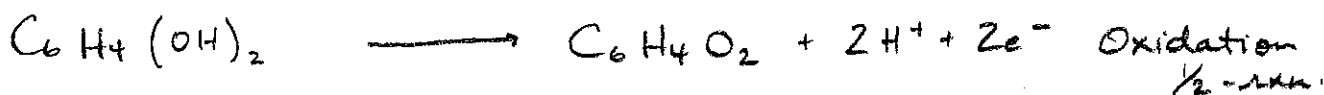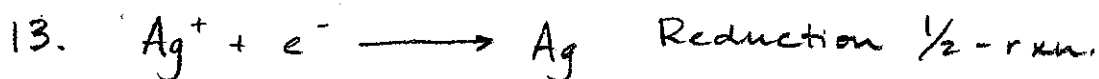9. O_2 (acidified) ag^d MnO_4^- (in water), and Fe^{3+}.

10. a) No Rxn (on same side of table) $\Rightarrow$ both Ox. Agents.

   b) Non-spontaneous

   c) Spontaneous: $AuCl_4^- + 3e^- \longrightarrow Au + 4Cl^-$

   $$\underline{Al \longrightarrow Al^{3+} + 3e^-}$$

   $$AuCl_4^- + Al \longrightarrow Au + 4Cl^- + Al^{3+}$$

11. $Mn^{2+} \longrightarrow MnO_4^-$ $ClO_4^- \longrightarrow Cl^- + 4H_2O$
   $+4H_2O$ $+8H^+ + 5e^-$ $+8H^+$
   $E° = -1.51\ V$ $+8e^-$ $E° = 1.39\ V$

$$E°cell = -0.12\ V$$

$$8\left(Mn^{2+} + 4H_2O \longrightarrow MnO_4^- + 8H^+ + 5e^-\right)$$
$$5\left(ClO_4^- + 8H^+ + 8e^- \longrightarrow Cl^- + 4H_2O\right)$$

$$8\ Mn^{2+} + 32\ H_2O \longrightarrow 8\ MnO_4^- + 64\ H^+ + 40e^-$$
$$\underline{5ClO_4^- + 40\ H^+ + 40e^- \longrightarrow 5Cl^- + 20\ H_2O}$$

$$8\ Mn^{2+} + 5\ ClO_4^- + 12\ H_2O \longrightarrow 8\ MnO_4^- + 24\ H^+ + 5Cl^-$$

12. $H_2BO_3^- + 8H^+ \longrightarrow BH_4^- + 3H_2O$
   $+8e^-$

$$8H_2O \longrightarrow 8H^+ + 8OH^-$$

$$\boxed{H_2BO_3^- + 5H_2O + 8e^- \longrightarrow BH_4^- + 8OH^-}$$

13. $Ag^+ + e^- \longrightarrow Ag$ Reduction ½-rxn.

$C_6H_4(OH)_2 \longrightarrow C_6H_4O_2 + 2H^+ + 2e^-$ Oxidation ½-rxn.

$2Ag^+ + C_6H_4(OH)_2 \longrightarrow 2Ag + C_6H_4O_2 + \cancel{2H^+}$

$\cancel{2H^+} + 2OH^- \longrightarrow 2H_2O$

$$\boxed{2Ag^+ + C_6H_4(OH)_2 + 2OH^- \longrightarrow 2Ag + C_6H_4O_2 + 2H_2O}$$

14.   Disproportionation

$3H_2O + IPO_4 \longrightarrow IO_3^- + PO_4^{3-} + 6H^+ + 2e^-$ $2IPO_4 + 6e^- \longrightarrow 2PO_4^{3-} + I_2$

$9H_2O + 3IPO_4 \longrightarrow 3IO_3^- + 3PO_4^{3-} + 18H^+$

$2IPO_4 \longrightarrow 2PO_4^{3-} + I_2$

$$\boxed{9H_2O + 5IPO_4 \longrightarrow 5PO_4^{3-} + 3IO_3^- + I_2 + 18H^+}$$

15. $6(MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O)$

$5(2Cr^{3+} + 7H_2O \longrightarrow Cr_2O_7^{2-} + 14H^+ + 6e^-)$

$6MnO_4^- + 48H^+ + 30e^- \longrightarrow 6Mn^{2+} + 24H_2O$

$10Cr^{3+} + 35H_2O \longrightarrow 5Cr_2O_7^{2-} + 70H^+ + 30e^-$

$6MnO_4^- + 10Cr^{3+} + 11H_2O \longrightarrow 6Mn^{2+} + 5Cr_2O_7^{2-} + 22H^+$

Mol $KMnO_4$ = mol MnO_4^- $(KMnO_4 \longrightarrow K^+ + MnO_4^-)$

= MV = $(0.0500 M)(0.02855 L) = 1.4275 \times 10^{-3}$ mol MnO_4^-

$$\frac{1.4275 \times 10^{-3} \text{ mol } MnO_4^-}{} \left| \frac{10 \text{ mol } Cr^{3+}}{6 \text{ mol } MnO_4^-} \right. = 2.3792 \times 10^{-3} \text{ mol } Cr^{3+}$$

$M = \dfrac{mol}{V} = \dfrac{2.3792 \times 10^{-3} \text{ mol}}{0.0100 \text{ L}} = \boxed{0.238 \text{ M } Cr^{3+}}$ --

16. $Na_2 C_2 O_4 \longrightarrow 2 Na^+ + C_2 O_4^{2-}$ ∴ mol $Na_2 C_2 O_4$ = mol $C_2 O_4^{2-}$
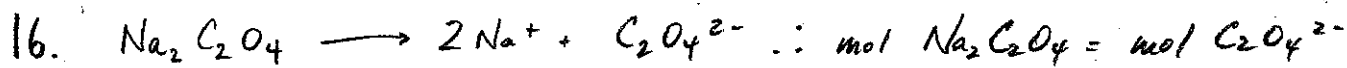
$$\frac{0.300g \ Na_2 C_2 O_4 \ | \ 1 mol \ Na_2 C_2 O_4}{| \ 134.0g \ Na_2 C_2 O_4} = 2.239 \times 10^{-3} \ mol \ C_2 O_4^{2-}$$

$$\frac{2.239 \times 10^{-3} mol \ C_2 O_4^{2-} \ | \ 2 \ mol \ MnO_4^-}{| \ 5 \ mol \ C_2 O_4^{2-}} = 8.955 \times 10^{-4} \ mol \ MnO_4^- = mol \ KMnO_4$$

$$(KMnO_4 \longrightarrow K^+ + MnO_4^-)$$

$$M = \frac{mol}{V} = \frac{8.955 \times 10^{-4} \ mol}{0.02342 \ L} = \boxed{3.82 \times 10^{-2} M \quad KMnO_4}$$

17. a) $X = Pb$ (Lead)
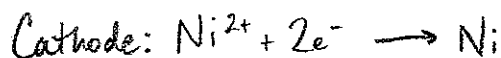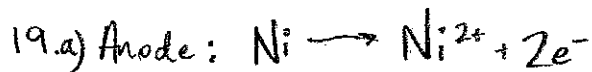   b) $Y = Pb(NO_3)_2$ (among others...)
   c) $Z = KNO_3$ (among others...)
   d) X to Ag (anode = X to cathode = Ag)
   (right to left).

18. Electrolytic cell (hint: MOLTEN NaBr)

   * need ≥ 3.8 V

   Cathode   Anode
   $Na^+ + e^- \rightarrow Na$ $2 Br^- \longrightarrow Br_2 + 2e^-$ (produced at anode)

19. a) Anode: $Ni \longrightarrow Ni^{2+} + 2e^-$
   Cathode: $Ni^{2+} + 2e^- \longrightarrow Ni$
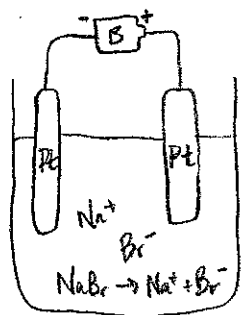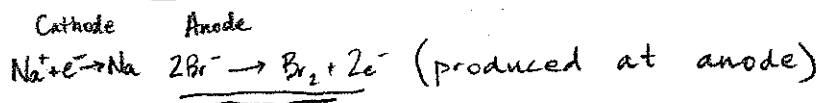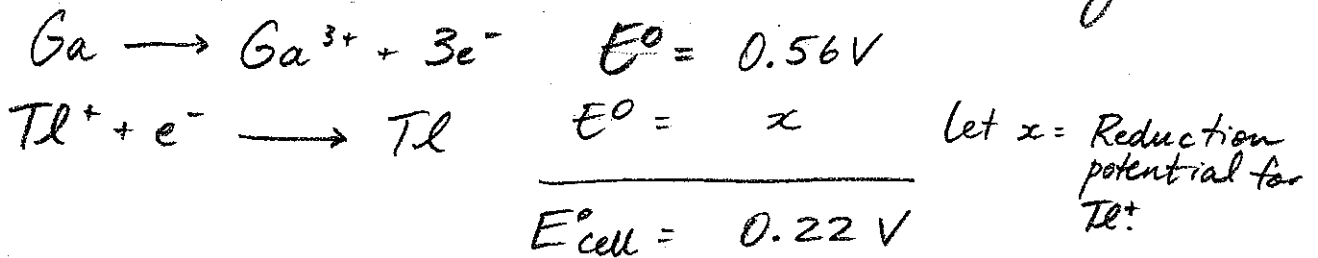
   Electrolytic cell
   (non-spontaneous)

   b) > 0.0 V (ie ANY voltage)

20.a) Gallium is ANODE $\Rightarrow$ see e^- flow in diagram!

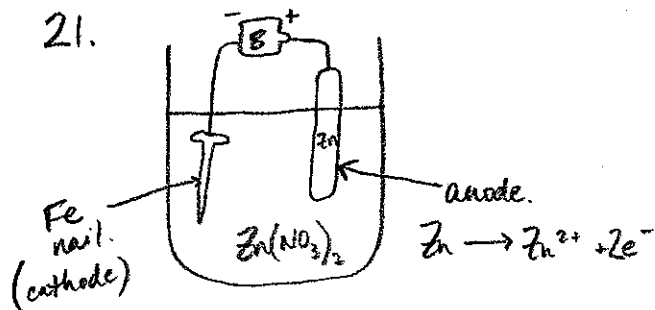$$Ga \longrightarrow Ga^{3+} + 3e^- \qquad E^0 = 0.56V$$

$$Tl^+ + e^- \longrightarrow Tl \qquad E^0 = \qquad x \qquad\qquad \text{let } x = \text{Reduction potential for } Tl^+$$

$$\overline{}$$

$$E^0_{cell} = \quad 0.22 \ V$$

$$0.56 \ V + x = 0.22 \ V$$

$$\boxed{x = -0.34 \ V}$$

b) O. Agent = whatever gets reduced = Tl^+

21.

$E^0_{rxn} = 0.00 \ V$

Fe nail. (cathode)

$Zn(NO_3)_2$

anode.

$Zn \longrightarrow Zn^{2+} + 2e^-$

$Zn^{2+} + 2e^- \longrightarrow Zn$
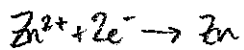
22. Oxygen and water.

$\downarrow$ acts as oxidizing agent.

$\rightarrow$ provides medium for migration of ions

Cathode: $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

Anode: $Fe \longrightarrow Fe^{2+} + 2e^-$
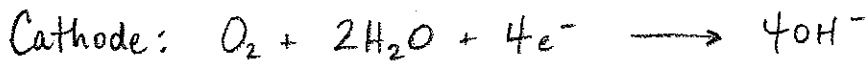
23. i) Painting – fairly cheap, forms barrier <u>BUT</u> eroded over time, constant maintenance required $\Rightarrow$ one chip can lead to rust

ii) Galvanizing – expensive, physical <u>and</u> chemical barrier Zinc oxide (zinc strips) adheres well to iron preventing further oxidation. (SACRIFICIAL ANODE: Zn, Cr, Mg, Al).

iii) Electric current: apply an electric current to the hull so cathode constantly receives e^-s (not from Fe). Expensive/constant monitoring/maintenance
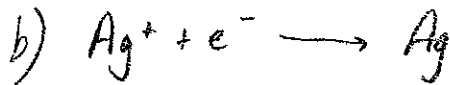
24. $2NO_3^- + 4H^+ + 3e^- \longrightarrow NO + 2H_2O$ $E^° = 0.96V$
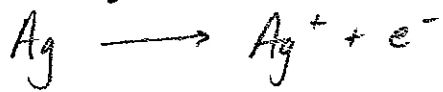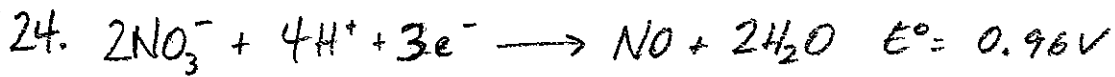
$Ag \longrightarrow Ag^+ + e^-$ $\underline{E^° = -0.80\,V}$

$E^°_{cell} = 0.16\,V$ <u>spontaneous</u>

H^+ and Ag is non-spontaneous.

* from Sulfuric Acid electrolysis example:

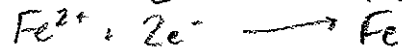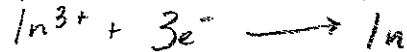HSO_4^- is a very weak Reducing Agent, unable to oxidize Ag.

25. a) Anode (Fe)

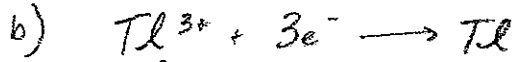b) $Ag^+ + e^- \longrightarrow Ag$

c) Fe

d) 1.25 V.

26. a)

on Metal	In^{3+}	Tl^{3+}	Fe^{2+}
In		rxn	no rxn.
Tl	no rxn.		no rxn.
Fe	rxn.	rxn	

b) $Tl^{3+} + 3e^- \longrightarrow Tl$

$In^{3+} + 3e^- \longrightarrow In$

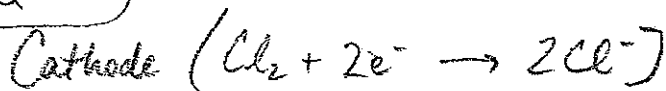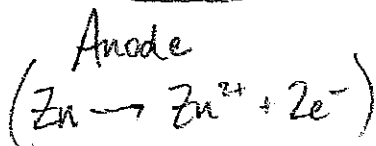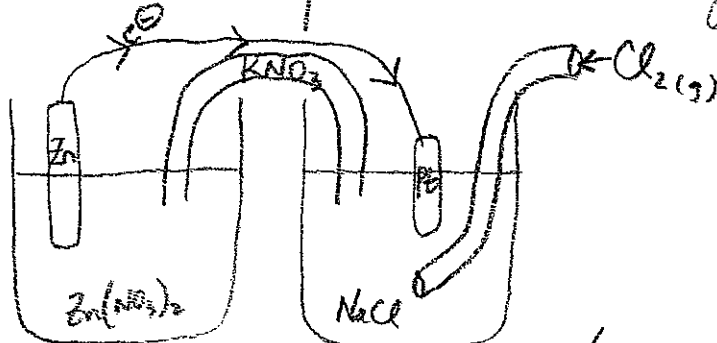$Fe^{2+} + 2e^- \longrightarrow Fe$

27. $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$ $(1\times10^{-7}M)$

gas = Hydrogen (H_2)

Water is a stronger oxidizing agent (more easily reduced) than Na^+, K^+, Li^+, and Cs^+ so it serves as the cathode.
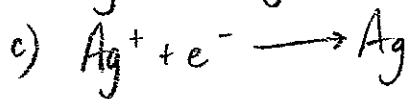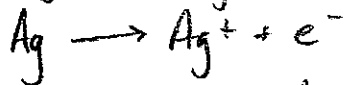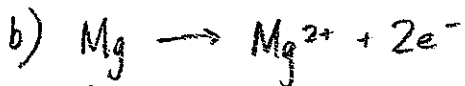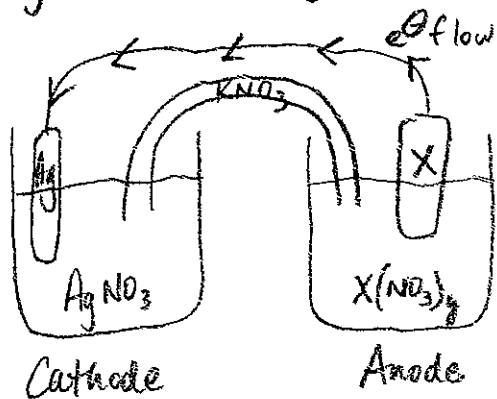
* preferred rxn requires least voltage input

28.

Anode

$(Zn \longrightarrow Zn^{2+} + 2e^-)$

Cathode $(Cl_2 + 2e^- \longrightarrow 2Cl^-)$

29. a) i) Mg to iron fork.
   ii) Ag on Ⓡ to Ag on Ⓛ

   b) $Mg \longrightarrow Mg^{2+} + 2e^-$
      $Ag \longrightarrow Ag^+ + e^-$

   c) $Ag^+ + e^- \longrightarrow Ag$

30.

X could be Mg, Na, Ca etc...
from our table.