Lecture 10

Aqueous Solutions and Chemical Reactions I

Electrolytic Solutions

Solubility

Precipitation Reactions

REDOX Reactions

Oxidation Numbers

Solutions

- A homogeneous mixture of a solvent and solute(s).
  - Solvent
    - The thing you have more of
  - Solute
    - The thing you have less of
- Aqueous Solutions
  - Solutions in which water is the solvent.

Electrolytic Solutions

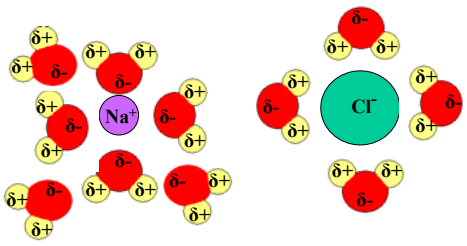
- An ionic compound dissolved in a polar solvent (e.g. NaCl in Water)
  - Most ionic compounds do this.
- Electrolytes (ions) conduct electricity on solution.
- If a solution conducts electricity, it must contain ions.
- The more ions the solution contains, the better able it is to conduct electricity.

Ionic Compounds in Polar Solvents.

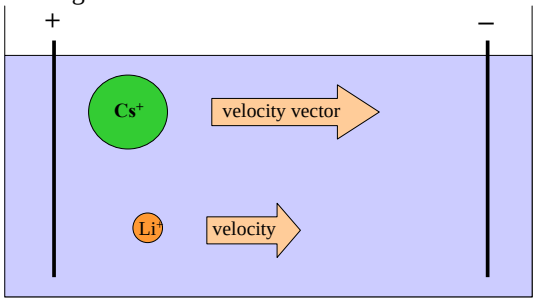
e.g. NaCl dissolves in water

$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$Na^+_{(aq)}$ and $Cl^-_{(aq)}$



Smaller ions have stronger electric fields so they drag more water molecules around with them.



Molecular Compounds in Water

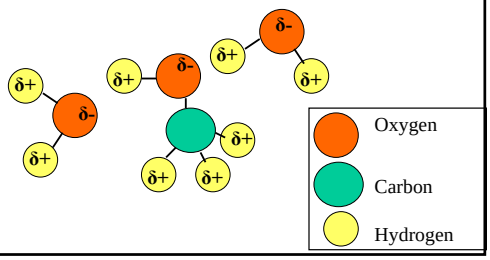
- Non-electrolytes
  - Most molecular compounds do not dissociate in water and therefore do not conduct electricity.
  - e.g. sugar, methanol
- Weak-electrolytes
  - Weak acids – some dissociation (low conductivity).
  - e.g. acidic acid: $CH_3COOH_{(aq)} \rightarrow H^+_{(aq)} + CH_3COO^-_{(aq)}$
- Strong-electrolytes
  - Strong acids – complete dissociation (high conductivity).
  - e.g. hydrochloric acid: $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

Like Dissolves Like

Non-polar Molecules Dissolve in Non-polar Solvents.

Polar Molecules Dissolve in Polar Solvents.

e.g. Water and Methanol



Precipitation Reactions

- In a precipitation reaction, the attractive forces between oppositely charged ions is greater than the forces of attraction between the H_2O molecules and the ions.

Ex1) Precipitation Reaction (Question #4 AP Exam)

Ex1) Write the net ionic equation, showing the reactants and products, for the reaction that takes place when an aqueous solution of barium chloride is added to an aqueous solution of sodium sulfate.

Ex1) Precipitation Reaction (Question #4 AP Exam)

$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow Ba^{2+}_{(aq)} + 2Cl^-_{(aq)} + 2Na^+_{(aq)} + SO_4^{2-}_{(aq)}$

$Ba^{2+}_{(aq)} + 2Cl^-_{(aq)} + 2Na^+_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO4(s) + 2Cl^-_{(aq)} + 2Na^+_{(aq)}$

The Balanced Net Ionic Equation:

Does not include spectator ions!

$Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_4(s)$

Solubility Table

Soluble Ions	Exceptions
Group 1A metals	
NH_4^+	
NO_3^-	
Cl^-	not with Ag^+, Hg_2^{2+}, Pb^{2+}
Br^-	not with Ag^+, Hg_2^{2+}, Pb^{2+}
I^-	not with Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	not with Ca^{2+}, Sr^{2+}, Ba^{2+}, Ag^+, Hg_2^{2+}, Pb^{2+}

Insolubility Table

Insoluble Ions	Exceptions
OH^-	alkali metals, NH_4^+, Ca^{2+}, Sr^{2+}, Ba^{2+}
S^{2-}	alkali metals, NH_4^+, Ca^{2+}, Sr^{2+}, Ba^{2+}
CO_3^{2-}	alkali metals, NH_4^+
PO_4^{3-}	alkali metals, NH_4^+

Colors of Precipitants (Question #5 AP Exam)

Solid Precipitant Formed	Color
PbI_2	Bright Yellow
CdS	Dark Yellow
PbS	Black
Ag_2S	Black
$Ni(OH)_2$	Green
$Al(OH)_3$	White
$PbSO_4$	White
$BaSO_4$	White
$Ca_3(PO_4)_2$	White
AgCl	White

Ex2) Precipitation Reaction (Question #4 AP Exam)

Ex2) Aqueous solutions of Lead (II) Nitrate and Sodium Iodide are mixed in a beaker.

$$Pb(NO_3)_{2\,(aq)} + 2NaI_{\,(aq)} \rightarrow PbI_{2\,(s)} + 2NaNO_{3(aq)}$$

Balanced Net Ionic Equation:

$$\mathbf{Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2\,(s)}}$$

Oxidation Reduction Reactions

Often referred to as REDOX Reactions

Electron transfer reactions

- One substance gets **oxidize**
  - **(referred to as the reducing agent)**
    - It loses electrons
- The other substance gets **reduced**
  - **(referred to as the oxidizing agent)**
    - It gains electrons.

Single Replacement REDOX Reaction

Ex) A piece of iron is immersed in a solution of copper (II) sulfate.

Reduction

Cu^{2+} is the oxidizing agent

$$Fe_{(s)} + Cu^{2+}_{(aq)} \rightarrow Fe^{2+}_{(aq)} + Cu(s)$$

Oxidation

Fe is the reducing agent

How can you tell what gets oxidized and what get reduced?

$$\mathbf{2Ca + O_2 \rightarrow 2CaO}$$

The answer is in the oxidation numbers

Rules for Determining Oxidation Numbers

1) For an atom in its elemental form, its oxidation number is zero.

Mg, Fe, H_2, O_2, Cl_2, O_3, etc.

Oxidation Number for each = 0

Rules for Determining Oxidation Numbers

2) For a monoatomic ion, its oxidation number is equal to its charge.

Mg^{2+}; Oxidation Number = +2

Cl^-; Oxidation Number = -1

Rules for Determining Oxidation Numbers

3) The oxidation number for Oxygen in a molecular compound is –2.

H_2O, CO_2

-2

2(-2) = -4

2(-1) = -2

Exception: Peroxides: ON = -1 (e.g. H_2O_2)

Rules for Determining Oxidation Numbers

4) Hydrogen

- +1 when it is bonded to a nonmetal (e.g.HCl)
- -1 when it is bonded to a metal (e.g. MgH_2)

Rules for Determining Oxidation Numbers

5) For other covalent compounds that do not contain Hydrogen or Oxygen, the most electronegative element has an oxidation number equal to its charge as an ion.

BF_3; the oxidation number for Fluorine = -1

PCl_5; the oxidation number for Chlorine = -1

Rules for Determining Oxidation Numbers

6) The sum of the oxidation numbers for all of the atoms in a compound must equal the overall charge of that compound.

e.g. H_2O

2(+1) = +2

-2

+2 – 2 = 0

Rules for Determining Oxidation Numbers

6) The sum of the oxidation numbers for all of the atoms in a compound must equal the overall charge of that compound.

e.g. ClO_3^-

Must be + 5 | 3(-2) = -6

-6 + (+5) = -1

Find the Oxidation Numbers

PCl_5

Chlorine is the most electronegative element.

- The oxidation number of chlorine is –1.

There are 5 chlorines

- The chlorines sum to –5.

The compound is neutral and there is one phosphorus.

- The oxidation number of phosphorus is +5.

+5 – 5 = 0

How can you tell what gets oxidized and what get reduced?

$$\mathbf{2Ca_{(s)} + O_{2(g)} \rightarrow 2CaO_{(s)}}$$

ON = 0 | ON = 0 | ON = +2 | ON = -2

Calcium metal gets oxidized. (loses electrons)

Oxygen gas gets reduced. (gains electrons)

The answer is in the oxidation numbers

What is oxidized and what is reduced?

$KClO_3 + 3HNO_2 \rightarrow KCl + 3HNO_3$

+1 +5 -2 +1 +3 -2 +1 -1 +1 +5 -2

Chlorine was reduced

Nitrogen was oxidized

Oxidation half-reaction

$KClO_3 + 6\ e^- \rightarrow KCl$

+5 -1

Chlorine gains 6 e^- as its oxidation number changes from +5 to -1

Reduction half-reaction

$3HNO_2 \rightarrow 3HNO_3 + 6\ e^-$

+3 +5

Each of the three Nitrogen atoms loses 2 e^- as its oxidation number changes from +3 to +5

What is oxidized and what is reduced?

$2PbS_{(s)} + 3O_{2(g)} \rightarrow 2PbO_{(s)} + 2SO_{2(g)}$