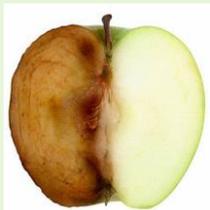


Oxidation-Reduction



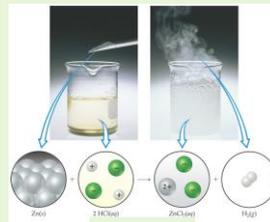
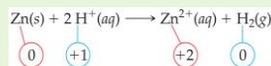
Oxidation numbers are charges on each atom.

2

Electrochemical Reactions

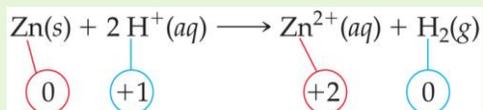
In electrochemical reactions, electrons are transferred from one species to another.

Oxidation Numbers



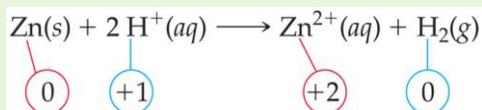
In order to keep track of what loses electrons and what gains them, we assign oxidation numbers.

Oxidation and Reduction



- ♦ A species is oxidized when it loses electrons.
 - Here, zinc loses two electrons to go from neutral zinc metal to the Zn^{2+} ion.

Oxidation and Reduction



- ♦ A species is reduced when it gains electrons.
 - Here, each of the H^+ gains an electron and they combine to form H_2 .



7

Assigning Oxidation Numbers

1. Elements in their elemental form have an oxidation number of 0.
examples: Na, He, C, N₂, O₃, O₂
2. The oxidation number of a monatomic ion is the same as its charge.
Cl⁻ = -1 Ba⁺² = +2

Assigning Oxidation Numbers

3. Nonmetals tend to have negative oxidation numbers, although some are positive in certain compounds or ions.
 - Oxygen has an oxidation number of -2, except in the peroxide ion in which it has an oxidation number of -1.
 - Hydrogen is -1 when bonded to a metal, +1 when bonded to a nonmetal.

Assigning Oxidation Numbers

3. Nonmetals tend to have negative oxidation numbers, although some are positive in certain compounds or ions.
 - Halogens always have an oxidation number of -1.

Assigning Oxidation Numbers

4. The sum of the oxidation numbers in a neutral compound is 0.
5. The sum of the oxidation numbers in a polyatomic ion is the charge on the ion.

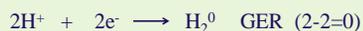
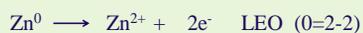
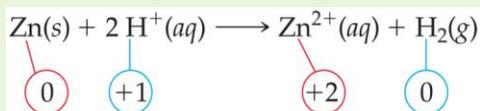
◆ Assign Oxidation Numbers

H ₂ O	NaOH
N ₂	H ₂
H ₂ SO ₄	Li
KCl	CaF ₂
Ca ₃ (PO ₄) ₂	K ₂ S
KMnO ₄	Ne
HBr	Sr ⁺²
Na ⁺¹	NiCl ₃

12

Half-Reaction Method

1. Assign oxidation numbers to determine what is oxidized and what is reduced.
2. Write the oxidation and reduction half-reactions.



Half-Reaction Method

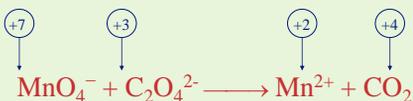


Consider the reaction between MnO_4^- and $\text{C}_2\text{O}_4^{2-}$:



Half-Reaction Method

First, we assign oxidation numbers.



Since the manganese goes from +7 to +2, it is reduced.

Since the carbon goes from +3 to +4, it is oxidized.

An oxidation-reduction (redox) reaction involves the transfer of electrons (e^-). (3.2d)

Sodium transfers its electrons to chlorine



The oxidation numbers of the atoms will change.... one oxidation number goes up (oxidation) and one oxidation number goes down (reduction)

16

Regents Question: 06/02 #20

Which particles are gained and lost during a redox reaction?

- (1) electrons
- (2) Protons
- (3) Neutrons
- (4) positrons

17

Regents Question: 08/02 #29

As a Ca atom undergoes oxidation to Ca^{2+} , the number of neutrons in its nucleus

- (1) decreases
- (2) increases
- (3) remains the same

18

Find the oxidation numbers of each element in a reaction and see which ones have changed.

♦ Rules for oxidation number

- An element that is not in a compound has an oxidation number of zero (0)
- Group 1 Metals are always 1+
- Group 2 Metals are always 2+
- Fluorine is always 1-
- Oxygen is always 2- except when combined with F (OF₂) or the peroxide ion (O₂²⁻)

19

Reduction is the gain of electrons. (3.2e)

Nonmetals gain electrons to form - ions

The oxidation number goes down (reduces)

20

A half-reaction can be written to represent reduction. (3.2f)



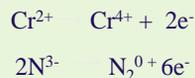
In reduction half reactions, electrons are written on the left because electrons are gained

21

Oxidation is the loss of electrons. (3.2g)

Metal atoms lose electrons to become + ions

The oxidation numbers go up (increases)



22

A half-reaction can be written to represent oxidation. (3.2h)



In oxidation half reactions, electrons are written on the right because electrons are lost

23

LEO says GER



Losing
Electrons
Oxidation

Gaining
Electrons
Reduction

24

Regents Question: 06/02 #18

Given the reaction:



Which species undergoes oxidation?

- (1) Mg(s)
- (2) H⁺(aq)
- (3) Cl⁻(aq)
- (4) H₂(g)

LEO grows GER

25

Regents Question: 06/02 #18

Given the equation:



Which species undergoes reduction?

- (1) C(s)
- (2) H⁺
- (3) C²⁺
- (4) H₂(g)

LEO grows GER

26

Regents Question: 08/02 #22

In any redox reaction, the substance that undergoes reduction will

- (1) lose electrons and have a decrease in oxidation number
- (2) lose electrons and have an increase in oxidation number
- (3) gain electrons and have a decrease in oxidation number
- (4) gain electrons and have an increase in oxidation

27

Regents Question: 06/03 #28

Given the equation:

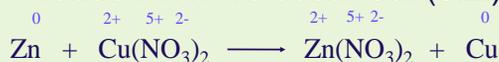


The reduction half-reaction is

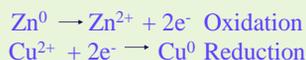
- (1) $\text{Al} \longrightarrow \text{Al}^{3+} + 3\text{e}^-$
- (2) $\text{Cu}^{2+} + 2\text{e}^- \longrightarrow \text{Cu}$
- (3) $\text{Al} + 3\text{e}^- \longrightarrow \text{Al}^{3+}$
- (4) $\text{Cu}^{2+} \longrightarrow \text{Cu} + 2\text{e}^-$

28

Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred. (3.2i)



Find the oxidation numbers and see which ones change.
Nitrate NO₃ is -1



29

The sum of the oxidation numbers of all the atoms in a compound is zero.

- ♦ CuO
 - Oxygen is -2
 - The oxidation number of copper must be calculated
 - $X + -2 = 0$
 - $\text{Cu} = +2$
- ♦ Na₂SO₄
 - Na is +1 because it is a group 1 metal
 - O is -2
 - The oxidation number of Sulfur must be calculated
 - $2(+1) + X + 4(-2) = 0$
 - $(2) + X + (-8) = 0$
 - $S = +6$

30

The sum of the oxidation numbers of all the atoms in a polyatomic ion is the charge of the ion.

- | | |
|---|--|
| ◆ NO_3^- | ◆ PO_4^{3-} |
| Oxygen is 2- | Oxygen is 2- |
| The oxidation number of nitrogen must be calculated | The oxidation number of phosphorous must be calculated |
| $X + 3(-2) = -1$ | $X + 4(-2) = -3$ |
| $X = +5$ | $X + (-8) = -3$ |
| | $X = +5$ |

31

Regents Question: 06/02 #21

What is the oxidation number of chromium in



- (1) +12
 (2) +2
 (3) +3
 (4) +6

32

Regents Question: 06/03 #26

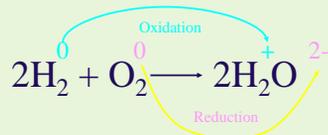
In which substance does chlorine have an oxidation number of +1?

- (1) Cl_2
 (2) HCl
 (3) HClO
 (4) HClO_2

33

During redox, one atom is oxidized while another atom is reduced. Reduction and oxidation happen together.

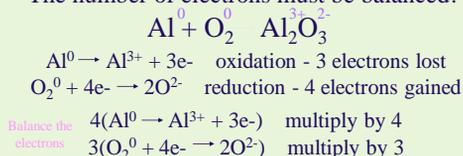
The oxidation numbers of the atoms will change.... one goes up (0 to +1) and one goes down (0 to -2)



34

In a redox reaction the number of electrons lost is equal to the number of electrons gained. (3.3b)

The number of electrons must be balanced!



12 electrons are transferred in this reaction

35

Table J tells us if a redox reaction can occur between an atom and an ion.

- ◆ A more active metal will replace an ion below it on Table J.
- ◆ A more active nonmetal will replace an ion below it on Table J.
- ◆ Any metal above H is more active than H and will react with an acid to produce $\text{H}_2(\text{g})$
 - The higher up the table, the more readily the replacement will take place.

36

Regents Question: 01/03 #46

According to Reference Table J, which of these metals will react most readily with 1.0 M HCl to produce H₂(g)?

- (1) Ca
- (2) K
- (3) Mg
- (4) Zn

37

A more active metal will replace a less active metal from its compound.



Zinc replaces copper because zinc is more active than copper.



Copper cannot replace zinc

Oxidation is on top

Reduction is on bottom

Table J
Activity Series**

Metals	Nonmetals
Li	F ₂
Rb	Cl ₂
K	Br ₂
Ca	I ₂
Na	
Mg	
Al	
Ti	
Mn	
Zn	
Cr	
Fe	
Co	
Ni	
Sn	
Pb	
**H ₂	
Cu	
Ag	
Au	

**Activity Series based on hydrogen standard

38

An electrochemical cell can be either voltaic or electrolytic. In an electrochemical cell, oxidation occurs at the anode and reduction at the cathode.



Red Cat – An Ox

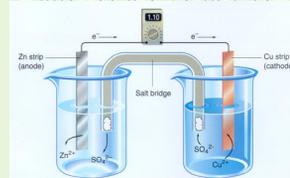
Reduction at the Cathode

Oxidation at the Anode

39

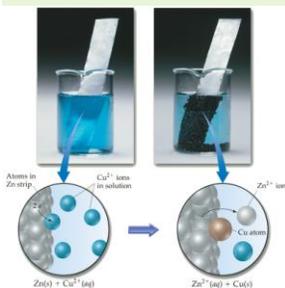
A voltaic cell spontaneously converts chemical energy to electrical energy. (3.2k)

Batteries are voltaic cells



40

Voltaic Cells



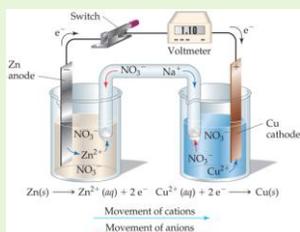
In spontaneous oxidation-reduction (redox) reactions, electrons are transferred and energy is released.

Voltaic Cells

- ♦ We can use that energy to do work if we make the electrons flow through an external device.
- ♦ We call such a setup a voltaic cell.

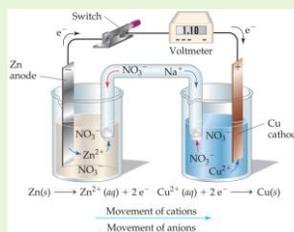


Voltaic Cells



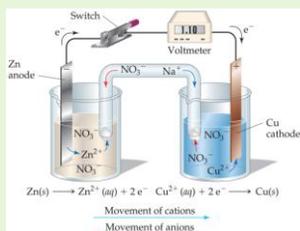
- ◆ A typical cell looks like this.
- ◆ The oxidation occurs at the anode.
- ◆ The reduction occurs at the cathode.

Voltaic Cells



Once even one electron flows from the anode to the cathode, the charges in each beaker would not be balanced and the flow of electrons would stop.

Voltaic Cells



- ◆ Therefore, we use a salt bridge, usually a U-shaped tube that contains a salt solution, to keep the charges balanced.
 - Cations move toward the cathode.
 - Anions move toward the anode.

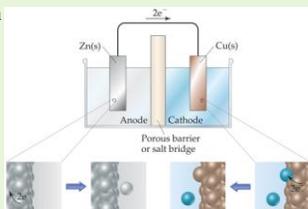
Voltaic Cells

- ◆ In the cell, then, electrons leave the anode and flow through the wire to the cathode.
- ◆ As the electrons leave the anode, the cations formed dissolve into the solution in the anode compartment

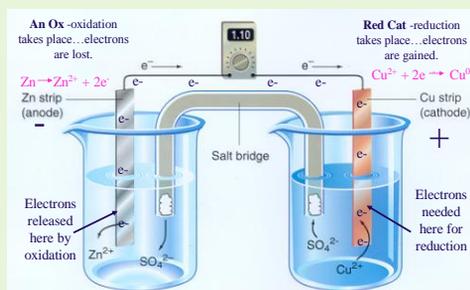


Voltaic Cells

- ◆ As the electrons reach the cathode, cations in the cathode are attracted to the now negative cathode.
- ◆ The electrons are taken by the cation, and the neutral metal is deposited on the cathode.

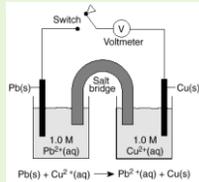


Electrons flow from the anode (- electrode) to the cathode (+ electrode) through the wire in a voltaic cell.



Regents Question: 06/03 #46

A diagram of a chemical cell and an equation are shown below.

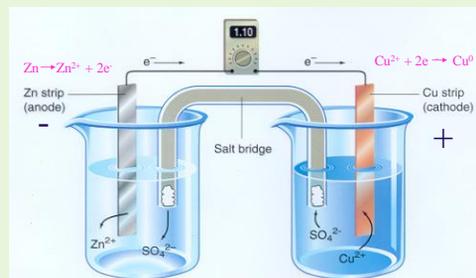


When the switch is closed, electrons will flow from

- (1) the Pb(s) to the Cu(s) (3) the Pb²⁺(aq) to the Pb(s)
 (2) the Cu(s) to the Pb(s) (4) the Cu²⁺(aq) to the Cu(s)

49

The salt bridge completes the circuit allows ions to flow from one ½ cell to the other ½ cell to maintain neutrality.



50

Regents Question: 06/03 #27

Which statement is true for any electrochemical cell?

- (1) Oxidation occurs at the anode, only.
 (2) Reduction occurs at the anode, only.
 (3) Oxidation occurs at both the anode and the cathode.
 (4) Reduction occurs at both the anode and the cathode.

51

An electrolytic cell requires electrical energy to produce chemical change. This process is known as electrolysis. (3.2I)

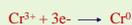
52

Regents Question: 06/02 #70-75

Base your answers to the next six questions on the following redox reaction, which occurs spontaneously in an electrochemical cell.

$$\text{Zn} + \text{Cr}^{3+} \longrightarrow \text{Zn}^{2+} + \text{Cr}$$

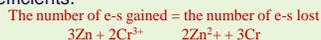
- Write the half-reaction for the reduction that occurs.



- Write the half-reaction for the oxidation that occurs.



- Balance the equation using the *smallest* whole-number coefficients.



53

Regents Question: 06/02 #70-75

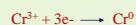
Base your answers to the next five questions on the following redox reaction, which occurs spontaneously in an electrochemical cell.

$$\text{Zn} + \text{Cr}^{3+} \longrightarrow \text{Zn}^{2+} + \text{Cr}$$

- Which species loses electrons and which species gains electrons?



- Which half-reaction occurs at the cathode?



Hint: Red Cat

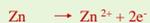
- State what happens to the number of protons in a Zn atom when it changes to Zn²⁺ as the redox reaction occurs.

The number of protons remains the same.

54

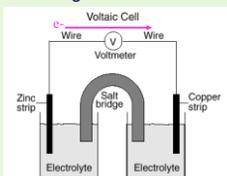
Regents Question: 01/03 #53-55

- Indicate with one or more arrows the direction of electron flow through the wire.
Hint: Zinc is above copper on table J so Zn is oxidized
- Write an equation for the half-reaction that occurs at the zinc electrode.



- Explain the function of the salt bridge

The salt bridge completes the circuit and allows ions to flow from one 1/2 cell to the other. This keeps the 1/2 cells neutral.



Uses of Electrolytic cells

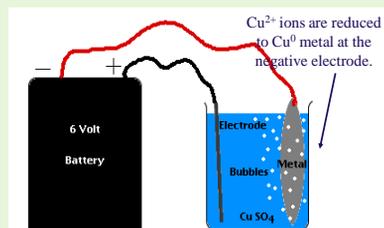
- Recharging a battery
- Electroplating
 - During copper plating, Cu^{2+} ions are reduced to Cu^0 metal at the cathode (Red Cat) which is the negative electrode
- Electrolysis
 - The Hoffman apparatus uses electricity to break water apart into hydrogen + oxygen

Regents Question: 06/02 #22

Which process requires an external power source?

- neutralization
- synthesis
- fermentation
- (4) electrolysis

The cathode is negative and is the site of reduction in an electrolytic cell.



Electroplating with Copper