2011

# Chemistry 30

## Unit 3 Electrochemical Change

### Practice Exam

RTD Learning

**RTD**
Diploma Preparation
1/1/2011

Potassium chlorate is a compound containing potassium, chlorine, and oxygen atoms. The molecular formula for potassium chlorate is $KClO_3$. It is a white crystalline substance in its pure form, and it is the most common chlorate used in industrial processes. Potassium chlorate, which is a strong oxidizing agent, finds applications in explosives, fireworks, disinfectants, and safety matches. Potassium chlorate is also used as a pesticide and herbicide. In Finland, it was sold under the trade name of 'Fegabit,' and in the former German Democratic Republic (GDR), its trade name 'Wegerein' meant 'clear paths.' A weed killer!

VEB Elektrochemisches Kombinat Bitterfeld,
producer of 'Wegerein,' former GDR, 1959
Fotographie ☺: A. Wolter

A student mixes acidified solutions of potassium chlorate with potassium chloride.

1. **Use the following half-reactions to answer this question.**

$ClO_3{}^-{}_{(aq)} + 6H^+{}_{(aq)} + 5e^- \rightarrow \frac{1}{2} Cl_{2\,(g)} + 3H_2O_{(l)}$ $E^\ominus = 1.47$ V

$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-{}_{(aq)}$ $E^\ominus = 1.36$ V

Which observation is incorrect?

A. Chlorine gas is produced
B. A spontaneous reaction occurs
C. The pH of the final solution decreases
D. The concentration of both perchlorate and chloride decreases

2. **Chloride acts as the (*i*) and the stronger oxidizing agent (*ii*) electrons**

| | *I* | *ii* |
|---|---|---|
| **A.** | Stronger reducing agent | Gains |
| **B.** | Stronger oxidizing agent | Loses |
| **C.** | Stronger reducing agent | Loses |
| **D.** | Stronger oxidizing agent | Gains |

The concentration of sodium hypochlorite in household bleach can be determined by titration with a reducing agent, such as iodide solution.

$OCl^{-}{}_{(aq)} + 2I^{-}{}_{(aq)} + 2H_3O^{+}{}_{(aq)} \rightarrow I_{2\,(aq)} + Cl^{-}{}_{(aq)} + 3H_2O_{(l)}$

Due to the formation of iodine, the colour changes from colourless to brown.

**3. If a lab technician used 10 mL of 0.050 mol/L iodide solution to titrate 50 mL of hypochlorite, then what was the concentration of hypochlorite in the bleach sample?**

A. 0.3 mol/L
B. 0.02 mol/L
C. 0.001 mol/L
D. 0.005 mol/L

**4. Which incomplete half-reaction is an oxidation?**

I $2H^{+}{}_{(aq)} + \frac{1}{2}O_2 \rightarrow H_2O_{(aq)}$
II $Cr_2O_7^{2-}{}_{(aq)} + 14H^{+}{}_{(aq)} \rightarrow 2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$
III $K^{+}{}_{(aq)} \rightarrow K_{(s)}$
IV $2I^{-}{}_{(aq)} \rightarrow I_{2(s)}$

A. I and II
B. IV only
C. III and IV
D. None of the above

When solid potassium chromate is dissolved in water, it forms a yellow solution. When solid potassium **dichromate** is dissolved in water, the resulting solution is orange. However, in solution, these ions are actually in equilibrium, which is pH-dependent, as indicated by the equation below:

**5. When an acid is added to a solution containing chromate ions, the reaction that occurs is:**

$2CrO_4^{2-}{}_{(aq)} + 2H^{+}{}_{(aq)} \rightarrow Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)}$

The change in the oxidation number for chromium is (*i*) and chromium undergoes (*ii*)

| | i | ii |
|---|---|---|
| **A.** | 2 | Neither reduction nor oxidation |
| **B.** | 2 | Oxidation |
| **C.** | 0 | Reduction |
| **D.** | 0 | Neither reduction nor oxidation |

6. **A true statement that can be made from a reading of the table of standard electrode potentials is that:**

A. Silver bromide gains electrons more readily than hydrogen ions do
B. Hydrogen gas gains electrons more readily than silver bromide does
C. Hydrogen ions gain electrons more readily than silver bromide does
D. Hydrogen gas loses electrons more readily than cadmium metal does

Fluorine is the most electronegative of the elements. Oxidation of fluorine by removing one electron requires so much energy that no known oxidant can oxidize fluorine to any positive oxidation state.

7. **If fluorine gas is bubbled through sodium iodide solution:**

A. $Na^+_{(aq)}$ is reduced
B. $I^-_{(aq)}$ is oxidized
C. $F_{2(g)}$ is oxidized
D. $I^-_{(aq)}$ is reduced

Chrome plating is a technique of electroplating a thin layer of chromium onto a metal object. The chromed layer provides corrosion protection and increases surface hardness.

**NR 1 The time required to produce 10.0 g of Chromium metal from a solution of Chromium (III) nitrate in an electrolytic cell, if 20 A current are applied, is: _________ in min**

8. **Use the following half-reactions to answer this question.**

$Ce^{3+}_{(aq)} + 3e^- \rightarrow Ce_{(s)} \quad E^\ominus = -2.34\ V$
$Cr^{2+}_{(aq)} + 2e^- \rightarrow Cr_{(s)} \quad E^\ominus = -0.91\ V$

When an operating electrochemical cell is constructed on the basis of these half-reactions, the oxidizing agent gains:

A. Six less electrons than the reducing agent gains
B. Two more electrons than the reducing agent loses
C. Three more electrons than the reducing agent loses
D. The same number of electrons as the reducing agent loses

9. **The standard reduction potential of a metallic ion is –0.3 V. Which of these metals will be the most easily oxidized by this ion?**

A. $Cd_{(s)}$
B. $Co_{(s)}$
C. $Pb_{(s)}$
D. $Cu_{(s)}$

**10. Use the following half-reactions to answer this question.**

$2X^{+}_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+} + 2X_{(s)}$ $E^{\ominus} = 2.60$ V

$Y_{(s)} + Cd^{2+}_{(aq)} \rightarrow Cd_{(s)} + Y^{2+}_{(aq)}$ $E^{\ominus} = 0.63$V

What is the $E^{\ominus}$ for the reaction $2X^{+}_{(aq)} + Y_{(s)} \rightarrow 2X_{(s)} + Y^{2+}_{(aq)}$

A. 3.23 V
B. 1.97 V
C. 1.26 V
D. 0.80 V

Use the following reactions to answer this question:

$Ir_{(s)} + Tl^{+}_{(aq)} \rightarrow$ no reaction

$Ir^{3+}_{(aq)} + Re_{(s)} \rightarrow$ no reaction

$3\,Tl^{+}_{(aq)} + Y_{(s)} \rightarrow 3Tl_{(s)} + Y^{3+}_{(aq)}$

**11. In these reactions, the strongest oxidizing agent is (*i*) and in a reaction with Y it will (*ii*) electrons**

| | i | Ii |
|---|---|---|
| A. | $Tl^{+}$ | **Lose** |
| B. | $Y^{3+}$ | **Gain** |
| C. | $Ir^{3+}$ | **Lose** |
| D. | $Re^{3+}$ | **Gain** |

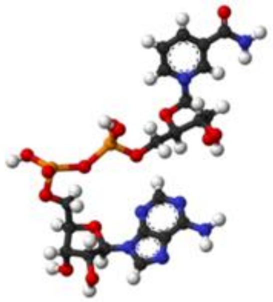
**NR 2 The standard cell potential for the following electrochemical cell**

**$Al_{(s)}$ / $Al^{3+}_{(aq)}$ // $Sn^{2+}_{(aq)}$ / $Sn_{(s)}$ is +/- _____________V**

**NR 3 Which statements about an electrochemical cell are true?**

1. The electrons flow through an external circuit
2. The stronger oxidizing agent gains electrons
3. Electrical energy is converted into chemical energy
4. The stronger reducing agent reacts at the anode
5. Chemical potential energy is transformed into electrical energy

_ , _ , _ and _



Nicotinamide adenine dinucleotide ($NAD^+$), is a coenzyme found in all living cells. The compound is a dinucleotide, because it consists of two nucleotides connected through their phosphate groups. One nucleotide contains an adenine base and the other one contains nicotinamide.

In plant chloroplasts, $NADP^+$ is reduced by ferredoxin-$NADP^+$ reductase during the last step of the electron transport chain of the photosynthetic light reactions. The NADPH produced is then used in the Calvin cycle for the biosynthetic reactions of photosynthesis.

**12.** $NADP^+ + 2e^- + H^+ \rightarrow NADPH$
$NAD^+ + 2e^- + H^+ \rightarrow NADH$

**In the $NAD^+_{(aq)}$ / $NADH_{(aq)}$ coenzyme, the oxidizing agent is *i* and the $NADP^+_{(aq)}$ / $NADPH_{(aq)}$ coenzyme, the electron acceptor is *ii*.**

| | i | ii |
|---|---|---|
| A. | $NAD^+$ | $NADP^+$ |
| B. | $NAD^+$ | NADPH |
| C. | NADH | $NADP^+$ |
| D. | NADH | NADPH |

NR 4 $Ni^{2+} + 2e^- \rightarrow Ni$

If the standard copper reduction half reaction had been chosen as a reference instead of the hydrogen half-reaction, then the electrical potential for nickel would be +/- _______________.

NR 5 A current of 5.00 A flows through a copper(I) sulfate solution until 6.35 g of copper are deposited. How long did it take to deposit 6.35 g of copper?

_________ min

The following half reaction occurred in an electrolytic cell: $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$

**13.** If 4.00 moles of electrons passed through the cell, what mass of chlorine would be produced?
A. 35.5 g
B. 71.0 g
C. 142 g
D. 284 g

A galvanic anode protects buried or submerged metal structures from corrosion. Galvanic anodes are made from a metal with a more negative electrochemical potential than the metal of the structure. The positive potential difference between the two metals means that the galvanic anode corrodes, so that the anode material is consumed and the structure is preserved. The loss/sacrifice of the anode material explains the alternative name, 'sacrificial anode.'

**14. Use the table below to answer this question. Which of the following metals might be used to provide cathodic protection (sacrificial anode) to prevent the corrosion of iron?**

$Pt^{2+} + 2e^- \rightarrow Pt \quad E^{\Theta} = 1.2\ V$
$Cu^{2+} + 2e^- \rightarrow Cu \quad E^{\Theta} = 0.34\ V$
$Re^{2+} + 2e^- \rightarrow Re \quad E^{\Theta} = 0.3\ V$
$Fe^{2+} + 2e^- \rightarrow Fe \quad E^{\Theta} = -0.44\ V$
$Ti^{2+} + 2e^- \rightarrow Ti \quad E^{\Theta} = -1.63\ V$

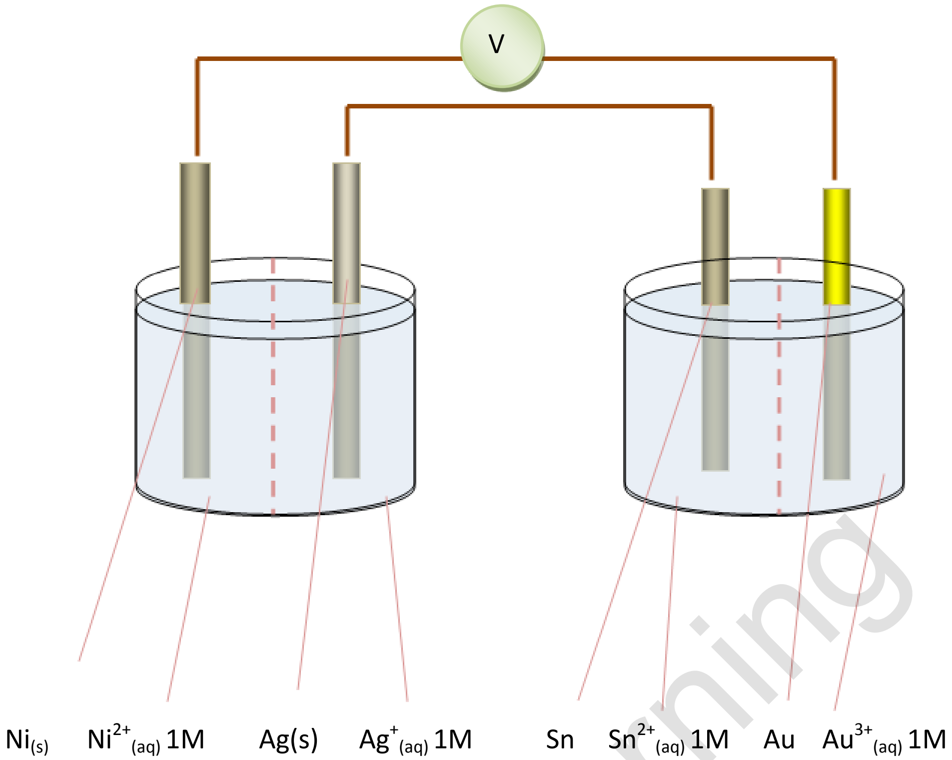
A. Pt
B. Cu
C. Re
D. Ti

**15. Which of the following redox reactions are examples of disproportionation (auto-oxidation)?**

**1.)** $SO_{3(l)} + H_2SO_{4(l)} \rightarrow H_2S_2O_{7(l)}$
**2.)** $3Fe^{2+}_{(aq)} \rightarrow 2Fe^{3+} + Fe_{(s)}$
**3.)** $7ClO_3^-{}_{(aq)} + 2H_3O^+{}_{(aq)} \rightarrow Cl_{2(g)} + 5ClO_4^-{}_{(aq)} + 3H_2O_{(l)}$
**4.)** $K_2Cr_2O_{7(aq)} + 14HCl_{(aq)} \rightarrow 2KCl_{(aq)} + 2CrCl_{3(aq)} + 7H_2O_{(l)} + 3Cl_{2(g)}$

A. 1 and 4
B. 2 and 3
C. 1 and 2
**D.** 3 and 4

**16.**



What will be the reading on the voltmeter?

A. 0.58 V
B. 0.82 V
C. 1.90 V
D. 2.70 V

**17. In the above circuit, the flow of electrons in the external circuit will be from:**

A. Ag to Sn and Au to Ni
B. Ni to Au and Ag to Sn
C. Sn to Ag and Au to Ni
D. Sn to Ag and Ni to Au

**18. A cell which converts electrical energy into chemical energy is called a/an:**

A. Electrochemical cell
B. Fuel cell
C. Voltaic cell
D. Electrolytic cell

**19. There is no evidence that sodium metal is produced at the cathode when an electric current is passed through an aqueous solution of sodium chloride because the:**

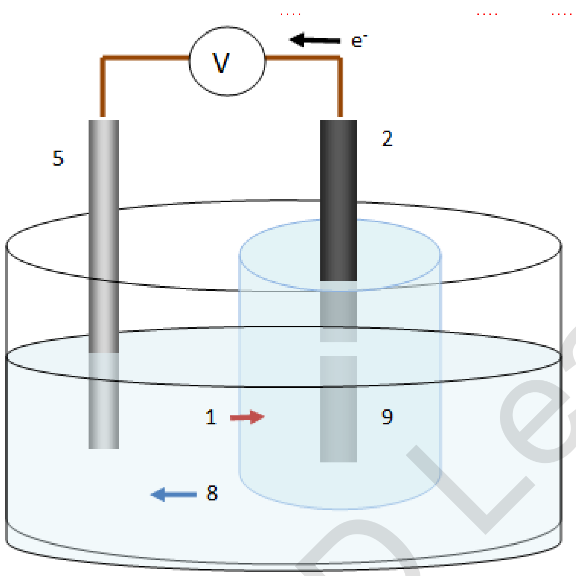
A. Water is more readily reduced than sodium ions

B. Sodium reacts with water as it forms

C. Voltage is too high to reduce the sodium ions

D. Water is oxidized faster than sodium ions

**20. The diagram below represents the cell $Sn_{(s)}/Sn^{2+}_{(aq)}$ // $MnO_4^{-}{}_{(aq)}$ , $H^{+}_{(aq)}$ / $C_{(s)}$**



**The anion migration is represented by?**

A. 9

B. 5

C. 1

D. 8

**21. The anode in the circuit above is represented by:**

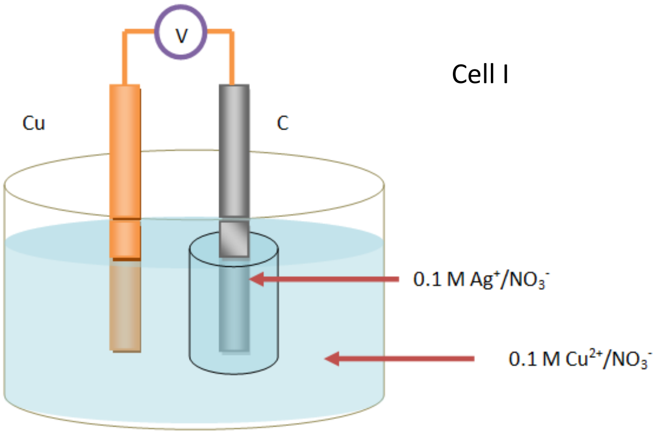
A. 2

B. 5

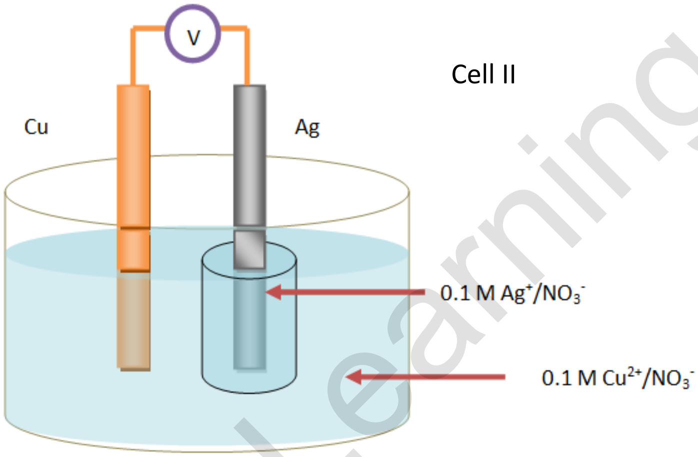
C. 9

D. 1

**22.**



Cell I



Cell II

A negative potential would be observed by:

A. Cell I only
B. Cell 2 only
C. Both cells
D. Neither cell 1 nor cell II

**23. If a block of refined magnesium was selected to serve as a sacrificial anode and if it was bolted onto an iron girder of a bridge, one would expect the:**

A. Iron to oxidize
B. Magnesium to oxidize before the iron
C. Magnesium to reduce before the iron
D. Both the iron and the magnesium to react

**24. Chlorine bleach is produced by the reaction**

**$Cl_{2(g)} + H_2O_{(l)} \rightarrow HOCl_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)}$**

**Which of the following best describes the changes occurring to chlorine?**

A. Chlorine loses 1 electron, and its oxidation state changes from 0 to +1
B. Chlorine gains 1 electron, and its oxidation state changes from 0 to -1
C. Chlorine gains 1 electron, and is a reducing agent
D. Chlorine undergoes disproportionation

**25. Iron is often coated with zinc to minimize corrosion of the iron.**

**The zinc coating acts as:**

A. Cathode and is oxidized
B. Cathode and is reduced
C. Anode and is oxidized
D. Anode and is reduced

**NR 6 An electrochemical cell uses the net reaction:**

**$Pb_{(s)} + 2Ag^+_{(aq)} \rightarrow Pb^{2+}_{(aq)} + 2Ag_{(s)}$**

**If a current of 3.0 amps flows for 1 h from this cell, find the mass of silver plated out in g, and the loss on the lead electrode in g.**

**$m_{Ag}$ _________ g**

**$m_{Pb}$ _________ g**

**26. Use the following equation…**

$H_3PO_4 + 2H^+ + 2e- \rightarrow H_3PO_3 + H_2O$ $E^\Theta = -0.27$ V

**…to decide which species below might be reduced by $H_3PO_4$:**

1.) $Cl_2$
2.) $Ag^+$
3.) $Zn^{2+}$
4.) $Pb^{2+}$

A. 1 and 2
B. 3
C. 1, 2, and 4
D. 1, 2, 3, and 4

**NR 7**

**$2\ V_2O_5 + 6\ Cl_2 \rightarrow VOCl_3 + 3O_2$**

When 10 g of reducing agent reacts, the mass of the oxidizing agent reacting is ___________ g.

**NR 8**

**$2NH_{3(g)} + 3O_{2(g)} + 2CH_{4(g)} \rightarrow 2HCN_{(g)} + 6H_2O + 940\ KJ$**

When 0.606 mol of oxidizing agent reacts, the heat produced is_______________KJ.

**NR 9**

**The oxidation number of Te in each of the ions/molecules $TeO_2$ , $TeO_3^{2-}$ , $TeO_4^{-}$ , $H_6TeO_6$ is respectively:**

_____ , _____ , ______ , ______ .

**NR 10**

**The following electrochemical cell is constructed $Fe_{(s)}$ / $Fe^{2+}_{(aq)}$ //$X^{3+}_{(aq)}$ / $X_{(s)}$**

If $E^{\ominus}$(cell) = 1.97 V, the reduction half-cell reaction = ______________ V.

**27. Ethanol reacts with acidified permanganate as presented by the equation:**

$5C_2H_5OH_{(l)} + 4MnO_4^{-}{}_{(aq)} + 12H^{+}_{(aq)} \rightarrow 5CH_3COOH_{(aq)} + 4Mn^{2+}_{(aq)} + 11H_2O_{(l)}$

In this reaction, the oxidation number for the oxidizing agent changes from:

A. +28 to +8
B. +7 to +2
C. +2 to 0
D. +10 to +2

Gold cyanidation is a metallurgical technique for extracting gold from ore. In this process, gold is converted into a water soluble coordination complex. This reaction was discovered by Carl Wilhelm Scheele, who had earlier discovered cyanide salts.

**28.** Given the following equation:

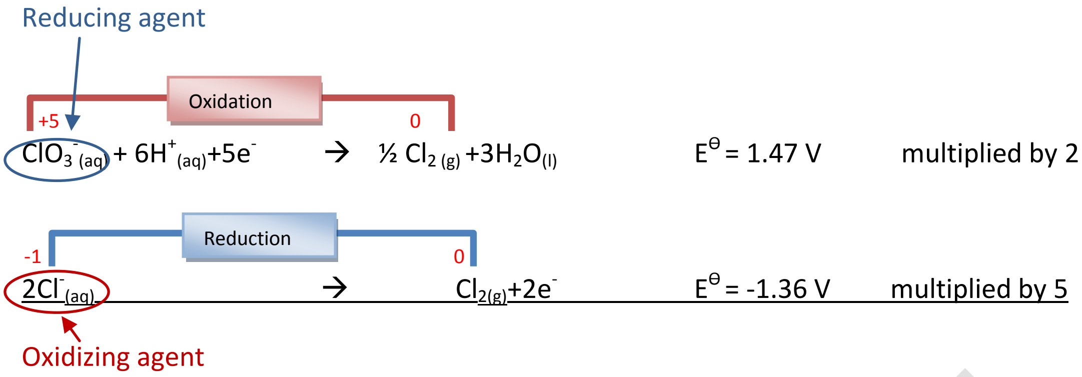
$4Au_{(s)} + 8CN^{-}_{(aq)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 4Au(CN^{-})_{2(aq)} + 4OH^{-}_{(aq)}$

The reducing agent is (*i*) and the oxidizing agent is (*ii*)

| | ***I*** | ***ii*** |
|---|---|---|
| **A.** | Cyanide | Water |
| **B.** | Water | Gold |
| **C.** | Gold | Oxygen |
| **D.** | Oxygen | Cyanide |

**Solutions**

1. C



$ClO_3^-{}_{(aq)} + 6H^+{}_{(aq)} + 5e^- \rightarrow \frac{1}{2} Cl_{2\,(g)} + 3H_2O_{(l)}$ $E^\ominus = 1.47$ V multiplied by 2

$2Cl^-{}_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$ $E^\ominus = -1.36$ V multiplied by 5

$2\,ClO_3^-{}_{(aq)} + 12H^+{}_{(aq)} + 10Cl^-{}_{(aq)} \rightarrow 6Cl_{2(g)} + 6H_2O_{(l)}$ + 0.11 V (spontaneous)

**The hydrogen ion concentration decreases and the pH increases**

2. C

**Chloride is the reducing agent because it undergoes oxidation and reduces chlorate to chlorine. Chloride undergoes oxidation and therefore loses electrons. The reaction is spontaneous (positive net potential) and chloride is on the reactant side. Therefore, chloride is the stronger reducing agent.**

3. D

**Mole ratio:**

$$\frac{n\ OCl^-}{n\ I^-} = \frac{1\ mol}{2\ mol}$$

**Solve for $n\ OCl^-$**

$$n\ OCl^- = \frac{1\ mol}{2\ mol} \times n\ I^-$$

**Remember: n=cV**

**Substitute n by cV**

$$(c \times V) OCl^- = \frac{1\ mol}{2\ mol} \times (c \times V)\ I^-$$

**Solve for the concentration of**

$$c OCl^- = \frac{1\ mol}{2\ mol} \times \frac{(c \times V)\ I^-}{V OCl^-}$$

$$cOCl^- = \frac{1\,mol}{2\,mol} \times \frac{(10\,mL \times 0.05\,mol)\;I^-}{50\,mL\;OCl^-\;L} = 0.005\,mol/L$$

4. B

$2I^-_{(aq)} \rightarrow I_{2(s)}$

**IV is the only oxidation half-reaction**

5. D

$2\overset{+6}{Cr}O_4{}^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightarrow \overset{+6}{Cr_2}O_7{}^{2-}{}_{(aq)} + H_2O_{(l)}$

The change in the oxidation number for chromium is *i* and chromium undergoes *ii*

| | I | ii |
|---|---|---|
| **A.** | 2 | Neither reduction nor oxidation |
| **B.** | 2 | Oxidation |
| **C.** | 0 | Reduction |
| [✓ **D.**] | 0 | Neither reduction nor oxidation |

6. **A**

**$AgBr_{(s)} + e^- \rightarrow Ag_{(s)} + Br^-_{(aq)}$** $E^\ominus = +0.07$ V

**$\underline{H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^-}$** $\underline{E^\ominus = 0.00\text{ V}}$

**$2\,AgBr_{(s)} + H_{2(g)} \rightarrow 2Ag_{(s)} + 2Br^-_{(aq)} + 2H^+_{(aq)}$** +0.07 V (spontaneous reaction)

AgBr is reduced more readily than $H^+$

or

**$AgBr_{(s)} + e^- \rightarrow Ag_{(s)} + Br^-_{(aq)}$** $E^\ominus = +0.07$ V

**$2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$** $E^\ominus = 0.00$ V

Negative slope → spontaneous reaction

7. B

$F_{2(g)} + 2e- \rightarrow 2F^-_{(aq)}$

$I_{2(g)} + 2e- \rightarrow 2I^-_{(aq)}$

Negative slope → spontaneous reaction

$I^-_{(aq)}$ is oxidized and $F_2$ reduced

NR 1

$$Q = I \times t$$

Q charge in C = As
I current in A
t time in s
$n_{e-}$= number of moles of electrons
$n_{Cr}$= number of moles of chromium
$m_{Cr}$ = 10 g
$M_{Cr}$= 52.00 g/mol
F = 95699 C/mol

$$t = \frac{Q}{I} = \frac{F \times n_{e-}}{I} = \frac{F}{I} \times \frac{2\ mol}{1\ mol} \times n_{Cr} = \frac{F}{I} \times \frac{2\ mol}{1\ mol} \times \left(\frac{m}{M}\right)_{Cr}$$

$$t = \frac{95600\ As}{20\ A\ mol} \times \frac{2\ mol}{1\ mol} \times \frac{10.0\ g\ mol}{52.00\ g} \times \frac{1\ min}{60\ s} = 31\ min$$

Unit analysis → all units cancel out except minutes

8. D $e^-$gain = $e^-$loss

9. A

$Cd_{(s)} \rightarrow Cd_{(aq)} + 2e^-$ $E^\ominus = -0.40\ V$
$E^\ominus_{\text{reduction potential cathode}} - E^\ominus_{\text{reduction potential anode}} = -0.30 - (-0.40) = +0.1\ V$

$Co_{(s)} \rightarrow Co_{(aq)} + 2e^-$ $E^\ominus = -0.28\ V$
$E^\ominus_{\text{reduction potential cathode}} - E^\ominus_{\text{reduction potential anode}} = -0.30 - (-0.28) = -0.02\ V$

$Pb_{(s)} \rightarrow Pb_{(aq)} + 2e^-$ $E^\ominus = -0.13\ V$
$E^\ominus_{\text{reduction potential cathode}} - E^\ominus_{\text{reduction potential anode}} = -0.30 - (-0.13) = -0.17\ V$

$Cu_{(s)} \rightarrow Cu_{(aq)} + 2e^-$ $E^\ominus = +0.34\ V$
$E^\ominus_{\text{reduction potential cathode}} - E^\ominus_{\text{reduction potential anode}} = -0.30 + 0.34 = +0.04\ V$

10. C

$2X^{+}_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+} + 2X_{(s)} \quad E^{\ominus} = 2.60\ V$

$E^{\ominus}_{\text{reduction potential cathode}} - E^{\ominus}_{\text{reduction potential anode}} = E^{\ominus}_{\text{reduction potential cathode}} - (-2.37\ V) = 2.60\ V$

$E^{\ominus}_{\text{reduction potential cathode}} = 0.23\ V$

$Y_{(s)} + Cd^{2+}_{(aq)} \rightarrow Cd_{(s)} + Y^{2+}_{(aq)} \quad E^{\ominus} = 0.63V$

$-0.4\ V - E^{\ominus}_{\text{reduction potential anode}} = 0.63\ V$

$E^{\ominus}_{\text{reduction potential anode}} = -1.03\ V$

What is the $E^{\ominus}$ for the reaction $2X^{+}_{(aq)} + Y_{(s)} \rightarrow 2X_{(s)} + Y^{2+}_{(aq)}$

$E^{\ominus}_{\text{reduction potential cathode}} - E^{\ominus}_{\text{reduction potential anode}} = 0.23\ V - (-1.03\ V) = \underline{1.26\ V}$

11. D

$Ir_{(s)} + Tl^{+}_{(aq)} \rightarrow$ no reaction

$Tl^{+}$ cannot oxidize Ir

$Ir^{3+}$ is therefore the stronger oxidizing agent

$Ir^{3+}_{(aq)} + Re_{(s)} \rightarrow$ no reaction

$Ir^{3+}$ cannot oxidize Re

$Re^{3+}$ is therefore the stronger oxidizing agent

$3\ Tl^{+}_{(aq)} + Y_{(s)} \rightarrow 3Tl_{(s)} + Y^{3+}_{(aq)}$

$Y^{3+}$ cannot oxidize Tl

$Tl^{+}$ is therefore the stronger oxidizing agent

| $Y^{3+}$ | $Tl^{+}$ | $Ir^{3+}$ | $Re^{3+}$ |
|---|---|---|---|
| **Increasing strength of oxidizing agent** → | | | |

$Re^{3+}$ is the strongest oxidizing agent and in a reaction with it, will gain electrons

**NR 2 The standard cell potential for the following electrochemical cell**

**$Al_{(s)}\ /\ Al^{3+}_{(aq)}\ //\ Sn^{2+}_{(aq)}\ /Sn_{(s)}$ is +/- _____________ V**

$E^{\ominus}_{\text{reduction potential cathode}} - E^{\ominus}_{\text{reduction potential anode}} = -0.14\ V - (-1.66\ V) = +1.52\ V$

**NR 3 Which statements about an electrochemical cell are true?**

1. The electrons flow through an external circuit (true)
2. The stronger oxidizing agent gains electrons (true, because the stronger oxidizing agent undergoes reduction and therefore gains electrons)
3. Electrical energy is converted into chemical energy (false)
4. The stronger reducing agent reacts at the anode (true, oxidation occurs on the anode and the stronger reducing agent undergoes oxidation)
5. Chemical potential energy is transformed into electrical energy (true)

1, 2, 4, and 5

12. **A**

**$NADP^+ + 2e^- + H^+ \rightarrow NADPH$**

**$NADP^+$ gains/accepts electrons**

**$NAD^+ + 2e^- + H^+ \rightarrow NADH$**

**$NAD^+$ is gaining electrons, undergoes reduction and is therefore the oxidizing agent**

**In the $NAD^+_{(aq)}$ / $NADH_{(aq)}$ coenzyme, the oxidizing agent is *i* and the $NADP^+_{(aq)}$ / $NADPH_{(aq)}$ coenzyme the electron acceptor is *ii*.**

| | i | Ii |
|---|---|---|
| [✓ A.] | $NAD^+$ | $NADP^+$ |
| B. | $NAD^+$ | NADPH |
| C. | NADH | $NADP^+$ |
| D. | NADH | NADPH |

NR 4 $Ni^{2+} + 2e^- \rightarrow Ni$ If the standard copper reduction half reaction had been chosen as a reference instead of the hydrogen half-reaction, then the electrical potential for nickel would be +/- ___________ .

| | |
|---|---|
| **0.34 V $Cu^{2+} + e^- \rightarrow Cu$** | **0.00 V $Cu^{2+} + e^- \rightarrow Cu$** |
| **0.00 V $2H^+ + 2e^- \rightarrow H_2$** | -0.34 V $2H^+ + 2e^- \rightarrow H_2$ |
| **-0.26 V $Ni^{2+} + e^- \rightarrow Ni$** | -0.60 V $Ni^{2+} + e^- \rightarrow Ni$ |

or

$Cu^{2+} + Ni \rightarrow Cu + Ni^{2+}$ $E^{\ominus}_{\text{reduction potential cathode}} - E^{\ominus}_{\text{reduction potential anode}} = 0.34 - (-0.26\text{ V}) = 0.6\text{ V}$ (SHE)

This potential difference is not going to change even if we use instead of SHE, a copper electrode as reference: $E^{\ominus}_{\text{reduction potential cathode}} - E^{\ominus}_{\text{reduction potential anode}} = 0.00\text{V} - X = 0.6\text{ V}$ (copper reduction as reference)

$X = -0.6\text{ V}$

NR 5 A current of 5.00 A flows through a copper(I) sulfate solution until 6.35 g of copper are deposited. How long did it take to deposit 6.35 g of copper?

_________ min

$$Q = I \times t$$

Q charge in C = As
I current in A
t time in s
$n_{e-}$= number of moles of electrons
$n_{Cu}$= number of moles of copper
$m_{Cu}$ = 6.35 g
$M_{Cu}$= 63.55 g/mol
F = 95699 C/mol

$$t = \frac{Q}{I} = \frac{F \times n_{e-}}{I} = \frac{F}{I} \times \frac{2\ mol}{1\ mol} \times n_{Cu} = \frac{F}{I} \times \frac{2\ mol}{1\ mol} \times \left(\frac{m}{M}\right)_{Cu}$$

$$t = \frac{95600\ As}{5\ A\ mol} \times \frac{2\ mol}{1\ mol} \times \frac{6.35\ g\ mol}{63.55\ g} \times \frac{1\ min}{60\ s} = 64.3\ min$$

Unit analysis → all units cancel out except minutes

13. C
The following half reaction occurred in an electrolytic cell: $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$
If 4.00 moles of electrons passed through the cell, what mass of chlorine would be produced?

$$n_{Cl_2} = \left(\frac{m}{M}\right)_{Cl_2} = \frac{1\ mol}{2\ mol} \times n_{e^-}$$

$$m_{Cl_2} = \frac{1\ mol}{2\ mol} \times n_{e^-} \times M_{Cl_2} = \frac{1\ mol}{2\ mol} \times 4\ mol \times 70.90\ \frac{g}{mol} = 142\ g$$

14. D
$Pt^{2+} + 2e^-$ → Pt $E^\ominus = 1.2\ V$
$Cu^{2+} + 2e^-$ → Cu $E^\ominus = 0.34\ V$
$Re^{2+} + 2e^-$ → Re $E^\ominus = 0.3\ V$
$Fe^{2+} + 2e^-$ → Fe $E^\ominus = -0.44\ V$
$Ti^{2+} + 2e^-$ → Ti $E^\ominus = -1.63\ V$

**Ti strongest reducing agent, easily undergoes oxidation**

15. B 2 and 3

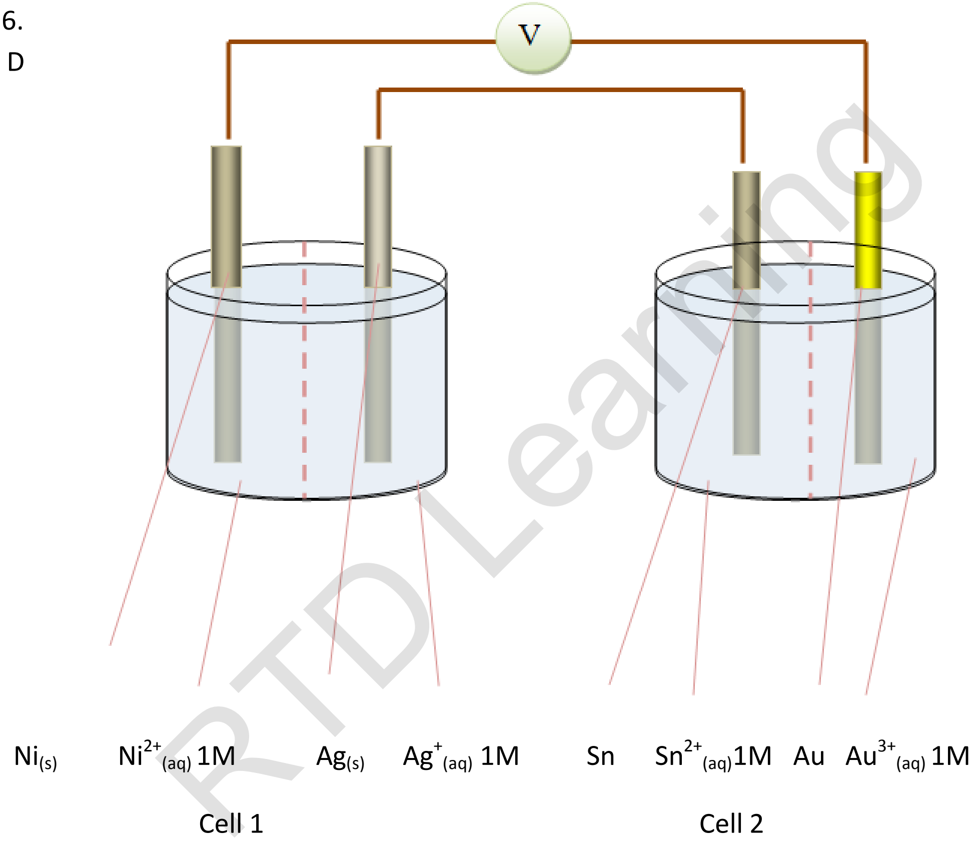
$\overset{+6}{S}O_{3(l)} + H_2\overset{+6}{S}O_{4(l)} \rightarrow H_2\overset{+6}{S_2}O_{7(l)}$

$3\ Fe^{2+}_{(aq)} \rightarrow 2Fe^{3+} + \overset{0}{Fe}_{(s)}$ disproportionation

$7\ \overset{+5}{Cl}O_3^- + 2H_3O^+ \rightarrow \overset{0}{Cl}_{2(g)} + 5\overset{+7}{Cl}O_4^-{}_{(aq)} + 3H_2O_{(l)}$ disproportionation

$K_2\overset{+6}{Cr_2}O_{7(aq)} + 14\ H\overset{-1}{Cl}_{(aq)} \rightarrow 2K\overset{-1}{Cl}_{(aq)} + 2\overset{+3}{Cr}\overset{-1}{Cl}_{3(aq)} + 7H_2O_{(l)} + 3\overset{0}{Cl}_{2(g)}$

16.
D



Cell 1

$Ni + 2Ag^+ \rightarrow Ni^{2+} + Ag$

$E^\ominus_{\text{reduction potential cathode}} - E^\ominus_{\text{reduction potential anode}} = 0.8\ V - (-0.26\ V) = 1.06\ V$

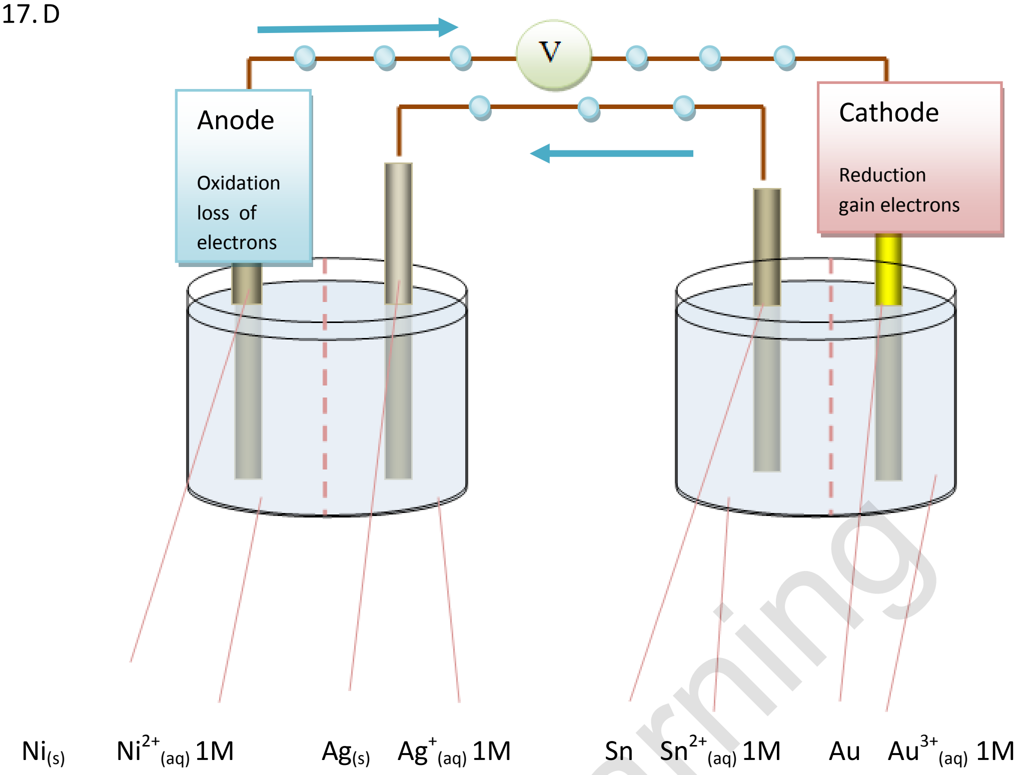
Cell 2

$3Sn + 2Au^{3+} \rightarrow 3Sn^{2+} + 2Au$

$E^\ominus_{\text{reduction potential cathode}} - E^\ominus_{\text{reduction potential anode}} = 1.50 – (-0.14\ V) = 2.70\ V$

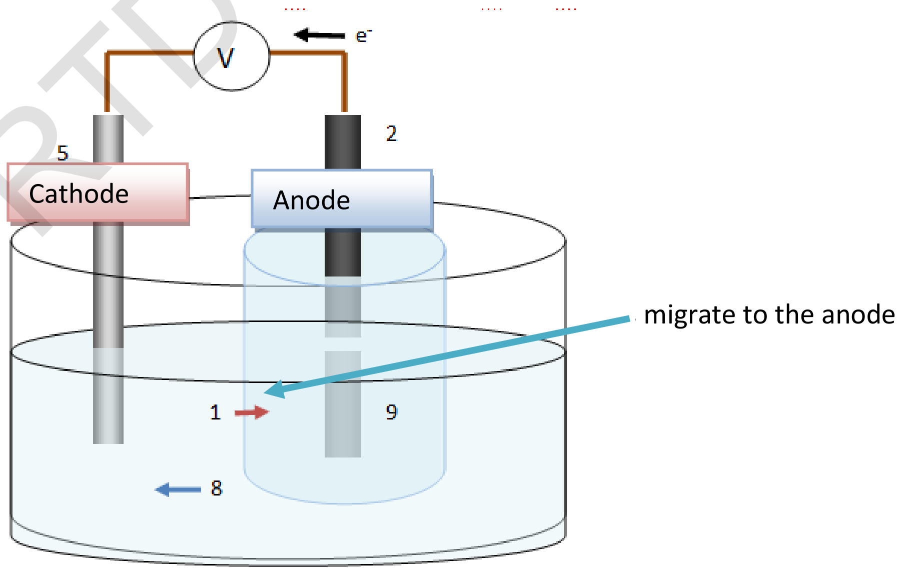
Cell1 + Cell2 = 2.70 V

17. D



Sn to Ag and Ni to Au

18. D
19. A
20. C



21. A
22. D (both cells are electrochemical cells and will have a positive cell potential)

23. B

    Mg is a stronger reducing agent than Fe and would be oxidized before Fe

24. D

$$\overset{0}{\mathbf{Cl}}_{2(g)} + \mathbf{H_2O}_{(l)} \rightarrow \mathbf{HO}\overset{+1}{\mathbf{Cl}}_{(aq)} + \mathbf{H}^{+}{}_{(aq)} + \overset{-1}{\mathbf{Cl}}{}^{-}{}_{(aq)}$$

Disproportionation

25. C

    Zn is a stronger reducing agent than Fe and would be oxidized before Fe

NR 6

$$Q = I \times t$$

Q charge in C = As

I current in A

t time in s

$n_{e-}$= number of moles of electrons

$n_{Ag}$= number of moles of silver

$n_{Pb}$= number of moles of lead

$M_{Ag}$=107.87 g/mol

$M_{Pb}$=207.21 g/mol

F = 95600 C/mol = 95600 As/mol

$$I \times t = Q = F \times n_{e-}$$

$$\frac{I \times t}{F} = n_{e^-} = \frac{1\ mol}{1\ mol} \times n_{Ag} = \frac{1\ mol}{1\ mol} \times \left(\frac{m}{M}\right)_{Ag}$$

$$\frac{1\ mol}{1\ mol} \times \frac{I \times t}{F} \times M_{Ag} = \frac{1\ mol}{1\ mol} \times \frac{3\ A \times 3600s\ mol}{96699\ As} \times 107.87\,\frac{g}{mol} = m_{Ag} = 12\text{ g}$$

$$\frac{1\ mol}{2\ mol} \times \frac{3\ A \times 3600s\ mol}{96699\ As} \times 207.21\,\frac{g}{mol} = m_{Pb} = 12\text{ g}$$

26. C

NR 7

**$2V_2O_5 + 6Cl_2 \rightarrow VOCl_3 + 3O_2$**

When 10 g of reducing agent reacts, the mass of the oxidizing agent reacting is __________ g.

$$m_{Cl_2} = \frac{6\ mol}{2\ mol} \times \left(\frac{m}{M}\right)_{V_2O_5} \times M_{Cl_2} = \frac{6\ mol}{2\ mol} \times \frac{10\ g\ mol}{181.89\ g} \times 70.90\frac{g}{mol} = 12\ g$$

NR 8

**$2NH_{3(g)} + 3O_{2(g)} + 2CH_{4(g)} \rightarrow 2HCN_{(g)} + 6H_2O_{(l)} + 940\ KJ$**

When 0.606 mol of oxidizing agent reacts, the heat produced is______________ KJ.

Oxygen is the oxidizing agent

Write a ratio:

$$\frac{0.606\ mol}{3\ mol} = \frac{x}{940\ kJ}$$

x= 190 kJ

**NR 9**

4476

**NR 10**

**The following electrochemical cell is constructed $Fe_{(s)}$ / $Fe^{2+}_{(aq)}$ // $X^{3+}_{(aq)}$ / $X_{(s)}$**

If $E^{\ominus}$(cell) = 1.97 V, the reduction half-cell reaction:

_____________ V.

$E^{\ominus}_{\text{reduction potential cathode}} - E^{\ominus}_{\text{reduction potential anode}} = E^{\ominus}_{\text{reduction potential cathode}} - (-0.46\ V) = 1.97\ V$

$E^{\ominus}_{\text{reduction potential cathode}} = 1.5\ V$

27. B

$5C_2H_5OH_{(l)} + 4\overset{+7}{Mn}O_4{}^{-}{}_{(aq)} + 12H^{+}{}_{(aq)} \rightarrow 5CH_3COOH_{(aq)} + 4\overset{+2}{Mn}{}^{2+}{}_{(aq)} + 11H_2O_{(l)}$

28 C Gold undergoes oxidation and is the reducing agent

Oxygen undergoes reduction and is the oxidizing agent