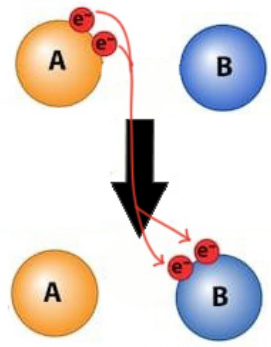
9.1 Oxidation and Reduction

Defining oxidation and reduction

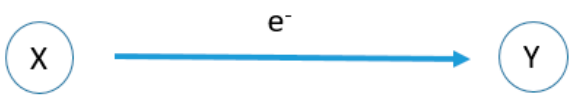
1. Fill in the following table defining oxidation and reduction.

Definitions	Oxidation	Reduction
Definition in terms of oxygen atoms		
Definition in terms of hydrogen atoms		
Definition in terms of electrons		
Definition in terms of oxidation number		

2. The image below shows an electron transfer reaction. Label/indicate the following
   a. The oxidizing agent
   b. The reducing agent
   c. The chemical that is oxidized
   d. The chemical that is reduced
   e. The oxidation state of the chemicals after the reaction (assuming they are both zero before the reaction)



3. In the following reaction, an electron is transferred from species X to species Y. Fill in the blanks



X is _____ by Y
X _____ electrons
X is a _____ agent
X _____ in oxidation number

Y is _____ by X
Y _____ electrons
Y is an _____ agent
Y _____ in oxidation number

Assigning oxidation states

4. Oxidation numbers **assume that the electrons in a bond are 'owned' by the more** _____ **atom.** That is, they assume that all bonds are _____ [ionic || covalent]

5. The bonding type for the NaCl molecule is _____ [ionic || covalent]
   a. Draw a Lewis dot structure for the molecule

NaCl

   b. Sodium has a charge of _____, while chlorine has a charge of _____
   c. Sodium has an oxidation state of _____, while chlorine has an oxidation state of _____

6. The bonding type for the H_2O molecule is _____ [ionic || covalent]
   a. Draw a Lewis dot structure for this molecule

H_2O

   b. Hydrogen has a charge of _____, while oxygen has a charge of _____
   c. Hydrogen has an oxidation state of _____, while oxygen has an oxidation state of_____

7. In the O_2 molecule, the bond type is _____ [ionic || covalent]
   a. Draw a Lewis dot structure for this molecule

O_2

   b. Each oxygen has a charge of _____
   c. Each oxygen has an oxidation state of _____

Rules for assignment

8. The oxidation state of an uncombined element is always _____
   a. Indicate the oxidation states of the following: Fe(s) ___ , Xe(g) ___ , H_2 (g) ___, S_8 (s) ___

9. The oxidation state of hydrogen is _____ when bonded to a non-_____
   a. And it is _____ when bonded to a_____. This is called a hy_____

10. When oxygen, forms compounds, its oxidation state is usually _____
    a. The primary exception is in pe_____, where its oxidation state is _____.

11. The oxidation state of fluorine is _____ [usually || always] _____

12. In a neutral polyatomic molecule, e.g._____, the sum of oxidation states must be _____

13. In a charged polyatomic ion, e.g. _____, the sum of oxidation states must be_____

14. Other atoms get the charges they 'prefer' (that would complete their oc___ structure

Practice assigning oxidation states

15. Work out the oxidation states of nitrogen in each of the following species

a. HNO_3

b. NO_2^-

c. N_2H_4

16. Work out the oxidation states of chlorine in the following species

a. HClO

b. Cl_2O

c. ClO_4^-

17. Work out the oxidation states of the element in bold in each of the following

a. $\mathbf{S}O_3^{2-}$

b. $\mathbf{C}_2H_4$

c. $\mathbf{C}O_2$

d. $\mathbf{Cr}_2O_7^{2-}$

e. $(NH_4)_2\mathbf{Cr}_2O_7$

f. $\mathbf{Na}H$

g. $\mathbf{S}O_3$

h. $H_2\mathbf{O}_2$

Naming compounds using oxidation numbers

18. Complete the table

Chemical Formula	Name
Cu_2O	
	Iron(II) sulphide
Ti_3N_4	
N_2O	
	Iron (III) sulphide
Cu_3N_2	
	Vanadium (V) oxide
MnO_2	
	Copper (II) hydroxide
$KMnO_4$	
$K_2Cr_2O_7$	

Identifying oxidation and reduction

19. Indicate whether the element in bold has been oxidized, reduced or neither for each of the below:

a. $\mathbf{F}_2O \rightarrow \mathbf{F}$

b. $\mathbf{P}Cl_3 \rightarrow \mathbf{P}Cl_5$

c. $\mathbf{Ca}O_2 \rightarrow \mathbf{Ca}O$

d. $\mathbf{C}_2H_6 \rightarrow \mathbf{C}O_2$

e. $\mathbf{Cr}_2O_7^{2-} \rightarrow \mathbf{Cr}_2O_4^{2-}$

f. $H\mathbf{N}O_3 \rightarrow H\mathbf{N}O_2$

g. $\mathbf{Cl}O_3^- \rightarrow Na\mathbf{Cl}O_3$

Balancing redox equations in neutral or acidic solution

20. The steps for balancing a redox equation are the following:

a. Separate out the re_____ and ox_____ half-_____

b. Balance each equation separately

i. For acidic solutions:

- Balance all atoms except _____
- Add _____ to the side deficient in oxygen
- Then add _____ to the side deficient in hydrogen
- Then balance the _____

c. Combine the half-equations, multiplying if necessary to balance the number of _____

21. Balance the following reaction that takes place in neutral solution. Indicate the oxidizing and reducing agents.

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

Oxidation half equation:

Reduction half equation :

Balanced equation

22. Balanced the equation below (which takes place in acidic solution). Indicate the oxidizing and reducing agents.

$$MnO_4^{-}(aq) + Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + Mn^{2+}(aq)$$

23. Balance the following reaction that takes place in acidic solution. Indicate the oxidizing and reducing agents.

$$H^+(aq) + Cr_2O_7^{2-}(aq) + C_2H_5OH(l) \longrightarrow Cr^{3+}(aq) + CO_2(g) + H_2O(l)$$

24. Balance the following reaction that takes place in acidic solution. Indicate the oxidizing and reducing agents.

$$HAsO_2(aq) + BrO_3^-(aq) \rightarrow Br_2(aq) + H_3AsO_4(aq)$$

25. Work out the balanced equation for the reversible reaction of copper(II) ions (aq) with nitrogen (IV) oxide gas to yield solid copper and nitrate ions in acidic solution.

The activity series

26. Using the activity series shown, mark the following as true or false. In addition, try to write a chemical equation illustrating each statement

a. Lithium has a very high tendency to be oxidized

b. Lithium has a very high tendency to be reduced

c. It is relatively easy to oxidize gold (compared to other metals)

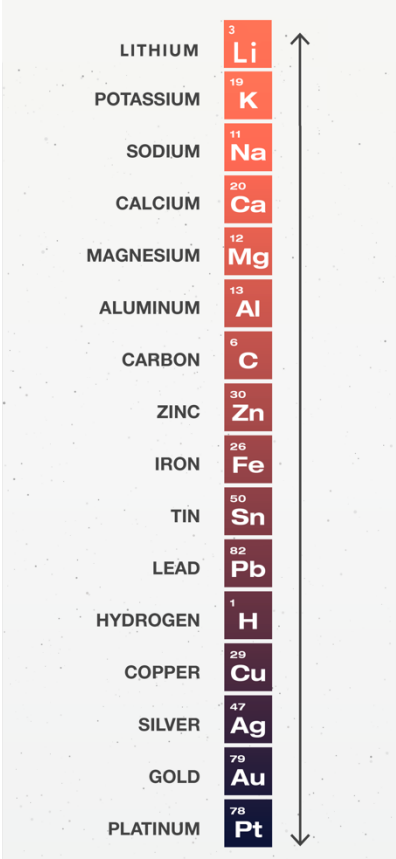
d. Potassium is a relatively strong reducing agent

e. Potassium would easily reduce Al^{3+} ions

f. Potassium forms negative ions more easily than calcium

g. Sodium loses electrons more readily than carbon

h. Sodium would displace aluminum from solution



i. The reaction $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ is energetically unfavorable

j. Carbon can be used to reduce iron oxide to pure iron

k. Gold can displace hydrogen gas from weak hydrochloric acid

l. Potassium reacts with a weak acid to liberate hydrogen gas

Redox titrations and biochemical oxygen demand

27. Define the term 'biochemical/biological oxygen demand'

28. (09M.3.sl.TZ1.E2)The Winkler method uses redox reactions to find the concentration of oxygen in water. 100 cm^3 of water was taken from a river and analysed using this method. The reactions taking place are summarized below.

Step 1: $2Mn^{2+}(aq) + 4OH^-(aq) + O_2(aq) \longrightarrow 2MnO_2(s) + 2H_2O(l)$

Step 2: $MnO_2(s) + 2I^-(aq) + 4H^+(aq) \longrightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$

Step 3: $2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

a. Describe what happened to the manganese ions in step 1 in terms of electron transfer
b. State the change in oxidation number for iodine in step 2. Has it been oxidized or reduced?
c. If 0.0002 moles of I^- were formed in step 3. Calculate the amount, in moles, of oxygen, O_2, dissolved in water.

29. (Cambridge, 384). The Winkler method was used to measure the concentration of dissolved oxygen in a sample of stream water. Manganese(II) sulfate, sulfuric acid and potassium iodide were added to 100.0 cm_3 of water. The iodine that was formed was titrated against a sodium thiosulfate solution with a concentration of 5.00×10^{-3} $moldm^{-3}$. It was found that 16.00cm^3 of sodium thiosulfate was required for the titration.

The equations for the reactions are:

$$2Mn(OH)_2(s) + O_2(aq) \longrightarrow 2MnO(OH)_2(s)$$

$$MnO(OH)_2 + 4H^+(aq) \longrightarrow Mn^{4+}(aq) + 3H_2O(l)$$

$$Mn^{4+}(aq) + 2I^- \longrightarrow Mn^{2+}(aq) + I_2(aq)$$

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

a. Calculate the number of moles of sodium thiosulfate used.
b. Calculate the number of moles of iodine in the solution.
c. Calculate the number of moles of manganese(IV) that produced this amount of I_2.
d. Calculate the concentration of dissolved oxygen in $mgdm^{-3}$ and in parts per million.
e. Another sample of water from the same source was incubated for 5 days at 20°C. At the end of the incubation the Winkler method was used to determine concentration of dissolved oxygen. It was found that the concentration of dissolved oxygen in the sample was 2.20$mgdm^{-3}$.Calculate the biochemical oxygen demand.

9.2 Electrochemical cells

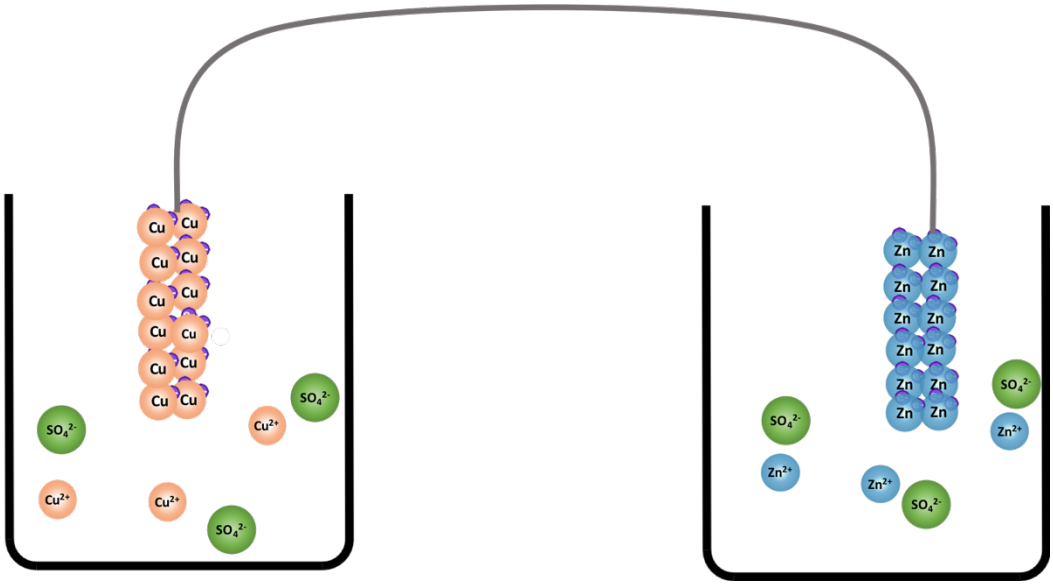
How voltaic (galvanic) cells generate current

1. The diagram below illustrates one example of a voltaic cell. Write down:
    a. The equilibrium equation at the copper electrode
    b. The equilibrium equation at the zinc electrode

    Then indicate:
    c. The anode
    d. The cathode
    e. The positive electrode
    f. The negative electrode
    g. The direction of electron flow

    Next, draw in an NaCl salt bridge, showing the ion flow necessary to neutralize built up charge

    Finally, write down the overall equation for the cell

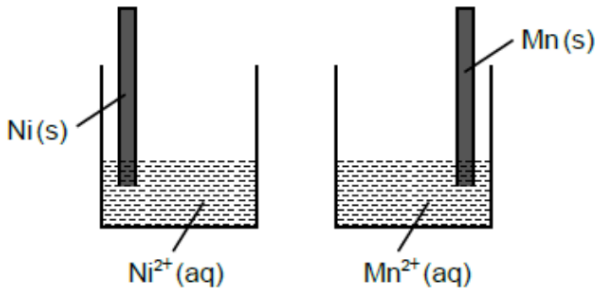


2. Give a definition for the cathode and the anode.

3. Describe the need for a salt bridge in a voltaic cell, and give two examples of salt bridges.

4. (17N.2.sl.TZ0.2) A voltaic cell is made up of a Mn^{2+}/Mn half-cell and a Ni^{2+}/Ni half-cell. Deduce the full equation for the cell reaction

The voltaic cell described above is partially shown below. Complete the diagram, showing the direction of electron movement and ion flow.



5. (15M.1.sl.TZ1.25) Two half-cells are connected via a salt bridge to make a voltaic cell. Which statement about this cell is correct?
[A. Oxidation occurs at the positive electrode (cathode). || B. It is also known as an electrolytic cell. || C. Ions flow through the salt bridge. || D. It requires a power supply to operate.]

Cell notation

6. Indicate the structure of the copper and zinc cell seen earlier using shorthand cell notation.

7. The single line in the half cell notation represents the _____ while the double line represents the _____

8. For the following pairs of metals, write out the shorthand cell notation
   a. Zinc and nickel
   b. Aluminium and magnesium

9. Given the following cell :

$Ni(s) \mid Ni^{2+}(aq) \parallel Ag^{+}(aq) \mid Ag(s)$

Write out the following

a. Half equation at the anode
b. Half equation at the cathode
c. Overall balanced equation

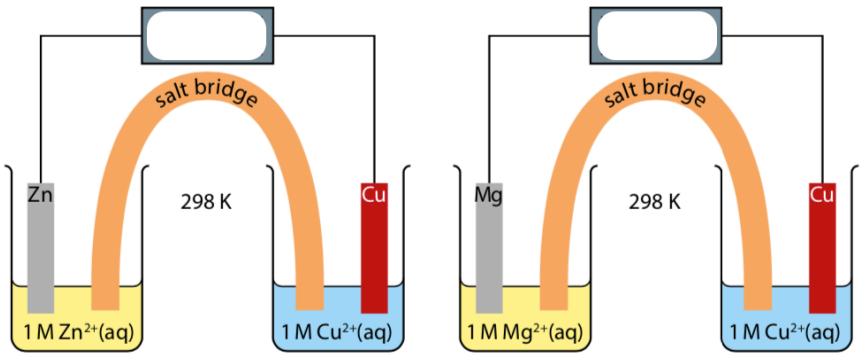
10. (14M.2.sl.TZ1.6) A reactivity series for the metals W, X, Y and Z was deduced by adding these metals to solutions of their metal ions. The following reactions were observed.

$$W^{2+}(aq) + X(s) \rightarrow W(s) + X^{2+}(aq)$$
$$Y(s) + W^{2+}(aq) \rightarrow Y^{2+}(aq) + W(s)$$
$$Z^{2+}(aq) + W(s) \rightarrow Z(s) + W^{2+}(aq)$$
$$Y(s) + X^{2+}(aq) \rightarrow Y^{2+}(aq) + X(s)$$

If a galvanic cell was constructed using the metals Y and Z, write out its cell notation below

Determining voltage size

11. On the diagram, indicate the voltage values we should expect.



12. Mark the following as true or false:

a. The larger the difference in electronegativity between metal electrodes, the greater the voltage
b. If there is no difference in electronegativity between the two electrodes, the cell will not function (zero voltage)
c. The metal with a greater electronegativity gets oxidized
d. The metal with a greater electronegativity becomes the anode

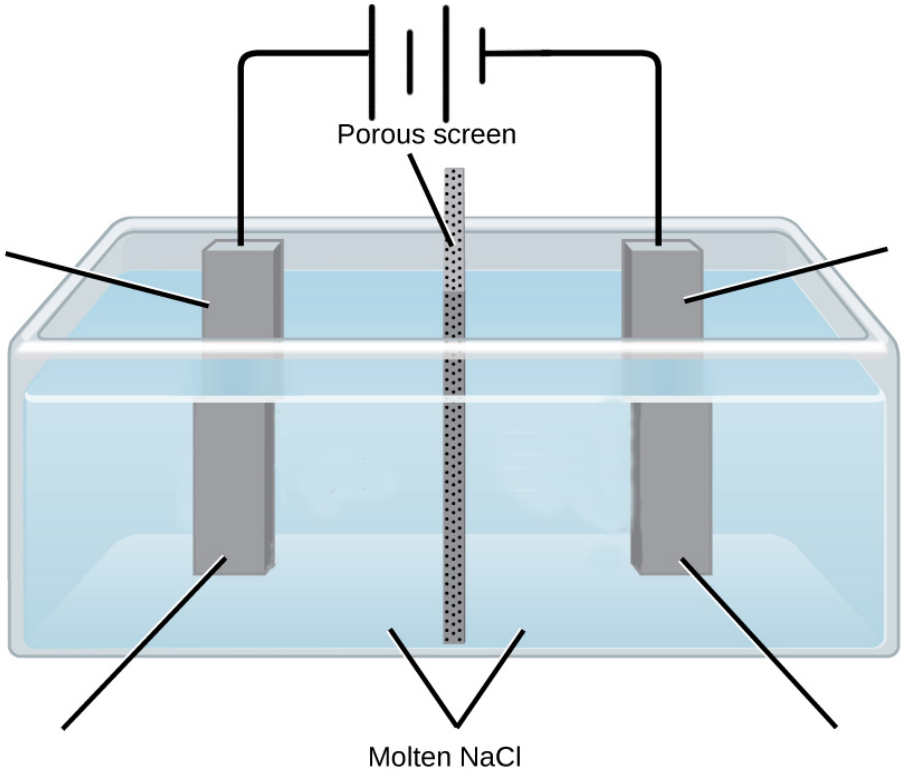
Electrolysis

13. Give a definition for the term 'electrolysis'

14. The diagram below illustrates the electrolysis of molten sodium chloride. On it, indicate:

a. The direction of electron flow
b. The electrode to which Na^+ ions migrate
c. The electrode to which Cl^- ions migrate
d. The cathode
e. The anode
f. The equation for the redox reaction at the cathode
g. The equation for the redox reaction at the anode

Finally, write out the balanced equation for the overall electrolysis process.



15. Graphite is often used as an electrode because it is relatively _____ [reactive || inert] and _____ [conducts || doesn't conduct] electricity

16. Give a definition for an electrolyte

17. _____ and _____will not function as an electrolyte. [$MgCl_2(aq)$ || $CaCl_2(l)$ || KBr(s) || NaBr(aq) || $NH_3(g)$]

18. For the following molten salts, write the equations at the cathode and anode during electrolysis.
    a. Al_2O_3
    b. KCl
    c. Lead (II) bromide
    d. Copper (II) chloride