Answers

WORKSHEET 12

ELECTROCHEMISTRY PROBLEMS

Syllabus reference 9.2.4

1 Check your understanding by completing the following.

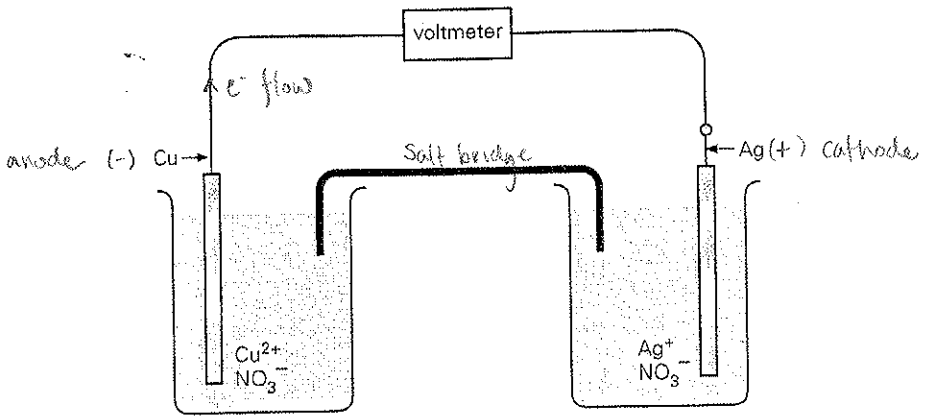
a A voltaic cell is a device in which a chemical reaction occurs in such a way that it generates electricity. Conversely, electrolytic cells use electrical energy to make chemical reactions occur. In either type of cell the electrode at which oxidation occurs is the anode and the electrode at which reduction occurs is the cathode.

b In a galvanic cell the chemical reactions occur at different locations. The solution in a half cell is called an electrolyte. The half cell solutions are connected by a salt bridge which permits the passage of ions between them. The positive ions or cations flow towards the cathode while the negative ions or anions flow towards the anode.

c The conductors of a cell which get connected to the external circuit are called electrodes. Reduction occurs at the cathode, the positively charged electrode while oxidation occurs at the anode, the negatively charged electrode. Electrons flow via an external circuit from the anode to the cathode. The cell voltage is the difference between the Std. reduction potential of the half cells.

d There are many different types of galvanic cells in everyday use. The common dry cell, often referred to as a Leclanche cell, is used in torches and radios. Disadvantages of this cell are that it cannot be recharged and it may develop leaks when it goes flat. The lead-acid battery is used in cars and trucks and is rechargeable.

2 On the diagram below, given that Ag is the positive electrode, label the cathode, anode, direction of electron flow and salt bridge.



3 Given the following two half cell reactions, write the balanced overall reaction.

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

$$Ag^+(aq) + e^- \rightarrow Ag(s)$$

$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

4 Given the overall cell reaction, write the two half cell reactions and identify the oxidation and reduction reactions.

$$3Pb^{2+}(aq) + 2Cr(s) \rightarrow 3Pb(s) + 2Cr^{3+}(aq)$$

$Cr(s) \rightarrow Cr^{3+} + 3e^-$ (ox)

$Pb^{2+} + 2e^- \rightarrow Pb(s)$ (red)

5 From the following shorthand representation identify the anode and cathode. Write the oxidation and reduction half-reactions given that Pb is positive.

$$Fe(s) \mid Fe^{2+}(aq) \parallel Pb^{2+}(aq) \mid Pb(s)$$

(anode) (cathode)

$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ (ox)

$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ (red)

6 Write the half-reactions, the overall reaction and the shorthand representation for the following electrochemical cell.

One electrode consists of a piece of silver dipping into a silver nitrate solution. It is connected by a salt bridge to another electrode consisting of a piece of platinum dipping into a chloride solution with chlorine gas bubbling through the solution over the inert platinum electrode. The platinum is the positive electrode.

$Ag | Ag^+ || Cl^- | Cl_2, Pt$

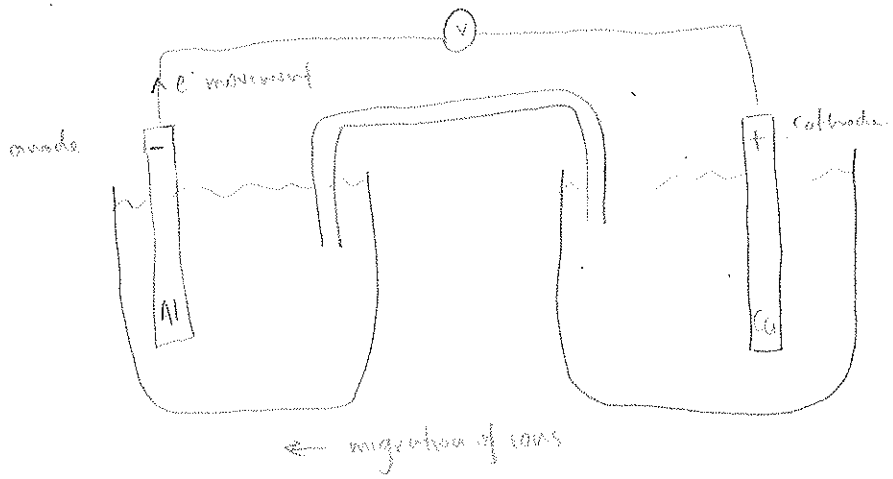
$Ag_{(s)} \rightarrow Ag^+ + 1e^-$ (oxid)

$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$ (red)

$2Ag_{(s)} + Cl_{2(g)} \rightarrow 2Ag^+_{(aq)} + 2Cl^-_{(aq)}$

7 Draw a diagram of an electrochemical cell with the following overall reaction. Identify the anode, cathode, direction of electron flow, migration of ions, and write the half cell reactions.

$$2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$$



$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^-$ (oxid)

$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$ (red)

8 Draw a diagram of the electrochemical cell represented by:

$$Mg \mid Mg^{2+} \parallel Hg^{2+} \mid Hg, Pt$$

Use your knowledge of the reactivity of metals to determine which metal will reduce (displace) which metal ion. Hence write equations for the half-reactions and the overall reaction that occur in this cell. Indicate which electrode is positive and show the direction of electron flow and migration of ions. Identify the anode and cathode.

Mg will displace Hg as Mg is more active

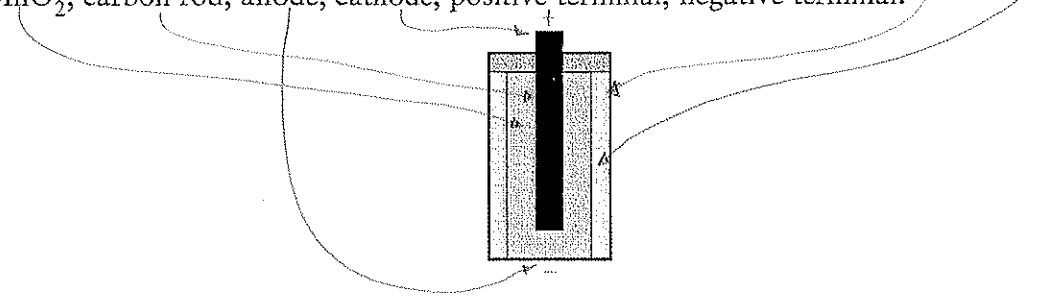
$Mg_{(s)} \rightarrow Mg^{2+} + 2e^-$ (oxid) anode (−)

$Hg^{2+} + 2e^- \rightarrow Hg_{(l)}$ (red) cathode (+)

e⁻ migrate from anode to cathode, ions migrate from cathode side to anode side

9 The ordinary dry cell is the most common and cheapest of the commercially available cells.

a Complete the following diagram of a dry cell using the terms: zinc cylinder, NH_4Cl paste, MnO_2, carbon rod, anode, cathode, positive terminal, negative terminal.



b The half cell reactions are:

$$Zn \rightarrow Zn^{2+} + 2e^- \quad \text{(oxid.)}$$

$$NH_4^+ + MnO_2 + H_2O + e^- \rightarrow Mn(OH)_3 + NH_3 \quad \text{(red.)}$$

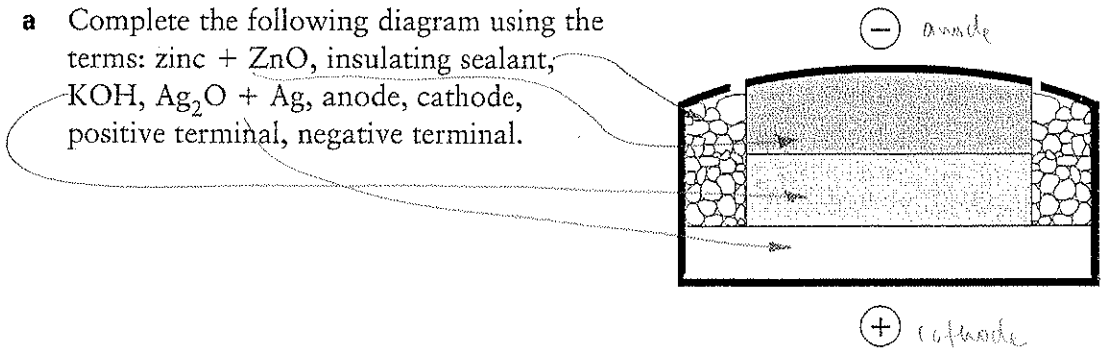
i Identify the oxidation and reduction half-reactions.

ii Write the overall cell reaction.

$Zn_{(s)} + 2NH_{4\,(aq)}^{+} + 2MnO_{2\,(s)} + 2H_2O_{(l)} \rightarrow Zn^{2+}_{(aq)} + 2Mn(OH)_3 + 2NH_3$

10 The silver oxide cell is referred to as a 'button' cell.

a Complete the following diagram using the terms: zinc + ZnO, insulating sealant, KOH, Ag_2O + Ag, anode, cathode, positive terminal, negative terminal.



b The half cell reactions are:

$$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$$

$$Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$$

Write the overall cell reaction.

$Zn_{(s)} + Ag_2O_{(s)} \rightarrow ZnO_{(s)} + 2Ag_{(s)}$

11 Use your textbook or a reference book to complete the following table.

CELL TYPE	ANODE	CATHODE	USE	ADVANTAGES	DISADVANTAGES
Dry cell Standard Zn-carbon cell also $MnO_2 + H_{2(g)}$	graphite (+) $Zn \rightarrow Zn^{2+} + 2e^-$	Zn casing $2NH_4^+ + 2e^- \rightarrow 2NH_{3(g)} + H_{2(g)}$ $\rightarrow Mn_2O_{3(s)} + H_2O_{(l)}$ (removal of $H_{2(g)}$)	Torches, Toys, walkmans etc.	- portable - widely available - easy to replace	- voltage decreases steadily (may be useless below certain voltage prior to being "flat") - $H_{2(g)}$ is produced (explosive) which is slowly removed by reaction with MnO_2
Silver oxide (button) cell	Zn $Zn + 2OH^- \rightarrow ZnO + 2H_2O + 2e^-$	Ag_2O $Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$	pacemakers cameras watches calculators	- small - long-shelf-life - long-lasting	- expensive - less available

- Zn reacts with NH_4^+ which deteriorates the battery ∴ short shelf-life

Alkaline cell overcomes these problems (NH_4^+ not present) $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$ (anode)

12 Use the table of standard reduction potentials to answer the following.

a Rank the following in order of decreasing tendency to be reduced: Cu^{2+}, Sn^{2+}, Ba^{2+}, Ag^+, Na^+.

$Ag^+, Cu^{2+}, Sn^{2+}, Na^+, Ba^{2+}$

b Rank the following in decreasing tendency to be oxidised: Cr, Mg, Au, Pb.

Mg, Cr, Pb, Au

13 Write down the cell reaction and $E°$ for a galvanic cell composed of the half cells

$$Fe^{3+}, Fe^{2+} \mid Pt \text{ and } Ni^{2+} \mid Ni$$

$+0.77$ -0.26

(You will need to refer to the table of standard reduction potentials.)

$Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$ (red) $E° = +0.77$

$Ni_{(s)} \rightarrow Ni^{2+}_{(aq)} + 2e^-$ (oxid) $E° = +0.26$

$E°_{cell} = +1.03$

14 Write the anode and cathode half cell equations and determine the EMF for the cell formed by linking the half cells

$Cl^-, Cl_2 \mid Pt$ and $I^-, I_2 \mid Pt$.

$Cl_2 + 2e^- \rightarrow 2Cl^- \quad E^\circ = +1.36$ (red)

$2I^- \rightarrow I_2 + 2e^- \quad E^\circ = -0.54$ (ox)

$E^\circ_{cell} = 1.36 - 0.54 = 0.82$

15 Write the half-reactions that make up the following overall reaction, then use a table of standard electrode potentials to decide whether or not the reaction occurs as written.

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l) \quad E^\circ = +1.51$ (red)

$Fe^{2+} \rightarrow Fe^{3+} + e^- \quad E^\circ = -0.77$

$E_{cell} = 1.51 - 0.77 = 0.74$