# Electrochemistry Problems

## Information Table: Standard Reduction Potentials in Aqueous solution at 25°C

<table>
<thead>
<tr>
<th>REACTION</th>
<th>( E_{\text{red}} ) (Volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{F}_2 (g) + 2e^- \rightarrow 2\text{F}^- (aq) )</td>
<td>2.87</td>
</tr>
<tr>
<td>( \text{Cl}_2 (g) + 2e^- \rightarrow 2\text{Cl}^- (aq) )</td>
<td>1.36</td>
</tr>
<tr>
<td>( \text{O}_2 (g) + 4\text{H}^+ + 4e^- \rightarrow 2\text{H}_2\text{O} (l) )</td>
<td>1.23</td>
</tr>
<tr>
<td>( \text{NO}_3^- (aq) + 4\text{H}^+ (aq) + 3e^- \rightarrow \text{NO}(g) + 2\text{H}_2\text{O}(aq) )</td>
<td>0.96</td>
</tr>
<tr>
<td>( \text{Ag}^+ (aq) + e^- \rightarrow \text{Ag} (s) )</td>
<td>0.800</td>
</tr>
<tr>
<td>( \text{Fe}^{3+}(aq) + e^- \rightarrow \text{Fe}^{2+} (aq) )</td>
<td>0.771</td>
</tr>
<tr>
<td>( \text{Cu}^{2+} (aq) + 2e^- \rightarrow \text{Cu} (s) )</td>
<td>0.337</td>
</tr>
<tr>
<td>( 2\text{H}^+ (aq) + 2e^- \rightarrow \text{H}_2 (g) )</td>
<td>0.000</td>
</tr>
<tr>
<td>( \text{Fe}^{3+}(aq) + 3 e^- \rightarrow \text{Fe} (s) )</td>
<td>-0.04</td>
</tr>
<tr>
<td>( \text{Sn}^{2+}(aq) + 2 e^- \rightarrow \text{Sn} (s) )</td>
<td>-0.14</td>
</tr>
<tr>
<td>( \text{Ni}^{2+} (aq) + 2 e^- \rightarrow \text{Ni} (s) )</td>
<td>-0.23</td>
</tr>
<tr>
<td>( \text{Cd}^{2+} (aq) + 2 e^- \rightarrow \text{Cd} (s) )</td>
<td>-0.40</td>
</tr>
<tr>
<td>( \text{Fe}^{2+}(aq) + 2 e^- \rightarrow \text{Fe} (s) )</td>
<td>-0.41</td>
</tr>
<tr>
<td>( \text{NiO}_2(s) + 2\text{H}_2\text{O}(l) + 2e^- \rightarrow \text{Ni(OH)}_2(s) + 2\text{OH}^- (aq) )</td>
<td>-0.49</td>
</tr>
<tr>
<td>( \text{Zn}^{2+} (aq) + 2e^- \rightarrow \text{Zn} (s) )</td>
<td>-0.763</td>
</tr>
<tr>
<td>( \text{Cd(OH)}_2 (s) + 2e^- \rightarrow \text{Cd} (s) + 2\text{OH}^- (aq) )</td>
<td>-0.82</td>
</tr>
<tr>
<td>( 2\text{H}_2\text{O} (l) + 2e^- \rightarrow \text{H}_2 (g) + 2\text{OH}^- (aq) )</td>
<td>-0.828</td>
</tr>
<tr>
<td>( \text{Al}^{3+} (aq) + 3 e^- \rightarrow \text{Al} (s) )</td>
<td>-1.67</td>
</tr>
<tr>
<td>( \text{Na}^+ (aq) + e^- \rightarrow \text{Na} (s) )</td>
<td>-2.714</td>
</tr>
</tbody>
</table>

1. Consider a galvanic cell in which one half cell contains a silver electrode and 1.0 M \( \text{AgNO}_3 \) solution and the other half cell has a zinc electrode and 1.0 M \( \text{Zn(NO}_3)_2 \) solution. Choose the left side to be the anode and the right side to be the cathode. Draw a **long and short** cell diagram
   a) Label the following: anode; cathode; + electrode; -electrode; zinc electrode; silver electrode; the solutions in each container; the direction electrons flow and the salt bridge.
   b) Write the half-cell reactions that occur below each half-cell and identify whether it is reduction or oxidation. Also write the overall reaction.
   c) In the box for the voltmeter indicate the expected initial voltage for this overall cell.
2. Balance the half reaction \( \text{C}_2\text{H}_5\text{OH} \rightarrow \text{CO}_2 \) under acidic conditions, and indicate how many electrons are transferred for each mole of ethanol (\( \text{C}_2\text{H}_5\text{OH} \)) consumed.

3. Calculate the cell voltage for the reaction
\[
\text{Zn} \mid \text{Zn}^{+2} (0.50 \text{ M}) \parallel \text{H}^+ (0.0010 \text{ M}) ; \text{H}_2(2.50 \text{ M}) \mid \text{graphite}.
\]

4. Balance the following redox reactions using the half reaction method. Label the **reduction and oxidation** half reactions and the **overall reaction**.
   a) \( \text{MnO}_4^{-1} (\text{aq}) + \text{SO}_3^{-2} (\text{aq}) \rightarrow \text{MnO}_2 (\text{s}) + \text{SO}_4^{-2} (\text{aq}) \) (basic)
   b) \( \text{Zn} (\text{s}) + \text{NO}_3^{-1} (\text{aq}) \rightarrow \text{Zn}^{+2} (\text{aq}) + \text{NO} (\text{g}) \) (acidic)
   (for part b: include the standard cell potentials of each half cell, the net cell potential and Predict whether you expect this to be spontaneous or nonspontaneous.)

5. In a copper-zinc voltaic cell what is the oxidizing agent?

6. In the electrolysis of \( \text{NaCl} (\text{aq}) \), \( \text{H}_2 \) gas is produced at the cathode instead of \( \text{Na} (\text{s}) \). Explain why.

7. The \( E^\circ \) value for the standard hydrogen electrode (SHE) is 0.00 volts. How is this value determined?
   a) Only by experiment
   b) Only by theory
   c) by international agreement
   d) a combination of experiment and theory
   e) none of the above

8. In a voltaic cell made of two metal electrodes and their ions in solution, one electrode gains mass and the other electrode loses mass. Identify each electrode
   a) Mass is gained at the negative electrode and lost at the positive electrode
   b) Mass is gained at the cathode and lost at the anode
   c) Mass is gained at the anode and lost at the cathode
   d) Voltaic cells are not spontaneous and neither reaction will occur without added current.
   e) None of the above

9. Predict the result of using iron nails to fasten an aluminum gutter to a house. Explain your answer with your knowledge of corrosion. Will the nail, gutter or neither oxidize and corrode?

10. Compare and contrast a fuel cell verses a primary voltaic cell and include an example of each.

11. Calculate the grams of aluminum that will be deposited by a current of 0.155 amperes during a period of 3 hour and 20 minutes from a solution of \( \text{Al(NO}_3\text{)}_3 \) . (atomic mass of \( \text{Al} = 27.0 \text{ g/mol} \)).
12. The same quantity of electrical charge that deposited 0.583 grams of silver in a AgNO₃ solution was passed through a solution of a gold salt and 0.355 grams of gold was deposited. What is the oxidation state of gold in this salt? (Au = 197.0 g/mol; Ag = 107.9 g/mol)

13. What are the 3 functions of a salt bridge in a voltaic cell? and What chemicals or substances may be in a typical salt bridge?

14. Using the table on the first page answer the following questions regarding the reactions below.
   \[
   \text{Fe}^{+3}/\text{Fe}^{+2} \quad \text{Zn}^{+2}/\text{Zn} \quad \text{Al}^{+3}/\text{Al} \quad \text{Ag}^+/\text{Ag} \quad \text{Cu}^{+2}/\text{Cu}
   \]
   a) Arrange the oxidizing agents in order of increasing strength.
      (Just show oxidizing agent ion or element)
   b) Which is the easiest to be oxidized?
   c) Which one(s) reduce Fe^{+3} ions to Fe^{+2}?
   d) In a voltaic cell what would be the shorthand way to write the spontaneous reaction of two half-cells under standard conditions, one contains Fe^{+3}/Fe^{+2} in contact with a platinum electrode, the other Cu^{+2}/Cu and what is the initial E°cell.

15. A cell is constructed in which identical copper electrodes are placed in 2 solutions. Solution A contains 1.200 M Cu(NO₃)₂. Solution B contains Cu^{+2} ions of a lower concentration. A salt bridge and exterior wire circuit connect the two solutions. The potential of the cell is observed to be initially 0.042 V.
   a) What is the [Cu^{+2}] in solution B initially?
   b) What is the concentration of [Cu^{+2}] in each of the solutions at equilibrium?

16. Calculate the oxidation potential (E_{OX}) for hydrogen gas in aqueous basic conditions if the partial pressure due to hydrogen is 0.750 atm and the pH is 10.85. Use the table on first page and choose the appropriate half reaction.

17. Calculate the ΔG° in units of kJ and the equilibrium constant K for the reaction as written.
   \[
   \text{Pt(s)}|\text{H}_2(\text{g});\text{H}^+(\text{aq})||\text{Cu}^{+2}(\text{aq})|\text{Cu(s)}
   \]

**Nuclear Problems**

18. Write the balanced nuclear equation for the following
   a) alpha emission of curium-242 (²⁴²Cm)
   b) beta emission of magnesium-28
   c) positron emission from xenon-118
   d) gamma emission from excited radon-222

19. The decay constant, k, for sodium-24, a radionuclide used medically in blood studies, is 4.63 x 10⁻² hr⁻¹. What is the half life in hours of ²⁴Na?
20. Charcoal found in the Lasaux cave in France, site of many prehistoric cave paintings, was observed to decay at a rate of 2.4 disintegrations per minute per gram of carbon. What is the age of the charcoal if current living organisms decay at the rate of 15.3 disintegrations per minute per gram of carbon? The half-life of $^{14}$C is 5730 yrs.

21. Californium was first synthesized by bombarding an element with an alpha particle. The products were Californium-245 and a neutron. What was the target element? Write the nuclear reaction and the abbreviated notation of the nuclear bombardment reaction.

22. Simply describe both nuclear fusion and nuclear fission. Which occurs with larger nuclides and which with smaller.

23. Predict the type of radioactive decay process that is likely for each of the following nuclides and write out the reaction. (There may be 2 choices on one)
   a) $^{14}$O  
   b) $^{210}$Po  
   c) $^{212}$Pb

24. Technetium-99, a major by product of nuclear weapons production, has a half-life of 210,000 years. Neutron bombardment converts it to technetium-100, which decays with a 16 second half-life to ruthenium-100. Write nuclear equations for these reactions.
   a) $^{99}$Tc  
   b) $^{100}$Tc

25. The most abundant isotope of boron is $^{11}$B, which has a natural abundance of 80.2%. The nucleonic mass of $^{11}$B is 11.006562 amu. Masses of a proton = 1.007276 amu and a neutron = 1.008665 amu. 1 MeV = 1.6022 x $10^{-13}$ J; 1 amu = 931.5 MeV
   a) Write out the balanced nuclear equation with boron-11 as the reactant and the products are only protons and neutrons.
   b) Solve for the mass defect of $^{11}$B in units of amu/boron-11
   c) Solve for the nuclear binding energy of the dissociation of $^{11}$B in units of
      a) MeV/boron-11, b) J/boron-11, and c) kJ/mol boron-11 broken into protons and neutrons.

26. Write the balanced nuclear equation for the following
   a) electron capture of $^{25}_{13}$Al
   b) beta emission of $^{65}_{29}$Cu

27. Predict the type of radioactive decay process that is likely for each of the following nuclides and write out the reaction.
   a) $^{214}_{82}$Pb  
   b) $^{232}_{90}$Th  
   c) $^{40m}_{18}$Ar  

28. Fill in the missing piece and write the abbreviated form of the following nuclear bombardment reactions.
   a) $^{109}_{47}\text{Ag} + _____ \rightarrow ^{112}_{49}\text{In} + ^{1}_{0}\text{n}$ abbrev.
   b) $^{98}_{42}\text{Mo} + _____ \rightarrow ^{0}_{0}\gamma + ^{99}_{42}\text{Mo}$ abbrev.

29. A sample of moon rock was analyzed by mass spectroscopy. Only 11.47% of the original $^{40}_{19}\text{K}$ remained the rest had decayed to $^{40}_{18}\text{Ar}$. The initial amount, $N_0$ would be 100%. Half-life of potassium-40, $t_{1/2} = 1.28 \times 10^9$ yrs.
   a) Solve for the rate constant, $k$.
   b) Approximately, how old is the moon rock?

30. There are no stable nuclides with an atomic number greater than ________.

31. Rate of Radioactive Decay—does not change with ________________, ______________ or ________________.

32. List several applications of nuclear chemistry.

33. Of the 2 isotopes, iodine-136 and iodine-122, one decays by beta emission and the other by positron emission. Identify which is which and write out the expected radioactive decay reactions.

   Organic Problems

34. What functional groups are present in CH3- C-CH2-CH-CH=CH-CH3 ?
   (a) ketone, alkene, alcohol
   (b) carboxylic ester, alkene, alcohol
   (c) aldehyde, alcohol, amine
   (d) phenol, carboxylic acid, alkene
   (e) amide, ether, thiol

35. What is the geometry of a propane molecule?
   a) Planar with bond angles of 120°.
   b) Three-dimensional with bond angles of 90°.
   c) Three-dimensional with bond angles of 109.5°.
   d) Three-dimensional with bond angles of 120°.
   e) Three-dimensional with bond angles of 180°.

36. Why is the following name incorrect?
   4-ethyl-5-methylcyclohexane
   a) It is not named with the lowest possible numbers.
   b) Cycloalkanes do not contain alkyl groups attached to the ring.
   c) Ethyl and methyl groups are not found adjacent to one another on a ring.
   d) All of the above.
37. How many hydrogen atoms are there in 1,4-dimethylbenzene?
   a) 2  b) 4  c) 6  d) 8  e) 10

38. When is Markovnikov's rule needed and what does is say?

39. Define what is meant by the term structural isomer and give an example.

40. **Reactions:**
   Finish and balance the following reactions,
   classify type of reaction as Addition, Substitution, or Combustion,
   and if there are two possible results show both and identify which is **favored.**

   ![Chemical Reaction](Image)

   a) ___________________________

   b) ___________________________

   c) ___________________________

   d) ___________________________

   e) ___________________________

   f) ___________________________

41. Ethers, like alkanes are virtually inert. This property makes them valuable as solvents.
   What are other important chemical properties of ethers that laboratory workers must remember?

42. **Draw the Structures:**
   If you skip the hydrogens at least put a line to indicate where H belong.
   (a) m-dichlorobenzene or 1,3 - dichlorobenzene
   (b) 2,2,3,3-tetrabromo-4-methyl-1-octanol
   (c) methyl acetate
   (d) 3-methyl-2-decanone
   (e) 3-ethyl-3,4,6-trimethyl-2-decanone
   (f) 2-chloro-3-hydroxy-4-methyl octanal
   (g) ortho-dichlorobenze
   (h) 3-ethyl-2- hexanone
43. **Name the Structures:**

(a) \[
\begin{align*}
\text{Cl} & \quad \text{O-H} & \quad \text{CH}_3 \\
\text{CH} & \quad \text{C} & \quad \text{C} & \quad \text{CH}-\text{CH}_2-\text{CH}_3 \\
\text{CH}_3 & \quad \text{Cl} & \quad \text{CH}_3 & \quad \text{CH}_2-\text{CH}_2-\text{CH}_3
\end{align*}
\]

(b) \[
\text{CH}_3-\text{O-CH}_2-\text{CH}_3
\]

(c) \[
\text{CH}_3-\text{C} & \quad \text{H} \\
\text{O}
\]

(d) \[
\text{CH}_3 & \quad \text{N} & \quad \text{CH}_3 \\
\text{CH}_3
\]

(e) \[
\text{H-C-CH}_2-\text{CH-CH}_2-\text{CH}_3 \\
\text{O} & \quad \text{CH}_3
\]

(f) \[
\text{C H}_3 & \quad \text{C} & \quad \text{N} & \quad \text{H}_2 \\
\text{O} & \quad \text{O}
\]

(g) \[
\text{C H}_3 & \quad \text{C} & \quad \text{O} & \quad \text{O-CH}_3
\]

44. **Draw and name** all the different possible structural isomers with the formula \(\text{C}_6\text{H}_{14}\)

45. How many hydrogen atoms are there in 1-chloro-2 methylbenzene

a) 3  b) 4  c) 5  d) 6  e) 7  f) 8  g) 9

46. Alkenes may have cis and trans isomers.
Draw and identify the cis and trans isomers of 3-heptene

47. How can one test for saturation or unsaturation of hydrocarbons, include observations one would see?

48. Circle and identify the functional groups in the structural formula for the low-calorie sweetener aspartame below.

\[
\text{O} \\
\text{H} & \quad \text{O} & \quad \text{C-O-CH}_3 \\
\text{H-N-C-C-NH-CH-CH}_2 & \quad \text{O} \\
\text{H} & \quad \text{CH}_2\text{COOH}
\]
49. Name the following coordination compound:  \([\text{Ni(NH}_3\text{)}_3(\text{H}_2\text{O})_3]\text{Cl}_2\)
   a) nickel(II)trihydrotriamminechloride
   b) nickel(I)triamminetrihydrochloride
   c) dichloronickel(II)triamminetrihydride
   d) nickel(III)chloride
   e) triamminetriaquanickel(II)chloride

50. Name the following coordination compound:  \(\text{K}_4[\text{PtBr}_6]\)
   a) potassium bromoplatinum(II)
   b) tetrapotassium bromoplatinate(II)
   c) tetrapotassium hexabromoplatinate(II)
   d) potassium hexabromoplatinate(II)
   e) potassium hexabromoplatinate(III)

51. Determine the formula for the compound, potassium diamminetetracyanocuprate(II).
   a) \(\text{K}_2[\text{Cu(NH}_3\text{)}_2(\text{CN})_4]\)
   b) \(\text{K}_2[\text{Cu(NH}_3\text{)}_2(\text{OCN})_4]\)
   c) \([\text{KCu(NH}_3\text{)}_2(\text{CN})_4]\)
   d) \(\text{K}[\text{Cu(NH}_3\text{)}_2(\text{CN})_4]\)
   e) \(\text{K}_2[(\text{NH}_3)_2(\text{CN})_4\text{Cu}]\)

52. Determine the chemical formula for the compound, diaquadicarbonylzinc dibromoargentate.
   a) \([\text{Ag(H}_2\text{O})_2][\text{Zn(CO)}_2]\text{Br}_2\)
   b) \([\text{Ag(H}_2\text{O})_2][\text{Zn(CO)}_2]\text{Br}_2\)
   c) \([\text{Zn(H}_2\text{O})_2(\text{CO})_2][\text{AgBr}_2]\)
   d) \([\text{Zn(H}_2\text{O})_2(\text{CO})_2][\text{AgBr}_2]\)
   e) \([\text{Zn(H}_2\text{O})_2(\text{CO})_2][\text{AgBr}_2]\)